



generatorNETBOX

DN2.60x-xx

**Ethernet/LXI remote generator
with 14 bit resolution**

**Hardware Manual
Software Driver Manual**

English version

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AHRENSFELDER WEG 13-17, 22927 GROSSHANS DORF, GERMANY

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Introduction

Preface

This manual provides detailed information on the hardware features of your Spectrum instrument. This information includes technical data, specifications, block diagrams and a connector description.

In addition, this guide takes you through the process of installing and recognizing your hardware and also describes the installation of the delivered driver package for each operating system.

Finally this manual provides you with the complete software information of the hardware and the related driver. The reader of this manual will be able to control the instrument from any PC system with one of the supported operating systems and one of the supported operating software packages.

Please note that this manual provides no description for specific driver parts such as those for IVI, LabVIEW or MATLAB. These driver manuals are available on USB-Stick or on the Spectrum website.

For any new information on the board as well as new available options or memory upgrades please contact our website www.spectrum-instrumentation.com. You will also find the current driver package with the latest bug fixes and new features on our site.



Please read this manual carefully before you install any hardware or software. Spectrum is not responsible for any hardware failures resulting from incorrect usage.

General Information

The DN2.60x series allows data replay on up to 8 channels in the medium speed segment. Due to the proven design of 14 bit AWG cards, reliable generator products can be offered. These products are available in several versions and different speed grades making it possible for the user to find a individual solution.

The generatorNETBOX products can be used with maximum update rates (sample rates) of up to 125 MS/s. The installed memory of up to 1 GSample per generator unit will be used for fast data generation. It can completely be used by the current active channels. If using slower sample rates the memory can be switched to a FIFO buffer and data will be transferred online over Ethernet from the PC memory or from hard disk.

Application examples: Laboratory equipment, Radar, Laser, prototype design, production test

generatorNETBOX Overview

The series of generatorNETBOX products are remote powerful generator instruments with GBit Ethernet connection following the LXI Core 2011 standard. The proven internal generator modules, a stable chassis, an embedded remote controller, sufficient air cooling and standard BNC connectors form an unique instrument that opens a lot of new application areas.

The generatorNETBOX can be either directly connected to a PC or Laptop or it can be connected to a company/institute LAN and can be accessed from any PC within that LAN. Using the generatorNETBOX offers the following benefits and new possibilities compared to generator plug-in cards:

- Use a powerful generator without opening the PC and without mounting hardware inside the PC.
- Share the generator within a group of engineers that only need the instrument from time to time.
- Place the generator directly near the signal sinks and control it remotely from the desk.
- Use the instrument at different location without moving a complete system. One just needs the generatorNETBOX, a few cables and a Laptop.
- Use the generator as a mobile data actuation device with the DC power option.



Internal Generator Modules

The generatorNETBOX products internally consist of generator modules that are accessed and programmed in a similar way as the Spectrum generator cards themselves.

Accessing the generatorNETBOX by software therefore is nearly identical to accessing the same plug-in cards. Throughout the manual all programming and software usage will be described for the internal generator modules.



Differences between plain cards and generator modules inside the generatorNETBOX

| Feature | Plain M2i-Express Card | Installed inside generatorNETBOX DN2.60x |
|-----------------|---|---|
| Trigger Input B | Only available as part of option BaseXIO | Available as standard |
| Option BaseXIO | Option can be ordered with purchase | Not available |
| Option Star-Hub | Option can be ordered and allows to connect 5 or 16 cards | Option installed internally in all generatorNETBOXes with 2 modules |
| Standard Memory | 256 MSamples per card | 512 MSamples per module |
| Maximum Memory | 1 GSamples per card | 1 GSamples per module |

| Feature | Plain M4i-Express Card | Installed inside generatorNETBOX DN2.66x | Installed inside generatorNETBOX DN6.66x |
|-----------------|---|---|---|
| Option Star-Hub | Option can be ordered and allows to connect 8 cards | Option installed internally in all digitizerNETBOXes with 2 modules | Option installed internally in all models |
| Standard Memory | 2 GSamples per card: M4i.66xx | 2 GSamples per module: DN6.66x | 2 GSamples per module: DN6.66x |
| Maximum Memory | 2 GSamples per card: M4i.66xx | 2 GSamples per module: DN6.66x | 2 GSamples per module: DN6.66x |

| Feature | Plain M2p-Express Card | Installed inside digitizerNETBOX DN2.65x | Installed inside digitizerNETBOX DN6.65x |
|-----------------|--|---|---|
| Option Star-Hub | Option can be ordered and allows to connect either 6 or 16 cards | Option installed internally in all models with two internal modules | Option installed internally in all models |
| Standard Memory | 512 MSamples per card | 512 MSamples per module | 512 MSamples per module |
| Maximum Memory | 512 MSamples per card | 512 MSamples per module | 512 MSamples per module |

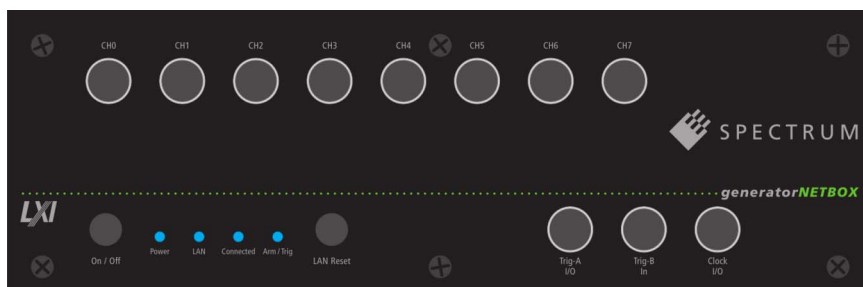
Different models of the DN2.60x series

The following overview shows the different available models of the DN2.60x series. They differ in the number of internally mounted generator modules and the number of available channels.

- DN2.603-04**



- DN2.603-08**



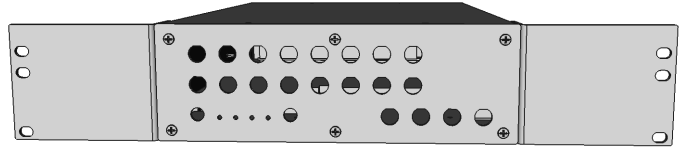
Additional options

19" Rack Mount Kit

The rack mount kit allows to mount the digitizerNETBOX/generatorNETBOX into a standard 19" rack. The digitizerNETBOX/generatorNETBOX DN2 requires two height units of the 19" rack.

Multiple digitizerNETBOX/generatorNETBOX products can be mounted one on top of the other.

It is not possible to mount two digitizerNETBOX/generatorNETBOX DN2 products side by side into one 19" slot.



DC Power Supply

The DC power supply option is factory mounted and allows the connection of a DC signal directly to the digitizerNETBOX/generatorNETBOX.

AC Cable Options

The system is delivered with a connection cable meeting your countries power connection. Other power cables can be ordered separately to connect your products with your local power connection system. A comprehensive list of all world-wide power plugs in use can be found on the IEC (International Electrotechnical Commission) website: <http://www.iec.ch/worldplugs/>

The following power cable options are available from Spectrum:

001: Universal Type for IEC Plug Type E and Type F

The power cable is suitable for Continental Europe, Korea and others.

Cab-Pwr-001: 180 cm cable to CEE 7/VII



002: IEC Plug Type B

The power cable complies to standards UL 62 and UL 1581 and is suitable for US, Canada, Taiwan and others.

Cab-Pwr-002: 180 cm cable for NEMA5-15P



003: IEC Plug Type G

The power cable is suitable for United Kingdom, Ireland, Hong Kong, Saudi Arabia and others.

Cab-Pwr-003: 180 cm cable to BS 1363A



004: IEC Plug Type J

The power cable is suitable for Switzerland and others.

Cab-Pwr-004: 180 cm cable for SEV type 12



005: IEC Plug Type I

The power cable is suitable for Mainland China, Australia, New Zealand, Argentina and others.

Cab-Pwr-005: 180 cm cable for AS 3112



006: IEC Plug Type M

The power cable is suitable for India, Singapore, South Africa and others.

Cab-Pwr-006: 180 cm cable for IEC 83-B



007: IEC Plug Type K

The power cable is suitable for Denmark and others.

Cab-Pwr-007: 180 cm cable for SR 107-2-D



008: IEC Plug Type H

The power cable is suitable for Israel.

Cab-Pwr-008: 180 cm cable for SI 32



009: IEC Plug Type B

The power cable complies to standard JIS C3306 and is suitable for Japan.

Cab-Pwr-009: 180 cm cable for NEMA5-15P




010: IEC Plug Type L

The power cable is suitable for Italy, Chile and others.

Cab-Pwr-010: 180 cm cable for CEI 23-16



The Spectrum type plate

| | | |
|---|----------------------------|-------------------------------------|
|  | 1 DN2.496-16 | |
| | Mem: 1 GS 3 | SN: 08085 4 |
| Options: 5 | | |
| Board 1: SN 08225 6 | | Board 2: SN 8226 7 |
| Version: 1 8 | | Prod. week: 18/2013 9 |
| MAC address: 00-03-2D-1E-8C-55 2 | | |

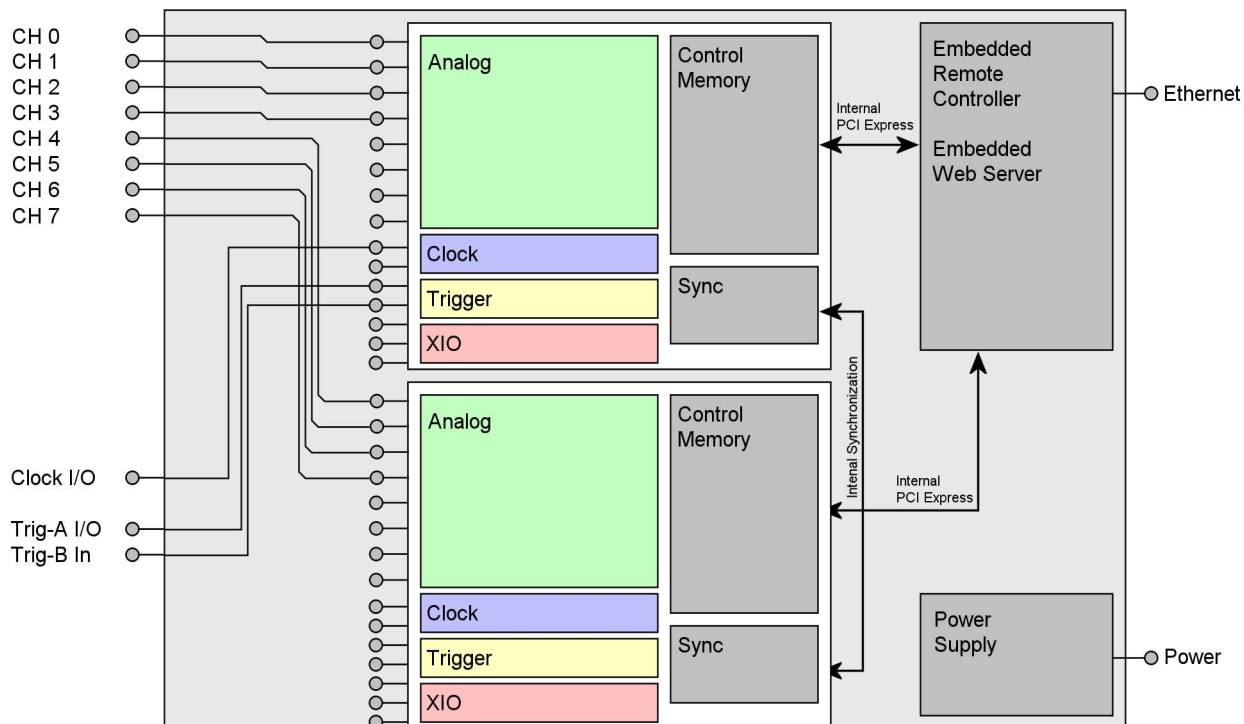
The Spectrum type plate, which consists of the following components, can be found on the back of all netbox products. Please check whether the printed information is the same as the information on your delivery note. All this information can also be read out by software:

- 1** The digitizerNETBOX/generatorNETBOX type, consisting of the abbreviation for the digitizerNETBOX/generatorNETBOX chassis type (DN2 in this example), the model type (496 in this example) and the number of channels (16 in this example)
- 2** The MAC address of the device. The MAC address is fixed and cannot be changed by the user. To check the MAC address by software one can use the integrated web pages of the digitizerNETBOX/generatorNETBOX.
- 3** The installed complete data acquisition memory of the digitizerNETBOX/generatorNETBOX. As in our example there are two internal digitizer/generator modules installed the memory is shared between them. Each internal digitizer/generator module has 512 MSamples installed.
- 4** The serial number of the digitizerNETBOX/generatorNETBOX itself. This is the serial number also found on the delivery note.
- 5** Installed options of the digitizerNETBOX/generatorNETBOX.
- 6** The serial number of the first internal digitizer/generator module.
- 7** The serial number of the second internal digitizer/generator module.
- 8** The hardware version of the digitizerNETBOX/generatorNETBOX. The hardware and firmware versions of the installed digitizer/generator modules are found using the Spectrum Control Center.
- 9** The date of production of the digitizerNETBOX/generatorNETBOX consisting of the calendar week and the year.

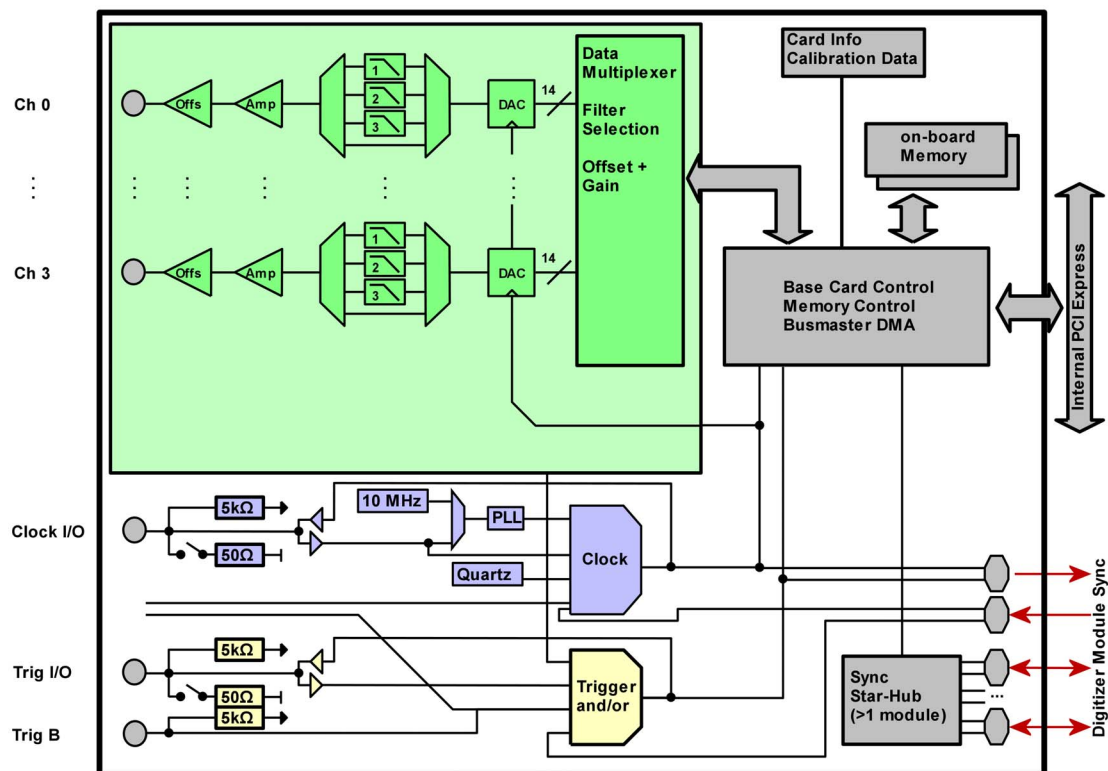
Please always supply us with the above information, especially the serial number in case of support request. That allows us to answer your questions as soon as possible. Thank you.

Hardware information

Block diagram of generatorNETBOX DN2



Block diagram of generatorNETBOX module DN2.60x



Technical Data

Analog Outputs

| | | |
|--------------------------------------|-----------------------|--|
| Resolution | | 14 bit |
| Output amplitude | software programmable | ±100 mV up to ±3 V in 1 mV steps (Amp option: ±333 mV up to ±10 V in 3 mV steps) |
| Output offset | software programmable | ±3 V in 1 mV steps (Amp option: ±10 V in 3 mV steps) |
| Filters | software programmable | no filter or one of 3 different filters as defined in technical data section |
| DAC Differential non linearity (DNL) | DAC only | ±1.5 LSB typical |
| DAC Integral non linearity (INL) | DAC only | ±1.0 LSB typical |
| Output resistance | | < 1 Ohm |
| Minimum output load | | 35 Ohm (not short circuit protected) |
| Max output swing in 50 Ohm | | ± 3 V (offset + amplitude) |
| Max slew rate (no filter) | | > 0.9 V/ns |
| Crosstalk @ 1 MHz signal ±3 V | | < -80 dB |
| Output accuracy | | < 1% |

Trigger

| | | |
|---|-----------------------|--|
| Running mode | software programmable | Singleshot, FIFO mode (Streaming), Repeated Replay, Single Restart, Sequence Mode |
| Trigger edge | software programmable | Rising edge, falling edge or both edges |
| Trigger pulse width | software programmable | 0 to [64k - 1] samples in steps of 1 sample |
| Trigger delay | software programmable | 0 to [64k - 1] samples in steps of 1 sample |
| Memory depth | software programmable | 8 up to [installed memory / number of active channels] samples in steps of 4 |
| Multiple Replay segment size | software programmable | 8 up to [installed memory / 2 / active channels] samples in steps of 4 |
| Multiple Replay, Gated Replay: re-arming time | | < 4 samples |
| Trigger output delay | | One positive edge after internal trigger event |
| Internal/External trigger accuracy | | 1 sample |
| External trigger type (input and output) | | 3.3V LVTTTL compatible (5V tolerant with base card hardware version > V20) |
| External trigger input | | Low ≤ 0.8 V, High ≥ 2.0 V, ≥ 8 ns in pulse stretch mode, ≥ 2 clock periods all other modes |
| External trigger maximum voltage | | -0.5 V up to +5.7 V (internally clamped to 5.0V, 100 mA max. clamping current) |
| Trigger impedance | software programmable | 50 Ohm / high impedance (> 4kOhm) |
| External trigger output type | | 3.3 V LVTTTL |
| External trigger output levels | | Low ≤ 0.4 V, High ≥ 2.4 V, TTL compatible |
| External trigger output drive strength | | Capable of driving 50 ohm load, maximum drive strength ±128 mA |
| Output delay trigger to 1st sample | | 15/16 clocks (2/1 channel/module) |
| Gate end to last replayed sample | | 15/16 clocks (2/1 channel/module) |
| Gate end alignment | | 2 samples (1 ch), 1 sample (2 or 4 ch) |

Clock

| | | |
|--|-----------------------|--|
| Clock Modes | software programmable | internal PLL, internal quartz, external clock, external divided, external reference clock, sync |
| Internal clock range (PLL mode) | software programmable | 1 kS/s to max using internal reference, 50kS/s to max using external reference clock |
| Internal clock accuracy | | ≤ 20 ppm |
| Internal clock setup granularity | | ≤ 1% of range (100M, 10M, 1M, 100k,...): Examples: range 1M to 10M: stepsize ≤ 100k |
| External reference clock range | software programmable | ≥ 1.0 MHz and ≤ 125.0 MHz |
| External clock impedance | software programmable | 50 Ohm / high impedance (> 4kOhm) |
| External clock range | | see „Dynamic Parameters“ table below |
| External clock delay to internal clock | | 5.4 ns |
| External clock type/edge | | 3.3V LVTTTL compatible, rising edge used |
| External clock input | | Low level ≤ 0.8 V, High level ≥ 2.0 V, duty cycle: 45% - 55% |
| External clock maximum voltage | | -0.5 V up to +3.8 V (internally clamped to 3.3V, 100 mA max. clamping current) (not 5V tolerant) |
| External clock output type | | 3.3 V LVTTTL |
| External clock output levels | | Low ≤ 0.4 V, High ≥ 2.4 V, TTL compatible |
| External clock output drive strength | | Capable of driving 50 ohm load, maximum drive strength ±128 mA |
| Synchronization clock divider | software programmable | 2 up to [8k - 2] in steps of 2 |
| ABA mode clock divider for slow clock | software programmable | 8 up to 524280 in steps of 8 |

Clock and Filter

| | M2i.6011 M2i.6012 | M2i.6021 M2i.6022 | M2i.6030 M2i.6031 M2i.6033 M2i.6034 DN2.603-xx |
|---------------------------|-----------------------|------------------------|--|
| max internal clock | 20 MS/s | 62.5 MS/s | 125 MS/s |
| max external clock | 20 MS/s | 62.5 MS/s | 125 MS/s |
| -3 dB bandwidth no filter | > 10 MHz | > 30 MHz | > 60 MHz |
| Filter 3: Characteristics | 4th order Butterworth | | 5th order Butterworth |
| Filter 3: -3 dB bandwidth | 5 MHz (typ. 5.4 MHz) | 10 MHz (typ. 11.4 MHz) | 25 MHz (typ. 26.5 MHz) |
| Filter 2: Characteristics | 4th order Butterworth | | 4th order Butterworth |
| Filter 2: -3 dB bandwidth | 1 MHz (typ. 1.2 MHz) | 2 MHz (typ. 2.4 MHz) | 5 MHz (typ. 5.8 MHz) |
| Filter 1: Characteristics | 4th order Butterworth | | 4th order Butterworth |
| Filter 1: -3 dB bandwidth | 100 kHz (typ. 96 kHz) | 200 kHz (typ. 200 kHz) | 500 kHz (typ. 495 kHz) |

Sequence Replay Mode

| | | |
|---------------------------------------|-----------------------|---|
| Number of sequence steps | software programmable | 1 up to 512 (sequence steps can be overloaded at runtime) |
| Number of memory segments | software programmable | 2 up to 256 (segment data can be overloaded at runtime) |
| Minimum segment size | software programmable | 32 samples in steps of 8 samples. |
| Maximum segment size | software programmable | Installed on-board memory (in samples) / active channels / number of sequence segments (round up to the next power of two) |
| Loop Count | software programmable | 1 to 1M loops |
| Sequence Step Commands | software programmable | Loop for #Loops, Next, Loop until Trigger, End Sequence |
| Special Commands | software programmable | Data Overload at runtime, sequence steps overload at runtime |
| Limitations for synchronized products | | Software commands changing the sequence as well as „Loop until trigger“ are not synchronized between cards. This also applies to multiple AWG modules in a generatorNETBOX. |

Connectors

| | | | |
|------------------------|------------------------|---|--------------------------|
| Analog Inputs | | 9 mm BNC female (one for each single-ended input) | Cable-Type: Cab-9m-xx-xx |
| Trigger A Input/Output | programmable direction | 9 mm BNC female | Cable-Type: Cab-9m-xx-xx |
| Trigger B Input | | 9 mm BNC female | Cable-Type: Cab-9m-xx-xx |
| Clock Input/Output | programmable direction | 9 mm BNC female | Cable-Type: Cab-9m-xx-xx |

Option digitizerNETBOX/generatorNETBOX embedded server (DN2.xxx-Emb, DN6.xxx-Emb)

| | | |
|-----------------------------|--|--|
| CPU | | Intel Quad Core 2 GHz |
| System memory | | 4 GByte RAM |
| System data storage | | Internal 128 GByte SSD |
| Development access | | Remote Linux command shell (ssh), no graphical interface (GUI) available |
| Accessible Hardware | | Full access to Spectrum instruments, LAN, front panel LEDs, RAM, SSD |
| Integrated operating system | | OpenSuse 12.2 with kernel 4.4.7. |
| Internal PCIe connection | | DN2.20, DN2.46, DN2.47, DN2.49, DN2.59, DN2.60 PCIe x1, Gen1 DN6.46, DN6.49, DN6.59 DN2.22, DN2.44, DN2.66 PCIe x1, Gen2 DN6.22, DN6.44, DN6.66 |

Ethernet specific details

| | | |
|---------------------------|--------------|---|
| LAN Connection | | Standard RJ45 |
| LAN Speed | | Auto Sensing: GBit Ethernet, 100BASE-T, 10BASE-T |
| LAN IP address | programmable | DHCP (IPv4) with AutoIP fall-back (169.254.x.y), fixed IP (IPv4) |
| Sustained Streaming speed | | DN2.20, DN2.46, DN2.47, DN2.49, DN2.60 up to 70 MByte/s DN6.46, DN6.49 DN2.59, DN2.22, DN2.44, DN2.66 up to 100 MByte/s DN6.59, DN6.22, DN6.44, DN6.66 |
| Used TCP/UDP Ports | | Webserver: 80 mDNS Daemon: 5353 VISA Discovery Protocol: 111, 9757 UPNP Daemon: 1900 Spectrum Remote Server: 1026, 5025 |

Power connection details

| | | |
|---------------------------|--|--|
| Mains AC power supply | | Input voltage: 100 to 240 VAC, 50 to 60 Hz |
| AC power supply connector | | IEC 60320-1-C14 (PC standard coupler) |
| Power supply cord | | power cord included for Schuko contact (CEE 7/7) |

Serial connection details (DN2.xxx with hardware ≥ V11)

| | | |
|---------------------------|--|--|
| Serial connection (RS232) | | For diagnostic purposes only. Do not use, unless being instructed by a Spectrum support agent. |
|---------------------------|--|--|

Certification, Compliance, Warranty

| | | |
|-------------------------------|--|---|
| EMC Immunity | | Compliant with CE Mark |
| EMC Emission | | Compliant with CE Mark |
| Product warranty | | 5 years starting with the day of delivery |
| Software and firmware updates | | Life-time, free of charge |

Environmental and Physical Details DN2.xxx

| | | |
|--|-----------|---------------------------------------|
| Dimension of Chassis without connectors or bumpers | L x W x H | 366 mm x 267 mm x 87 mm |
| Dimension of Chassis with 19" rack mount option | L x W x H | 366 mm x 482.6 mm x 87 mm (2U height) |
| Weight (1 internal acquisition/generation module) | | 6.3 kg, with rack mount kit: 6.8 kg |
| Weight (2 internal acquisition/generation modules) | | 6.7 kg, with rack mount kit 7.2 kg |
| Warm up time | | 20 minutes |
| Operating temperature | | 0°C to 40°C |
| Storage temperature | | -10°C to 70°C |
| Humidity | | 10% to 90% |
| Dimension of packing (single DN2) | L x W x H | 470 mm x 390 mm x 180 mm |
| Volume weight of Packing (single DN2) | | 7.0 kgs |

Power Consumption

| | 230 VAC | | 12 VDC | | 24 VDC | |
|---|---------|------|--------|-----|--------|-----|
| 4 channel version, standard memory | 0.14 A | 32 W | TBD | TBD | TBD | TBD |
| 8 channel version, standard memory | TBD | TBD | TBD | TBD | TBD | TBD |
| 4 channel version, 1 x 1 GSample memory | TBD | TBD | TBD | TBD | TBD | TBD |
| 8 channel version, 2 x 1 GSample memory | TBD | TBD | TBD | TBD | TBD | TBD |

MTBF

MTBF

100000 hours

Dynamic Parameters

| | M2i.6011 M2i.6012 | M2i.6011 M2i.6012 | M2i.6011 M2i.6012 | M2i.6021 M2i.6022 | M2i.6021 M2i.6022 | M2i.6030 M2i.6031 M2i.6033 M2i.6034 DN2.603-xx | M2i.6030 M2i.6031 M2i.6033 M2i.6034 DN2.603-xx | M2i.6030 M2i.6031 M2i.6033 M2i.6034 DN2.603-xx | M2i.6030 M2i.6031 M2i.6033 M2i.6034 DN2.603-xx |
|-------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|--|--|--|--|
| max internal / external clock | 20 MS/s | 20 MS/s | 20 MS/s | 62.5 MS/s | 62.5 MS/s | 62.5 MS/s | 62.5 MS/s | 125 MS/s | 125 MS/s |
| min internal clock | 1 kS/s | 1 kS/s | 1 kS/s | 1 kS/s | 1 kS/s | 1 kS/s | 1 kS/s | 1 kS/s | 1 kS/s |
| min external clock | DC | DC | DC | DC | DC | DC | DC | DC | DC |
| Test - Samplerate | 20 MS/s | 20 MS/s | 20 MS/s | 62.5 MS/s | 62.5 MS/s | 62.5 MS/s | 62.5 MS/s | 125 MS/s | 125 MS/s |
| Output Frequency | 80 kHz | 800 kHz | 4 MHz | 170 kHz | 1.7 MHz | 400 kHz | 4 MHz | 400 kHz | 4 MHz |
| Output Level | ±2 V | ±2 V | ±2 V | ±2 V | ±2 V | ±2 V | ±2 V | ±2 V | ±2 V |
| Used Filter | 100 kHz | 1 MHz | 5 MHz | 200 kHz | 2 MHz | 500 kHz | 5 MHz | 500 kHz | 5 MHz |
| SNR (typ) | > 61.5 dB | > 60.2 dB | > 54.5 dB | > 61.5 dB | > 59.5 dB | > 61.5 dB | > 55.0 dB | > 61.0 dB | > 56.0 dB |
| THD (typ) | < -70.4 dB | < -67.5 dB | < -45.0 dB | < -72.7 dB | < -62.5 dB | < -71.5 dB | < -55.6 dB | < -71.5 dB | < -56.0 dB |
| SFDR (typ), excl harm. | > 85.5 dB | > 72.0 dB | > 60.0 dB | > 81.5 dB | > 68.5 dB | > 82.8 dB | > 66.5 dB | > 72.0 dB | > 67.0 dB |

Dynamic parameters are measured at the given output level and 50 Ohm termination with a high resolution data acquisition card and are calculated from the spectrum. The sample rate that is selected is the maximum possible one. All available channels are activated for the tests. SNR and SFDR figures may differ depending on the quality of the used PC. SNR = Signal to Noise Ratio, THD = Total Harmonic Distortion, SFDR = Spurious Free Dynamic Range

Order Information

The generatorNETBOX is equipped with a large internal memory and supports standard replay, FIFO replay (streaming), Multiple Replay, Gated Replay, Continuous Replay (Loop), Single-Restart as well as Sequence. Operating system drivers for Windows/Linux 32 bit and 64 bit, drivers and examples for C/C++, IVI (Function Generator class), LabVIEW (Windows), MATLAB (Windows and Linux), .NET, Delphi, Java, Python and a Professional license of the oscilloscope software SBench 6 are included.

The system is delivered with a connection cable meeting your countries power connection. Additional power connections with other standards are available as option.

generatorNETBOX DN2 - Ethernet/LXI Interface

| Order no. | D/A Resolution | Bandwidth | Single-Ended Channels | Update Rate | Installed Memory | Available Memory Options |
|------------|----------------|-----------|-----------------------|---|------------------|--------------------------|
| DN2.603-04 | 14 Bit | 60 MHz | 4 channels | 125 MS/s (2 channels) 60 MS/s (4 channels) | 1 x 512MS | 1 x 1GS |
| DN2.603-08 | 14 Bit | 60 MHz | 8 channels | 125 MS/s (4 channels) 60 MS/s (8 channels) | 2 x 512MS | 2 x 1GS |

Options

| Order no. | Option |
|---------------|--|
| DN2.xxx-Rack | 19" rack mounting set for self mounting |
| DN2.xxx-Emb | Extension to Embedded Server: CPU, more memory, SSD. Access via remote Linux secure shell (ssh) |
| DN2.xxx-1x1GS | Memory extension to 1 x 1 GSample for 46x-04, 46x-08, 49x-04, 49x-08 versions |
| DN2.xxx-2x1GS | Memory extension to 2 x 1 GSample for 46x-16 and 49x-16 versions |
| DN2.xxx-DC12 | 12 VDC internal power supply. Replaces AC power supply. Accepts 9 V to 18 V DC input. Screw terminals. |
| DN2.xxx-DC24 | 24 VDC internal power supply. Replaces AC power supply. Accepts 18 V to 36 V DC input. Screw terminals |
| DN2.xxx-BTPWR | Boot on Power On: the digitizerNETBOX/generatorNETBOX automatically boots if power is switched on. |

Calibration

| Order no. | Option |
|---------------|--|
| DN2.xxx-Recal | Recalibration of complete digitizerNETBOX/generatorNETBOX DN2 including calibration protocol |

BNC Cables

The standard adapter cables are based on RG174 cables and have a nominal attenuation of 0.3 dB/m at 100 MHz.

| for Connections | Connection | Length | to SMA male | to SMA female | to BNC male | to SMB female |
|-----------------|------------|--------|----------------|----------------|---------------|---------------|
| All | BNC male | 80 cm | Cab-9m-3mA-80 | Cab-9m-3fA-80 | Cab-9m-9m-80 | Cab-9m-3f-80 |
| All | BNC male | 200 cm | Cab-9m-3mA-200 | Cab-9m-3fA-200 | Cab-9m-9m-200 | Cab-9m-3f-200 |

Hardware Installation

Warnings

ESD Precautions

The digitizerNETBOX/generatorNETBOX products internally contain electronic components that can be damaged by electrostatic discharge (ESD). The grounded chassis itself gives a very good protection against ESD.

Before installing the board in your system or protective conductive packaging, discharge yourself by touching a grounded bare metal surface or approved anti-static mat before picking up this ESD sensitive product.



Opening the Chassis

There are no components inside the chassis that need any operating by the user. In contrary there are a lot of components that may be harmed when operated improperly by a use.

As Spectrum only gives a warranty on the complete instrument, opening the chassis will make you loose the warranty.

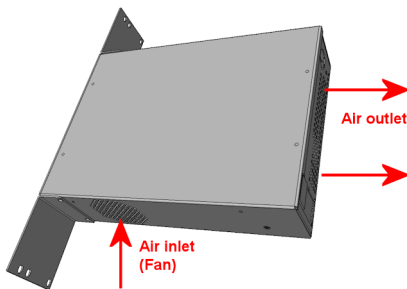


Cooling Precautions

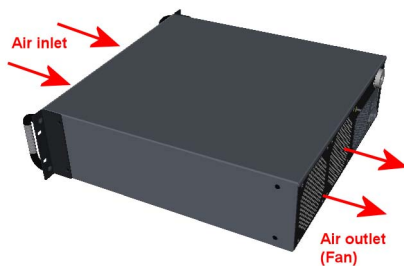
The high performance digitizers/generators of the digitizerNETBOX/generatorNETBOX operate with components having very high power consumption. Therefore the digitizerNETBOX/generatorNETBOX models have sufficient cooling fans.

Make sure that the air inlets and air outlets are free and uncovered and in case of a DN6 ensure that the installed filters at the inlet are cleaned regularly.

DN2 airflow:



DN6 airflow:



Sources of noise

The digitizerNETBOX/generatorNETBOX is using electrical components with very high resolution and high sensitivity. The signal inputs will acquire your signals with a high quality but will also collect spurious noise signals from various sources - especially if using the inputs in high impedance mode. To minimize this effect the cabling must be made with care.

Keep away the cables from any sources that may inject noise into the signals like other instruments, crossing or even worse running in parallel with other cables with high frequency signals on them. If possible use differential signalling to minimize the effects of injected noise.



A standard GND screw on the back of the chassis allows to connect the metal chassis to measurement ground to reduce noise based on ground loops and ground level differences.



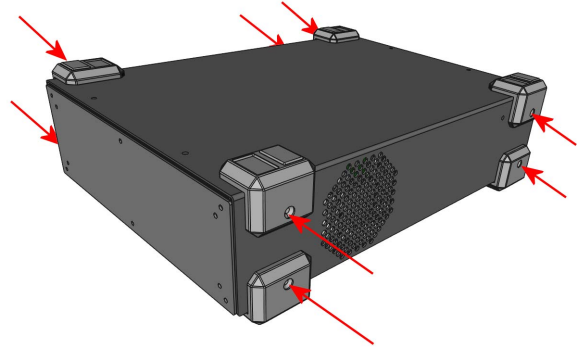
Installing 19" rack mount option for DN2

This option has to be ordered separately. It can be ordered together with the digitizerNETBOX/generatorNETBOX at the time of purchase or it can be ordered later on, if it is becoming necessary to mount the digitizerNETBOX/generatorNETBOX into a 19" rack. In any case the digitizerNETBOX/generatorNETBOX comes pre-configured as a standalone unit, which has then to manually be converted to the rackmount configuration by the user.

Step 1

The rackmount option comes with the required Torx T20 size screw driver to un-mount the default screws holding the bumper feet.

Unscrew these 8 Torx T20 screws with the provided screw driver and keep them together with the un-mounted bumpers for possible later use in case the rackmount option shall be un-mounted again in the future.



Step 2

Mount the 19" rack mount extension using the four phillips-head screws that are also provided with each rack mount extension. Two screws are required for each rack mounting bracket.

Care should be taken to not overtighten the screws.



Installing 19" rack mount option for DN6

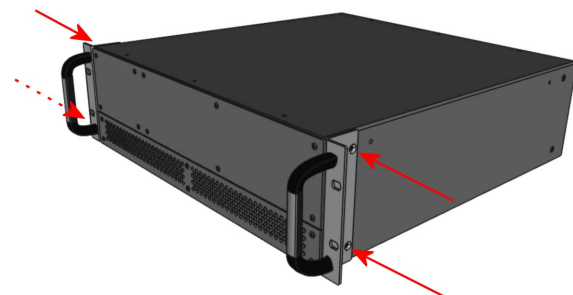
Installing the rack mount extension for the DN6 series follows the same principles as for the DN2 models shown above.

Step 1

Unscrew the existing bumper corner pieces with the provided screw driver and keep them together with the un-mounted bumpers for possible later use in case the rackmount option shall be un-mounted again in the future.

Step 2

Mount the 19" rack mount extension using the four phillips-head screws that are also provided with each rack mount extension. Two screws are required for each rack mounting bracket. Care should be taken to not overtighten the screws.



In addition to using the provided rack mount extension for fastening the DN6 device within the 19" rack, the user must take additional measures, suitable for the used rack, to provide adequate mechanical support at the backside of the device.

This support is required for DN6 devices due to their higher weight compared to DN2 devices.

Setup of digitizerNETBOX/generatorNETBOX

Connections

First of all the digitizerNETBOX/generatorNETBOX needs to be connected to both power line and LAN environment:

Power

Connect the power line cable to a matching power source. First connect the cable to the digitizerNETBOX/generatorNETBOX, second connect the cable to the power plug. Please check the technical data section to see the requirements for the power supply.

If using a DC power option please be sure to have the external DC power source switched off while connecting the power lines. Only switch on the power supply after all connections have been done and are checked.



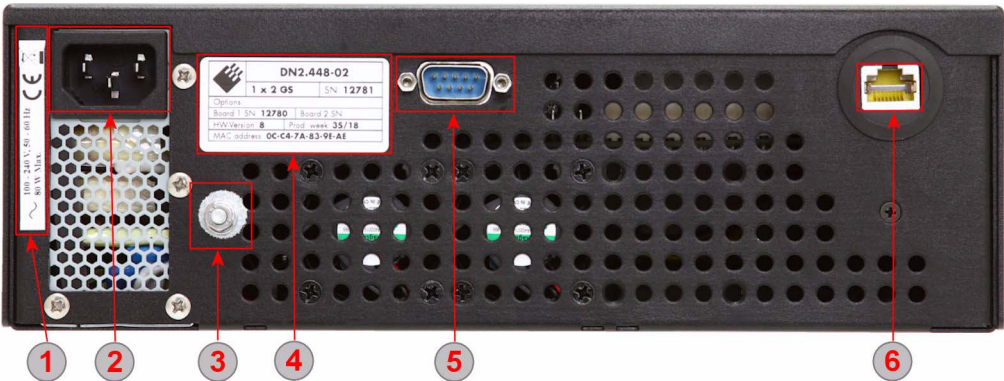
Ethernet

Connect the digitizerNETBOX/generatorNETBOX to either your company LAN or directly to your PC. Please use a standard Cat-5 or better Ethernet cable for the connection.

Back Side DN2

The right hand pictures shows the back side of one digitizerNETBOX/generatorNETBOX with standard AC power supply. The different power supply options are described later in this chapter. The picture is taken from a digitizerNETBOX hardware revision V8. Older version look different.

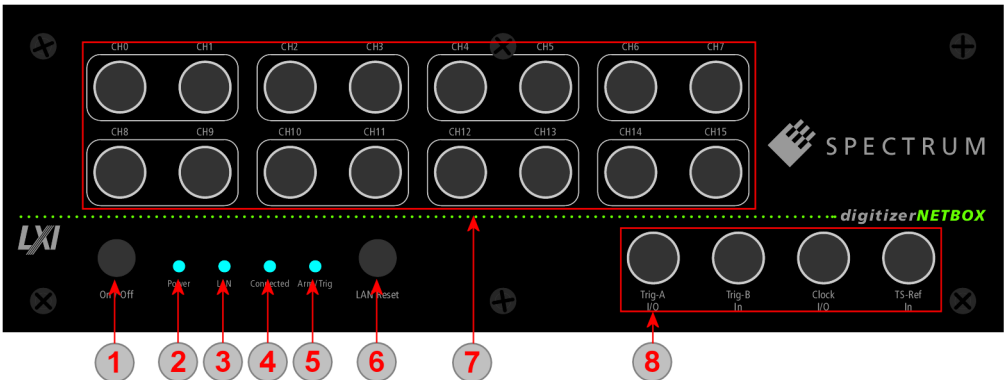
Please see the table below for a description of the different marked areas:



| Area | Name | Description |
|------|----------------------|---|
| 1 | Power Label | The label shows the power specification in detail. Please check the listed specification before connection the power line |
| 2 | Power Connector (AC) | Standard three pole power connector. A matching power cable is included in the delivery. Separate power cables for other country standards are available upon request. |
| 3 | GND Screw | This screw is directly connected to Chassis ground and be used to add a low resistance ground connection to the system |
| 4 | Type plate | The type plate shows exact type, option, serial number, versions and production week. A more detailed description of the type plate is found in a separate chapter of the manual |
| 5 | Debug Port (DSUB) | This port is for debug purposes only. Please only connect a cable when asked by the Spectrum support group. The debug connector is a feature of hardware revision V8 and is not available on earlier versions |
| 6 | LAN Connection | A standard Ethernet port. Please connect the device with your PC/Laptop or company LAN before start |

Front Panel DN2

The right-hand drawing gives you an overview on one digitizerNETBOX DN2 front panel. Depending on the version of the digitizerNETBOX or generatorNETBOX you have the area 7 may differ in terms of number of channels or grouping of the channels.



In area 8 a version with 4 BNC connectors is shown. Other versions with 5 SMA, 6 BNC or 7 SMA connectors are also available. Please see the table below for the different connections.

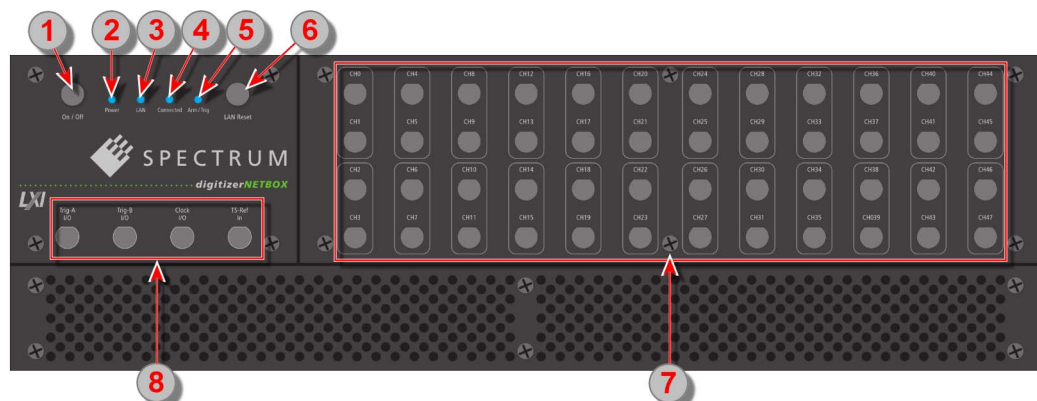
| Area | Name | Status | Description |
|------|--|---|---|
| 1 | Power On/Off | press while device stopped short press while device is running long press while device is running | digitizerNETBOX/generatorNETBOX is started digitizerNETBOX/generatorNETBOX is closing the embedded controller and is going into standby mode digitizerNETBOX/generatorNETBOX is aborted and is going into standby. Please only use this stop method if the digitizerNETBOX/generatorNETBOX is not responding |
| 2 | Power LED | LED off LED orange LED green | no power connected to the device power is connected, device is in standby mode device has started and is working |
| 3 | LAN LED | LED off LED red LED green LED green flashing | Only off during boot up, turning to either red or green afterwards. If permanently off, contact support. Error while trying to get a LAN connection Device is connected to LAN. Device is connected to LAN. Flashing indicates LAN ID (see webserver) |
| 4 | Connected LED | LED off LED green | Device is not in use Device is in use by other PC |
| 5 | Arm/Trigger | LED off LED green | No trigger detected, device is waiting for trigger event, or not armed at all Trigger detected, acquisition is running or already finished |
| 6 | LAN Reset | press once | Does a reset of the LAN settings to default state. The reset button needs to be pressed for 4 seconds to issue the reset. The reset command is then issued immediately independent of the current run state of the device. |
| 7 | Signal Connections | | Connect your input signals here. For differential connections use even channels for positive phase and odd channels for negative phase. |
| 8 | Control Connections (4 BNC connector version, for M2i module based products) | Trig-A I/O Trig-B In Clock I/O TS-Ref In | Trigger A with programmable input or output. This is the main external trigger Trigger B, input only. This trigger is referenced in the manual as TRIG_XIO0 Clock with programmable input or output Timestamp Reference Clock Input |
| 8 | Control Connections (5 SMA connector version, for M3i module based products) | Clock In Clock Out Trig-A In Trig-B I/O TS_Ref In | External clock input External clock output Trigger A, input only. This is the main external trigger. The trigger line is reference in the manual as EXT0 Trigger B/Multi Purpose X0 with programmable direction. The connection is referenced in the manual as X0 Timestamp Reference Clock Input |
| 8 | Control Connections (6 BNC connector version, for M2p module based products) | Clock In Trig In X0 Out X1 I/O X2 I/O X3 I/O | External clock input Trigger, input only. This is the main external trigger. The trigger line is reference in the manual as EXT0 Multi Purpose X0, output only. Clock output available. The connection is referenced in the manual as X0 Multi Purpose X1 with programmable direction. The connection is referenced in the manual as X1 Multi Purpose X2 with programmable direction. The connection is referenced in the manual as X2 Multi Purpose X3 with programmable direction. The connection is referenced in the manual as X3 |
| 8 | Control Connections (7 SMA connector version, for M4i module based products) | Clock In Clock Out Trig0 In Trig1 In X0 I/O X1 I/O X2 I/O | External clock input External clock output Trigger 0, input only. This is the main external trigger. The trigger line is reference in the manual as EXT0 Trigger 1, input only. This is the secondary external trigger. This line is reference in the manual as EXT1 Multi Purpose X0 with programmable direction. The connection is referenced in the manual as X0 Multi Purpose X1 with programmable direction. The connection is referenced in the manual as X1 Multi Purpose X2 with programmable direction. The connection is referenced in the manual as X2 |

Front Panel DN6

The right-hand drawing gives you an overview on one digitizerNETBOX DN6 front panel.

Depending on the version of the digitizerNETBOX or generatorNETBOX you have, the area 7 may differ in terms of number of channels or grouping of the channels.

In area 8 a version with 4 BNC connectors is shown. Other versions with 5 SMA, 6 BNC or 7 SMA connectors are also available. Please see the table below for the different connections.



| Area | Name | Status | Description |
|------|--------------|---|--|
| 1 | Power On/Off | press while device stopped short press while device is running long press while device is running | digitizerNETBOX/generatorNETBOX is started digitizerNETBOX/generatorNETBOX is closing the embedded controller and is going into standby mode digitizerNETBOX/generatorNETBOX is aborted and is going into standby. Please only use this stop method if the digitizerNETBOX/generatorNETBOX is not responding |
| 2 | Power LED | LED off LED orange LED green | no power connected to the device power is connected, device is in standby mode device has started and is working |
| 3 | LAN LED | LED off LED red LED green LED green flashing | Only off during boot up, turning to either red or green afterwards. If permanently off, contact support. Error while trying to get a LAN connection. Device is connected to LAN. Device is connected to LAN. Flashing indicates LAN ID (see webserver). |

| Area | Name | Status | Description |
|------|--|------------|--|
| 4 | Connected LED | LED off | Device is not in use |
| | | LED green | Device is in use by other PC |
| 5 | Arm/Trigger | LED off | No trigger detected, device is waiting for trigger event, or not armed at all |
| | | LED green | Trigger detected, acquisition is running or already finished |
| 6 | LAN Reset | press once | Does a reset of the LAN settings to default state. The reset button needs to be pressed for 4 seconds to issue the reset. The reset command is then issued immediatley independent of the current run state of the device. |
| 7 | Signal Connections | | Connect your input signals here. For differential connections use even channels for positive phase and odd channels for negative phase. |
| 8 | Control Connections (4 BNC connector version, for M2i module based products) | Trig-A I/O | Trigger A with programmable input or output. This is the main external trigger |
| | | Trig-B In | Trigger B, input only. This trigger is referenced in the manual as TRIG_XIO0 |
| | | Clock I/O | Clock with programmable input or output |
| | | TS-Ref In | Timestamp Reference Clock Input |
| 8 | Control Connections (6 BNC connector version, for M2p module based products)) | Clock In | External clock input |
| | | Trig In | Trigger, input only. This is the main external trigger. The trigger line is reference in the manual as EXT0 |
| | | X0 Out | Multi Purpose X0, output only. Clock output available. The connection is referenced in the manual as X0 |
| | | X1 I/O | Multi Purpose X1 with programmable direction. The connection is referenced in the manual as X1 |
| | | X2 I/O | Multi Purpose X2 with programmable direction. The connection is referenced in the manual as X2 |
| | | X3 I/O | Multi Purpose X3 with programmable direction. The connection is referenced in the manual as X3 |
| 8 | Control Connections (7 SMA connector version, for M4i module based products) | Clock In | External clock input |
| | | Clock Out | External clock output |
| | | Trig0 In | Trigger 0, input only. This is the main external trigger. The trigger line is reference in the manual as EXT0 |
| | | Trig1 In | Trigger 1, input only. This is the secondary external trigger. This line is reference in the manual as EXT1 |
| | | X0 I/O | Multi Purpose X0 with programmable direction. The connection is referenced in the manual as X0 |
| | | X1 I/O | Multi Purpose X1 with programmable direction. The connection is referenced in the manual as X1 |
| | | X2 I/O | Multi Purpose X2 with programmable direction. The connection is referenced in the manual as X2 |
| | | | |

Ethernet Default Settings

The digitizerNETBOX/generatorNETBOX is started with the following Ethernet configuration:

| Setting | Default Setup |
|-----------|---|
| DHCP | enabled |
| Auto IP | enabled |
| Host Name | Default hostname as netbox type + serial number Example: DN2_465-08_sn8085 |

Detecting the digitizerNETBOX

Before accessing the digitizerNETBOX/generatorNETBOX one has to determine the IP address of the digitizerNETBOX/generatorNETBOX. Normally that can be done using one of the two methods described below:

Discovery Function

The digitizerNETBOX/generatorNETBOX responds to the VISA described Discovery function. The next chapter will show how to install and use the Spectrum control center to execute the discovery function and to find the Spectrum hardware. As the discovery function is a standard feature of all LXI devices there are other software packages that can find the digitizerNETBOX/generatorNETBOX using the discovery function:

- Spectrum control center (limited to Spectrum remote products)
- free LXI System Discovery Tool from the LXI consortium (www.lxistandard.org)
- Measurement and Automation Explorer from National Instruments (NI MAX)
- Keysight Connection Expert from Keysight Technologies

Additionally the discovery procedure can also be started from ones own specific application:

```
#define TIMEOUT_DISCOVERY    5000 // timeout value in ms

const uint32 dwMaxNumRemoteCards = 50;

char* pszVisa[dwMaxNumRemoteCards] = { NULL };
char* pszIdn[dwMaxNumRemoteCards] = { NULL };

const uint32 dwMaxIdnStringLen = 256;
const uint32 dwMaxVisaStringLen = 50;

// allocate memory for string list
for (uint32 i = 0; i < dwMaxNumRemoteCards; i++)
{
    pszVisa[i] = new char [dwMaxVisaStringLen];
    pszIdn[i] = new char [dwMaxIdnStringLen];
    memset (pszVisa[i], 0, dwMaxVisaStringLen);
    memset (pszIdn[i], 0, dwMaxIdnStringLen);
}

// first make discovery - check if there are any LXI compatible remote devices
dwError = spcm_dwDiscovery ((char**)pszVisa, dwMaxNumRemoteCards, dwMaxVisaStringLen, TIMEOUT_DISCOVERY);

// second: check from which manufacturer the devices are
spcm_dwSendIDNRequest ((char**)pszIdn, dwMaxNumRemoteCards, dwMaxIdnStringLen);

// Use the VISA strings of these devices with Spectrum as manufacturer
// for accessing remote devices without previous knowledge of their IP address
```

Finding the digitizerNETBOX/generatorNETBOX in the network

As the digitizerNETBOX/generatorNETBOX is a standard network device it has its own IP address and host name and can be found in the computer network. The standard host name consist of the model type and the serial number of the digitizerNETBOX/generatorNETBOX. The serial number is also found on the type plate on the back of the digitizerNETBOX/generatorNETBOX chassis.

As default DHCP (IPv4) will be used and an IP address will be automatically set. In case no DHCP server is found, an IP will be obtained using the AutoIP feature. This will lead to an IPv4 address of 169.254.x.y (with x and y being assigned to a free IP in the network) using a subnet mask of 255.255.0.0.

The default IP setup can also be restored, by using the „LAN Reset“ button on the device.

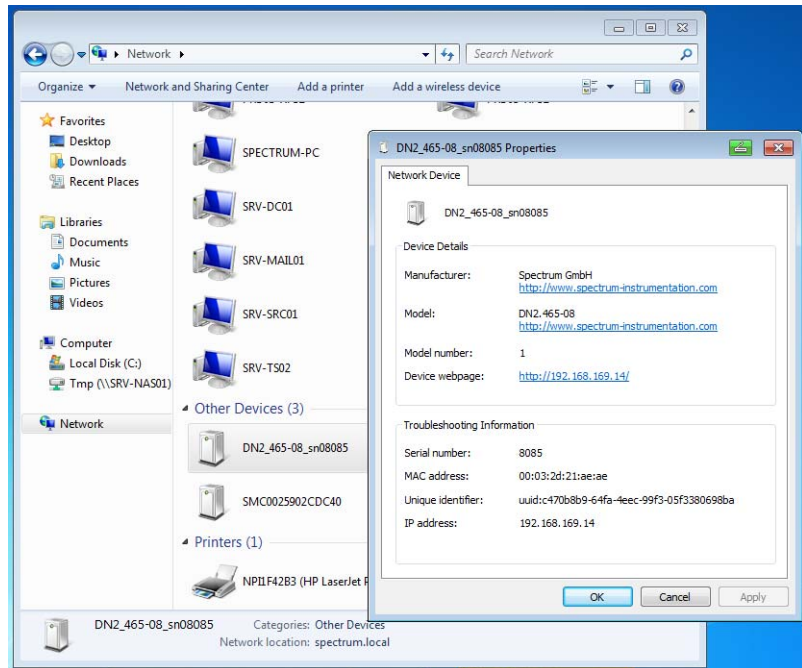
If a fixed IP address should be used instead, the parameters need to be set according to the current LAN requirements.

Windows 7, Windows 8, Windows 10

Under Windows 7, Windows 8 and Windows 10 the digitizerNETBOX and generatorNETBOX devices are listed under the „other devices“ tree with their given host name.

A right click on the digitizerNETBOX or generatorNETBOX device opens the properties window where you find further information on the device including the IP address.

From here it is possible to go the website of the device where all necessary information are found to access the device from software.

**Troubleshooting**

If the above methods do not work please try one of the following steps:

- Ask your network administrator for the IP address of the digitizerNETBOX/generatorNETBOX and access it directly over the IP address.
- Check your local firewall whether it allows access to the device and whether it allows to access the ports listed in the technical data section.
- Check with your network administrator whether the subnet, the device and the ports that are listed in the technical data section are accessible from your system due to company security settings.

Software Driver Installation

Before using the digitizerNETBOX/generatorNETBOX a software package and the appropriate API drivers must be installed that matches the operating system. The installation is done in different ways depending on the used operating system. The driver that is on USB-Stick supports all products of the digitizerNETBOX/generatorNETBOX family as well as all cards of the M2i/M3i/M4i/M4x/M2p series. That means that you can use the same driver for all products of these families.

Needed Software for operating

The digitizerNETBOX/generatorNETBOX comes fully installed and ready to start. However to operate the digitizerNETBOX or generatorNETBOX from the client PC there need to be some software packages to be installed there:

Spectrum driver API

The Spectrum API is installed automatically under Windows when installing the Card Control Center. Under Linux it is necessary to install the matching driver API for your Linux client system before installing the Card Control Center.

Spectrum Card Control Center

This software is the maintenance tool for all Spectrum products. In here the digitizerNETBOX/generatorNETBOX can be searched inside the LAN (Discovery function), all hardware information is found, updates and product tests can be done. The Card Control Center and all of its functions are explained in greater detail later on in this manual.

The card control center is available for Windows and Linux, both 32 bit and 64 bit (Windows 32 bit version also runs on WOW64)

SBench 6

SBench 6 allows to operate the digitizerNETBOX/generatorNETBOX in all hardware modes, displays data, streams to hard disk and allows to make calculations and exports. The digitizerNETBOX/generatorNETBOX is equipped with a full SBench 6 Professional license. Even if you want to operate the digitizerNETBOX/generatorNETBOX from your self written software it is recommended that you install SBench 6 to do first hardware tests and to validate your own software results with the software from the hardware manufacturer. For SBench 6 a dedicated manual is installed with the software package.

SBench 6 is available for Windows and Linux, both 32 bit and 64 bit (Windows 32 bit version also runs on WOW64)

Examples and Drivers

If you intend to operate the digitizerNETBOX/generatorNETBOX from a self written program, be it IVI based, C++, C#, LabVIEW, MATLAB or something else, it is necessary to install the matching drivers and examples for the platform you want to run.

Location

The needed software for operating the digitizerNETBOX/generatorNETBOX can be found on three different locations. Please choose the one most convenient for you.

Install software packages from USB-Stick

The USB-Stick that is delivered together with the digitizerNETBOX/generatorNETBOX contains the complete software and documentation package that is available for your digitizerNETBOX/generatorNETBOX. You find the software packages at the following locations on the USB-Stick:

| Software Package | Operating System | Location |
|--|------------------|------------------------------------|
| Card Control Center | Windows | \Install\Win |
| SBench 6 | Windows | \Install\Win |
| LabVIEW, MATLAB, IVI | Windows | \Install\Win |
| C++, C#, VB.NET, Delphi, Python, Java, LabWindows/CVI... | Windows | \Examples\... |
| Driver API | Linux | /Driver/linux/install_libonly.sh |
| Card Control Center | Linux | /Install/linux/SBench6 |
| SBench 6 | Linux | /Install/linux/spcm_control_center |
| MATLAB (64bit only) | Linux | /Install/linux |
| C++, Python, Java | Linux | /Examples/... |

Install software packages from the internet

All software packages are found on the download page under www.spectrum-instrumentation.com

Inhere the latest versions and updates are available.

Install software packages from the digitizerNETBOX/generatorNETBOX

For easy installation or for installation on machines that don't have access to a USB thumb drive, all software packages are also available for download directly from the digitizerNETBOX/generatorNETBOX.

Please go to the download page of the integrated webserver and download and execute the software packages.

Linux

Overview

The Spectrum M2i/M3i/M4i/M4x/M2p cards and digitizerNETBOX/generatorNETBOX products are delivered with Linux drivers suitable for Linux installations based on kernel 2.6, 3.x, 4.x or 5.x, single processor (non-SMP) and SMP systems, 32 bit and 64 bit systems. As each Linux distribution contains different kernel versions and different system setup it is in nearly every case necessary, to have a directly matching kernel driver for card level products to run it on a specific system. For digitizerNETBOX/generatorNETBOX products the library is sufficient and no kernel driver has to be installed.

Spectrum delivers pre-compiled kernel driver modules for a number of common distributions with the cards. You may try to use one of these kernel modules for different distributions which have a similar kernel version. Unfortunately this won't work in most cases as most Linux system refuse to load a driver which is not exactly matching. In this case it is possible to get the kernel driver sources from Spectrum. Please contact your local sales representative to get more details on this procedure.

The Standard delivery contains the pre-compiled kernel driver modules for the most popular Linux distributions, like Suse, Debian, Fedora and Ubuntu. The list with all pre-compiled and readily supported distributions and their respective kernel version can be found under: <http://spectrum-instrumentation.com/en/supported-linux-distributions> or via the shown QR code.

The Linux drivers have been tested with all above mentioned distributions by Spectrum. Each of these distributions has been installed with the default setup using no kernel updates. A lot more different distributions are used by customers with self compiled kernel driver modules.



Standard Driver Installation

The driver is delivered as installable kernel modules together with libraries to access the kernel driver. The installation script will help you with the installation of the kernel module and the library.

This installation is only needed if you are operating real locally installed cards. For software emulated demo cards, remotely installed cards or for digitizerNETBOX/generatorNETBOX products it is only necessary to install the libraries without a kernel as explained further below.



Login as root

It is necessary to have the root rights for installing a driver.

Call the `install.sh <install_path>` script

This script will install the kernel module and some helper scripts to a given directory. If you do not specify a directory it will use your home directory as destination. It is possible to move the installed driver files later to any other directory.

The script will give you a list of matching kernel modules. Therefore it checks for the system width (32 bit or 64 bit) and the processor (single or smp). The script will only show matching kernel modules. Select the kernel module matching your system. The script will then do the following steps:

- copy the selected kernel module to the install directory (spcm.o or spcm.ko)
- copy the helper scripts to the install directory (spcm_start.sh and spc_end.sh)
- copy and rename the matching library to /usr/lib (/usr/lib/libspcm_linux.so)

Udev support

Once the driver is loaded it automatically generates the device nodes under /dev. The cards are automatically named to /dev/spcm0, /dev/spcm1,...

You may use all the standard naming and rules that are available with udev.

Start the driver

Starting the driver can be done with the `spcm_start.sh` script that has been placed in the install directory. If udev is installed the script will only load the driver. If no udev is installed the start script will load the driver and make the required device nodes /dev/spcm0... for accessing the drivers. Please keep in mind that you need root rights to load the kernel module and to make the device nodes!

Using the dedicated start script makes sure that the device nodes are matching your system setup even if new hardware and drivers have been added in between. Background: when loading the device driver it gets assigned a „major“ number that is used to access this driver. All device nodes point to this major number instead of the driver name. The major numbers are assigned first come first served. This means that installing new hardware may result in different major numbers on the next system start.

Get first driver info

After the driver has been loaded successfully some information about the installed boards can be found in the `/proc/spcm_cards` file. Some basic information from the on-board EEPROM is listed for every card.

```
cat /proc/spcm_cards
```

Stop the driver

You may want to unload the driver and clean up all device nodes. This can be done using the `spcm_end.sh` script that has also been placed in the `install` directory

Standard Driver Update

A driver update is done with the same commands as shown above. Please make sure that the driver has been stopped before updating it. To stop the driver you may use the `spcm_end.sh` script.

Compilation of kernel driver sources (optional and local cards only)

The driver sources are only available for existing customers on special request and against a signed NDA. The driver sources are not part of the standard delivery. The driver source package contains only the sources of the kernel module, not the sources of the library.

Please do the following steps for compilation and installation of the kernel driver module:

Login as root

It is necessary to have the root rights for installing a driver.

Call the compile script `make_spcm_linux_kerneldrv.sh`

This script will examine the type of system you use and compile the kernel with the correct settings. If using a kernel 2.4 the makefile expects two symbolic links in your system:

- `/usr/src/linux` pointing to the correct kernel source directory
- `/usr/src/linux/.config` pointing to the currently used kernel configuration

The compile script will then automatically call the install script and install the just compiled kernel module in your home directory. The rest of the installation procedure is similar as explained above.

Update of a self compiled kernel driver

If the kernel driver has changed, one simply has to perform the same steps as shown above and recompile the kernel driver module. However the kernel driver module isn't changed very often.

Normally an update only needs new libraries. To update the libraries only you can either download the full Linux driver (`spcm_linux_drv_v123b4567`) and only use the libraries out of this or one downloads the library package which is much smaller and doesn't contain the pre-compiled kernel driver module (`spcm_linux_lib_v123b4567`).

The update is done with a dedicated script which only updates the library file. This script is present in both driver archives:

```
sh install_libonly.sh
```

Installing the library only without a kernel (for remote devices)

The kernel driver module only contains the basic hardware functions that are necessary to access locally installed card level products. The main part of the driver is located inside a dynamically loadable library that is delivered with the driver. This library is available in 3 different versions:

- `spcm_linux_32bit_std++6.so` - supporting `libstd++6.so.6` on 32 bit systems
- `spcm_linux_64bit_std++6.so` - supporting `libstd++6.so.6` on 64 bit systems

The matching version is installed automatically in the `/usr/lib` directory by the kernel driver install script for card level products. The library is renamed for easy access to `libspcm_linux.so`.

For digitizerNETBOX/generatorNETBOX products and also for evaluating or using only the software simulated demo cards the library is installed with a separate install script:

```
sh install_libonly.sh
```

To access the driver library one must include the library in the compilation:

```
gcc -o test_prg -lspcm_linux test.cpp
```

To start programming the cards under Linux please use the standard C/C++ examples which are all running under Linux and Windows.

Control Center

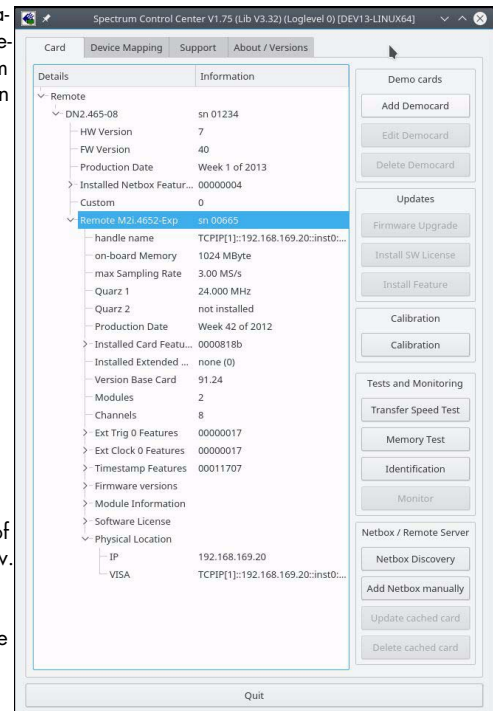
The Spectrum Control Center is also available for Linux and needs to be installed separately. The features of the Control Center are described in a later chapter in deeper detail. The Control Center has been tested under all Linux distributions for which Spectrum delivers pre-compiled kernel modules. The following packages need to be installed to run the Control Center:

- X-Server
- expat
- freetype
- fontconfig
- libpng
- libspcm_linux (the Spectrum linux driver library)

Installation

Use the supplied packages in either *.deb or *.rpm format found in the driver section of the USB-Stick by double clicking the package file root rights from a X-Windows window.

The Control Center is installed under KDE, Gnome or Unity in the system/system tools section. It may be located directly in this menu or under a „More Programs“ menu. The final location depends on the used Linux distribution. The program itself is installed as /usr/bin/spcmcontrol and may be started directly from here.



Manual Installation

To manually install the Control Center, first extract the files from the rpm matching your distribution:

```
rpm2cpio spcmcontrol-{Version}.rpm > ~/spcmcontrol-{Version}.cpio
cd ~/
cpio -id < spcmcontrol-{Version}.cpio
```

You get the directory structure and the files contained in the rpm package. Copy the binary spcmcontrol to /usr/bin. Copy the .desktop file to /usr/share/applications. Run ldconfig to update your systems library cache. Finally you can run spcmcontrol.

Troubleshooting

If you get a message like the following after starting spcmcontrol:

```
spcm_control: error while loading shared libraries: libz.so.1: cannot open shared object file: No such file or directory
```

Run ldd spcm_control in the directory where spcm_control resides to see the dependencies of the program. The output may look like this:

```
libXext.so.6 => /usr/X11R6/lib/libXext.so.6 (0x4019e000)
libX11.so.6 => /usr/X11R6/lib/libX11.so.6 (0x401ad000)
libz.so.1 => not found
libdl.so.2 => /lib/libdl.so.2 (0x402ba000)
libpthread.so.0 => /lib/tls/libpthread.so.0 (0x402be000)
libstdc++.so.6 => /usr/lib/libstdc++.so.6 (0x402d0000)
```

As seen in the output, one of the libraries isn't found inside the library cache of the system. Be sure that this library has been properly installed. You may then run ldconfig. If this still doesn't help please add the library path to /etc/ld.so.conf and run ldconfig again.

If the libspcm_linux.so is quoted as missing please make sure that you have installed the card driver properly before. If any other library is stated as missing please install the matching package of your distribution.

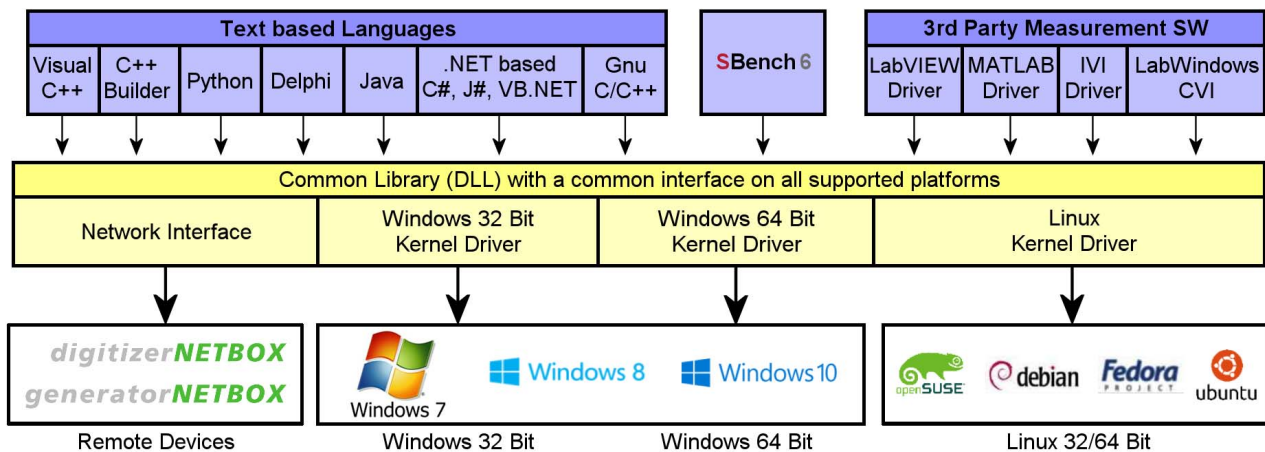
Software

This chapter gives you an overview about the structure of the drivers and the software, where to find and how to use the examples. It shows in detail, how the drivers are included using different programming languages and deals with the differences when calling the driver functions from them.



This manual only shows the use of the standard driver API. For further information on programming drivers for third-party software like LabVIEW, MATLAB or IVI an additional manual is required that is available on USB-Stick or by download on the internet.

Software Overview



The Spectrum drivers offer you a common and fast API for using all of the board hardware features. This API is the same on all supported operating systems. Based on this API one can write own programs using any programming language that can access the driver API. This manual describes in detail the driver API, providing you with the necessary information to write your own programs. The drivers for third-party products like LabVIEW or MATLAB are also based on this API. The special functionality of these drivers is not subject of this document and is described with separate manuals available on the USB-Stick or on the website.

Card Control Center

A special card control center is available on USB-Stick and from the internet for all Spectrum M2i/M3i/M4i/M4x/M2p cards and for all digitizerNETBOX or generatorNETBOX products. Windows users find the Control Center installer on the USB-Stick under „Install\win\spcmcontrol_install.exe“.

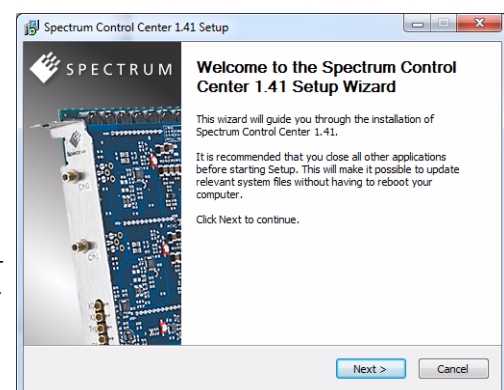
Linux users find the versions for the different stdc++ libraries under /Install/linux/spcm_control_center/ as RPM packages.

When using a digitizerNETBOX/generatorNETBOX the Card Control Center installers for Windows and Linux are also directly available from the integrated webserver.

The Control Center under Windows and Linux is available as an executive program. Under Windows it is also linked as a system control and can be accessed directly from the Windows control panel. Under Linux it is also available from the KDE System Settings, the Gnome or Unity Control Center. The different functions of the Spectrum card control center are explained in detail in the following passages.



To install the Spectrum Control Center you will need to be logged in with administrator rights for your operating system. On all Windows versions, starting with Windows Vista, installations with enabled UAC will ask you to start the installer with administrative rights (run as administrator).



Discovery of Remote Cards and digitizerNETBOX/generatorNETBOX products

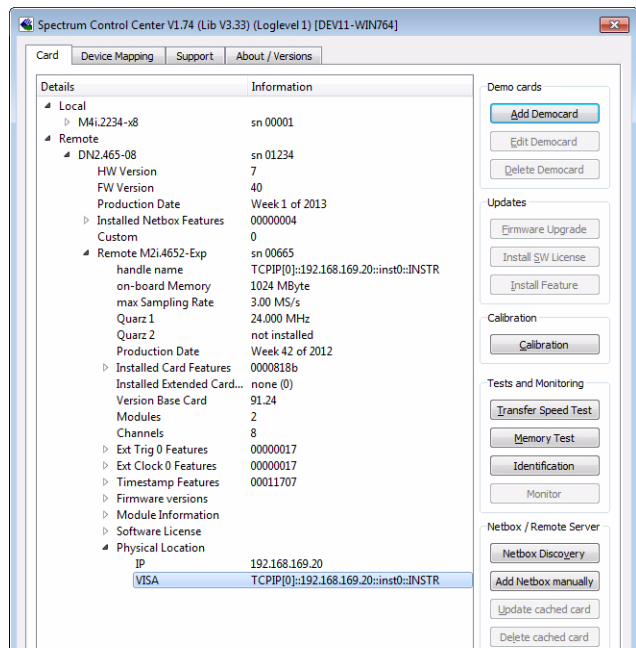
The Discovery function helps you to find and identify the Spectrum LXI instruments like digitizerNETBOX/generatorNETBOX available to your computer on the network. The Discovery function will also locate Spectrum card products handled by an installed Spectrum Remote Server somewhere on the network. The function is not needed if you only have locally installed cards.

Please note that only remote products are found that are currently not used by another program. Therefore in a bigger network the number of Spectrum products found may vary depending on the current usage of the products.

Execute the Discovery function by pressing the „Discovery“ button. There is no progress window shown. After the discovery function has been executed the remotely found Spectrum products are listed under the node Remote as separate card level products. Inhere you find all hardware information as shown in the next topic and also the needed VISA resource string to access the remote card.

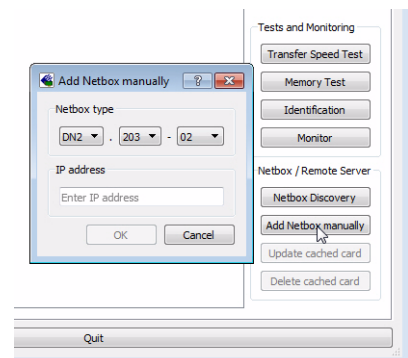
Please note that these information is also stored on your system and allows Spectrum software like SBench 6 to access the cards directly once found with the Discovery function.

After closing the control center and re-opening it the previously found remote products are shown with the prefix cached, only showing the card type and the serial number. This is the stored information that allows other Spectrum products to access previously found cards. Using the „Update cached cards“ button will try to re-open these cards and gather information of it. Afterwards the remote cards may disappear if they're in use from somewhere else or the complete information of the remote products is shown again.



Enter IP Address of digitizerNETBOX/generatorNETBOX manually

If for some reason an automatic discovery is not suitable, such as the case where the remote device is located in a different subnet, it can also be manually accessed by its type and IP address.



Wake On LAN of digitizerNETBOX/generatorNETBOX

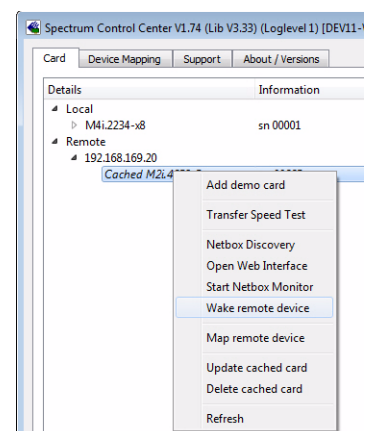
Cached digitizerNETBOX/generatorNETBOX products that are currently in standby mode can be woken up by using the „Wake remote device“ entry from the context menu.

The Control Center will broadcast a standard Wake On LAN „Magic Packet“, that is sent to the device's MAC address.

It is also possible to use any other Wake On LAN software to wake a digitizerNETBOX by sending such a „Magic Packet“ to the MAC address, which must be then entered manually.

It is also possible to wake a digitizerNETBOX/generatorNETBOX from your own application software by using the SPC_NETBOX_WAKEONLAN register. To wake a digitizerNETBOX/generatorNETBOX with the MAC address „00:03:2d:20:48“, the following command can be issued:

```
spcm_dwSetParam_i64 (NULL, SPC_NETBOX_WAKEONLAN, 0x00032d2048ec);
```



Netbox Monitor

The Netbox Monitor permanently monitors whether the digitizerNETBOX/generatorNETBOX is still available through LAN. This tool is helpful if the digitizerNETBOX is located somewhere in the company LAN or located remotely or directly mounted inside another device. Starting the Netbox Monitor can be done in two different ways:

- Starting manually from the Spectrum Control Center using the context menu as shown above
- Starting from command line. The Netbox Monitor program is automatically installed together with the Spectrum Control Center and is located in the selected install folder. Using the command line tool one can place a simple script into the autostart folder to have the Netbox Monitor running automatically after system boot. The command line tool needs the IP address of the digitizerNETBOX/generatorNETBOX to monitor:

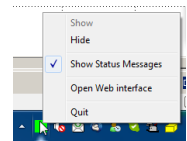
```
NetboxMonitor 192.168.169.22
```

The Netbox Monitor is shown as a small window with the type of digitizerNETBOX/generatorNETBOX in the title and the IP address under which it is accessed in the window itself. The Netbox Monitor runs completely independent of any other software and can be used in parallel to any application software. The background of the IP address is used to display the current status of the device. Pressing the Escape key or alt + F4 (Windows) terminates the Netbox Monitor permanently.



After starting the Netbox Monitor it is also displayed as a tray icon under Windows. The tray icon itself shows the status of the digitizerNETBOX/generatorNETBOX as a color. Please note that the tray icon may be hidden as a Windows default and need to be set to visible using the Windows tray setup.

Left clicking on the tray icon will hide/show the small Netbox Monitor status window. Right clicking on the tray icon as shown in the picture on the right will open up a context menu. In here one can again select to hide/show the Netbox Monitor status window, one can directly open the web interface from here or quit the program (including the tray icon) completely.



The checkbox „Show Status Message“ controls whether the tray icon should emerge a status message on status change. If enabled (which is default) one is notified with a status message if for example the LAN connection to the digitizerNETBOX/generatorNETBOX is lost.

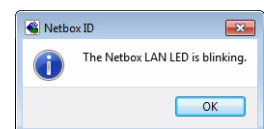
The status colors:

- Green: digitizerNETBOX/generatorNETBOX available and accessible over LAN
- Cyan: digitizerNETBOX/generatorNETBOX is used from my computer
- Yellow: digitizerNETBOX/generatorNETBOX is used from a different computer
- Red: LAN connection failed, digitizerNETBOX/generatorNETBOX is no longer accessible

Device identification

Pressing the *Identification* button helps to identify a certain device in either a remote location, such as inside a 19" rack where the back of the device with the type plate is not easily accessible, or a local device installed in a certain slot. Pressing the button starts flashing a visible LED on the device, until the dialog is closed, for:

- On a digitizerNETBOX or generatorNETBOX: the LAN LED light on the front plate of the device
- On local or remote M4i, M4x or M2p card: the indicator LED on the card's bracket

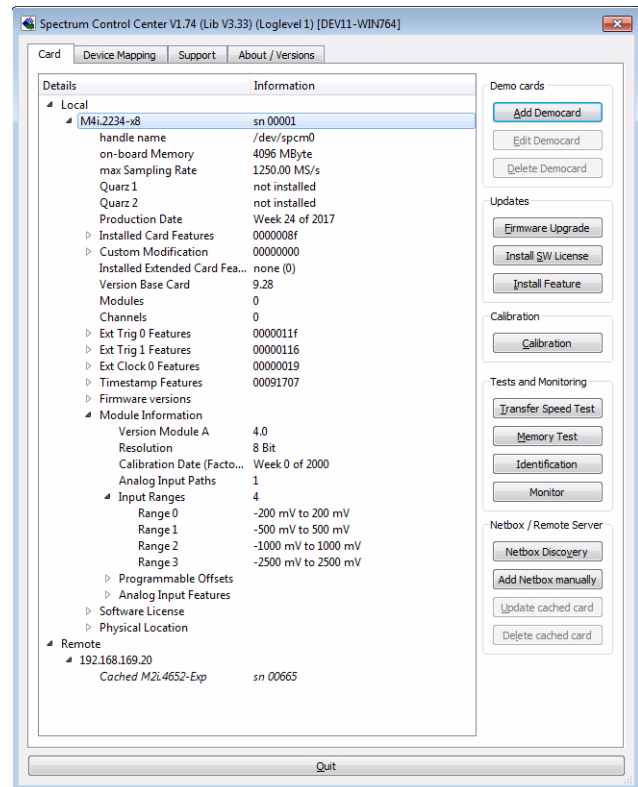


This feature is not available for M2i/M3i cards, either local or remote, other than inside a digitizerNETBOX or generatorNETBOX.

Hardware information

Through the control center you can easily get the main information about all the installed Spectrum hardware. For each installed card there is a separate tree of information available. The picture shows the information for one installed card by example. This given information contains:

- Basic information as the type of card, the production date and its serial number, as well as the installed memory, the hardware revision of the base card, the number of available channels and installed acquisition modules.
- Information about the maximum sampling clock and the available quartz clock sources.
- The installed features/options in a sub-tree. The shown card is equipped for example with the option Multiple Recording, Gated Sampling, Timestamp and ABA-mode.
- Detailed Information concerning the installed acquisition modules. In case of the shown analog acquisition card the information consists of the module's hardware revision, of the converter resolution and the last calibration date as well as detailed information on the available analog input ranges, offset compensation capabilities and additional features of the inputs.



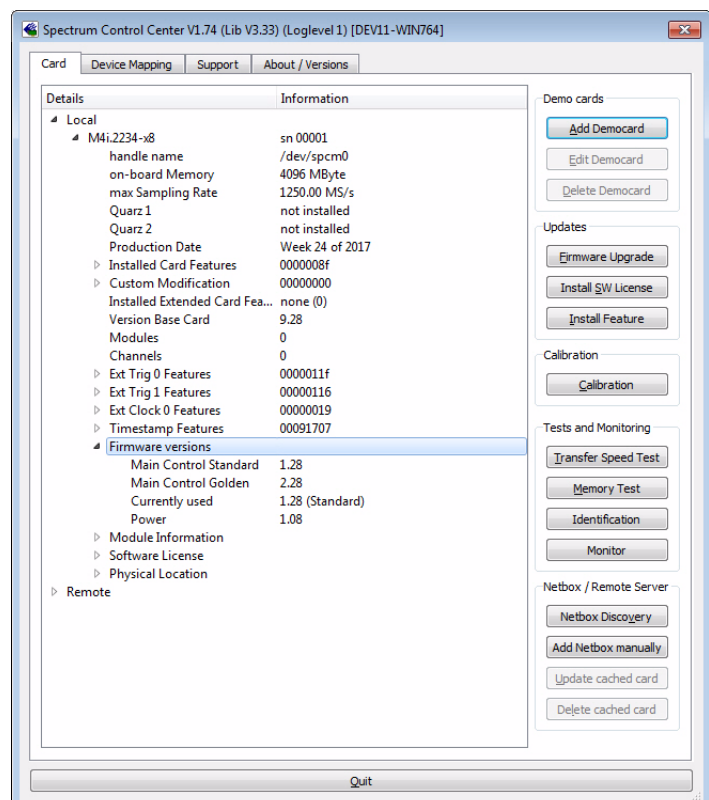
Firmware information

Another sub-tree is informing about the cards firmware version. As all Spectrum cards consist of several programmable components, there is one firmware version per component.

Nearly all of the components firmware can be updated by software. The only exception is the configuration device, which only can receive a factory update.

The procedure on how to update the firmware of your Spectrum card with the help of the card control center is described in a dedicated section later on.

The procedure on how to update the firmware of your digitizerNETBOX/generatorNETBOX with the help of the integrated Webserver is described in a dedicated chapter later on.

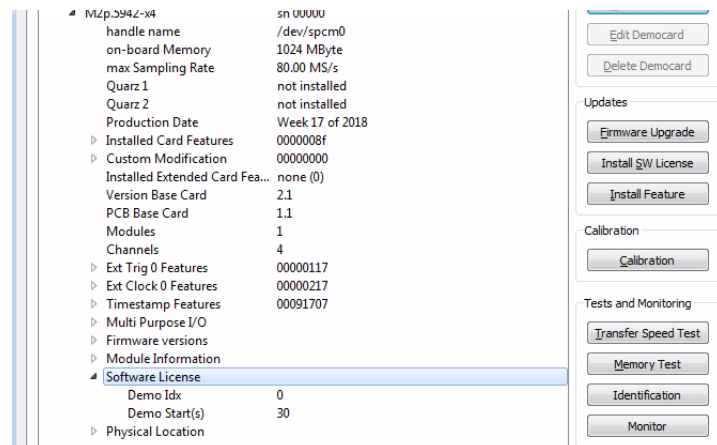


Software License information

This sub-tree is informing about installed possible software licenses.

As a default all cards come with the demo professional license of SBench6, that is limited to 30 starts of the software with all professional features unlocked.

The number of demo starts left can be seen here.



Driver information

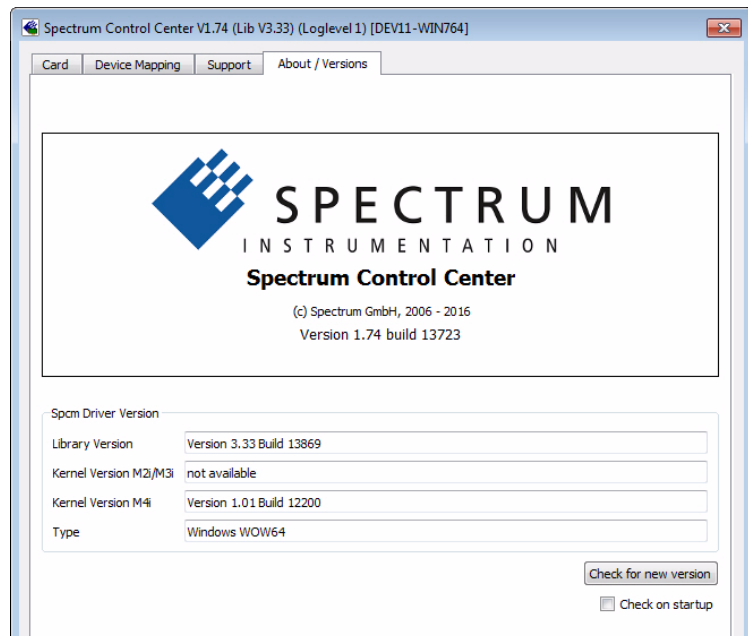
The Spectrum card control center also offers a way to gather information on the installed and used Spectrum driver.

The information on the driver is available through a dedicated tab, as the picture is showing in the example.

The provided information informs about the used type, distinguishing between Windows or Linux driver and the 32 bit or 64 bit type.

It also gives direct information about the version of the installed Spectrum kernel driver, separately for M2i/M2iM3i cards and M4i/M4x/M2p cards and the version of the library (which is the *.dll file under Windows).

The information given here can also be found under Windows using the device manager from the control panel. For details in driver details within the control panel please stick to the section on driver installation in your hardware manual.

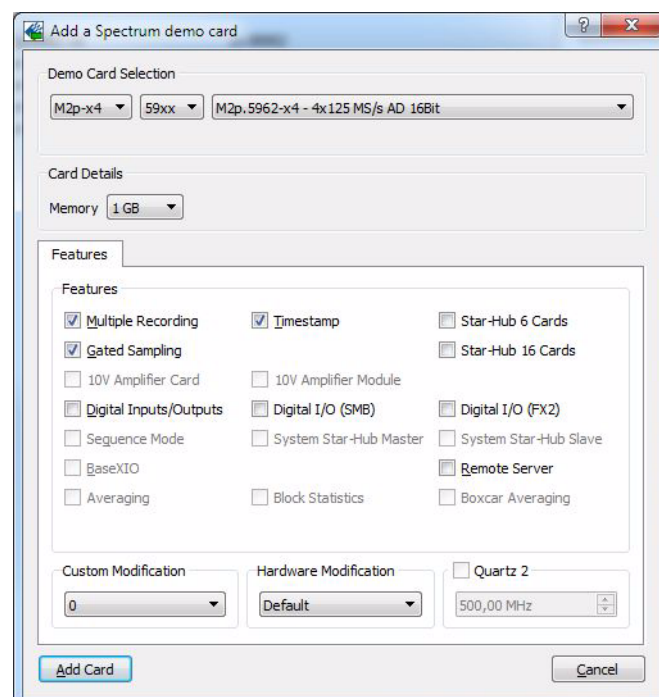


Installing and removing Demo cards

With the help of the card control center one can install demo cards in the system. A demo card is simulated by the Spectrum driver including data production for acquisition cards. As the demo card is simulated on the lowest driver level all software can be tested including SBench, own applications and drivers for third-party products like LabVIEW. The driver supports up to 64 demo cards at the same time. The simulated memory as well as the simulated software options can be defined when adding a demo card to the system.

Please keep in mind that these demo cards are only meant to test software and to show certain abilities of the software. They do not simulate the complete behavior of a card, especially not any timing concerning trigger, recording length or FIFO mode notification. The demo card will calculate data every time directly after been called and give it to the user application without any more delay. As the calculation routine isn't speed optimized, generating demo data may take more time than acquiring real data and transferring them to the host PC.

Installed demo cards are listed together with the real hardware in the main information tree as described above. Existing demo cards can be deleted by clicking the related button. The demo card details can be edited by using the edit button. It is for example possible to virtually install additional feature to one card or to change the type to test with a different number of channels.



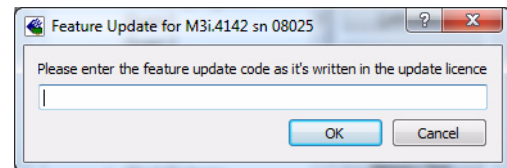
For installing demo cards on a system without real hardware simply run the Control Center installer. If the installer is not detecting the necessary driver files normally residing on a system with real hardware, it will simply install the Spcm_driver.



Feature upgrade

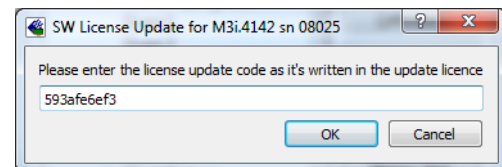
All optional features of the M2i/M3i/M4i/M4x/M2p cards that do not require any hardware modifications can be installed on fielded cards. After Spectrum has received the order, the customer will get a personalized upgrade code. Just start the card control center, click on „install feature“ and enter that given code. After a short moment the feature will be installed and ready to use. No restart of the host system is required.

For details on the available options and prices please contact your local Spectrum distributor.



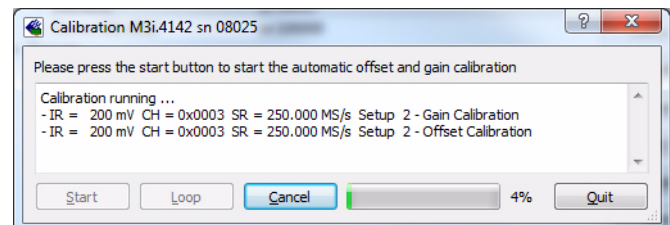
Software License upgrade

The software license for SBench 6 Professional is installed on the hardware. If ordering a software license for a card that has already been delivered you will get an upgrade code to install that software license. The upgrade code will only match for that particular card with the serial number given in the license. To install the software license please click the „Install SW License“ button and type in the code exactly as given in the license.



Performing card calibration

The card control center also provides an easy way to access the automatic card calibration routines of the Spectrum A/D converter cards. Depending on the used card family this can affect offset calibration only or also might include gain calibration. Please refer to the dedicated chapter in your hardware manual for details.

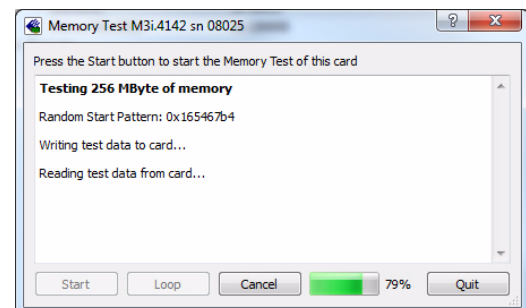


Performing memory test

The complete on-board memory of the Spectrum M2i/M3i/M4i/M4x/M2p cards can be tested by the memory test included with the card control center.

When starting the test, randomized data is generated and written to the on-board memory. After a complete write cycle all the data is read back and compared with the generated pattern.

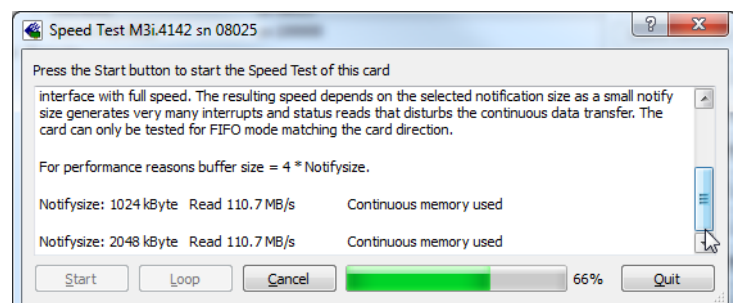
Depending on the amount of installed on-board memory, and your computer's performance this operation might take a while.



Transfer speed test

The control center allows to measure the bus transfer speed of an installed Spectrum card. Therefore different setup is run multiple times and the overall bus transfer speed is measured. To get reliable results it is necessary that you disable debug logging as shown below. It is also highly recommended that no other software or time-consuming background threads are running on that system. The speed test program runs the following two tests:

- Repetitive Memory Transfers: single DMA data transfers are repeated and measured. This test simulates the measuring of pulse repetition frequency when doing multiple single-shots. The test is done using different block sizes. One can estimate the transfer in relation to the transferred data size on multiple single-shots.
- FIFO mode streaming: this test measures the streaming speed in FIFO mode. The test can only use the same direction of transfer the card has been designed for (card to PC=read for all DAQ cards, PC to card=write for all generator cards and both directions for I/O cards). The streaming speed is tested without using the front-end to measure the maximum bus speed that can be reached. The Speed in FIFO mode depends on the selected notify size which is explained later in this manual in greater detail.



The results are given in MB/s meaning MByte per second. To estimate whether a desired acquisition speed is possible to reach one has to calculate the transfer speed in bytes. There are a few things that have to be put into the calculation:

- 12, 14 and 16 bit analog cards need two bytes for each sample.
- 16 channel digital cards need 2 bytes per sample while 32 channel digital cards need 4 bytes and 64 channel digital cards need 8 bytes.
- The sum of analog channels must be used to calculate the total transfer rate.
- The figures in the Speed Test Utility are given as MBytes, meaning $1024 * 1024$ Bytes, 1 MByte = 1048576 Bytes

As an example running a card with 2 14 bit analog channels with 28 MHz produces a transfer rate of $[2 \text{ channels} * 2 \text{ Bytes/Sample} * 28000000] = 112000000$ Bytes/second. Taking the above figures measured on a standard 33 MHz PCI slot the system is just capable of reaching this transfer speed: $108.0 \text{ MB/s} = 108 * 1024 * 1024 = 113246208$ Bytes/second.

Unfortunately it is not possible to measure transfer speed on a system without having a Spectrum card installed.

Debug logging for support cases

For answering your support questions as fast as possible, the setup of the card, driver and firmware version and other information is very helpful.

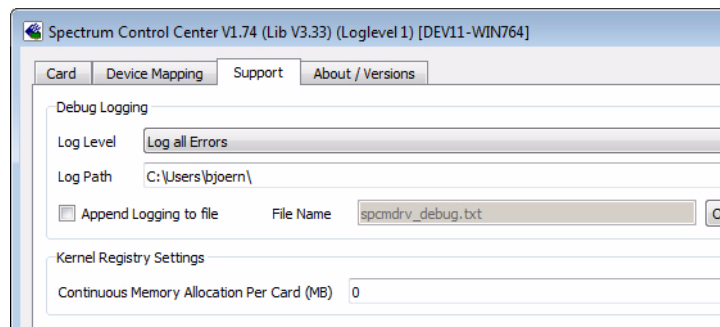
Therefore the card control center provides an easy way to gather all that information automatically.

Different debug log levels are available through the graphical interface. By default the log level is set to „no logging“ for maximum performance.

The customer can select different log levels and the path of the generated ASCII text file. One can also decide to delete the previous log file first before creating a new one automatically or to append different logs to one single log file.



For maximum performance of your hardware, please make sure that the debug logging is set to „no logging“ for normal operation. Please keep in mind that a detailed logging in append mode can quickly generate huge log files.



Device mapping

Within the „Device mapping“ tab of the Spectrum Control Center, one can enable the re-mapping of Spectrum devices, be it either local cards, remote instruments such as a digitizerNETBOX or generatorNETBOX or even cards in a remote PC and accessed via the Spectrum remote server option.

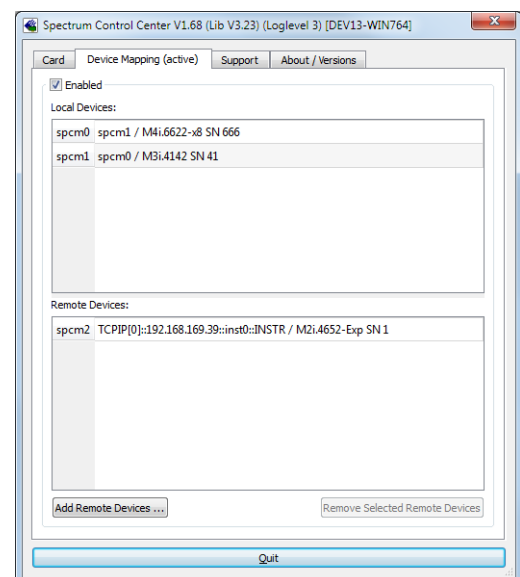
In the left column the re-mapped device name is visible that is given to the device in the right column with its original un-mapped device string.

In this example the two local cards „spcm0“ and „spcm1“ are re-mapped to „spcm1“ and „spcm0“ respectively, so that their names are simply swapped.

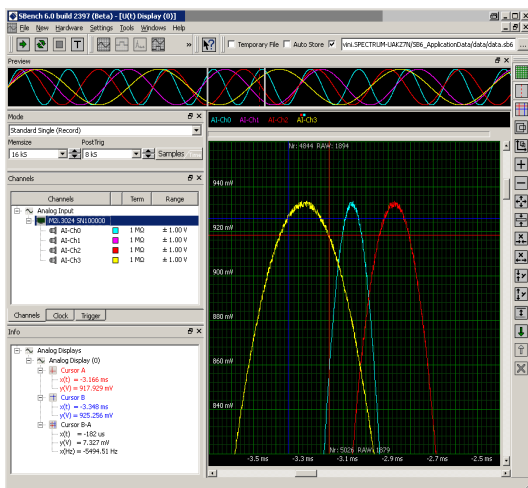
The remote digitizerNETBOX device is mapped to spcm2.

The application software can then use the re-mapped name for simplicity instead of the quite long VISA string.

Changing the order of devices within one group (either local cards or remote devices) can simply be accomplished by dragging&dropping the cards to their desired position in the same table.



Accessing the hardware with SBench 6



After the installation of the cards and the drivers it can be useful to first test the card function with a ready to run software before starting with programming. If accessing a digitizerNETBOX/generatorNETBOX a full SBench 6 Professional license is installed on the system and can be used without any limitations. For plug-in card level products a base version of SBench 6 is delivered with the card on USB-Stick also including a 30 starts Professional demo version for plain card products. If you already have bought a card prior to the first SBench 6 release please contact your local dealer to get a SBench 6 Professional demo version. All digitizerNETBOX/generatorNETBOX products come with a pre-installed full SBench 6 Professional.

SBench 6 supports all current acquisition and generation cards and digitizerNETBOX/generatorNETBOX products from Spectrum. Depending on the used product and the software setup, one can use SBench as a digital storage oscilloscope, a spectrum analyzer, a signal generator, a pattern generator, a logic analyzer or simply as a data recording front end. Different export and import formats allow the use of SBench 6 together with a variety of other programs.

On the USB-Stick you'll find an install version of SBench 6 in the directory „/Install/SBench6“.

The current version of SBench 6 is available free of charge directly from the Spectrum website: www.spectrum-instrumentation.com. Please go to the download section and get the latest version there.

SBench 6 has been designed to run under Windows 7, Windows 8 and Windows 10 as well as Linux using KDE, Gnome or Unity Desktop.

C/C++ Driver Interface

C/C++ is the main programming language for which the drivers have been designed for. Therefore the interface to C/C++ is the best match. All the small examples of the manual showing different parts of the hardware programming are done with C. As the libraries offer a standard interface it is easy to access the libraries also with other programming languages like Delphi, Basic, Python or Java. Please read the following chapters for additional information on this.

Header files

The basic task before using the driver is to include the header files that are delivered on USB-Stick together with the board. The header files are found in the directory /Driver/c_header. Please don't change them in any way because they are updated with each new driver version to include the new registers and new functionality.

| | |
|------------|--|
| dlltyp.h | Includes the platform specific definitions for data types and function declarations. All data types are based on these definitions. The use of this type definition file allows the use of examples and programs on different platforms without changes to the program source. The header file supports Microsoft Visual C++, Borland C++ Builder and GNU C/C++ directly. When using other compilers it might be necessary to make a copy of this file and change the data types according to this compiler. |
| regs.h | Defines all registers and commands which are used in the Spectrum driver for the different boards. The registers a board uses are described in the board specific part of the documentation. This header file is common for all cards. Therefore this file also contains a huge number of registers used on other card types than the one described in this manual. Please stick to the manual to see which registers are valid for your type of card. |
| spcm_drv.h | Defines the functions of the used SpcM driver. All definitions are taken from the file dlltyp.h. The functions themselves are described below. |
| spcerr.h | Contains all error codes used with the Spectrum driver. All error codes that can be given back by any of the driver functions are also described here briefly. The error codes and their meaning are described in detail in the appendix of this manual. |

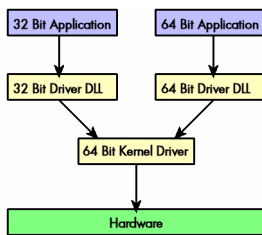
Example for including the header files:

```
// ----- driver includes -----
#include "dlltyp.h"      // 1st include
#include "regs.h"        // 2nd include
#include "spcerr.h"      // 3rd include
#include "spcm_drv.h"    // 4th include
```



Please always keep the order of including the four Spectrum header files. Otherwise some or all of the functions do not work properly or compiling your program will be impossible!

General Information on Windows 64 bit drivers



After installation of the Spectrum 64 bit driver there are two general ways to access the hardware and to develop applications. If you're going to develop a real 64 bit application it is necessary to access the 64 bit driver dll (spcm_win64.dll) as only this driver dll is supporting the full 64 bit address range.

But it is still possible to run 32 bit applications or to develop 32 bit applications even under Windows 64 bit. Therefore the 32 bit driver dll (spcm_win32.dll) is also installed in the system. The Spectrum SBench5 software is for example running under Windows 64 bit using this driver. The 32 bit dll of course only offers the 32 bit address range and is therefore limited to access only 4 GByte of memory. Beneath both drivers the 64 bit kernel driver is running.

Mixing of 64 bit application with 32 bit dll or vice versa is not possible.

Microsoft Visual C++ 6.0, 2005 and newer 32 Bit

Include Driver

The driver files can be directly included in Microsoft C++ by simply using the library file spcm_win32_msvcpp.lib that is delivered together with the drivers. The library file can be found on the USB-Stick in the path /examples/c_cpp/c_header. Please include the library file in your Visual C++ project as shown in the examples. All functions described below are now available in your program.

Examples

Examples can be found on USB-Stick in the path /examples/c_cpp. This directory includes a number of different examples that can be used with any card of the same type (e.g. A/D acquisition cards, D/A acquisition cards). You may use these examples as a base for own programming and modify them as you like. The example directories contain a running workspace file for Microsoft Visual C++ 6.0 (*.dsw) as well as project files for Microsoft Visual Studio 2005 and newer (*.vcproj) that can be directly loaded or imported and compiled. There are also some more board type independent examples in separate subdirectory. These examples show different aspects of the cards like programming options or synchronization and can be combined with one of the board type specific examples.

As the examples are build for a card class there are some checking routines and differentiation between cards families. Differentiation aspects can be number of channels, data width, maximum speed or other details. It is recommended to change the examples matching your card type to obtain maximum performance. Please be informed that the examples are made for easy understanding and simple showing of one aspect of programming. Most of the examples are not optimized for maximum throughput or repetition rates.

Microsoft Visual C++ 2005 and newer 64 Bit

Depending on your version of the Visual Studio suite it may be necessary to install some additional 64 bit components (SDK) on your system. Please follow the instructions found on the MSDN for further information.

Include Driver

The driver files can be directly included in Microsoft C++ by simply using the library file spcm_win64_msvcpp.lib that is delivered together with the drivers. The library file can be found on the USB-Stick in the path /examples/c_cpp/c_header. All functions described below are now available in your program.

C++ Builder 32 Bit

Include Driver

The driver files can be easily included in C++ Builder by simply using the library file spcm_win32_bcppb.lib that is delivered together with the drivers. The library file can be found on the USB-Stick in the path /examples/c_cpp/c_header. Please include the library file in your C++ Builder project as shown in the examples. All functions described below are now available in your program.

Examples

The C++ Builder examples share the sources with the Visual C++ examples. Please see above chapter for a more detailed documentation of the examples. In each example directory are project files for Visual C++ as well as C++ Builder.

Linux Gnu C/C++ 32/64 Bit

Include Driver

The interface of the linux drivers does not differ from the windows interface. Please include the `spcm_linux.lib` library in your makefile to have access to all driver functions. A makefile may look like this:

```
COMPILER = gcc
EXECUTABLE = test_prg
LIBS = -lspcm_linux

OBJECTS = test.o\
          test2.o

all: $(EXECUTABLE)

$(EXECUTABLE): $(OBJECTS)
    $(COMPILER) $(CFLAGS) -o $(EXECUTABLE) $(LIBS) $(OBJECTS)

%.o: %.cpp
    $(COMPILER) $(CFLAGS) -o $*.o -c $*.cpp
```

Examples

The Gnu C/C++ examples share the source with the Visual C++ examples. Please see above chapter for a more detailed documentation of the examples. Each example directory contains a makefile for the Gnu C/C++ examples.

C++ for .NET

Please see the next chapter for more details on the .NET inclusion.

Other Windows C/C++ compilers 32 Bit

Include Driver

To access the driver, the driver functions must be loaded from the 32 bit driver DLL. Most compilers offer special tools to generate a matching library (e.g. Borland offers the `implib` tool that generates a matching library out of the windows driver DLL). If such a tool is available it is recommended to use it. Otherwise the driver functions need to be loaded from the dll using standard Windows functions. There is one example in the example directory `/examples/c_cpp/dll_loading` that shows the process.

Example of function loading:

```
hDLL = LoadLibrary ("spcm_win32.dll"); // Load the 32 bit version of the Spcm driver
pfn_spcm_hOpen = (SPCM_HOPEN*) GetProcAddress (hDLL, "_spcm_hOpen@4");
pfn_spcm_vClose = (SPCM_VCLOSE*) GetProcAddress (hDLL, "_spcm_vClose@4");
```

Other Windows C/C++ compilers 64 Bit

Include Driver

To access the driver, the driver functions must be loaded from the 64 bit the driver DLL. Most compilers offer special tools to generate a matching library (e.g. Borland offers the `implib` tool that generates a matching library out of the windows driver DLL). If such a tool is available it is recommended to use it. Otherwise the driver functions need to be loaded from the dll using standard Windows functions. There is one example in the example directory `/examples/c_cpp/dll_loading` that shows the process for 32 bit environments. The only line that needs to be modified is the one loading the DLL:

Example of function loading:

```
hDLL = LoadLibrary ("spcm_win64.dll"); // Modified: Load the 64 bit version of the Spcm driver here
pfn_spcm_hOpen = (SPCM_HOPEN*) GetProcAddress (hDLL, "spcm_hOpen");
pfn_spcm_vClose = (SPCM_VCLOSE*) GetProcAddress (hDLL, "spcm_vClose");
```

Driver functions

The driver contains seven main functions to access the hardware.

Own types used by our drivers

To simplify the use of the header files and our examples with different platforms and compilers and to avoid any implicit type conversions we decided to use our own type declarations. This allows us to use platform independent and universal examples and driver interfaces. If you do not stick to these declarations please be sure to use the same data type width. However it is strongly recommended that you use our defined

type declarations to avoid any hard to find errors in your programs. If you're using the driver in an environment that is not natively supported by our examples and drivers please be sure to use a type declaration that represents a similar data width

| Declaration | Type | Declaration | Type |
|-------------|---|-------------|--|
| int8 | 8 bit signed integer (range from -128 to +127) | uint8 | 8 bit unsigned integer (range from 0 to 255) |
| int16 | 16 bit signed integer (range from -32768 to 32767) | uint16 | 16 bit unsigned integer (range from 0 to 65535) |
| int32 | 32 bit signed integer (range from -2147483648 to 2147483647) | uint32 | 32 bit unsigned integer (range from 0 to 4294967295) |
| int64 | 64 bit signed integer (full range) | uint64 | 64 bit unsigned integer (full range) |
| drv_handle | handle to driver, implementation depends on operating system platform | | |

Notation of variables and functions

In our header files and examples we use a common and reliable form of notation for variables and functions. Each name also contains the type as a prefix. This notation form makes it easy to see implicit type conversions and minimizes programming errors that result from using incorrect types. Feel free to use this notation form for your programs also-

| Declaration | Notation | Declaration | Notation |
|-------------|--------------------------|-------------|---------------------------------------|
| int8 | byName (byte) | uint8 | cName (character) |
| int16 | nName | uint16 | wName (word) |
| int32 | lName (long) | uint32 | dwName (double word) |
| int64 | llName (long long) | uint64 | qwName (quad word) |
| int32* | plName (pointer to long) | char | szName (string with zero termination) |

Function spcm_hOpen

This function initializes and opens an installed card supporting the new SpcM driver interface, which at the time of printing, are all cards of the M2i/M3i/M4i/M4x/M2p series and the related digitizerNETBOX/generatorNETBOX devices. The function returns a handle that has to be used for driver access. If the card can't be found or the loading of the driver generated an error the function returns a NULL. When calling this function all card specific installation parameters are read out from the hardware and stored within the driver. It is only possible to open one device by one software as concurrent hardware access may be very critical to system stability. As a result when trying to open the same device twice an error will be raised and the function returns NULL.

Function spcm_hOpen (const char* szDeviceName):

```
drv_handle _stdcall spcm_hOpen (          // tries to open the device and returns handle or error code
    const char* szDeviceName);           // name of the device to be opened
```

Under Linux the device name in the function call needs to be a valid device name. Please change the string according to the location of the device if you don't use the standard Linux device names. The driver is installed as default under /dev/spcm0, /dev/spcm1 and so on. The kernel driver numbers the devices starting with 0.

Under Windows the only part of the device name that is used is the tailing number. The rest of the device name is ignored. Therefore to keep the examples simple we use the Linux notation in all our examples. The tailing number gives the index of the device to open. The Windows kernel driver numbers all devices that it finds on boot time starting with 0.

Example for local installed cards

```
drv_handle hDrv;                          // returns the handle to the opened driver or NULL in case of error
hDrv = spcm_hOpen ("/dev/spcm0");         // string to the driver to open
if (!hDrv)
    printf ("open of driver failed\n");
```

Example for digitizerNETBOX/generatorNETBOX and remote installed cards

```
drv_handle hDrv;                          // returns the handle to the opened driver or NULL in case of error
hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INST0::INSTR");
if (!hDrv)
    printf ("open of driver failed\n");
```

If the function returns a NULL it is possible to read out the error description of the failed open function by simply passing this NULL to the error function. The error function is described in one of the next topics.

Function spcm_vClose

This function closes the driver and releases all allocated resources. After closing the driver handle it is not possible to access this driver any more. Be sure to close the driver if you don't need it any more to allow other programs to get access to this device.

Function spcm_vClose:

```
void _stdcall spcm_vClose (                // closes the device
    drv_handle hDevice);                  // handle to an already opened device
```


Example:

```
spcm_vClose (hDrv);
```

Function **spcm_dwSetParam**

All hardware settings are based on software registers that can be set by one of the functions `spcm_dwSetParam`. These functions set a register to a defined value or execute a command. The board must first be initialized by the `spcm_hOpen` function. The parameter `lRegister` must have a valid software register constant as defined in `regs.h`. The available software registers for the driver are listed in the board specific part of the documentation below. The function returns a 32 bit error code if an error occurs. If no error occurs the function returns `ERR_OK`, what is zero.

Function `spcm_dwSetParam`

```
uint32_stdcall spcm_dwSetParam_i32 ( // Return value is an error code
    drv_handle hDevice,              // handle to an already opened device
    int32 lRegister,                  // software register to be modified
    int32 lValue);                    // the value to be set

uint32_stdcall spcm_dwSetParam_i64m ( // Return value is an error code
    drv_handle hDevice,              // handle to an already opened device
    int32 lRegister,                  // software register to be modified
    int32 lValueHigh,                // upper 32 bit of the value. Containing the sign bit !
    uint32 dwValueLow);               // lower 32 bit of the value.

uint32_stdcall spcm_dwSetParam_i64 ( // Return value is an error code
    drv_handle hDevice,              // handle to an already opened device
    int32 lRegister,                  // software register to be modified
    int64 llValue);                   // the value to be set
```

Example:

```
if (spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, 16384) != ERR_OK)
    printf ("Error when setting memory size\n");
```

This example sets the memory size to 16 kSamples (16384). If an error occurred the example will show a short error message

Function **spcm_dwGetParam**

All hardware settings are based on software registers that can be read by one of the functions `spcm_dwGetParam`. These functions read an internal register or status information. The board must first be initialized by the `spcm_hOpen` function. The parameter `lRegister` must have a valid software register constant as defined in the `regs.h` file. The available software registers for the driver are listed in the board specific part of the documentation below. The function returns a 32 bit error code if an error occurs. If no error occurs the function returns `ERR_OK`, what is zero.

Function `spcm_dwGetParam`

```
uint32_stdcall spcm_dwGetParam_i32 ( // Return value is an error code
    drv_handle hDevice,              // handle to an already opened device
    int32 lRegister,                  // software register to be read out
    int32* plValue);                 // pointer for the return value

uint32_stdcall spcm_dwGetParam_i64m ( // Return value is an error code
    drv_handle hDevice,              // handle to an already opened device
    int32 lRegister,                  // software register to be read out
    int32* plValueHigh,              // pointer for the upper part of the return value
    uint32* pdwValueLow);             // pointer for the lower part of the return value

uint32_stdcall spcm_dwGetParam_i64 ( // Return value is an error code
    drv_handle hDevice,              // handle to an already opened device
    int32 lRegister,                  // software register to be read out
    int64* pllValue);                 // pointer for the return value
```

Example:

```
int32 lSerialNumber;
spcm_dwGetParam_i32 (hDrv, SPC_PCISERIALNO, &lSerialNumber);
printf ("Your card has serial number: %05d\n", lSerialNumber);
```

The example reads out the serial number of the installed card and prints it. As the serial number is available under all circumstances there is no error checking when calling this function.

Different call types of `spcm_dwSetParam` and `spcm_dwGetParam`: `_i32`, `_i64`, `_i64m`

The three functions only differ in the type of the parameters that are used to call them. As some of the registers can exceed the 32 bit integer range (like memory size or post trigger) it is recommended to use the `_i64` function to access these registers. However as there are some

programs or compilers that don't support 64 bit integer variables there are two functions that are limited to 32 bit integer variables. In case that you do not access registers that exceed 32 bit integer please use the `_i32` function. In case that you access a register which exceeds 64 bit value please use the `_i64m` calling convention. Inhere the 64 bit value is split into a low double word part and a high double word part. Please be sure to fill both parts with valid information.

If accessing 64 bit registers with 32 bit functions the behavior differs depending on the real value that is currently located in the register. Please have a look at this table to see the different reactions depending on the size of the register:

| Internal register | read/write | Function type | Behavior |
|-------------------|------------|-----------------------------------|---|
| 32 bit register | read | <code>spcm_dwGetParam_i32</code> | value is returned as 32 bit integer in <code>pIValue</code> |
| 32 bit register | read | <code>spcm_dwGetParam_i64</code> | value is returned as 64 bit integer in <code>pIIValue</code> |
| 32 bit register | read | <code>spcm_dwGetParam_i64m</code> | value is returned as 64 bit integer, the lower part in <code>pIValueLow</code> , the upper part in <code>pIValueHigh</code> . The upper part can be ignored as it's only a sign extension |
| 32 bit register | write | <code>spcm_dwSetParam_i32</code> | 32 bit value can be directly written |
| 32 bit register | write | <code>spcm_dwSetParam_i64</code> | 64 bit value can be directly written, please be sure not to exceed the valid register value range |
| 32 bit register | write | <code>spcm_dwSetParam_i64m</code> | 32 bit value is written as <code>IIValueLow</code> , the value <code>IIValueHigh</code> needs to contain the sign extension of this value. In case of <code>IIValueLow</code> being a value ≥ 0 <code>IIValueHigh</code> can be 0, in case of <code>IIValueLow</code> being a value < 0 , <code>IIValueHigh</code> has to be -1. |
| 64 bit register | read | <code>spcm_dwGetParam_i32</code> | If the internal register has a value that is inside the 32 bit integer range $[-2G \text{ up to } (2G - 1)]$ the value is returned normally. If the internal register exceeds this size an error code <code>ERR_EXCEEDSINT32</code> is returned. As an example: reading back the installed memory will work as long as this memory is < 2 GByte. If the installed memory is ≥ 2 GByte the function will return an error. |
| 64 bit register | read | <code>spcm_dwGetParam_i64</code> | value is returned as 64 bit integer value in <code>pIIValue</code> independent of the value of the internal register. |
| 64 bit register | read | <code>spcm_dwGetParam_i64m</code> | the internal value is split into a low and a high part. As long as the internal value is within the 32 bit range, the low part <code>pIValueLow</code> contains the 32 bit value and the upper part <code>pIValueHigh</code> can be ignored. If the internal value exceeds the 32 bit range it is absolutely necessary to take both value parts into account. |
| 64 bit register | write | <code>spcm_dwSetParam_i32</code> | the value to be written is limited to 32 bit range. If a value higher than the 32 bit range should be written, one of the other function types need to be used. |
| 64 bit register | write | <code>spcm_dwSetParam_i64</code> | the value has to be split into two parts. Be sure to fill the upper part <code>IIValueHigh</code> with the correct sign extension even if you only write a 32 bit value as the driver every time interprets both parts of the function call. |
| 64 bit register | write | <code>spcm_dwSetParam_i64m</code> | the value can be written directly independent of the size. |

Function `spcm_dwGetContBuf`

This function reads out the internal continuous memory buffer in bytes, in case one has been allocated. If no buffer has been allocated the function returns a size of zero and a NULL pointer. You may use this buffer for data transfers. As the buffer is continuously allocated in memory the data transfer will speed up by up to 15% - 25%, depending on your specific kind of card. Please see further details in the appendix of this manual.

```
uint32_stdcall spcm_dwGetContBuf_i64 ( // Return value is an error code
    drv_handle hDevice,                // handle to an already opened device
    uint32 dwBufType,                  // type of the buffer to read as listed above under SPCM_BUF_XXXX
    void** ppvDataBuffer,              // address of available data buffer
    uint64* pqwContBufLen);            // length of available continuous buffer

uint32_stdcall spcm_dwGetContBuf_i64m (// Return value is an error code
    drv_handle hDevice,                // handle to an already opened device
    uint32 dwBufType,                  // type of the buffer to read as listed above under SPCM_BUF_XXXX
    void** ppvDataBuffer,              // address of available data buffer
    uint32* pdwContBufLenH,            // high part of length of available continuous buffer
    uint32* pdwContBufLenL);           // low part of length of available continuous buffer
```



These functions have been added in driver version 1.36. The functions are not available in older driver versions.



These functions also only have effect on locally installed cards and are neither useful nor usable with any digitizerNETBOX or generatorNETBOX products, because no local kernel driver is involved in such a setup. For remote devices these functions will return a NULL pointer for the buffer and 0 Bytes in length.

Function `spcm_dwDefTransfer`

The `spcm_dwDefTransfer` function defines a buffer for a following data transfer. This function only defines the buffer, there is no data transfer performed when calling this function. Instead the data transfer is started with separate register commands that are documented in a later chapter. At this position there is also a detailed description of the function parameters.

Please make sure that all parameters of this function match. It is especially necessary that the buffer address is a valid address pointing to memory buffer that has at least the size that is defined in the function call. Please be informed that calling this function with non valid parameters may crash your system as these values are base for following DMA transfers.

The use of this function is described in greater detail in a later chapter.

Function `spcm_dwDefTransfer`

```

uint32_stdcall spcm_dwDefTransfer_i64m ( // Defines the transfer buffer by 2 x 32 bit unsigned integer
    drv_handle hDevice,                // handle to an already opened device
    uint32 dwBufType,                  // type of the buffer to define as listed above under SPCM_BUF_XXXX
    uint32 dwDirection,                // the transfer direction as defined above
    uint32 dwNotifySize,               // no. of bytes after which an event is sent (0=end of transfer)
    void* pvDataBuffer,                // pointer to the data buffer
    uint32 dwBrdOffsH,                 // high part of offset in board memory
    uint32 dwBrdOffsL,                 // low part of offset in board memory
    uint32 dwTransferLenH,             // high part of transfer buffer length
    uint32 dwTransferLenL);            // low part of transfer buffer length

uint32_stdcall spcm_dwDefTransfer_i64 ( // Defines the transfer buffer by using 64 bit unsigned integer values
    drv_handle hDevice,                // handle to an already opened device
    uint32 dwBufType,                  // type of the buffer to define as listed above under SPCM_BUF_XXXX
    uint32 dwDirection,                // the transfer direction as defined above
    uint32 dwNotifySize,               // no. of bytes after which an event is sent (0=end of transfer)
    void* pvDataBuffer,                // pointer to the data buffer
    uint64 qwBrdOffs,                  // offset for transfer in board memory
    uint64 qwTransferLen);             // buffer length

```

This function is available in two different formats as the `spcm_dwGetParam` and `spcm_dwSetParam` functions are. The background is the same. As long as you're using a compiler that supports 64 bit integer values please use the `_i64` function. Any other platform needs to use the `_i64m` function and split offset and length in two 32 bit words.

Example:

```

int16* pnBuffer = (int16*) pvAllocMemPageAligned (16384);
if (spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_CARDTOPC, 0, (void*) pnBuffer, 0, 16384) != ERR_OK)
    printf ("DefTransfer failed\n");

```

The example defines a data buffer of 8 kSamples of 16 bit integer values = 16 kByte (16384 byte) for a transfer from card to PC memory. As notify size is set to 0 we only want to get an event when the transfer has finished.

Function `spcm_dwInvalidateBuf`

The invalidate buffer function is used to tell the driver that the buffer that has been set with `spcm_dwDefTransfer` call is no longer valid. It is necessary to use the same buffer type as the driver handles different buffers at the same time. Call this function if you want to delete the buffer memory after calling the `spcm_dwDefTransfer` function. If the buffer already has been transferred after calling `spcm_dwDefTransfer` it is not necessary to call this function. When calling `spcm_dwDefTransfer` any further defined buffer is automatically invalidated.

Function `spcm_dwInvalidateBuf`

```

uint32_stdcall spcm_dwInvalidateBuf ( // invalidate the transfer buffer
    drv_handle hDevice,                // handle to an already opened device
    uint32 dwBufType);                // type of the buffer to invalidate as
                                      // listed above under SPCM_BUF_XXXX

```

Function `spcm_dwGetErrorInfo`

The function returns complete error information on the last error that has occurred. The error handling itself is explained in a later chapter in greater detail. When calling this function please be sure to have a text buffer allocated that has at least `ERRORTXTLEN` length. The error text function returns a complete description of the error including the register/value combination that has raised the error and a short description of the error details. In addition it is possible to get back the error generating register/value for own error handling. If not needed the buffers for register/value can be left to `NULL`.

Note that the timeout event (`ERR_TIMEOUT`) is not counted as an error internally as it is not locking the driver but as a valid event. Therefore the `GetErrorInfo` function won't return the timeout event even if it had occurred in between. You can only recognize the `ERR_TIMEOUT` as a direct return value of the wait function that was called.

Function `spcm_dwGetErrorInfo`

```

uint32_stdcall spcm_dwGetErrorInfo_i32 (
    drv_handle hDevice,                // handle to an already opened device
    uint32* pdwErrorReg,               // address of the error register (can be zero if not of interest)
    int32* plErrorValue,               // address of the error value (can be zero if not of interest)
    char pszErrorTextBuffer[ERRORTXTLEN]); // text buffer for text error

```

Example:

```
char szErrorBuf[ERRORTEXTLEN];
if (spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, -1))
{
    spcm_dwGetErrorInfo_i32 (hDrv, NULL, NULL, szErrorBuf);
    printf ("Set of memsize failed with error message: %s\n", szErrorBuf);
}
```

Delphi (Pascal) Programming Interface

Driver interface

The driver interface is located in the sub-directory `d_header` and contains the following files. The files need to be included in the delphi project and have to be put into the „uses“ section of the source files that will access the driver. Please do not edit any of these files as they're regularly updated if new functions or registers have been included.

file `spcm_win32.pas`

The file contains the interface to the driver library and defines some needed constants and variable types. All functions of the delphi library are similar to the above explained standard driver functions:

```
// ----- device handling functions -----
function spcm_hOpen (strName: pchar): int32; stdcall; external 'spcm_win32.dll' name '_spcm_hOpen@4';
procedure spcm_vClose (hDevice: int32); stdcall; external 'spcm_win32.dll' name '_spcm_vClose@4';

function spcm_dwGetErrorInfo_i32 (hDevice: int32; var lErrorReg, lErrorValue: int32; strError: pchar): uint32;
stdcall; external 'spcm_win32.dll' name '_spcm_dwGetErrorInfo_i32@16';

// ----- register access functions -----
function spcm_dwSetParam_i32 (hDevice, lRegister, lValue: int32): uint32;
stdcall; external 'spcm_win32.dll' name '_spcm_dwSetParam_i32@12';

function spcm_dwSetParam_i64 (hDevice, lRegister: int32; llValue: int64): uint32;
stdcall; external 'spcm_win32.dll' name '_spcm_dwSetParam_i64@16';

function spcm_dwGetParam_i32 (hDevice, lRegister: int32; var plValue: int32): uint32;
stdcall; external 'spcm_win32.dll' name '_spcm_dwGetParam_i32@12';

function spcm_dwGetParam_i64 (hDevice, lRegister: int32; var pllValue: int64): uint32;
stdcall; external 'spcm_win32.dll' name '_spcm_dwGetParam_i64@12';

// ----- data handling -----
function spcm_dwDefTransfer_i64 (hDevice, dwBufType, dwDirection, dwNotifySize: int32; pvDataBuffer: Pointer;
llBrdOffs, llTransferLen: int64): uint32;
stdcall; external 'spcm_win32.dll' name '_spcm_dwDefTransfer_i64@36';

function spcm_dwInvalidateBuf (hDevice, lBuffer: int32): uint32;
stdcall; external 'spcm_win32.dll' name '_spcm_dwInvalidateBuf@8';
```

The file also defines types used inside the driver and the examples. The types have similar names as used under C/C++ to keep the examples more simple to understand and allow a better comparison.

file `SpcRegs.pas`

The `SpcRegs.pas` file defines all constants that are used for the driver. The constant names are the same names as used under the C/C++ examples. All constants names will be found throughout this hardware manual when certain aspects of the driver usage are explained. It is recommended to only use these constant names for better visibility of the programs:

```
const SPC_M2CMD = 100; { write a command }
const M2CMD_CARD_RESET = $00000001; { hardware reset }
const M2CMD_CARD_WRITESETUP = $00000002; { write setup only }
const M2CMD_CARD_START = $00000004; { start of card (including writesetup) }
const M2CMD_CARD_ENABLETRIGGER = $00000008; { enable trigger engine }
...
```

file `SpcErr.pas`

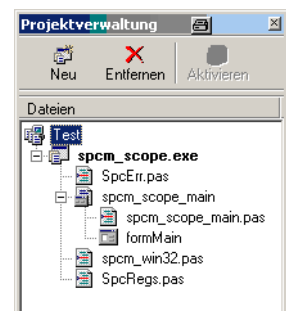
The `SpcErr.pas` file contains all error codes that may be returned by the driver.

Including the driver files

To use the driver function and all the defined constants it is necessary to include the files into the project as shown in the picture on the right. The project overview is taken from one of the examples delivered on USB-Stick. Besides including the driver files in the project it is also necessary to include them in the uses section of the source files where functions or constants should be used:

```
uses
  Windows, Messages, SysUtils, Classes, Graphics, Controls, Forms, Dialogs,
  StdCtrls, ExtCtrls,

  SpcRegs, SpcErr, spcm_win32;
```



Examples

Examples for Delphi can be found on USB-Stick in the directory /examples/delphi. The directory contains the above mentioned delphi header files and a couple of universal examples, each of them working with a certain type of card. Please feel free to use these examples as a base for your programs and to modify them in any kind.

spcm_scope

The example implements a very simple scope program that makes single acquisitions on button pressing. A fixed setup is done inside the example. The spcm_scope example can be used with any analog data acquisition card from Spectrum. It covers cards with 1 byte per sample (8 bit resolution) as well as cards with 2 bytes per sample (12, 14 and 16 bit resolution)

The program shows the following steps:

- Initialization of a card and reading of card information like type, function and serial number
- Doing a simple card setup
- Performing the acquisition and waiting for the end interrupt
- Reading of data, re-scaling it and displaying waveform on screen

.NET programming languages

Library

For using the driver with a .NET based language Spectrum delivers a special library that encapsulates the driver in a .NET object. By adding this object to the project it is possible to access all driver functions and constants from within your .NET environment.

There is one small console based example for each supported .NET language that shows how to include the driver and how to access the cards. Please combine this example with the different standard examples to get the different card functionality.

Declaration

The driver access methods and also all the type, register and error declarations are combined in the object Spcm and are located in one of the two DLLs either SpcmDrv32.NET.dll or SpcmDrv64.NET.dll delivered with the .NET examples.



For simplicity, either file is simply called „SpcmDrv.NET.dll“ in the following passages and the actual file name must be replaced with either the 32bit or 64bit version according to your application.

Spectrum also delivers the source code of the DLLs as a C# project. These sources are located in the directory SpcmDrv.NET.

```
namespace Spcm
{
    public class Drv
    {
        [DllImport("spcm_win32.dll")]public static extern IntPtr spcm_hOpen (string szDeviceName);
        [DllImport("spcm_win32.dll")]public static extern void spcm_vClose (IntPtr hDevice);
    ...
    public class CardType
    {
        public const int TYP_M2I2020          = unchecked ((int)0x00032020);
        public const int TYP_M2I2021          = unchecked ((int)0x00032021);
        public const int TYP_M2I2025          = unchecked ((int)0x00032025);
    ...
    public class Regs
    {
        public const int SPC_M2CMD            = unchecked ((int)100);
        public const int M2CMD_CARD_RESET     = unchecked ((int)0x00000001);
        public const int M2CMD_CARD_WRITESUP  = unchecked ((int)0x00000002);
    ...
}
```

Using C#

The SpcmDrv.NET.dll needs to be included within the Solution Explorer in the References section. Please use right mouse and select „AddReference“. After this all functions and constants of the driver object are available.

Please see the example in the directory CSharp as a start:

```
// ----- open card -----
hDevice = Drv.spcm_hOpen("/dev/spcm0");
if ((int)hDevice == 0)
{
    Console.WriteLine("Error: Could not open card\n");
    return 1;
}

// ----- get card type -----
dwErrorCode = Drv.spcm_dwGetParam_i32(hDevice, Regs.SPC_PCITYP, out lCardType);
dwErrorCode = Drv.spcm_dwGetParam_i32(hDevice, Regs.SPC_PCISERIALNR, out lSerialNumber);
```

Example for digitizerNETBOX/generatorNETBOX and remotely installed cards:

```
// ----- open remote card -----
hDevice = Drv.spcm_hOpen("TCPIP::192.168.169.14::INST0::INSTR");
```

Using Managed C++/CLI

The SpcmDrv.NET.dll needs to be included within the project options. Please select „Project“ - „Properties“ - „References“ and finally „Add new Reference“. After this all functions and constants of the driver object are available.

Please see the example in the directory CppCLR as a start:

```
// ----- open card -----
hDevice = Drv::spcm_hOpen("/dev/spcm0");
if ((int)hDevice == 0)
{
    Console::WriteLine("Error: Could not open card\n");
    return 1;
}

// ----- get card type -----
dwErrorCode = Drv::spcm_dwGetParam_i32(hDevice, Regs::SPC_PCITYP, lCardType);
dwErrorCode = Drv::spcm_dwGetParam_i32(hDevice, Regs::SPC_PCISERIALNR, lSerialNumber);
```

Example for digitizerNETBOX/generatorNETBOX and remotely installed cards:

```
// ----- open remote card -----
hDevice = Drv::spcm_hOpen("TCPIP::192.168.169.14::INST0::INSTR");
```

Using VB.NET

The SpcmDrv.NET.dll needs to be included within the project options. Please select „Project“ - „Properties“ - „References“ and finally „Add new Reference“. After this all functions and constants of the driver object are available.

Please see the example in the directory VB.NET as a start:

```
' ----- open card -----
hDevice = Drv.spcm_hOpen("/dev/spcm0")

If (hDevice = 0) Then
    Console.WriteLine("Error: Could not open card\n")
Else

    ' ----- get card type -----
    dwError = Drv.spcm_dwGetParam_i32(hDevice, Regs.SPC_PCITYP, lCardType)
    dwError = Drv.spcm_dwGetParam_i32(hDevice, Regs.SPC_PCISERIALNR, lSerialNumber)
```

Example for digitizerNETBOX/generatorNETBOX and remotely installed cards:

```
' ----- open remote card -----
hDevice = Drv.spcm_hOpen("TCPIP::192.168.169.14::INST0::INSTR")
```

Using J#

The SpcmDrv.NET.dll needs to be included within the Solution Explorer in the References section. Please use right mouse and select „AddReference“. After this all functions and constants of the driver object are available.

Please see the example in the directory JSharp as a start:

```
// ----- open card -----
hDevice = Drv.spcm_hOpen("/dev/spcm0");

if (hDevice.ToInt32() == 0)
    System.out.println("Error: Could not open card\n");
else
{
    // ----- get card type -----
    dwErrorCode = Drv.spcm_dwGetParam_i32(hDevice, Regs.SPC_PCITYP, lCardType);
    dwErrorCode = Drv.spcm_dwGetParam_i32(hDevice, Regs.SPC_PCISERIALNR, lSerialNumber);
```

Example for digitizerNETBOX/generatorNETBOX and remotely installed cards:

```
' ----- open remote card -----
hDevice = Drv.spcm_hOpen("TCPIP::192.168.169.14::INST0::INSTR")
```


Python Programming Interface and Examples

Driver interface

The driver interface contains the following files. The files need to be included in the python project. Please do not edit any of these files as they are regularly updated if new functions or registers have been included. To use pypscm you need either python 2 (2.4, 2.6 or 2.7) or python 3 (3.x) and ctypes, which is included in python 2.6 and newer and needs to be installed separately for Python 2.4.

file pypscm.py

The file contains the interface to the driver library and defines some needed constants. All functions of the python library are similar to the above explained standard driver functions and use ctypes as input and return parameters:

```
# ----- Windows -----
spcmDll = windll.LoadLibrary ("c:\\windows\\system32\\spcm_win32.dll")

# load spcm_hOpen
spcm_hOpen = getattr (spcmDll, "_spcm_hOpen@4")
spcm_hOpen.argtype = [c_char_p]
spcm_hOpen.restype = drv_handle

# load spcm_vClose
spcm_vClose = getattr (spcmDll, "_spcm_vClose@4")
spcm_vClose.argtype = [drv_handle]
spcm_vClose.restype = None

# load spcm_dwGetErrorInfo
spcm_dwGetErrorInfo_i32 = getattr (spcmDll, "_spcm_dwGetErrorInfo_i32@16")
spcm_dwGetErrorInfo_i32.argtype = [drv_handle, ptr32, ptr32, c_char_p]
spcm_dwGetErrorInfo_i32.restype = uint32

# load spcm_dwGetParam_i32
spcm_dwGetParam_i32 = getattr (spcmDll, "_spcm_dwGetParam_i32@12")
spcm_dwGetParam_i32.argtype = [drv_handle, int32, ptr32]
spcm_dwGetParam_i32.restype = uint32

# load spcm_dwGetParam_i64
spcm_dwGetParam_i64 = getattr (spcmDll, "_spcm_dwGetParam_i64@12")
spcm_dwGetParam_i64.argtype = [drv_handle, int32, ptr64]
spcm_dwGetParam_i64.restype = uint32

# load spcm_dwSetParam_i32
spcm_dwSetParam_i32 = getattr (spcmDll, "_spcm_dwSetParam_i32@12")
spcm_dwSetParam_i32.argtype = [drv_handle, int32, int32]
spcm_dwSetParam_i32.restype = uint32

# load spcm_dwSetParam_i64
spcm_dwSetParam_i64 = getattr (spcmDll, "_spcm_dwSetParam_i64@16")
spcm_dwSetParam_i64.argtype = [drv_handle, int32, int64]
spcm_dwSetParam_i64.restype = uint32

# load spcm_dwSetParam_i64m
spcm_dwSetParam_i64m = getattr (spcmDll, "_spcm_dwSetParam_i64m@16")
spcm_dwSetParam_i64m.argtype = [drv_handle, int32, int32, int32]
spcm_dwSetParam_i64m.restype = uint32

# load spcm_dwDefTransfer_i64
spcm_dwDefTransfer_i64 = getattr (spcmDll, "_spcm_dwDefTransfer_i64@36")
spcm_dwDefTransfer_i64.argtype = [drv_handle, uint32, uint32, uint32, c_void_p, uint64, uint64]
spcm_dwDefTransfer_i64.restype = uint32

spcm_dwInvalidateBuf = getattr (spcmDll, "_spcm_dwInvalidateBuf@8")
spcm_dwInvalidateBuf.argtype = [drv_handle, uint32]
spcm_dwInvalidateBuf.restype = uint32

# ----- Linux -----
# use cdll because all driver access functions use cdecl calling convention under linux
spcmDll = cdll.LoadLibrary ("libspcm_linux.so")

# the loading of the driver access functions is similar to windows:

# load spcm_hOpen
spcm_hOpen = getattr (spcmDll, "spcm_hOpen")
spcm_hOpen.argtype = [c_char_p]
spcm_hOpen.restype = drv_handle

# ...
```

file regs.py

The regs.py file defines all constants that are used for the driver. The constant names are the same names compared to the C/C++ examples. All constant names will be found throughout this hardware manual when certain aspects of the driver usage are explained. It is recommended to only use these constant names for better readability of the programs:

```
SPC_M2CMD = 1001                # write a command
M2CMD_CARD_RESET = 0x000000011  # hardware reset
M2CMD_CARD_WRITESETUP = 0x000000021 # write setup only
M2CMD_CARD_START = 0x000000041    # start of card (including writesetup)
M2CMD_CARD_ENABLETRIGGER = 0x000000081 # enable trigger engine
...
```

file spcerr.py

The spcerr.py file contains all error codes that may be returned by the driver.

Examples

Examples for Python can be found on USB-Stick in the directory /examples/python. The directory contains the above mentioned header files and some examples, each of them working with a certain type of card. Please feel free to use these examples as a base for your programs and to modify them in any kind.



When allocating the buffer for DMA transfers, use the following function to get a mutable character buffer:
ctypes.create_string_buffer(init_or_size[, size])

Java Programming Interface and Examples

Driver interface

The driver interface contains the following Java files (classes). The files need to be included in your Java project. Please do not edit any of these files as they are regularly updated if new functions or registers have been included. The driver interface uses the Java Native Access (JNA) library.

This library is licensed under the LGPL (<https://www.gnu.org/licenses/lgpl-3.0.en.html>) and has also to be included to your Java project.

To download the latest jna.jar package and to get more information about the JNA project please check the projects GitHub page under: <https://github.com/java-native-access/jna>

The following files can be found in the „SpcmDrv“ folder of your Java examples install path.

SpcmDrv32.java / SpcmDrv64.java

The files contain the interface to the driver library and defines some needed constants. All functions of the driver interface are similar to the above explained standard driver functions. Use the SpcmDrv32.java for 32 bit and the SpcmDrv64.java for 64 bit projects:

```
...

public interface SpcmWin64 extends StdCallLibrary {

    SpcmWin64 INSTANCE = (SpcmWin64)Native.loadLibrary ("spcm_win64"), SpcmWin64.class);

    int spcm_hOpen (String sDeviceName);
    void spcm_vClose (int hDevice);
    int spcm_dwSetParam_i64 (int hDevice, int lRegister, long llValue);
    int spcm_dwGetParam_i64 (int hDevice, int lRegister, LongByReference pllValue);
    int spcm_dwDefTransfer_i64 (int hDevice, int lBufType, int lDirection, int lNotifySize,
                               Pointer pDataBuffer, long llBrdOffs, long llTransferLen);
    int spcm_dwInvalidateBuf (int hDevice, int lBufType);
    int spcm_dwGetErrorInfo_i32 (int hDevice, IntByReference plErrorReg,
                                IntByReference plErrorValue, Pointer sErrorTextBuffer);
}

...
```

SpcmRegs.java

The SpcmRegs class defines all constants that are used for the driver. The constants names are the same names compared to the C/C++ examples. All constant names will be found throughout this hardware manual when certain aspects of the driver usage are explained. It is recommended to only use these constant names for better readability of the programs:

```
...

public static final int SPC_M2CMD = 100;
public static final int M2CMD_CARD_RESET = 0x00000001;
public static final int M2CMD_CARD_WRITESETUP = 0x00000002;
public static final int M2CMD_CARD_START = 0x00000004;
public static final int M2CMD_CARD_ENABLETRIGGER = 0x00000008;
...
```

SpcmErrors.java

The SpcmErrors class contains all error codes that may be returned by the driver.

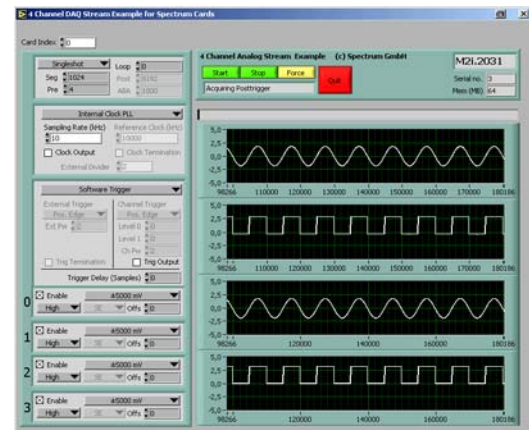
Examples

Examples for Java can be found on USB-Stick in the directory /examples/java. The directory contains the above mentioned header files and some examples, each of them working with a certain type of card. Please feel free to use these examples as a base for your programs and to modify them in any kind.

LabVIEW driver and examples

A full set of drivers and examples is available for LabVIEW for Windows. LabVIEW for Linux is currently not supported. The LabVIEW drivers have their own manual. The LabVIEW drivers, examples and the manual are found on the USB-Stick that has been included in the delivery. The latest version is also available on our webpage www.spectrum-instrumentation.com

Please follow the description in the LabVIEW manual for installation and useage of the LabVIEW drivers for this card.

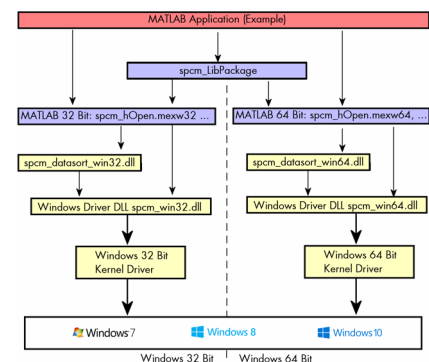


MATLAB driver and examples

A full set of drivers and examples is available for Mathworks MATLAB for Windows (32 bit and 64 bit versions) and also for MATLAB for Linux (64 bit version). There is no additional toolbox needed to run the MATLAB examples and drivers.

The MATLAB drivers have their own manual. The MATLAB drivers, examples and the manual are found on the USB-Stick that has been included in the delivery. The latest version is also available on our webpage www.spectrum-instrumentation.com

Please follow the description in the MATLAB manual for installation and useage of the MATLAB drivers for this card.

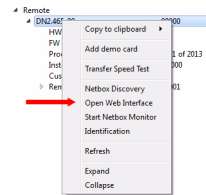


Integrated Webserver

The digitizerNETBOX/generatorNETBOX has an integrated webserver following the LXI standards. The web pages give information about the device, allows to set up ethernet details or make firmware updates.

The webserver can be reached in three different ways:

- Directly by typing the IP address into the URL field of a Web Browser.
- By selecting it from the Spectrum Control Center via the context menu on the remote device node (as shown on the screen shot on the right).
- On Windows machines (starting with Windows 7) on the device properties page, as described in the section „Finding the digitizerNETBOX in the network“ earlier in this manual.



Home Screen

The home screen gives an overview about the instrument showing all main information:



| Name | Description |
|----------------------------------|---|
| Instrument Model | The specific model code of your digitizerNETBOX or generatorNETBOX |
| Manufacturer | Manufacturer of the device - Spectrum GmbH |
| Serial Number | The unique serial number of the product. The serial number is also found on the type plate on the back of the chassis of the digitizerNETBOX/generatorNETBOX. |
| Description | A free definable description of the specific device that you can edit by yourself in the LAN configuration page. It is recommended to include the location of the device and any other information that helps your network administrator. |
| LXI Features | Listing the supported LXI features |
| LXI Version | Listing the used LXI specification for designing this device |
| Host Name | The host name given by the DNS server. If the DNS server does not generate a host name, the IP address is shown |
| mDNS Host Name | The internal mDNS host name which allows to find the device in the network environment. The mDNS host name can also be changed in the LAN configuration page |
| MAC Address | The unique MAC address of the device which can also be found on the type plate on the back of the device |
| TCP/IP Address | The current TCP/IP address as given by the DNS |
| Firmware revision | The revision of the installed firmware files for the digitizerNETBOX/generatorNETBOX itself. The integrated digitizer modules have their own firmware versioning and can be read out by the Spectrum control center |
| Software Revision | The software revision of the integrated remote server software |
| Instrument Address String (VISA) | The instrument address string following the VISA notification. Using this address string one can access the digitizerNETBOX/generatorNETBOX from the software. |
| LAN ID Indicator | Pressing this button starts flashing the LAN LED light on the front plate of the device. This helps to find the device inside a 19" rack where the back of the device with the type plate is not easily accessible. |

| Home | Instrument Welcome Page |
|-----------------------------------|--|
| LAN Configuration | Instrument Model: DN2.465-08 |
| Status | Manufacturer: Spectrum GmbH |
| Security | Serial Number: 1234 |
| Documentation | Description: Spectrum GmbH, DN2.465-08, 1234, 3.32.13608 |
| Firmware Update | LXI Features: LXI Core 2011 |
| Power | LXI Version: LXI Device Specification 2011 rev. 1.4 |
| Downloads | Host Name: 192.168.169.20 |
| Logging | mDNS Host Name: DN2_465-08_sn1234.local |
| Access | MAC Address: 0C:C4:7A:B3:C2:A2 |
| Embedded Server | TCP/IP Address: 192.168.169.20 |
| | Firmware Revision: 40 |
| | Software Revision: 3.32.13608 |
| | Instrument Address String [VISA]: TCPIP::192.168.169.20::INSTR |
| | LAN ID Indicator: <input type="button" value="Enable"/> |



digitizerNETBOX DN2.465-08 sn1234

LAN Configuration

The LAN configuration page allows to change the LAN configuration of the device. This page is password protected if a password is given in the security page.

| Name | Description |
|-----------------|---|
| Host Name | The official host name as given by the DNS |
| mDNS Host Name | The local host name which can be changed here |
| Domain | The domain in which the digitizerNETBOX is placed if the DNS server has filled this information correctly |
| Description | The device description which can be changed here |
| DHCP | DHCP (Dynamic Host Configuration Protocol) setting |
| IP Address | The current IP address as given by the DHCP server (DHCP enable) or entered manually |
| Subnet Mask | The current subnet mask as given by the DHCP server (DHCP enable) or entered manually |
| Default Gateway | The current default gateway address as given by the DHCP server (DHCP enable) or entered manually |
| DNS Server(s) | The current DNS server address as given by the DHCP server (DHCP enable) or entered manually |

| Home | Current Network Configuration |
|-----------------------------------|--|
| LAN Configuration | Host Name: 192.168.169.22 |
| Status | mDNS Host Name: DN2_462-08_sn9680.local |
| Security | Domain: |
| Documentation | Description: Spectrum GmbH, DN2.462-08, 9680, 3.17.11382 |
| Firmware Update | DHCP: enabled |
| Power | IP Address: 192.168.169.22 |
| Downloads | Subnet Mask: 255.255.255.0 |
| Logging | Default Gateway: 192.168.169.250 |
| Access | DNS Server(s): 192.168.169.202 |
| Embedded Server | <input type="button" value="Edit configuration"/> |

digitizerNETBOX

As default DHCP (IPv4) will be used and an IP address will be automatically set. In case no DHCP server is found, an IP will be obtained using the AutoIP feature. This will lead to an IPv4 address of 169.254.x.y (with x and y being assigned to a free IP in the network) using a subnet mask of 255.255.0.0.

The default IP setup can also be restored, by using the „LAN Reset“ button on the device.

If a fixed IP address should be used instead, the parameters need to be set according to the current LAN requirements.

Pressing the „edit configuration“ button will issue a new edit page. If a password is given in the security pages the password must be entered before the edit screen is available

| Name | Description |
|-----------------|---|
| Host Name | Enter a new host name for the mDNS host name. Please note that host names can only contain letters, numbers, minus and underscore, no dots or blanks are allowed |
| Domain | The domain in which the digitizerNETBOX/generatorNETBOX is placed |
| Submit Button | After review this button submits the changes and changes host name and description permanently |
| Reset Button | Discards the changes and returns host name and description to the previous values. |
| TCP/IP Mode | Select between DHCP + AutoIP to have all configuration done automatically or Manual to enter all IP related settings manual. |
| IP Address | Only available if manual TCP/IP mode is selected |
| Subnet Mask | Only available if manual TCP/IP mode is selected |
| Default Gateway | Only available if manual TCP/IP mode is selected |
| DNS Server(s) | Only available if manual TCP/IP mode is selected |
| Submit Button | Submits the changes. If you set the IP details manually please be sure that your device is addressable within your network. In case of a failure the LAN reset button on the front page of the device will set back the LAN configuration to DHCP |
| Reset Button | Discards the changes and returns IP settings to the previous values |

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Network Configuration

| | |
|-------------|---------------------------------|
| Host Name | DN2_462-08_sn9680 |
| Domain | |
| Description | Spectrum GmbH, DN2.462-08, 9680 |

Attention: Leaving a field empty will set the default value

Submit Reset

Network Configuration

TCP/IP Mode ☒ DHCP + AutoIP ☐ Manual

| | |
|-----------------|--------------------|
| IP Address | 192 .168 .169 .22 |
| Subnet Mask | 255 .255 .255 .0 |
| Default Gateway | 192 .168 .169 .250 |
| DNS Server(s) | 192 .168 .169 .202 |

Submit Reset

digitizerNETBOX

Status

Shows the internal device status. For each internal digitizer/generator module the status whether the module is available or locked by a user is shown. A digitizer/generator module is locked as soon as it is opened from any software on any PC.

In case the instrument is locked, the IP address of the current control PC can be obtained here.

Also the current temperature will be displayed here. DN6.xxxx models of either the digitizerNETBOX or generatorNETBOX will also display the case fan speed here as well (not shown on screen shot).

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Status

| | |
|--------------------------------------|------------------------|
| TCP/IP::192.168.169.39::inst0::INSTR | used by 192.168.169.29 |
| TCP/IP::192.168.169.39::inst1::INSTR | available |

Temperature

| | |
|-----|--------------------|
| CPU | +43.0°C / +109.4°F |
|-----|--------------------|

digitizerNETBOX

Security

Allows to set a password to protect the device from changes. The password secures access to LAN configuration, power settings like reboot or power down and firmware updates of the instrument. As default no password is set for the configuration.

To change the password the old password has to be entered once and the new password twice to avoid typing errors.

In case of a lost password the LAN reset button on the front plate of the digitizerNETBOX/generatorNETBOX will delete the password and set the complete device to the default stage again.

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Security

| | |
|---------------------|-------|
| Old Password | ***** |
| New Password | ***** |
| Repeat New Password | ***** |

Submit Reset

digitizerNETBOX

Documentation

All related documents for the device that may be needed to operate the digitizerNETBOX/generatorNETBOX or to program it are available by download as pdf documents from here.

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Documentation

| | |
|------------|----------------------------------|
| Manuals | DN2.46x |
| Datasheets | DN2.46x |
| Flyer | Netbox |
| Homepage | www.spectrum-instrumentation.com |

digitizerNETBOX

Firmware Update

The complete firmware of the device can be updated with a single firmware update file which is available for download directly here by clicking the „check online“ button or on the Spectrum webpage www.spectrum-instrumentation.com. The firmware file contains update files for the following parts:

- firmware files of the integrated digitizer/generator modules
- drivers for the digitizer/generator modules
- software and setup of the underlying operating system
- webserver and integrated web pages and manuals
- remote server software
- initialization scripts and tools

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Firmware Update

Please select the firmware archive: No file selected.

New Firmware

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Power

From here the digitizerNETBOX/generatorNETBOX can be remotely shut down or remotely rebooted. Please make sure that no software is currently accessing the digitizerNETBOX or generatorNETBOX before using any of these power options.

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Power settings

Reboot NETBOX

Shut down NETBOX

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Downloads

The webserver gives access to all necessary software components for download. All these software installers are also available on the USB-Stick that is delivered with the digitizerNETBOX/generatorNETBOX and on the internet.

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Downloads

Windows

SBench 6 [32Bit](#)

Control Center & Driver [32Bit](#)

Linux

Driver [32 & 64Bit](#)

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Logging

This is a debug setting only. You shouldn't change any of these settings unless our support team requested you to do so. Operating the digitizerNETBOX/generatorNETBOX with log-level „Log all“ will slow down the operation as each single call is logged as a text entry in the internal log file.

These debug log settings are similar to the ones described in the chapter about the Spectrum control center. Using this logging the internal communication between the remote server and the locally installed Spectrum driver is logged.

Please note that some digitizerNETBOX/generatorNETBOX products (having only one internal digitizer/generator installed) show an error message „KernelOpen /dev/spcm1 failed“. This error message is not an error but simply the remote server trying to open the second internal digitizer that isn't installed.

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Logging

DO NOT CHANGE ANYTHING HERE UNLESS YOU HAVE BEEN PROMPTED TO!

On-board Log Level

Log all, including library calls

☐ Append logging to file

00000.000 s: Wed Sep 23 16:46:31 2015

```
00000.000 s: *****
00000.000 s: InitLibrary
00000.000 s: Library Version 3.17 build 11382
00000.000 s: Operating System: Linux 32 Bit
00000.000 s: Registry Debug LogLevel: 3
00000.000 s: *****
00000.004 s: Clean Library
00000.004 s: *****
00000.004 s:
00000.009 s: KernelOpen 0x3
```

digitizerNETBOX

Access

In here it is possible to restrict the access to the digitizerNETBOX/generatorNETBOX to certain IP addresses. As long as the access list is clear, everybody who has a TCP/IP connection to the digitizerNETBOX/generatorNETBOX can get control of it and use it with any software like SBench 6.

Use the add IP to list field with the submit button to add an IP address to the list. As a default your current IP address is shown in the entry field.

After having setup an access list everybody else who is not on the access restricted IP list can still see the digitizerNETBOX or generatorNETBOX in the network and use the discovery function but access to the internal digitizers/generators is restricted and no longer possible.

Use this option together with the password option to completely secure the digitizerNETBOX/generatorNETBOX from unwanted access.

digitizerNETBOX

Embedded Server

The embedded server is an option and is only available if ordered with and installed on your particular digitizerNETBOX/generatorNETBOX. Please see the dedicated Embedded Server Option chapter for more information on this feature.

Using the „Reset password“ button the password for the user „embedded“ is reset to the default password which is also „embedded“

The autostart feature allows the user to automatically start scripts, programs or services on the device during boot process. If something fails with the start, the autostart feature can be disabled using the „Autostart [Disable]“ button. After fixing the automatically starting programs one can enable the autostart feature again.

digitizerNETBOX

Login/Logout

As soon as a password has been entered in the security settings a login/logout command is available from the webpage menu.

After entering the password once the login stays valid until a logout or until closing the web browser.

digitizerNETBOX

IVI Driver

The IVI Foundation is an open consortium founded in 1998 to promote standards for programming test instruments. Composed primarily of instrument manufacturers, end-users, software vendors, and system integrators, the Foundation strives to create specifications that govern the development of instrument drivers.

-> <http://IVIfoundation.org>

About IVI

The IVI standards define an open driver architecture, a set of instrument classes, and shared software components. Together these provide critical elements needed for instrument interchangeability.

Benefits

IVI offers several benefits to measurement system designers:

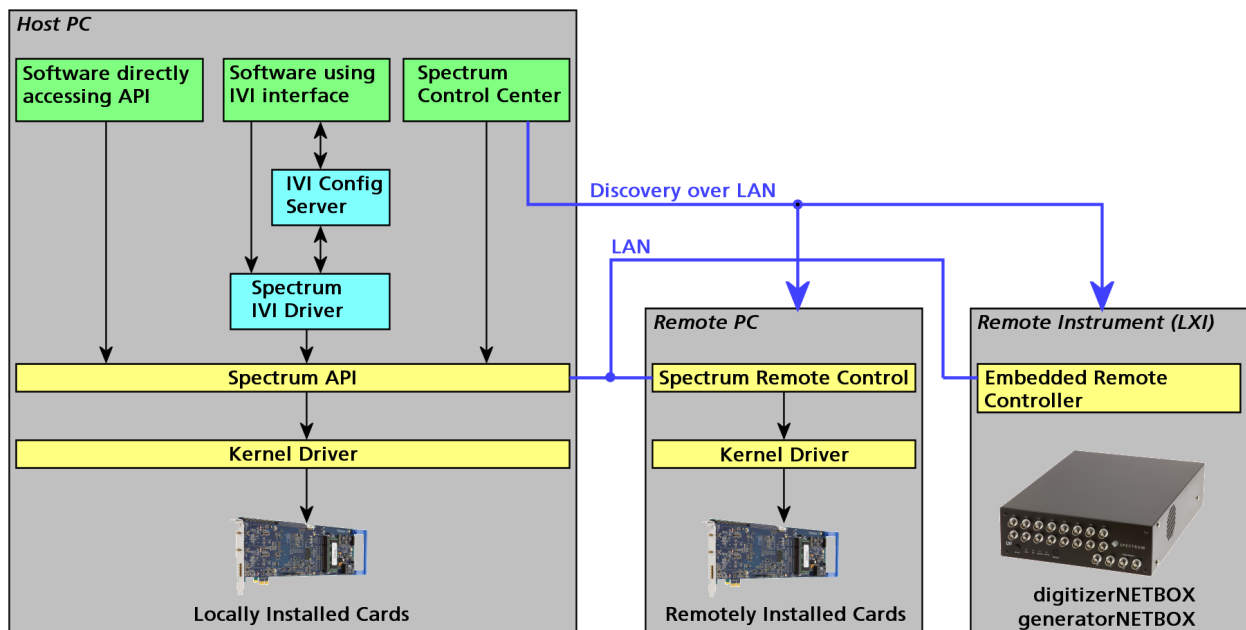
- IVI's defined Application Programming Interfaces (APIs) standardize common measurement functions reducing the time needed to learn a new IVI instrument.
- Instrument simulation allows developers to run code without an instrument. This feature reduces the need for sometimes scarce measurement hardware resources and it can simplify testing of measurement applications.
- IVI drivers feature enhanced ease of use in popular Application Development Environments. IVI's standard APIs, combined with IVI driver wrappers where appropriate, provide fast, intuitive access to driver functions.
- IVI drivers provide for interchangeability. Interchangeability reduces the time and effort needed to integrate measurement devices into new or existing systems

Interchangeability

Systems designed with IVI drivers enjoy the benefits of standardized code that can be interchanged into other systems. This code also supports interchange of measurement devices – helping to prevent hardware obsolescence. Interchangeability is supported on three levels: The IVI architecture specifications allow architectural interchangeability – that is a standard driver architecture that can be reused. The class specifications provide syntactic interchangeability which supports instrument exchange with minimal code changes. The highest level of interchangeability is achieved by using the IVI signal specifications.

General Concept of the Spectrum IVI driver

The Spectrum IVI driver is based on the standard Spectrum API and can be used with any Spectrum products specified below in the supported hardware chapter. The Spectrum products to be accessed with the IVI driver can be locally installed data acquisition cards, remotely installed data acquisition cards or remote LXI instruments like a digitizerNETBOX or generatorNETBOX.



Supported Spectrum Hardware

All Spectrum analog data acquisition hardware based on the SPCM driver structure is supported by the IVI driver. There is only one IVI driver for all hardware.

Supported data acquisition card families:

- M2i.20xx and M2i.20xx-exp family
- M3i.21xx and M3i.21xx-exp family
- M4i.22xx-x8 and M4x.22xx-x4 family
- M2i.30xx and M2i.30xx-exp family
- M2i.31xx and M2i.31xx-exp family
- M3i.32xx and M3i.32xx-exp family
- M2i.40xx and M2i.40xx-exp family
- M3i.41xx and M3i.41xx-exp family
- M4i.44xx-x8 and M4x.44xx-x4 family
- M2i.46xx and M2i.46xx-exp family
- M2i.47xx and M2i.47xx-exp family
- M3i.48xx and M3i.48xx-exp family
- M2i.49xx and M2i.49xx-exp family
- M2p.59xx-x4 family
- M2p.65xx-x4 family
- M2i.60xx and M2i.60xx-exp family
- M4i.66xx-x8 and M4x.66xx-x4 family

Supported digitizerNETBOX families

- DN2.20x-xx family
- DN2.22x-xx and DN6.22x-xx family
- DN2.44x-xx and DN6.44x-xx family
- DN2.46x-xx and DN6.46x-xx family
- DN2.49x-xx and DN6.49x-xx family
- DN2.59x-xx and DN6.59x-xx family

Supported generatorNETBOX families

- DN2.60x-xx family
- DN2.65x-xx and DN6.65x-xx family
- DN2.66x-xx and DN6.66x-xx family

IVI Compliance

General information on the Spectrum IVI driver:

| | |
|---------------------------------|---------------|
| IVI class specification version | Version 3.3 |
| IVI-C interface | supported |
| IVI-COM interface | supported |
| IVI.NET interface | not supported |

The following IVI classes are supported by different instrument types:

| IVI Class | Supported by Spectrum hardware | IVI specific driver function prefix |
|------------------|---|--|
| IVIScope | Supported by all digitizerNETBOX devices and analog data acquisition cards listed above | SpecScope_ |
| VIDigitizer | Supported by all digitizerNETBOX devices and analog data acquisition cards listed above | SpecDigitizer_ |
| IVIFgen | Supported by all generatorNETBOX devices and analog data generator cards listed above | SpecFGen_ |

Supported Operating Systems

| 32 bit operating systems | 64 bit operating systems |
|---------------------------------|---------------------------------|
| Windows 7 | Windows 7 |
| Windows 8 | Windows 8 |
| Windows 10 | Windows 10 |

Supported Standard Driver Features

| Feature | Supported | Description of the Feature |
|----------------------------|--|---|
| State caching | yes standard feature of the API which is permanently active | To minimize the number of I/O calls needed to configure an instrument to a new state, IVI specific drivers may implement state caching. IVI specific drivers can choose to implement state caching for all, some, or none of the instrument settings. If the user enables state caching and the IVI specific driver implements caching for hardware configuration attributes, driver functions perform instrument I/O when the current state of the instrument settings is different from what the user requests. |
| Range checking | yes standard feature of the API which is permanently active | If range checking is enabled, an IVI specific driver checks that input parameters are within the valid range for the instrument. |
| Instrument Status Checking | yes standard feature of the API which is permanently active | If instrument status checking is enabled, an IVI specific driver automatically checks the status of the instrument after most operations. If the instrument indicates that it has an error, the driver returns a special error code. The user then calls the Error Query function to retrieve the instrument specific error code from the instrument. |
| Multithread Safety | yes | IVI drivers are multithread safe. Multithread safety means that multiple threads in the same process can use the same IVI driver session and that different sessions of the same IVI driver can run simultaneously on different threads. |
| Simulation | yes | If simulation is enabled, an IVI specific driver does not perform instrument I/O, and the driver creates simulated data for output parameters. This allows the user to execute instrument driver calls in the application program even though the instrument is not available. |

IVIScope Supported Class Capabilities

| Feature | Supported | Description of Feature |
|--------------------------------|-----------|---|
| IVIScopeBase | yes | Base Capabilities of the IVIScope specification. This group includes the capability to acquire waveforms using edge triggering. |
| IVIScopeInterpolation | no | Extension: IVIScope with the ability to configure the oscilloscope to interpolate missing points in a waveform. |
| IVIScopeTVTrigger | no | Extension: IVIScope with the ability to trigger on standard television signals. |
| IVIScopeRunTrigger | no | Extension: IVIScope with the ability to trigger on runs. |
| IVIScopeGlitchTrigger | no | Extension: IVIScope with the ability to trigger on glitches. |
| IVIScopeWidthTrigger | no | Extension: IVIScope with the ability to trigger on a variety of conditions regarding pulse widths. |
| IVIScopeACLineTrigger | no | Extension: IVIScope with the ability to trigger on zero crossings of a network supply voltage. |
| IVIScopeWaveformMeas | no | Extension: IVIScope with the ability to calculate waveform measurements, such as rise time or frequency. |
| IVIScopeMinMaxWaveform | no | Extension: IVIScope with the ability to acquire a minimum and maximum waveforms that correspond to the same time range. |
| IVIScopeProbeAutoSense | no | Extension: IVIScope with the ability to automatically sense the probe attenuation of an attached probe. |
| IVIScopeContinuous Acquisition | no | Extension: IVIScope with the ability to continuously acquire data from the input and display it on the screen. |
| IVIScopeAverage Acquisition | no | Extension: IVIScope with the ability to create a waveform that is the average of multiple waveform acquisitions. |
| IVIScopeSampleMode | no | Extension: IVIScope with the ability to return the actual sample mode. |
| IVIScopeTrigger Modifier | no | Extension: IVIScope with the ability to modify the behavior of the triggering subsystem in the absence of a expected trigger. |
| IVIScopeAutoSetup | no | Extension: IVIScope with the automatic configuration ability. |

IVIDigitizer Supported Class Capabilities

| Feature | Supported | Description of Feature |
|-------------------------------------|-----------|--|
| IVIDigitizerBase | yes | Base Capabilities of the IVIDigitizer specification. This group includes the capability to acquire waveforms using edge triggering. |
| IVIDigitizerMultiRecordAcquisition | yes | Extension: IVIDigitizer with the ability to do multi-record acquisitions. |
| IVIDigitizerBoardTemperature | no | Extension: IVIDigitizer with the ability to report the temperature of the digitizer. |
| IVIDigitizerChannelFilter | no | Extension: IVIDigitizer with the ability to control the channel input filter frequency. |
| IVIDigitizerChannelTemperature | no | Extension: IVIDigitizer with the ability to report the temperature of individual digitizer channels. |
| IVIDigitizerTimeInterleavedChannels | no | Extension: IVIDigitizer with the ability to combine two or more input channels to achieve higher acquisitions rates and/or record lengths. |
| IVIDigitizerDataInterleavedChannels | no | Extension: IVIDigitizer with the ability to interleave the data from two or more input channels, usually to create complex (I/Q) data. |
| IVIDigitizerReferenceOscillator | no | Extension: IVIDigitizer with the ability to use an external reference oscillator. |
| IVIDigitizerSampleClock | yes | Extension: IVIDigitizer with the ability to use an external sample clock. |
| IVIDigitizerSampleMode | no | Extension: IVIDigitizer with the ability to control whether the digitizer is using real-time or equivalent-time sampling. |
| IVIDigitizerSelfCalibration | yes | Extension: IVIDigitizer with the ability to perform self calibration. |
| IVIDigitizerDownconversion | no | Extension: IVIDigitizer with the ability to do frequency translation or downconversion in hardware. |
| IVIDigitizerArm | no | Extension: IVIDigitizer with the ability to arm on positive or negative edges. |
| IVIDigitizerMultiArm | no | Extension: IVIDigitizer with the ability to arm on one or more sources. |
| IVIDigitizerGlitchArm | no | Extension: IVIDigitizer with the ability to arm on glitches. |
| IVIDigitizerRunArm | no | Extension: IVIDigitizer with the ability to arm on runs. |
| IVIDigitizerSoftwareArm | no | Extension: IVIDigitizer with the ability to arm acquisitions. |
| IVIDigitizerTVArm | no | Extension: IVIDigitizer with the ability to arm on standard TV signals. |
| IVIDigitizerWidthArm | no | Extension: IVIDigitizer with the ability to arm on a variety of conditions regarding pulse widths. |
| IVIDigitizerWindowArm | no | Extension: IVIDigitizer with the ability to arm on signals entering or leaving a defined voltage range. |
| IVIDigitizerTriggerModifier | no | Extension: IVIDigitizer with the ability to perform an alternative triggering function in the event that the specified trigger event doesn't occur. |
| IVIDigitizerMultiTrigger | yes | Extension: IVIDigitizer with the ability to trigger on one or more sources. |
| IVIDigitizerPretriggerSamples | yes | Extension: IVIDigitizer with the ability to specify a number of samples to fill up the data buffer with pre-trigger data. |
| IVIDigitizerTriggerHoldoff | no | Extension: IVIDigitizer with the ability to specify a length of time after the digitizer detects a trigger during which the digitizer ignores additional triggers. |
| IVIDigitizerGlitchTrigger | no | Extension: IVIDigitizer with the ability to trigger on glitches. |
| IVIDigitizerRunTrigger | no | Extension: IVIDigitizer with the ability to trigger on runs. |
| IVIDigitizerSoftwareTrigger | no | Extension: IVIDigitizer with the ability to trigger acquisitions. |
| IVIDigitizerTVTrigger | no | Extension: IVIDigitizer with the ability to trigger on standard television signals. |
| IVIDigitizerWidthTrigger | no | Extension: IVIDigitizer with the ability to trigger on a variety of conditions regarding pulse widths. |
| IVIDigitizerWindowTrigger | yes | Extension: IVIDigitizer with the ability to trigger on signals entering or leaving a defined voltage range. |

IVIFGen Supported Class Capabilities

| Feature | Supported | Description of Feature |
|------------------------|------------------|--|
| IvIFgenBase | yes | Base Capabilities. |
| IvIFgenArbFrequency | no | Extension: IVIFgen with the ability to generate arbitrary waveforms with user-defined sample rate. |
| IvIFgenArbWfm | yes | Extension: IVIFgen with the ability to generate user-defined arbitrary waveforms. |
| IvIFgenArbSeq | no | Extension: IVIFgen with the ability to generate of arbitrary sequences |
| IvIFgenBurst | no | Extension: IVIFgen with the ability to generate discrete numbers of waveform cycles. |
| IvIFgenInternalTrigger | no | Extension: IVIFgen with the ability to use internally generated triggers |
| IvIFgenModulateAM | no | Extension: IVIFgen with the ability to apply amplitude modulation to an output signal |
| IvIFgenModulateFM | no | Extension: IVIFgen with the ability to apply frequency modulation to an output signal |
| IvIFgenSoftwareTrigger | no | Extension: IVIFgen with the ability to generate signals based on software triggers |
| IvIFgenStdFunc | yes | Extension: IVIFgen with the ability to generate standard waveforms |
| IvIFgenTrigger | no | Extension: IVIFgen with the ability to use user-definable trigger sources |

Find more Information on IVI

The official IVI foundation webpage offers a lot of additional information on setup and programming of the IVI drivers using different environments.

General Information on IVI

-><http://ivifoundation.org>

The website of the IVI foundation offers several documents and detailed explanations for the useage of IVI drivers and the benefits.

IVI Getting Started Guides and Videos

-> <http://ivifoundation.org/resources/default.aspx>

In here you find getting started guides and videos for different environments:

- Using IVI with Visual C++
- Using IVI Visual C# and Visual Basic .NET
- Using IVI with LabVIEW
- Using IVI with LabWindows/CVI
- Using IVI with MATLAB
- Using IVI with Measure Foundry
- Using IVI with Visual Basic 6.0
- Using IVI with Keysight VEE Pro

Installation

Installer

The Spectrum IVI Driver Installer is shipped as an executable containing all IVI related software parts. There is only one installer for both 32 bit and 64 bit environments. The insaller automatically detects the components that are necessary to install.



Please be sure to have the latest drivers available. You find the current driver archieves on the Spectrum webpage www.spectrum-instrumentation.com available for download.

Shared Components

To improve users' experience when they combine drivers and other software from various vendors, it is important to have some key software components common to all implementations. In order to accomplish this, the IVI Foundation provides a standard set of shared components that must be used by all compliant drivers and ancillary software. These components provide services to drivers and driver clients that need to be common to all drivers, for instance, the administration of system-wide configuration.

The IVI shared components are available directly at the IVI Foundation homepage www.ivifoundation.org. Please download the lates version of the IVI shared components there.

The IVI Shared Component installer creates a directory structure to house the IVI Shared Components as well as IVI drivers themselves. The root of this directory structure is referred to as the IVI install directory [IVIInstallDir] and is typically located under [program files]\IVI Foundation\IVI.

Installation Procedure

Please stick to this installation order to avoid any problems with the drivers:

Spectrum Card locally installed

- Install card into the system as described in the hardware manual
- Start the system and let Windows install the hardware driver from USB-Stick or from your download folder
- Install the Spectrum Control Center
- Install the IVI shared components from www.ivifoundation.org
- Install the IVI driver package

Spectrum Card remotely installed

- Install card into the remote system as described in the hardware manual
- Start the remote system and let Windows install the hardware driver from USB-Stick or from your download folder
- Install the Spectrum Remote Package onto the remote PC as described in the manual
- Install the Spectrum Control Center on the host system
- Setup the remote connection inside the Control Center as described in the hardware manual
- Install the IVI shared components from www.ivifoundation.org
- Install the IVI driver package on the host system

Spectrum digitizerNETBOX/generatorNETBOX remotely controlled

- Connect the digitizerNETBOX/generatorNETBOX to your LAN or directly to your host PC
- Install the Spectrum Control Center on the host system
- Setup the remote connection inside the Control Center as described in the hardware manual
- Install the IVI shared components from www.ivifoundation.org
- Install the IVI driver package on the host system

No Spectrum hardware available, only simulated cards

- Install the Spectrum Control Center on the system
- Setup one or more demo cards inside the Spectrum Control Center
- Install the IVI shared components from www.ivifoundation.org
- Install the IVI driver package on the host system

Installation of the IVI driver package

Please start the installation by doubleclicking the install file

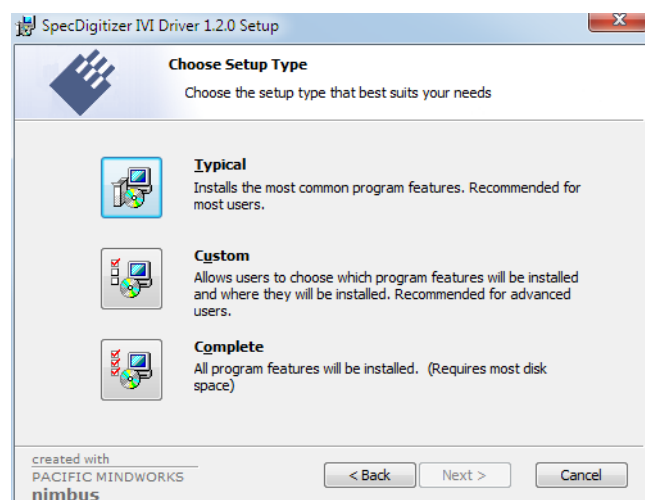
There is one installer for the IVI scope class driver and one installer for the IVI digitizer class driver. You may install one of them or both.



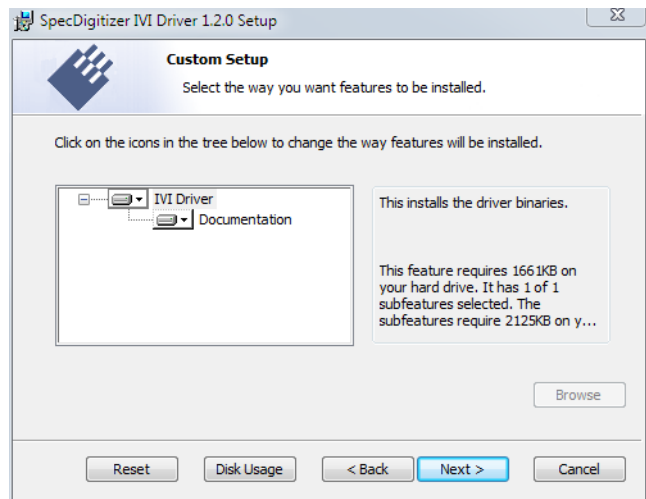
Select the setup type for the installation:

- Typical setup will install the most common program features
- Custom setup allows user to choose which program features will be installed.
- Complete setup will install all prgra, features.

Typical and Complete setup runs without any further user interaction and install the needed components of the driver.



The custom setup allows users to deselect certain parts of the driver package



Configuration Store

General Information

The IVI Configuration Server is the run-time module that is responsible for providing system database services to IVI based measurement system applications. Specifically, it provides system initialization and configuration information. The IVI Configuration Server is used by several of the IVI compliant modules. For instance, the Configuration Server indicates which physical instrument and IVI driver will be used by a particular application to provide a particular measurement capability.

Since a typical system intermixes instruments and drivers from multiple vendors this system configuration service needs to be accessed in a vendor independent fashion. Therefore, the IVI Configuration Server is an IVI shared component (that is, the code is owned by the IVI Foundation). The IVI Configuration Server is provided by the IVI Foundation because the architecture requires a single Configuration Server be installed on any system, therefore having a single shared implementation eliminates potential conflicts from divergent implementations.

The IVI Configuration Server is a single executable and one or more XML configuration stores (databases) made up of the following basic components:

- The physical database (known as the configuration store). A physical configuration store is a single XML file. APIs are available to read and write the data to arbitrary files, thus providing complex applications with the ability to directly manage system configurations.
- The API (and its implementation) used to read information from the configuration store(s). The IVI modules typically use this API when they are instantiated and configured.
- The API (and its implementation) to write information to the configuration store(s). This API is typically used by GUI or other applications that set up the initial configuration.
- The API (and its implementation) used to bind an instance of the Configuration Server code to a particular copy of the configuration information stored on a system. This includes appropriate algorithms for gaining access to the master configuration store.

Repeated Capabilities

In many instruments there are capabilities that are duplicated either identically or very similarly across the instrument. Such capabilities are called repeated capabilities. The IVI class-compliant APIs represent repeated capabilities by a parameter that indicates which instance of the duplicate capability this function is intended to access. The IVI C APIs include this parameter as an additional parameter to function calls.

The IVI Configuration Server provides a way for software modules to publish the functionality that is duplicated and the strings that the software module recognizes to access the repeated capabilities. The IVI Configuration Server also provides a way for the client to supply aliases for the physical identifiers recognized by the drivers.

The Spectrum IVI driver for example uses the channel index as repeated capability allowing to give channel names as an identifier.

Programming the Board

Overview

The following chapters show you in detail how to program the different aspects of the board. For every topic there's a small example. For the examples we focused on Visual C++. However as shown in the last chapter the differences in programming the board under different programming languages are marginal. This manual describes the programming of the whole hardware family. Some of the topics are similar for all board versions. But some differ a little bit from type to type. Please check the given tables for these topics and examine carefully which settings are valid for your special kind of board.

Register tables

The programming of the boards is totally software register based. All software registers are described in the following form:

| The name of the software register as found in the regs.h file. Could directly be used by C/C++, Delphi and Basic com- | The decimal value of the software register. Also found in the regs.h file. This value must be used with all programs or compilers that cannot use the header file directly. | Describes whether the register can be read (r) and/or written (w). | Short description of the functionality of the register. A more detailed description is found above or below the register tables. |
|---|--|--|--|
| | | | |
| Register | Value | Direction | Description |
| SPC_M2CMD | 100 | w | Command register of the board. |
| M2CMD_CARD_START | 4h | | Starts the board with the current register settings. |
| M2CMD_CARD_STOP | 40h | | Stops the board manually. |
| | | | |
| Any constants that can be used to program the register directly are shown inserted beneath the register table. | The decimal or hexadecimal value of the constant, also found in the regs.h file. Hexadecimal values are indicated with an „h“ at the end. This value must be used with all programs or compilers that cannot use the header file directly. | Short description of the use of this constant. | |

If no constants are given below the register table, the dedicated register is used as a switch. All such registers are activated if written with a "1" and deactivated if written with a "0".



Programming examples

In this manual a lot of programming examples are used to give you an impression on how the actual mentioned registers can be set within your own program. All of the examples are located in a separated colored box to indicate the example and to make it easier to differ it from the describing text.

All of the examples mentioned throughout the manual are written in C/C++ and can be used with any C/C++ compiler for Windows or Linux.

Complete C/C++ Example

```
#include "../c_header/dlltyp.h"
#include "../c_header/regs.h"
#include "../c_header/spcm_drv.h"

#include <stdio.h>

int main()
{
    drv handle hDrv; // the handle of the device
    int32 lCardType; // a place to store card information

    hDrv = spcm_hOpen ("/dev/spcm0"); // Opens the board and gets a handle
    if (!hDrv) // check whether we can access the card
        return -1;

    spcm_dwGetParam_i32 (hDrv, SPC_PCITYP, &lCardType); // simple command, read out of card type
    printf ("Found card M2i/M3i/M4i/M4x/M2p.%04x in the system\n", lCardType & TYP_VERSIONMASK);
    spcm_vClose (hDrv);

    return 0;
}
```

Initialization

Before using the card it is necessary to open the kernel device to access the hardware. It is only possible to use every device exclusively using the handle that is obtained when opening the device. Opening the same device twice will only generate an error code. After ending the driver use the device has to be closed again to allow later re-opening. Open and close of driver is done using the `spcm_hOpen` and `spcm_vClose` function as described in the "Driver Functions" chapter before.

Open/Close Example

```
drv_handle hDrv;                                // the handle of the device

hDrv = spcm_hOpen ("/dev/spcm0");                // Opens the board and gets a handle
if (!hDrv)                                       // check whether we can access the card
{
    printf "Open failed\n";
    return -1;
}

... do any work with the driver

spcm_vClose (hDrv);
return 0;
```

Initialization of Remote Products

The only step that is different when accessing remotely controlled cards or digitizerNETBOXes is the initialization of the driver. Instead of the local handle one has to open the VISA string that is returned by the discovery function. Alternatively it is also possible to access the card directly without discovery function if the IP address of the device is known.

```
drv_handle hDrv;                                // the handle of the device

hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INSTR"); // Opens the remote board and gets a handle
if (!hDrv)                                       // check whether we can access the card
{
    printf "Open of remote card failed\n";
    return -1;
}

...
```

Multiple cards are opened by indexing the remote card number:

```
hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INSTR"); // Opens the remote board #0
// or alternatively
hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INST0::INSTR"); // Opens the remote board #0
// all other boards require an index:
hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INST1::INSTR"); // Opens the remote board #1
hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INST2::INSTR"); // Opens the remote board #2
```

Error handling

If one action caused an error in the driver this error and the register and value where it occurs will be saved.



The driver is then locked until the error is read out using the error function `spcm_dwGetErrorInfo_i32`. Any calls to other functions will just return the error code `ERR_LASTERR` showing that there is an error to be read out.

This error locking functionality will prevent the generation of unseen false commands and settings that may lead to totally unexpected behavior. For sure there are only errors locked that result on false commands or settings. Any error code that is generated to report a condition to the user won't lock the driver. As example the error code `ERR_TIMEOUT` showing that the a timeout in a wait function has occurred won't lock the driver and the user can simply react to this error code without reading the complete error function.

As a benefit from this error locking it is not necessary to check the error return of each function call but just checking the error function once at the end of all calls to see where an error occurred. The enhanced error function returns a complete error description that will lead to the call that produces the error.

Example for error checking at end using the error text from the driver:

```
char szErrorText[ERRORTXTLEN];

spcm_dwSetParam_i64 (hDrv, SPC_SAMPLERATE, 1000000);           // correct command
spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, -345);                // faulty command
spcm_dwSetParam_i64 (hDrv, SPC_POSTTRIGGER, 1024);            // correct command
if (spcm_dwGetErrorInfo_i32 (hDrv, NULL, NULL, szErrorText) != ERR_OK) // check for an error
{
    printf (szErrorText);                                       // print the error text
    spcm_vClose (hDrv);                                         // close the driver
    exit (0);                                                  // and leave the program
}
```

This short program then would generate a printout as:

```
Error occurred at register SPC_MEMSIZE with value -345: value not allowed
```

All error codes are described in detail in the appendix. Please refer to this error description and the description of the software register to examine the cause for the error message.



Any of the parameters of the spcm_dwGetErrorInfo_i32 function can be used to obtain detailed information on the error. If one is not interested in parts of this information it is possible to just pass a NULL (zero) to this variable like shown in the example. If one is not interested in the error text but wants to install its own error handler it may be interesting to just read out the error generating register and value.

Example for error checking with own (simple) error handler:

```
uint32 dwErrorReg;
int32 lErrorValue;
uint32 dwErrorCode;

spcm_dwSetParam_i64 (hDrv, SPC_SAMPLERATE, 1000000);           // correct command
spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, -345);                // faulty command
spcm_dwSetParam_i64 (hDrv, SPC_POSTTRIGGER, 1024);            // correct command
dwErrorCode = spcm_dwGetErrorInfo_i32 (hDrv, &dwErrorReg, &lErrorValue, NULL);
if (dwErrorCode) // check for an error
{
    printf ("Errorcode: %d in register %d at value %d\n", lErrorCode, dwErrorReg, lErrorValue);
    spcm_vClose (hDrv);                                         // close the driver
    exit (0);                                                  // and leave the program
}
```

Gathering information from the card

When opening the card the driver library internally reads out a lot of information from the on-board eeprom. The driver also offers additional information on hardware details. All of this information can be read out and used for programming and documentation. This chapter will show all general information that is offered by the driver. There is also some more information on certain parts of the card, like clock machine or trigger machine, that is described in detail in the documentation of that part of the card.

All information can be read out using one of the spcm_dwGetParam functions. Please stick to the “Driver Functions” chapter for more details on this function.

Card type

The card type information returns the specific card type that is found under this device. When using multiple cards in one system it is highly recommended to read out this register first to examine the ordering of cards. Please don't rely on the card ordering as this is based on the BIOS, the bus connections and the operating system.

| Register | Value | Direction | Description |
|------------|-------|-----------|---|
| SPC_PCITYP | 2000 | read | Type of board as listed in the table below. |

One of the following values is returned, when reading this register. Each card has its own card type constant defined in regs.h. Please note that when reading the card information as a hex value, the lower word shows the digits of the card name while the upper word is a indication for the used bus type.

| Card type | Card type as defined in regs.h | Value hexadecimal | Value decimal | | | Card type as defined in regs.h | Value hexadecimal | Value decimal | |
|--------------|--------------------------------|-------------------|---------------|--|--|--------------------------------|-------------------|---------------|--------|
| M2i.6011 | TYP_M2i6011 | 36011h | 221201 | | | M2i.6030 | TYP_M2i6030 | 36030h | 221232 |
| M2i.6012 | TYP_M2i6012 | 36012h | 221202 | | | M2i.6031 | TYP_M2i6031 | 36031h | 221233 |
| M2i.6021 | TYP_M2i6021 | 36021h | 221217 | | | M2i.6033 | TYP_M2i6033 | 36033h | 221235 |
| M2i.6022 | TYP_M2i6022 | 36022h | 221218 | | | M2i.6034 | TYP_M2i6034 | 36034h | 221236 |
| | | | | | | | | | |
| M2i.6011-exp | TYP_M2i6011EXP | 46011h | 286737 | | | M2i.6030-exp | TYP_M2i6030EXP | 46030h | 286768 |
| M2i.6012-exp | TYP_M2i6012EXP | 46012h | 286738 | | | M2i.6031-exp | TYP_M2i6031EXP | 46031h | 286769 |
| M2i.6021-exp | TYP_M2i6021EXP | 46021h | 286753 | | | M2i.6033-exp | TYP_M2i6033EXP | 46033h | 286771 |
| M2i.6022-exp | TYP_M2i6022EXP | 46022h | 286754 | | | M2i.6034-exp | TYP_M2i6034EXP | 46034h | 286772 |

Hardware version

Since all of the boards from Spectrum are modular boards, they consist of one base board and one or two piggy-back front-end modules and eventually of an extension module like the star-hub. Each of these three kinds of hardware has its own version register. Normally you do not need this information but if you have a support question, please provide the revision together with it.

| Register | Value | Direction | Description |
|----------------------|-------|-----------|--|
| SPC_PCIVERSION | 2010 | read | Base card version: the upper 16 bit show the hardware (PCB) version, the lower 16 bit show the firmware version. |
| SPC_PCIMODULEVERSION | 2012 | read | Module version: the upper 16 bit show the hardware (PCB) version, the lower 16 bit show the firmware version. |

If your board has a additional piggy-back extension module mounted you can get the hardware version with the following register.

| Register | Value | Direction | Description |
|-------------------|-------|-----------|---|
| SPC_PCIEXTVERSION | 2011 | read | Extension module version: the upper 16 bit show the hardware (PCB) version, the lower 16 bit show the firmware version. |

Firmware versions

All the cards from Spectrum typically contain multiple programmable devices such as FPGAs, CPLDs and the like. Each of these have their own dedicated firmware version. This version information is readable for each device through the various version registers. Normally you do not need this information but if you have a support question, please provide us with this information. Please note that number of devices and hence the readable firmware information is card series dependent:

| Register | Value | Direction | Description | Available for | | | | |
|---------------------|--------|-----------|--|---------------|-----|-----|-----|-----|
| | | | | M2i | M3i | M4i | M4x | M2p |
| SPCM_FW_CTRL | 210000 | read | Main control FPGA version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the standard release firmware, the type has always a value of 1. | X | X | X | X | X |
| SPCM_FW_CTRL_GOLDEN | 210001 | read | Main control FPGA golden version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the golden (recovery) firmware, the type has always a value of 2. | — | — | X | X | X |
| SPCM_FW_CLOCK | 210010 | read | Clock distribution version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the standard release firmware, the type has always a value of 1. | X | — | — | — | — |
| SPCM_FW_CONFIG | 210020 | read | Configuration controller version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the standard release firmware, the type has always a value of 1. | X | X | — | — | — |
| SPCM_FW_MODULEA | 210030 | read | Front-end module A version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the standard release firmware, the type has always a value of 1. | X | X | X | X | X |
| SPCM_FW_MODULEB | 210031 | read | Front-end module B version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the standard release firmware, the type has always a value of 1. The version is zero if no second front-end module is installed on the card. | X | — | — | — | X |
| SPCM_FW_MODEXTRA | 210050 | read | Extension module (Star-Hub) version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the standard release firmware, the type has always a value of 1. The version is zero if no extension module is installed on the card. | X | X | X | — | X |
| SPCM_FW_POWER | 210060 | read | Power controller version: the upper 16 bit show the firmware type, the lower 16 bit show the firmware version. For the standard release firmware, the type has always a value of 1. | — | — | X | X | X |

Cards that do provide a golden recovery image for the main control FPGA, the currently booted firmware can additionally read out:

| Register | Value | Direction | Description | M2i | M3i | M4i | M4x | M2p |
|---------------------|--------|-----------|--|-----|-----|-----|-----|-----|
| SPCM_FW_CTRL_ACTIVE | 210002 | read | Cards that do provide a golden (recovery) firmware additionally have a register to read out the version information of the currently loaded firmware version string, do determine if it is standard or golden. The hexadecimal 32bit format is: TVVVUUUUh T: the currently booted type (1: standard, 2: golden) V: the version U: unused, in production versions always zero | — | — | X | X | X |

Production date

This register informs you about the production date, which is returned as one 32 bit long word. The lower word is holding the information about the year, while the upper word informs about the week of the year.

| Register | Value | Direction | Description |
|-------------|-------|-----------|--|
| SPC_PCIDATE | 2020 | read | Production date: week in bits 31 to 16, year in bits 15 to 0 |

The following example shows how to read out a date and how to interpret the value:

```
spcm_dwGetParam_i32 (hDrv, SPC_PCIDATE, &lProdDate);
printf ("Production: week %d of year %d\n", (lProdDate >> 16) & 0xffff, lProdDate & 0xffff);
```

Last calibration date (analog cards only)

This register informs you about the date of the last factory calibration. When receiving a new card this date is similar to the delivery date when the production calibration is done. When returning the card to calibration this information is updated. This date is not updated when just doing an on-board calibration by the user. The date is returned as one 32 bit long word. The lower word is holding the information about the year, while the upper word informs about the week of the year.

| Register | Value | Direction | Description |
|--------------|-------|-----------|--|
| SPC_CAUIDATE | 2025 | read | Last calibration date: week in bit 31 to 16, year in bit 15 to 0 |

Serial number

This register holds the information about the serial number of the board. This number is unique and should always be sent together with a support question. Normally you use this information together with the register SPC_PCITYP to verify that multiple measurements are done with the exact same board.

| Register | Value | Direction | Description |
|-----------------|-------|-----------|----------------------------|
| SPC_PCISERIALNO | 2030 | read | Serial number of the board |

Maximum possible sampling rate

This register gives you the maximum possible sampling rate the board can run. The information provided here does not consider any restrictions in the maximum speed caused by special channel settings. For detailed information about the correlation between the maximum sampling rate and the number of activated channels please refer to the according chapter.

| Register | Value | Direction | Description |
|-------------------|-------|-----------|---|
| SPC_PCISAMPLERATE | 2100 | read | Maximum sampling rate in Hz as a 64 bit integer value |

Installed memory

This register returns the size of the installed on-board memory in bytes as a 64 bit integer value. If you want to know the amount of samples you can store, you must regard the size of one sample of your card. All 8 bit A/D and D/A cards use only one byte per sample, while all other A/D and D/A cards with 12, 14 and 16 bit resolution use two bytes to store one sample. All digital cards need one byte to store 8 data bits.

| Register | Value | Direction | Description |
|----------------|-------|-----------|---|
| SPC_PCIMEMSIZE | 2110 | read_i32 | Installed memory in bytes as a 32 bit integer value. Maximum return value will 1 GByte. If more memory is installed this function will return the error code ERR_EXCEEDINT32. |
| SPC_PCIMEMSIZE | 2110 | read_i64 | Installed memory in bytes as a 64 bit integer value |

The following example is written for a „two bytes“ per sample card (12, 14 or 16 bit board), on any 8 bit card memory in MSamples is similar to memory in MBytes.

```
spcm_dwGetParam_i64 (hDrv, SPC_PCIMEMSIZE, &llInstMemsize);
printf ("Memory on card: %d MBytes\n", (int32) (llInstMemsize / 1024/1024));
printf ("          : %d MSamples\n", (int32) (llInstMemsize / 1024/1024/2));
```

Installed features and options

The SPC_PCIFEATURES register informs you about the features, that are installed on the board. If you want to know about one option being installed or not, you need to read out the 32 bit value and mask the interesting bit. In the table below you will find every feature that may be installed on a M2i/M3i/M4i/M4x/M2p card. Please refer to the ordering information to see which of these features are available for your card series.

| Register | Value | Direction | Description |
|----------------------------|-----------|-----------|---|
| SPC_PCIFEATURES | 2120 | read | PCI feature register. Holds the installed features and options as a bitfield. The read value must be masked out with one of the masks below to get information about one certain feature. |
| SPCM_FEAT_MULTI | 1h | | Is set if the feature Multiple Recording / Multiple Replay is available. |
| SPCM_FEAT_GATE | 2h | | Is set if the feature Gated Sampling / Gated Replay is available. |
| SPCM_FEAT_DIGITAL | 4h | | Is set if the feature Digital Inputs / Digital Outputs is available. |
| SPCM_FEAT_TIMESTAMP | 8h | | Is set if the feature Timestamp is available. |
| SPCM_FEAT_STARHUB6_EXTM | 20h | | Is set on the card, that carries the star-hub extension or piggy-back module for synchronizing up to 6 cards (M2p). |
| SPCM_FEAT_STARHUB8_EXTM | 20h | | Is set on the card, that carries the star-hub extension or piggy-back module for synchronizing up to 8 cards (M4i). |
| SPCM_FEAT_STARHUB4 | 20h | | Is set on the card, that carries the star-hub piggy-back module for synchronizing up to 4 cards (M3i). |
| SPCM_FEAT_STARHUB5 | 20h | | Is set on the card, that carries the star-hub piggy-back module for synchronizing up to 5 cards (M2i). |
| SPCM_FEAT_STARHUB16_EXTM | 40h | | Is set on the card, that carries the star-hub piggy-back module for synchronizing up to 16 cards (M2p). |
| SPCM_FEAT_STARHUB8 | 40h | | Is set on the card, that carries the star-hub piggy-back module for synchronizing up to 8 cards (M3i). |
| SPCM_FEAT_STARHUB16 | 40h | | Is set on the card, that carries the star-hub piggy-back module for synchronizing up to 16 cards (M2i). |
| SPCM_FEAT_ABA | 80h | | Is set if the feature ABA mode is available. |
| SPCM_FEAT_BASEXIO | 100h | | Is set if the extra BaseXIO option is installed. The lines can be used for asynchronous digital I/O, extra trigger or timestamp reference signal input. |
| SPCM_FEAT_AMPLIFIER_10V | 200h | | Arbitrary Waveform Generators only: card has additional set of calibration values for amplifier card. |
| SPCM_FEAT_STARHUBSYSMASTER | 400h | | Is set in the card that carries a System Star-Hub Master card to connect multiple systems (M2i). |
| SPCM_FEAT_DIFFMODE | 800h | | M2i.30xx series only: card has option -diff installed for combining two SE channels to one differential channel. |
| SPCM_FEAT_SEQUENCE | 1000h | | Only available for output cards or I/O cards: Replay sequence mode available. |
| SPCM_FEAT_AMPMODULE_10V | 2000h | | Is set on the card that has a special amplifier module for mounted (M2i.60xx/61xx only). |
| SPCM_FEAT_STARHUBSYS_SLAVE | 4000h | | Is set in the card that carries a System Star-Hub Slave module to connect with System Star-Hub master systems (M2i). |
| SPCM_FEAT_NETBOX | 8000h | | The card is physically mounted within a digitizerNETBOX or generatorNETBOX. |
| SPCM_FEAT_REMOTESERVER | 10000h | | Support for the Spectrum Remote Server option is installed on this card. |
| SPCM_FEAT_SCAPP | 20000h | | Support for the SCAPP option allowing CUDA RDMA access to supported graphics cards for GPU calculations (M4i and M2p). |
| SPCM_FEAT_DIG16_SMB | 40000h | | M2p: Set if option M2p.xxxx-DigSMB is installed, adding 16 additional digital I/Os via SMB connectors. |
| SPCM_FEAT_DIG16_FX2 | 80000h | | M2p: Set if option M2p.xxxx-DigFX2 is installed, adding 16 additional digital I/Os via FX2 multipin connectors. |
| SPCM_FEAT_DIGITALBWFILTER | 100000h | | A digital (boxcar) bandwidth filter is available that can be globally enabled/disabled for all channels. |
| SPCM_FEAT_CUSTOMMOD_MASK | F0000000h | | The upper 4 bit of the feature register is used to mark special custom modifications. This is only used if the card has been specially customized. Please refer to the extra documentation for the meaning of the custom modifications. (M2i/M3i). For M4i, M4x and M2p cards see „Custom modifications“ chapter instead. |

The following example demonstrates how to read out the information about one feature.

```
spcm_dwGetParam_i32 (hDrv, SPC_PCIFEATURES, &lFeatures);
if (lFeatures & SPCM_FEAT_DIGITAL)
    printf("Option digital inputs/outputs is installed on your card");
```

The following example demonstrates how to read out the custom modification code.

```
spcm_dwGetParam_i32 (hDrv, SPC_PCIFEATURES, &lFeatures);
lCustomMod = (lFeatures >> 28) & 0xF;
if (lCustomMod != 0)
    printf("Custom modification no. %d is installed.", lCustomMod);
```

Installed extended Options and Features

Some cards (such as M4i/M4x/M2p cards) can have advanced features and options installed. This can be read out with the following register:

| Register | Value | Direction | Description |
|-------------------|-------|-----------|---|
| SPC_PCIXTFEATURES | 2121 | read | PCI extended feature register. Holds the installed extended features and options as a bitfield. The read value must be masked out with one of the masks below to get information about one certain feature. |

| | | |
|----------------------------|----|---|
| SPCM_FEAT_EXTFW_SEGSTAT | 1h | Is set if the firmware option „Block Statistics“ is installed on the board, which allows certain statistics to be on-board calculated for data being recorded in segmented memory modes, such as Multiple Recording or ABA. |
| SPCM_FEAT_EXTFW_SEGAVERAGE | 2h | Is set if the firmware option „Block Average“ is installed on the board, which allows on-board hardware averaging of data being recorded in segmented memory modes, such as Multiple Recording or ABA. |
| SPCM_FEAT_EXTFW_BOXCAR | 4h | Is set if the firmware mode „Boxcar Average“ is supported in the installed firmware version. |

Miscellaneous Card Information

Some more detailed card information, that might be useful for the application to know, can be read out with the following registers:

| Register | Value | Direction | Description |
|---------------------------|-------|-----------|--|
| SPC_MIINST_MODULES | 1100 | read | Number of the installed front-end modules on the card. |
| SPC_MIINST_CHPERMODULE | 1110 | read | Number of channels installed on one front-end module. |
| SPC_MIINST_BYTESPERSAMPLE | 1120 | read | Number of bytes used in memory by one sample. |
| SPC_MIINST_BITSPERSAMPLE | 1125 | read | Resolution of the samples in bits. |
| SPC_MIINST_MAXADCVALUE | 1126 | read | Decimal code of the full scale value. |
| SPC_MIINST_MINEXTCLOCK | 1145 | read | Minimum external clock that can be fed in for direct external clock (if available for card model). |
| SPC_MIINST_MAXEXTCLOCK | 1146 | read | Maximum external clock that can be fed in for direct external clock (if available for card model). |
| SPC_MIINST_MINEXTREFCLOCK | 1148 | read | Minimum external clock that can be fed in as a reference clock. |
| SPC_MIINST_MAXEXTREFCLOCK | 1149 | read | Maximum external clock that can be fed in as a reference clock. |
| SPC_MIINST_ISDEMOCARD | 1175 | read | Returns a value other than zero, if the card is a demo card. |

Function type of the card

This register register returns the basic type of the card:

| Register | Value | Direction | Description |
|---------------|-------|-----------|--|
| SPC_FNCTYPE | 2001 | read | Gives information about what type of card it is. |
| SPCM_TYPE_AI | 1h | | Analog input card (analog acquisition; the M2i.4028 and M2i.4038 also return this value) |
| SPCM_TYPE_AO | 2h | | Analog output card (arbitrary waveform generators) |
| SPCM_TYPE_DI | 4h | | Digital input card (logic analyzer card) |
| SPCM_TYPE_DO | 8h | | Digital output card (pattern generators) |
| SPCM_TYPE_DIO | 10h | | Digital I/O (input/output) card, where the direction is software selectable. |

Used type of driver

This register holds the information about the driver that is actually used to access the board. Although the driver interface doesn't differ between Windows and Linux systems it may be of interest for a universal program to know on which platform it is working.

| Register | Value | Direction | Description |
|-----------------|-------|-----------|---|
| SPC_GETDRVTYPE | 1220 | read | Gives information about what type of driver is actually used |
| DRVTYPE_LINUX32 | 1 | | Linux 32bit driver is used |
| DRVTYPE_WDM32 | 4 | | Windows WDM 32bit driver is used (XP/Vista/Windows 7/Windows 8/Windows 10). |
| DRVTYPE_WDM64 | 5 | | Windows WDM 64bit driver is used by 64bit application (XP64/Vista/Windows 7/Windows 8/Windows 10). |
| DRVTYPE_WOW64 | 6 | | Windows WDM 64bit driver is used by 32bit application (XP64/Vista/Windows 7/Windows 8/ Windows 10). |
| DRVTYPE_LINUX64 | 7 | | Linux 64bit driver is used |

Driver version

This register holds information about the currently installed driver library. As the drivers are permanently improved and maintained and new features are added user programs that rely on a new feature are requested to check the driver version whether this feature is installed.

| Register | Value | Direction | Description |
|-------------------|-------|-----------|--|
| SPC_GETDRVVERSION | 1200 | read | Gives information about the driver library version |

The resulting 32 bit value for the driver version consists of the three version number parts shown in the table below:

| Driver Major Version | Driver Minor Version | Driver Build |
|------------------------------|------------------------------|------------------------------|
| 8 Bit wide: bit 24 to bit 31 | 8 Bit wide: bit 16 to bit 23 | 16 Bit wide: bit 0 to bit 15 |

Kernel Driver version

This register informs about the actually used kernel driver. Windows users can also get this information from the device manager. Please refer to the „Driver Installation“ chapter. On Linux systems this information is also shown in the kernel message log at driver start time.

| Register | Value | Direction | Description |
|----------------------|-------|-----------|--|
| SPC_GETKERNELVERSION | 1210 | read | Gives information about the kernel driver version. |

The resulting 32 bit value for the driver version consists of the three version number parts shown in the table below:

| Driver Major Version | Driver Minor Version | Driver Build |
|------------------------------|------------------------------|------------------------------|
| 8 Bit wide: bit 24 to bit 31 | 8 Bit wide, bit 16 to bit 23 | 16 Bit wide, bit 0 to bit 15 |

The following example demonstrates how to read out the kernel and library version and how to print them.

```
spcm_dwGetParam_i32 (hDrv, SPC_GETDRVVERSION, &lLibVersion);
spcm_dwGetParam_i32 (hDrv, SPC_GETKERNELVERSION, &lKernelVersion);
printf("Kernel V %d.%d build %d\n", lKernelVersion >> 24, (lKernelVersion >> 16) & 0xff, lKernelVersion & 0xffff);
printf("Library V %d.%d build %d\n", lLibVersion >> 24, (lLibVersion >> 16) & 0xff, lLibVersion & 0xffff);
```

This small program will generate an output like this:

```
Kernel V 1.11 build 817
Library V 1.1 build 854
```

Reset

Every Spectrum card can be reset by software. Concerning the hardware, this reset is the same as the power-on reset when starting the host computer. In addition to the power-on reset, the reset command also brings all internal driver settings to a defined default state. A software reset is automatically performed, when the driver is first loaded after starting the host system.



It is recommended, that every custom written program performs a software reset first, to be sure that the driver is in a defined state independent from possible previous setting.

Performing a board reset can be easily done by the related board command mentioned in the following table.

| Register | Value | Direction | Description |
|------------------|-------|-----------|---|
| SPC_M2CMD | 100 | w | Command register of the board. |
| M2CMD_CARD_RESET | 1h | | A software and hardware reset is done for the board. All settings are set to the default values. The data in the board's on-board memory will be no longer valid. Any output signals like trigger or clock output will be disabled. |

digitizerNETBOX/generatorNETBOX specific registers

Information about the digitizerNETBOX/generatorNETBOX, in which the card is installed, can be read out via the card handle.

The following digitizerNETBOX/generatorNETBOX specific information registers can be used:

| Register | Value | Direction | Description |
|---------------------------|--------|-----------|---|
| SPC_NETBOX_TYPE | 400000 | read | Hex coded version of the digitizerNETBOX/generatorNETBOX, example 02490110h: bit 24 to 31: Series: example 02h = DN2 bit 16 to 23: Family: example 49h = 49 bit 8 to 15: Speed grade: example 01h = 1 bit 0 to 7: Channels: example 10h = 16 Decoded example: DN2.491-16 |
| SPC_NETBOX_SERIALNO | 400001 | read | Serial number of the digitizerNETBOX/generatorNETBOX itself. In most cases the serial numbers of the digitizerNETBOX/generatorNETBOX and the embedded cards are consecutive but there is no guarantee for this. |
| SPC_NETBOX_PRODUCTIONDATE | 400002 | read | Production date: week in bit 31 to 16, year in bit 15 to 0 |
| SPC_NETBOX_HWVERSION | 400003 | read | The hardware version of the digitizerNETBOX/generatorNETBOX products |
| SPC_NETBOX_SWVERSION | 400004 | read | The software version of the installed remote server |
| SPC_NETBOX_FEATURES | 400005 | read | Features of the digitizerNETBOX/generatorNETBOX. Holds the installed features and options as a bitfield. The read value must be masked out with one of the masks below to get information about one certain feature. |
| NETBOX_FEAT_DCPOWER | 1h | | Is set if one of the DC power options are installed in the system. |
| NETBOX_FEAT_BOOTATPOWERON | 2h | | Is set if the special feature automatic boot on power on is installed. This would allow remote devices to automatically reboot after a failure of the power supply. |
| NETBOX_FEAT_EMBEDDEDSEVER | 4h | | Is set if the option Embedded Server is installed. |

| Register | Value | Direction | Description |
|------------------------|--------|-----------|---|
| SPC_NETBOX_CUSTOM | 400006 | read | Custom code for custom modifications of the digitizerNETBOX/generatorNETBOX. |
| SPC_NETBOX_WAKEONLAN | 400007 | write | This command is issued to wake a digitizerNETBOX/generatorNETBOX that is currently in standby-mode with a special wake-on-lan message. Please note that the card handle is NULL in this case as there is no opened card here. The argument is the MAC address of that device |
| SPC_NETBOX_MACADDRESS | 400008 | read | Reads out the MAC address of the digitizerNETBOX/generatorNETBOX. |
| SPC_NETBOX_LANIDFLASH | 400009 | write | By writing 1 to this register, one can start the automatic flashing of the LAN Id to detect a particular digitizerNETBOX/generatorNETBOX that is installed in a Rack of multiple digitizerNETBOX or generatorNETBOX devices. Writing a 0 to this register will stop the flashing again. |
| SPC_NETBOX_TEMPERATURE | 400010 | read | Read out the temperature inside the digitizerNETBOX/generatorNETBOX (same as displayed in the webinterface status information) in Kelvin. |
| SPC_NETBOX_SHUTDOWN | 400011 | write | Remotely shut down the digitizerNETBOX/generatorNETBOX. Value must be set to 0. |
| SPC_NETBOX_RESTART | 400012 | write | Remotely restart the digitizerNETBOX/generatorNETBOX. Value must be set to 0. |

Analog Outputs

Channel Selection

One key setting that influences all other possible settings is the channel enable register. A unique feature of the Spectrum cards is the possibility to program the number of channels you want to use. All on-board memory can then be used by these activated channels.

This description shows you the channel enable register for the complete card family. However, your specific board may have less channels depending on the card type that you have purchased and therefore does not allow you to set the maximum number of channels shown here.

| Register | Value | Direction | Description |
|--------------|-------|------------|--|
| SPC_CHENABLE | 11000 | read/write | Sets the channel enable information for the next card run. |
| CHANNEL0 | 1 | | Activates channel 0 |
| CHANNEL1 | 2 | | Activates channel 1 |
| CHANNEL2 | 4 | | Activates channel 2 |
| CHANNEL3 | 8 | | Activates channel 3 |

The channel enable register is set as a bitmap. That means that one bit of the value corresponds to one channel to be activated. To activate more than one channel the values have to be combined by a bitwise OR.

Example showing how to activate 4 channels:

```
spcm_dwSetParam_i64 (hDrv, SPC_CHENABLE, CHANNEL0 | CHANNEL1 | CHANNEL2 | CHANNEL3);
```

The following table shows all allowed settings for the channel enable register when your card has a maximum of 1 channel.

| Channels to activate | Values to program | Value as hex | Value as decimal |
|----------------------|-------------------|--------------|------------------|
| Ch0 | | | |
| X | CHANNEL0 | 1h | 1 |

The following table shows all allowed settings for the channel enable register when your card has a maximum of 2 channels.

| Channels to activate | | | | |
|----------------------|-----|---------------------|--------------|------------------|
| Ch0 | Ch1 | Values to program | Value as hex | Value as decimal |
| X | | CHANNEL0 | 1h | 1 |
| | X | CHANNEL1 | 2h | 2 |
| X | X | CHANNEL0 CHANNEL1 | 3h | 3 |

The following table shows all allowed settings for the channel enable register in case that you have a four channel card.

| Channels to activate | | | | | | | |
|----------------------|---------------------|-----|-----|---------------------|---|------------------|----|
| Ch0 | Ch1 | Ch2 | Ch3 | Values to program | Value as hex | Value as decimal | |
| X | X | X | X | CHANNEL0 | 1h | 1 | |
| | | | | CHANNEL1 | 2h | 2 | |
| | | | | CHANNEL2 | 4h | 4 | |
| | | | | CHANNEL3 | 8h | 8 | |
| X | X | X | X | CHANNEL0 CHANNEL1 | 3h | 3 | |
| X | CHANNEL0 CHANNEL2 | | | 5h | 5 | | |
| X | CHANNEL0 CHANNEL3 | | | 9h | 9 | | |
| X | CHANNEL1 CHANNEL2 | | | 6h | 6 | | |
| | X | X | X | CHANNEL1 CHANNEL3 | Ah | 10 | |
| | X | | | CHANNEL2 CHANNEL3 | Ch | 12 | |
| X | X | | | X | CHANNEL0 CHANNEL1 CHANNEL2 CHANNEL3 | Fh | 15 |



Any channel activation mask that is not shown here is not valid. If programming an other channel activation, the driver will return with an error code ERR_VALUE.

To help user programs it is also possible to read out the number of activated channels that correspond to the currently programmed bitmap.

| Register | Value | Direction | Description |
|-------------|-------|-----------|--|
| SPC_CHCOUNT | 11001 | read | Reads back the number of currently activated channels. |

Reading out the channel enable information can be done directly after setting it or later like this:

```
spcm_dwSetParam_i32 (hDrv, SPC_CHENABLE, CHANNEL0 | CHANNEL1);
spcm_dwGetParam_i32 (hDrv, SPC_CHENABLE, &lActivatedChannels);
spcm_dwGetParam_i32 (hDrv, SPC_CHCOUNT, &lChCount);

printf ("Activated channels bitmask is: 0x%08x\n", lActivatedChannels);
printf ("Number of activated channels with this bitmask: %d\n", lChCount);
```


Assuming that the two channels are available on your card the program will have the following output:

```
Activated channels bitmask is: 0x00000003
Number of activated channels with this bitmask: 2
```

Important note on channel selection

As some of the manuals passages are used in more than one hardware manual most of the registers and channel settings throughout this handbook are described for the maximum number of possible channels that are available on one card of the current series. There can be less channels on your actual type of board or bus-system. Please refer to the technical data section to get the actual number of available channels.



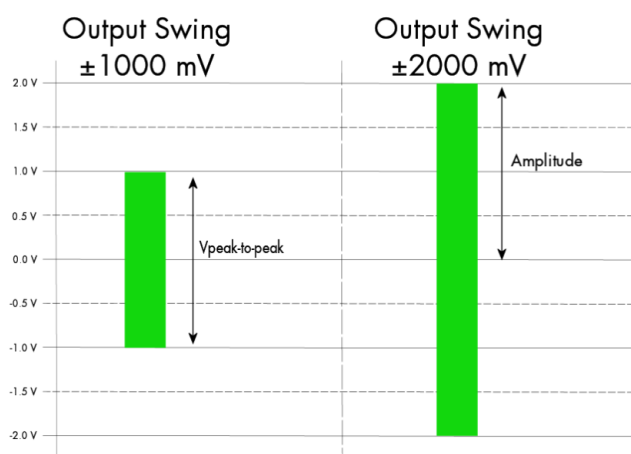
Setting up the outputs

Output Amplifiers

This arbitrary waveform generator board uses separate output amplifiers for each channel. This gives you the possibility to separately set up the channel outputs to best suit your application.

The output amplifiers can easily be set by the corresponding amplitude registers.

The table below shows the available registers to set up the output amplitude for your type of board.



| Register | Value | Direction | Description | Amplitude range |
|----------|-------|------------|--|------------------------|
| SPC_AMP0 | 30010 | read/write | Defines the amplitude of channel0 in mV. | 100 up to 3000 (in mV) |
| SPC_AMP1 | 30110 | read/write | Defines the amplitude of channel1 in mV. | 100 up to 3000 (in mV) |
| SPC_AMP2 | 30210 | read/write | Defines the amplitude of channel2 in mV. | 100 up to 3000 (in mV) |
| SPC_AMP3 | 30310 | read/write | Defines the amplitude of channel3 in mV. | 100 up to 3000 (in mV) |

The amplitude can be changed at any time even if the board is running and outputting a signal to the connectors. The board will not be stopped when changing these settings.

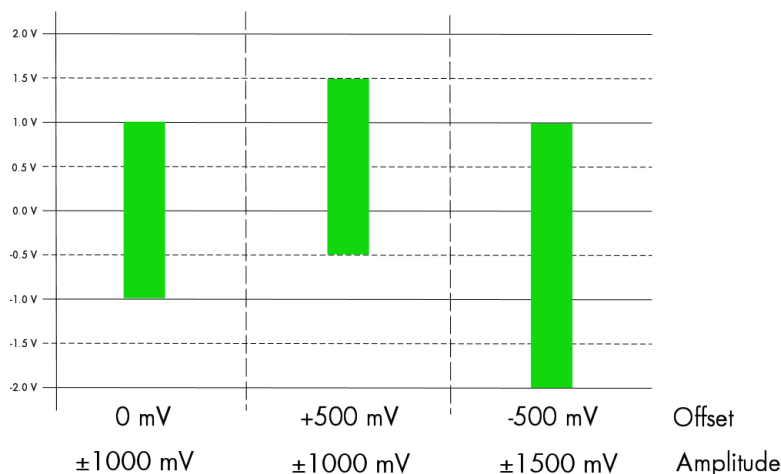


Output offset

In many applications an output of symmetrical signals is required. But in some cases, depending on your application, it can be necessary to generate signals that are not symmetrical.

For such cases you can adjust the offset of the outputs for each channel separately.

The figure at the right shows some examples, how to set up the offset in combination with different amplitudes.



| Register | Value | Direction | Description | Offset range |
|-----------|-------|------------|--|--------------------------------|
| SPC_OFFS0 | 30000 | read/write | Defines output offset and therefore shifts the output of channel0. | ± 3000 mV in steps of 1 mV |
| SPC_OFFS1 | 30100 | read/write | Defines output offset and therefore shifts the output of channel1. | ± 3000 mV in steps of 1 mV |
| SPC_OFFS2 | 30200 | read/write | Defines output offset and therefore shifts the output of channel2. | ± 3000 mV in steps of 1 mV |
| SPC_OFFS3 | 30300 | read/write | Defines output offset and therefore shifts the output of channel3. | ± 3000 mV in steps of 1 mV |

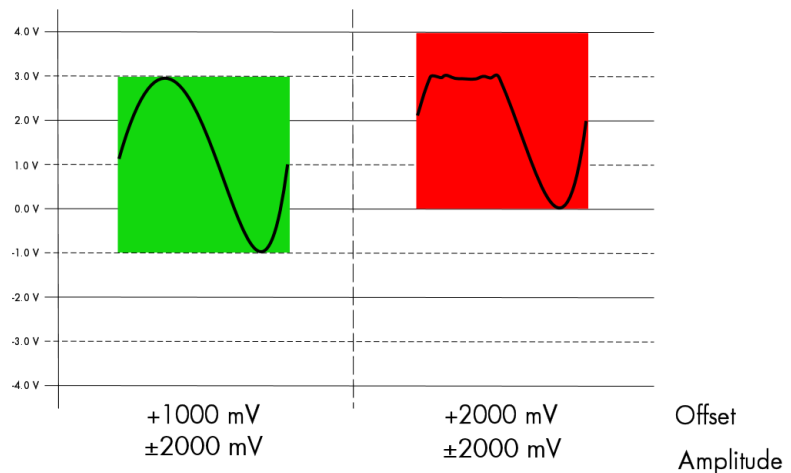


The offset settings can be changed at any time even if the board is running and outputting a signal to the connectors. The board will not be stopped when changing these settings.

Maximum Output Range

In order not to generate distorted signals it is necessary to keep the total output range as a combination of the set amplitude and offset within a range of ± 3000 mV.

If this limit is exceeded a heavy distorted signal will be seen and the signals waveform will be cut off at the maximum range of $+3000$ mV or at the minimum range of -3000 mV.



To avoid heavily distorted output signals please make sure to keep the signals in a range of ± 3000 mV.

To give you an example how the registers of the amplitude and the offset are to be used, the following example shows a setup to match all of the three signals shown in the offset figure.

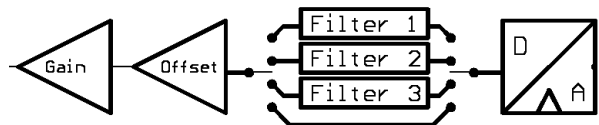
```

SpcSetParam (hDrv, SPC_AMP0, 1000); // Set up amplitude of channel0 to  $\pm 1.0$  V
SpcSetParam (hDrv, SPC_AMP1, 1000); // Set up amplitude of channel1 to  $\pm 1.0$  V
SpcSetParam (hDrv, SPC_AMP2, 1500); // Set up amplitude of channel2 to  $\pm 1.5$  V
SpcSetParam (hDrv, SPC_OFFS0, 0); // Set the output offsets
SpcSetParam (hDrv, SPC_OFFS1, 500);
SpcSetParam (hDrv, SPC_OFFS2, -500);

```

Output Filters

Every output of your Spectrum D/A board is equipped with a bypass path and three fixed filters that can be used for signal smoothing. The filters are located in the signal chain between the output amplification section and the DAC, as shown in the right figure. Depending on your type of board these filters are of different filter types and have different cut off frequencies, as shown below. As well as the setting for amplitude and offset, the settings for the filters can be changed at any time. The board will not be stopped for changing the different filters. You can choose between the different filters easily by setting the dedicated filter registers. The registers and the possible values are shown in the table below.



| Register | Value | Direction | Description |
|-------------|-------|------------|--|
| SPC_FILTER0 | 30080 | read/write | Sets the signal filter of channel0. |
| SPC_FILTER1 | 30180 | read/write | Sets the signal filter of channel1. |
| SPC_FILTER2 | 30280 | read/write | Sets the signal filter of channel2. |
| SPC_FILTER3 | 30380 | read/write | Sets the signal filter of channel3. |
| | 0 | | No filter is used on the corresponding channel. |
| | 1 | | Filter 1 is used on the corresponding channel. The type of filter depends on the type of board and is shown below. |

| | |
|---|--|
| 2 | Filter 2 is used on the corresponding channel. The type of filter depends on the type of board and is shown below. |
| 3 | Filter 3 is used on the corresponding channel. The type of filter depends on the type of board and is shown below. |

| Filter | Specifications | MI.6011 M2i.6011 | MI.6012 M2i.6012 | MI.6021 M2i.6021 | MI.6022 M2i.6022 | MI.6030 M2i.6030 | MI.6031 M2i.6031 | MI.6033 M2i.6033 | MI.6034 M2i.6034 |
|----------|-----------------|-------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| filter 0 | | No filter will be used. | | | | | | | |
| filter 1 | -3 dB bandwidth | 100 kHz | | 200 kHz | | 500 kHz | | | |
| filter 2 | -3 dB bandwidth | 1 MHz | | 2 MHz | | 5 MHz | | | |
| filter 3 | -3 dB bandwidth | 5 MHz | | 10 MHz | | 25 MHz | | | |

Differential Output

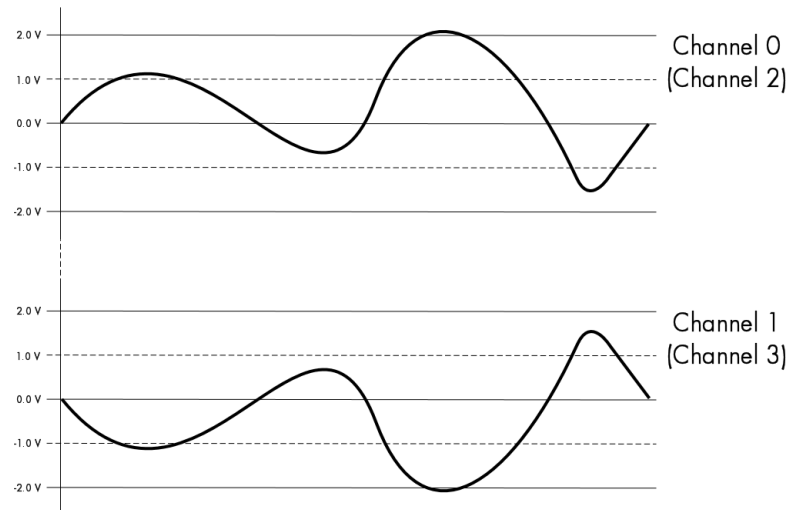
The differential mode outputs the data on the even channels and the inverted data on the odd channels of one module, as the figure on the right is showing.

As a result you have differential signals, which are more resistant against noise when being transmitted via long cables. Because of the hardware generation, only one data sample in memory is needed for one pair of differential outputs.

The dedicated registers to set up the differential mode are shown below.

If your board has four installed channels you can generate two pairs of differential signals, otherwise one pair is possible.

Differential outputs are not available for all types of boards. Please refer to the table below, which mentions the boards this mode is available on.



| Register | Value | Direction | Description |
|-----------|-------|------------|--|
| SPC_DIFF0 | 30040 | read/write | Sets channel 0/1 to differential mode. |
| SPC_DIFF2 | 30240 | read/write | Sets channel 2/3 to differential mode. |

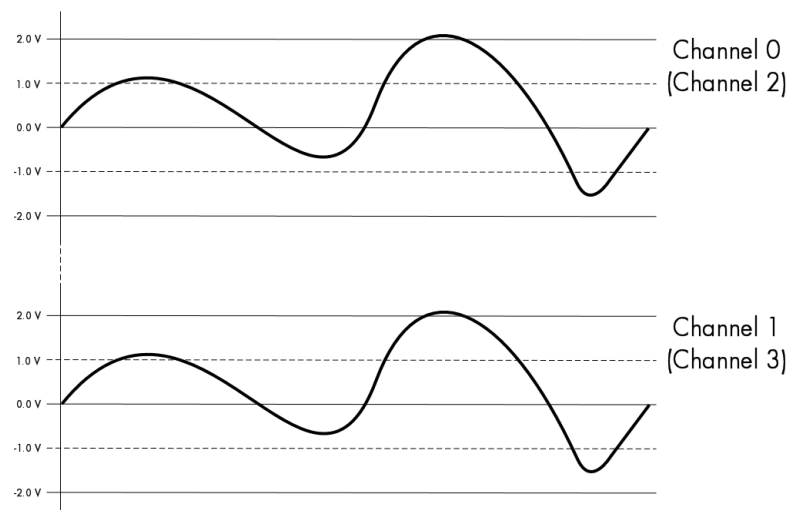
| Mode | MI.6011 M2i.6011 | MI.6012 M2i.6012 | MI.6021 M2i.6021 | MI.6022 M2i.6022 | MI.6030 M2i.6030 | MI.6031 M2i.6031 | MI.6033 M2i.6033 | MI.6034 M2i.6034 |
|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Differential Output | installed | installed | installed | installed | not available | not available | installed | installed |

Double Out Mode

The double out mode outputs the data on the even channels and the same data on the odd channels of one module, as the figure on the right is showing. The dedicated registers to set up the differential mode are shown below.

If your board has four installed channels you can generate two pairs of identical signals, otherwise only one pair is possible.

The double out mode is not available for all types of boards. Please refer to the table below, which mentions the boards this mode is available on.



| Register | Value | Direction | Description |
|----------------|-------|------------|--------------------------------------|
| SPC_DOUBLEOUT0 | 30041 | read/write | Sets channel 0/1 to double out mode. |
| SPC_DOUBLEOUT2 | 30241 | read/write | Sets channel 2/3 to double out mode. |

| Mode | MI.6011 M2i.6011 | MI.6012 M2i.6012 | MI.6021 M2i.6021 | MI.6022 M2i.6022 | MI.6030 M2i.6030 | MI.6031 M2i.6031 | MI.6033 M2i.6033 | MI.6034 M2i.6034 |
|-----------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Double out mode | installed | installed | installed | installed | not available | not available | installed | installed |

Programming the behaviour in pauses and after replay

Usually the used outputs of the analog generation boards are set to zero level after replay. This is in most cases adequate. In some cases it can be necessary to hold the last sample, to output the maximum positive level or maximum negative level after replay. The stoplevel will stay on the defined level until the next output has been made. With the following registers you can define the behaviour after replay:

| Register | Value | Direction | Description |
|-----------------------|--------|------------|---|
| SPC_CH0_STOPLEVEL | 206020 | read/write | Defines the behavior after replay for channel 0 |
| SPC_CH1_STOPLEVEL | 206021 | read/write | Defines the behavior after replay for channel 1 |
| SPC_CH2_STOPLEVEL | 206022 | read/write | Defines the behavior after replay for channel 2 |
| SPC_CH3_STOPLEVEL | 206023 | read/write | Defines the behavior after replay for channel 3 |
| SPCM_STOPLVL_ZERO | 16 | | Defines the analog output to enter zero level (D/A converter is fed with digital zero value) |
| SPCM_STOPLVL_LOW | 2 | | Defines the analog output to enter maximum negative level (D/A converter is fed with most negative level) |
| SPCM_STOPLVL_HIGH | 4 | | Defines the analog output to enter maximum positive level (D/A converter is fed with most positive level) |
| SPCM_STOPLVL_HOLDLAST | 8 | | Holds the last replayed sample on the analog output |

All outputs that are not activated for replay, will keep the programmed stoplevel also while the replay is in progress.



Because the STOPLEVEL registers impact the digital samples fed to the D/A converter, the output is still shifted by the programmed output offset, as described before.

Read out of output features

The analog outputs of the different cards do have different features implemented, that can be read out to make the software more general. If you only operate one single card type in your software it is not necessary to read out these features.

Please note that the following table shows all output feature settings that are available throughout all Spectrum generator cards. Some of these features are not installed on your specific hardware.

| Register | Value | Direction | Description |
|---------------------|-----------|-----------|---|
| SPC_READAOFEATURES | 3102 | read | Returns a bit map with the available features of the analog output path. The possible return values are listed below. |
| SPCM_AO_SE | 00000002h | | Output is single-ended. If available together with SPC_AO_DIFF: output type is software selectable |
| SPCM_AO_DIFF | 00000004h | | Output is differential. If available together with SPC_AO_SE: output type is software selectable |
| SPCM_AO_PROGFILTER | 00000008h | | Software selectable output filters are available. |
| SPCM_AO_PROGOFFSET | 00000010h | | Output offset is software programmable. |
| SPCM_AO_PROGGAIN | 00000020h | | Output gain is software programmable. |
| SPCM_AO_PROGSTOPLVL | 00000040h | | The output level between segments and after replay of generated data is programmable. |
| SPCM_AO_DOUBLEOUT | 00000080h | | Double out mode is available allowing to generate cheap copies of even channel data on odd channels outputs for driving multiple loads. |
| SPCM_AO_ENABLEOUT | 00000100h | | The output of each channel can be completely disabled by software command at any time. |

Generation modes

Your card is able to run in different modes. Depending on the selected mode there are different registers that each define an aspect of this mode. The single modes are explained in this chapter. Any further modes that are only available if an option is installed on the card is documented in a later chapter.

Overview

This chapter gives you a general overview on the related registers for the different modes. The use of these registers throughout the different modes is described in the following chapters.

Setup of the mode

The mode register is organized as a bitmap. Each mode corresponds to one bit of this bitmap. When defining the mode to use, please be sure just to set one of the bits. All other settings will return an error code.

The main difference between all standard and all FIFO modes is that the standard modes are limited to on-board memory and therefore can run with full sampling rate. The FIFO modes are designed to transfer data continuously over the bus to PC memory or to hard disk and can therefore run much longer. The FIFO modes are limited by the maximum bus transfer speed the PC can use. The FIFO mode uses the complete installed on-board memory as a FIFO buffer.

However as you'll see throughout the detailed documentation of the modes the standard and the FIFO mode are similar in programming and behavior and there are only a very few differences between them.

| Register | Value | Direction | Description |
|--------------------|-------|------------|--|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode, a read command will return the currently used mode. |
| SPC_AVAILCARDMODES | 9501 | read | Returns a bitmap with all available modes on your card. The modes are listed below. |

Replay modes

| Mode | Value | Description |
|---------------------------|--------|---|
| SPC_REP_STD_SINGLE | 100h | Data generation from on-board memory repeating the complete programmed memory either once, infinite or for a defined number of times after one single trigger event. |
| SPC_REP_STD_MULTI | 200h | Data generation from on-board memory for multiple trigger events. Each generated segment has the same size. This mode is described in greater detail in a special chapter about the Multiple Replay mode. |
| SPC_REP_STD_GATE | 400h | Data generation from on-board memory using an external gate signal. Data is only generated as long as the gate signal has a programmed level. The mode is described in greater detail in a special chapter about the Gated Replay mode. |
| SPC_REP_STD_SINGLERESTART | 8000h | Data generation from on-board memory. The programmed memory is repeated once after each single trigger event. |
| SPC_REP_STD_SEQUENCE | 40000h | Data generation from on-board memory splitting the memory into several segments and replaying the data using a special sequence memory. The mode is described in greater detail in a special chapter about the Sequence mode. |
| SPC_REP_FIFO_SINGLE | 800h | Continuous data generation after one single trigger event. The on-board memory is used completely as FIFO buffer. |
| SPC_REP_FIFO_MULTI | 1000h | Continuous data generation after multiple trigger events. The on-board memory is used completely as FIFO buffer. |
| SPC_REP_FIFO_GATE | 2000h | Continuous data generation using an external gate signal. The on-board memory is used completely as FIFO buffer. |

Commands

The data acquisition/data replay is controlled by the command register. The command register controls the state of the card in general and also the state of the different data transfers. Data transfers are explained in an extra chapter later on.

The commands are split up into two types of commands: execution commands that fulfill a job and wait commands that will wait for the occurrence of an interrupt. Again the commands register is organized as a bitmap allowing you to set several commands together with one call. As not all of the command combinations make sense (like the combination of reset and start at the same time) the driver will check the given command and return an error code ERR_SEQUENCE if one of the given commands is not allowed in the current state.

| Register | Value | Direction | Description |
|-----------|-------|------------|---|
| SPC_M2CMD | 100 | write only | Executes a command for the card or data transfer. |

Card execution commands

| | | |
|---------------------------|-----|--|
| M2CMD_CARD_RESET | 1h | Performs a hard and software reset of the card as explained further above. |
| M2CMD_CARD_WRITESSETUP | 2h | Writes the current setup to the card without starting the hardware. This command may be useful if changing some internal settings like clock frequency and enabling outputs. |
| M2CMD_CARD_START | 4h | Starts the card with all selected settings. This command automatically writes all settings to the card if any of the settings has been changed since the last one was written. After card has been started, only some of the settings might be changed while the card is running, such as e.g. output level and offset for D/A replay cards. |
| M2CMD_CARD_ENABLETRIGGER | 8h | The trigger detection is enabled. This command can be either sent together with the start command to enable trigger immediately or in a second call after some external hardware has been started. |
| M2CMD_CARD_FORCETRIGGER | 10h | This command forces a trigger even if none has been detected so far. Sending this command together with the start command is similar to using the software trigger. |
| M2CMD_CARD_DISABLETRIGGER | 20h | The trigger detection is disabled. All further trigger events are ignored until the trigger detection is again enabled. When starting the card the trigger detection is started disabled. |
| M2CMD_CARD_STOP | 40h | Stops the current run of the card. If the card is not running this command has no effect. |

Card wait commands

These commands do not return until either the defined state has been reached which is signaled by an interrupt from the card or the timeout counter has expired. If the state has been reached the command returns with an ERR_OK. If a timeout occurs the command returns with ERR_TIMEOUT. If the card has been stopped from a second thread with a stop or reset command, the wait function returns with ERR_ABORT.

| | | |
|------------------------|-------|--|
| M2CMD_CARD_WAITPREFULL | 1000h | Acquisition modes only: the command waits until the pretrigger area has once been filled with data. After pretrigger area has been filled the internal trigger engine starts to look for trigger events if the trigger detection has been enabled. |
| M2CMD_CARD_WAITTRIGGER | 2000h | Waits until the first trigger event has been detected by the card. If using a mode with multiple trigger events like Multiple Recording or Gated Sampling there only the first trigger detection will generate an interrupt for this wait command. |
| M2CMD_CARD_WAITREADY | 4000h | Waits until the card has completed the current run. In an acquisition mode receiving this command means that all data has been acquired. In a generation mode receiving this command means that the output has stopped. |

Wait command timeout

If the state for which one of the wait commands is waiting isn't reached any of the wait commands will either wait forever if no timeout is defined or it will return automatically with an ERR_TIMEOUT if the specified timeout has expired.

| Register | Value | Direction | Description |
|-------------|--------|------------|---|
| SPC_TIMEOUT | 295130 | read/write | Defines the timeout for any following wait command in a millisecond resolution. Writing a zero to this register disables the timeout. |

As a default the timeout is disabled. After defining a timeout this is valid for all following wait commands until the timeout is disabled again by writing a zero to this register.

A timeout occurring should not be considered as an error. It did not change anything on the board status. The board is still running and will complete normally. You may use the timeout to abort the run after a certain time if no trigger has occurred. In that case a stop command is necessary after receiving the timeout. It is also possible to use the timeout to update the user interface frequently and simply call the wait function afterwards again.

Example for card control:

```
// card is started and trigger detection is enabled immediately
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER);

// we wait a maximum of 1 second for a trigger detection. In case of timeout we force the trigger
spcm_dwSetParam_i32 (hDrv, SPC_TIMEOUT, 1000);
if (spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_WAITTRIGGER) == ERR_TIMEOUT)
{
    printf ("No trigger detected so far, we force a trigger now!\n");
    spcm_dwSetParam (hDrv, SPC_M2CMD, M2CMD_CARD_FORCETRIGGER);
}

// we disable the timeout and wait for the end of the run
spcm_dwSetParam_i32 (hDrv, SPC_TIMEOUT, 0);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_WAITREADY);
printf ("Card has stopped now!\n");
```

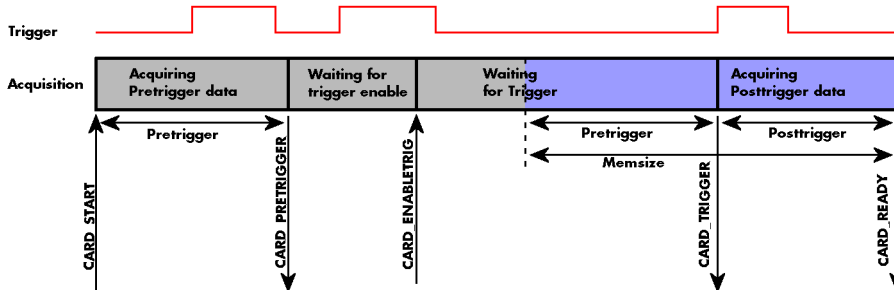
Card Status

In addition to the wait for an interrupt mechanism or completely instead of it one may also read out the current card status by reading the SPC_M2STATUS register. The status register is organized as a bitmap, so that multiple bits can be set, showing the status of the card and also of the different data transfers.

| Register | Value | Direction | Description |
|----------------------------|-------|-----------|--|
| SPC_M2STATUS | 110 | read only | Reads out the current status information |
| M2STAT_CARD_PRETRIGGER | 1h | | Acquisition modes only: the pretrigger area has been filled. |
| M2STAT_CARD_TRIGGER | 2h | | The first trigger has been detected. |
| M2STAT_CARD_READY | 4h | | The card has finished its run and is ready. |
| M2STAT_CARD_SEGMENT_PRETRG | 8h | | Multi/ABA/Gated acquisition of M4i/M4x/M2p only: the pretrigger area of one segment has been filled. |

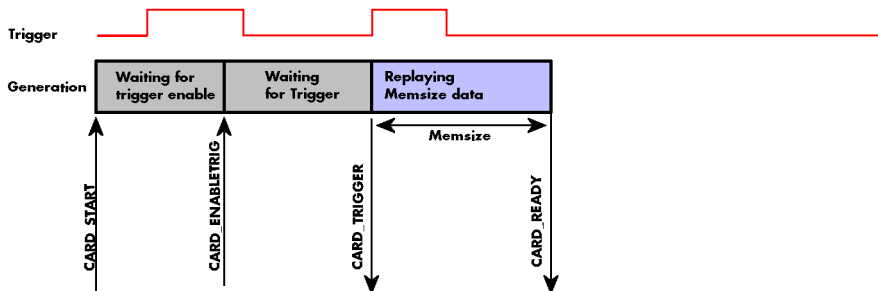
Acquisition cards status overview

The following drawing gives you an overview of the card commands and card status information. After start of card with M2CMD_CARD_START the card is acquiring pretrigger data until one time complete pretrigger data has been acquired. Then the status bit M2STAT_CARD_PRETRIGGER is set. Either the trigger has been enabled together with the start command or the card now waits for trigger enable command M2CMD_CARD_ENABLETRIGGER. After receiving this command the trigger engine is enabled and card checks for a trigger event. As soon as the trigger event is received the status bit M2STAT_CARD_TRIGGER is set and the card acquires the programmed posttrigger data. After all post trigger data has been acquired the status bit M2STAT_CARD_READY is set and data can be read out:



Generation card status overview

This drawing gives an overview of the card commands and status information for a simple generation mode. After start of card with the M2CMD_CARD_START the card is armed and waiting. Either the trigger has been enabled together with the start command or the card now waits for trigger enable command M2CMD_CARD_ENABLETRIGGER. After receiving this command the trigger engine is enabled and card checks for a trigger event. As soon as the trigger event is received the status bit M2STAT_CARD_TRIGGER is set and the card starts with the data replay. After replay has been finished - depending on the programmed mode - the status bit M2STAT_CARD_READY is set and the card stops.



Data Transfer

Data transfer consists of two parts: the buffer definition and the commands/status information that controls the transfer itself. Data transfer shares the command and status register with the card control commands and status information. In general the following details on the data transfer are valid for any data transfer in any direction:

- The memory size register (SPC_MEMSIZE) must be programmed before starting the data transfer.
- When the hardware buffer is adjusted from its default (see „Output latency“ section later in this manual), this must be done before defining the transfer buffers in the next step via the `spcm_dwDefTransfer` function.
- Before starting a data transfer the buffer must be defined using the `spcm_dwDefTransfer` function.
- Each defined buffer is only used once. After transfer has ended the buffer is automatically invalidated.
- If a buffer has to be deleted although the data transfer is in progress or the buffer has at least been defined it is necessary to call the `spcm_dwInvalidateBuf` function.

Definition of the transfer buffer

Before any data transfer can start it is necessary to define the transfer buffer with all its details. The definition of the buffer is done with the `spcm_dwDefTransfer` function as explained in an earlier chapter.

```
uint32_stdcall spcm_dwDefTransfer_i64 (// Defines the transfer buffer by using 64 bit unsigned integer values
    drv_handle hDevice,           // handle to an already opened device
    uint32 dwBufType,             // type of the buffer to define as listed below under SPCM_BUF_XXXX
    uint32 dwDirection,           // the transfer direction as defined below
    uint32 dwNotifySize,          // number of bytes after which an event is sent (0=end of transfer)
    void* pDataBuffer,            // pointer to the data buffer
    uint64 qwBrdOffs,             // offset for transfer in board memory
    uint64 qwTransferLen);        // buffer length
```

This function is used to define buffers for standard sample data transfer as well as for extra data transfer for additional ABA or timestamp information. Therefore the `dwBufType` parameter can be one of the following:

| | | |
|--------------------|------|---|
| SPCM_BUF_DATA | 1000 | Buffer is used for transfer of standard sample data |
| SPCM_BUF_ABA | 2000 | Buffer is used to read out slow ABA data. Details on this mode are described in the chapter about the ABA mode option |
| SPCM_BUF_TIMESTAMP | 3000 | Buffer is used to read out timestamp information. Details on this mode are described in the chapter about the timestamp option. |

The `dwDirection` parameter defines the direction of the following data transfer:

| | | |
|--------------------|---|---|
| SPCM_DIR_PCTOCARD | 0 | Transfer is done from PC memory to on-board memory of card |
| SPCM_DIR_CARDTOPC | 1 | Transfer is done from card on-board memory to PC memory. |
| SPCM_DIR_CARDTOGPU | 2 | RDMA transfer from card memory to GPU memory, SCAPP option needed, Linux only |
| SPCM_DIR_GPUCARD | 3 | RDMA transfer from GPU memory to card memory, SCAPP option needed, Linux only |



The direction information used here must match the currently used mode. While an acquisition mode is used there's no transfer from PC to card allowed and vice versa. It is possible to use a special memory test mode to come beyond this limit. Set the SPC_MEMTEST register as defined further below.

The `dwNotifySize` parameter defines the amount of bytes after which an interrupt should be generated. If leaving this parameter zero, the transfer will run until all data is transferred and then generate an interrupt. Filling in notify size > zero will allow you to use the amount of data that has been transferred so far. The notify size is used on FIFO mode to implement a buffer handshake with the driver or when transferring large amount of data where it may be of interest to start data processing while data transfer is still running. Please see the chapter on handling positions further below for details.



The Notify size sticks to the page size which is defined by the PC hardware and the operating system. Therefore the notify size must be a multiple of 4 kByte. For data transfer it may also be a fraction of 4k in the range of 16, 32, 64, 128, 256, 512, 1k or 2k. No other values are allowed. For ABA and timestamp the notify size can be 2k as a minimum. If you need to work with ABA or timestamp data in smaller chunks please use the polling mode as described later.

The `pvDataBuffer` must point to an allocated data buffer for the transfer. Please be sure to have at least the amount of memory allocated that you program to be transferred. If the transfer is going from card to PC this data is overwritten with the current content of the card on-board memory.



The `pvDataBuffer` needs to be aligned to a page size (4096 bytes). Please use appropriate software commands when allocating the data buffer. Using a non-aligned buffer may result in data corruption.

When not doing FIFO mode one can also use the `qwBrdOffs` parameter. This parameter defines the starting position for the data transfer as byte value in relation to the beginning of the card memory. Using this parameter allows it to split up data transfer in smaller chunks if one has acquired a very large on-board memory.

The `qwTransferLen` parameter defines the number of bytes that has to be transferred with this buffer. Please be sure that the allocated memory has at least the size that is defined in this parameter. In standard mode this parameter cannot be larger than the amount of data defined with memory size.

Memory test mode

In some cases it might be of interest to transfer data in the opposite direction. Therefore a special memory test mode is available which allows random read and write access of the complete on-board memory. While memory test mode is activated no normal card commands are processed:

| Register | Value | Direction | Description |
|-------------|--------|------------|--|
| SPC_MEMTEST | 200700 | read/write | Writing a 1 activates the memory test mode, no commands are then processed. Writing a 0 deactivates the memory test mode again. |

Invalidation of the transfer buffer

The command can be used to invalidate an already defined buffer if the buffer is about to be deleted by user. This function is automatically called if a new buffer is defined or if the transfer of a buffer has completed

```
uint32_stdcall spcm_dwInvalidateBuf ( // invalidate the transfer buffer
    drv_handle hDevice,             // handle to an already opened device
    uint32 dwBufType);              // type of the buffer to invalidate as listed above under SPCM_BUF_XXXX
```

The `dwBufType` parameter need to be the same parameter for which the buffer has been defined:

| | | |
|--------------------|------|--|
| SPCM_BUF_DATA | 1000 | Buffer is used for transfer of standard sample data |
| SPCM_BUF_ABA | 2000 | Buffer is used to read out slow ABA data. Details on this mode are described in the chapter about the ABA mode option. The ABA mode is only available on analog acquisition cards. |
| SPCM_BUF_TIMESTAMP | 3000 | Buffer is used to read out timestamp information. Details on this mode are described in the chapter about the timestamp option. The timestamp mode is only available on analog or digital acquisition cards. |

Commands and Status information for data transfer buffers.

As explained above the data transfer is performed with the same command and status registers like the card control. It is possible to send commands for card control and data transfer at the same time as shown in the examples further below.

| Register | Value | Direction | Description |
|---------------------|--------|------------|--|
| SPC_M2CMD | 100 | write only | Executes a command for the card or data transfer |
| M2CMD_DATA_STARTDMA | 10000h | | Starts the DMA transfer for an already defined buffer. In acquisition mode it may be that the card hasn't received a trigger yet, in that case the transfer start is delayed until the card receives the trigger event |
| M2CMD_DATA_WAITDMA | 20000h | | Waits until the data transfer has ended or until at least the amount of bytes defined by notify size are available. This wait function also takes the timeout parameter described above into account. |
| M2CMD_DATA_STOPDMA | 40000h | | Stops a running DMA transfer. Data is invalid afterwards. |

The data transfer can generate one of the following status information:

| Register | Value | Direction | Description |
|------------------------|-------|-----------|---|
| SPC_M2STATUS | 110 | read only | Reads out the current status information |
| M2STAT_DATA_BLOCKREADY | 100h | | The next data block as defined in the notify size is available. It is at least the amount of data available but it also can be more data. |
| M2STAT_DATA_END | 200h | | The data transfer has completed. This status information will only occur if the notify size is set to zero. |
| M2STAT_DATA_OVERRUN | 400h | | The data transfer had on overrun (acquisition) or underrun (replay) while doing FIFO transfer. |
| M2STAT_DATA_ERROR | 800h | | An internal error occurred while doing data transfer. |

Example of data transfer

```
void* pvData = pvAllocMemPageAligned (1024);

// transfer data from PC memory to card memory (on replay cards) ...
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD , 0, pvData, 0, 1024);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// ... or transfer data from card memory to PC memory (acquisition cards)
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_CARDTOPC , 0, pvData, 0, 1024);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// explicitly stop DMA transfer prior to invalidating buffer
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STOPDMA);
spcm_dwInvalidateBuf (hDrv, SPCM_BUF_DATA);
vFreeMemPageAligned (pvData, 1024);
```

To keep the example simple it does no error checking. Please be sure to check for errors if using these command in real world programs!

Users should take care to explicitly send the M2CMD_DATA_STOPDMA command prior to invalidating the buffer, to avoid crashes due to race conditions when using higher-latency data transportation layers, such as to remote Ethernet devices.



Standard Single Replay modes

The standard single modes are the easiest and mostly used modes to generate analog or digital data with a Spectrum arbitrary waveform generation or digital output card. In standard single replay mode the card is working totally independent from the PC, after the card setup is done and the data has been transferred into the on-board memory. The advantage of the Spectrum boards is that regardless to the system usage the card will refresh the outputs with equidistant time intervals.

The data for replay is stored in the on-board memory and is held there for being replayed after the trigger event. This mode allows sample generation at very high refresh rates without the need to transfer the data from the memory of the host system to the card at high speed.

Card mode

The card mode has to be set to the correct mode SPC_REP_STD_SINGLE.

| Register | Value | Direction | Description |
|---------------------------|-------|------------|--|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode, a read command will return the currently used mode. |
| SPC_REP_STD_SINGLE | 100h | | Data generation from on-board memory repeating the complete programmed memory either once, infinite or for a defined number of times after one single trigger event. |
| SPC_REP_STD_SINGLERESTART | 8000h | | Data generation from on-board memory replaying the complete programmed memory on every detected trigger event. The number of replays can be programmed by loops. |

Memory setup

You have to define, how many samples are to be replayed from the on-board memory and how many times the complete memory should be replayed after the trigger event.



Please note that the memory size must be programmed to the correct value PRIOR to making any data transfer to the card memory. An incorrect memory size value at the time the data transfer is initiated will result in corrupted data and a wrong output.

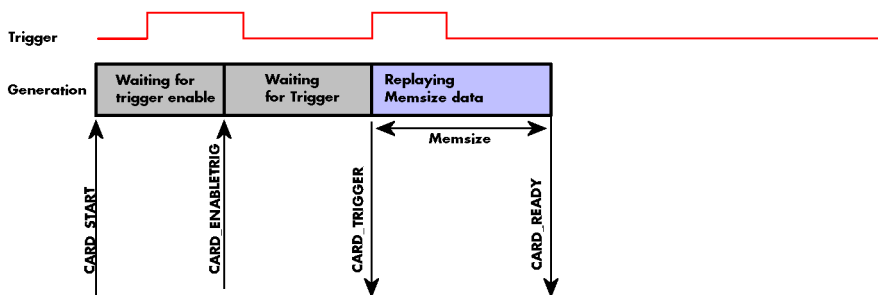
| Register | Value | Direction | Description |
|-------------|-------|------------|--|
| SPC_MEMSIZE | 10000 | read/write | Sets the memory size in samples per channel. The memory size setting must be set before transferring data to the card. |
| SPC_LOOPS | 10020 | read/write | Number of times the memory is replayed. If set to zero the generation will run continuously until it is stopped by the user. |

The maximum memsize that can be used for generating data is of course limited by the installed amount of memory and by the number of channels to be replayed. Please have a look at the topic "Limits of pre, post memsize, loops" later in this chapter.

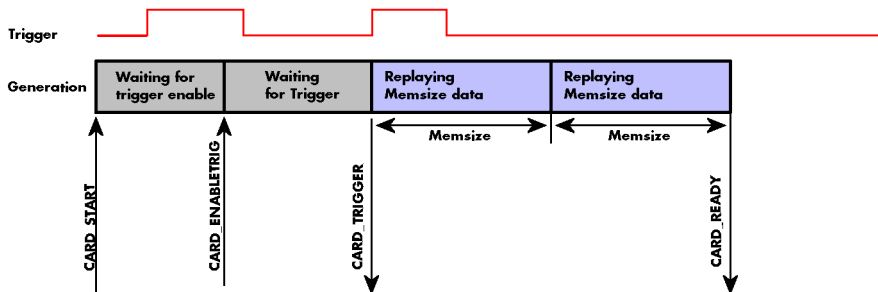
SPC_REP_STD_SINGLE

This mode waits for one trigger events and after this it starts to replay the programmed memory either once, a pre-defined number of times or infinitely until explicitly stopped by the user. The SPC_LOOPS register is used to define the number of possible repetitions. Setting this register to 0 the generation will continue until explicitly stopped by the user. Any other value than 0 for SPC_LOOPS will result in the signal being replayed SPC_LOOPS times until the card stops automatically. For replaying the memory content only once after a trigger the SPC_LOOPS values hence must be set to a value of 1.

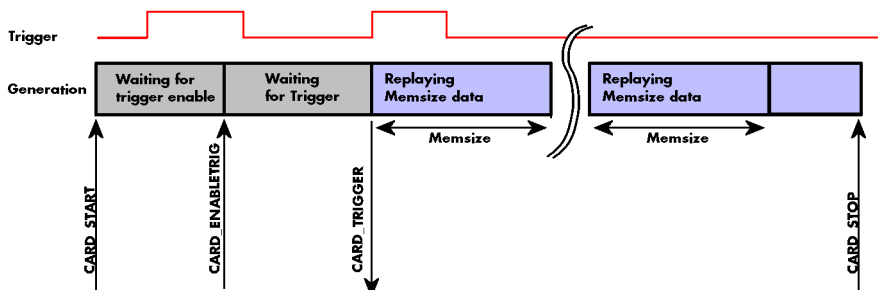
Replay of a data pattern just once



Replay for a defined number of times (2 in the example shown)

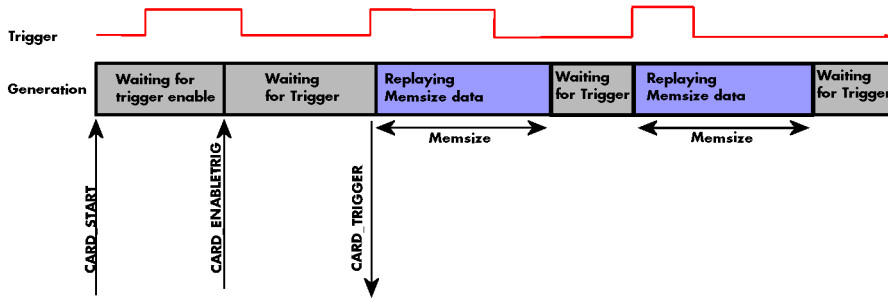


Replay continuously until the replay is stopped by the user



SPC REP STD SINGLERESTART

This mode behaves like multiple shots of SPC_REP_STD_SINGLE but with a very small re-arming time in between. When using this mode the memory content is replayed on every detected trigger event. The SPC_LOOPS parameter defines how long this replay should continue. A value of zero defines the mode to run continuously until stopped by the user.



Between the different replayed pieces the output will go to the programmed stoplevel.

Overview of settings and resulting modes

This table gives a brief overview on the setup of loops and the resulting behavior of the output

| | SPC_LOOPS = 0 | SPC_LOOPS = 1 | SPC_LOOPS = N |
|---------------------------|---|--|--|
| SPC_REP_STD_SINGLE | Replay starts with the first trigger event and then the programmed data is replayed in a continuous loop until stopped by the user. | The programmed memory content is replayed once after detection of the trigger event. | Replay starts with the first trigger event and then the programmed data is replayed in a continuous loop until the programmed number N of loops has been replayed. Afterward the card stops. |
| SPC_REP_STD_SINGLERESTART | The programmed memory is replayed once on every trigger event. This continues until stopped by the user. | n.a. (similar to SPC_REP_STD_SINGLE) | The programmed memory is replayed once on every trigger event. This continues until the memory is N-times replayed. Afterwards the card stops. |

Continuous marker output

If using the continuous output with internal trigger one can activate a marker output on the trigger I/O connector marking the beginning of each loop.

The marker output will generate a TTL pulse on the trigger output connector. The pulse length is of $\frac{1}{2}$ of programmed memory up to a maximum trigger pulse width of 256 samples. If memory is larger than 512 samples the trigger pulse width will still be 256 samples. Please be sure to have the trigger output enabled for this function. This function requires driver version \geq build 1604 and firmware version \geq 11.

| Register | Value | Direction | Description |
|-----------------|--------|------------|--|
| SPC_CONTOUTMARK | 200450 | read/write | Writing a 1 enables the marker output on every loop (M2i.60xx/M2i.61xx only) |

Example

The following example shows a simple standard single mode data generation setup with the transfer of data before the card is started. To keep this example simple there is no error checking implemented.

```
int32 lMemsize = 16384; // replay length is set to 16 kSamples

spcm_dwSetParam_i32 (hDrv, SPC_CHENABLE, CHANNEL0); // only one channel activated
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_STD_SINGLE); // set the standard single replay mode
spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, lMemsize); // replay length
spcm_dwSetParam_i64 (hDrv, SPC_LOOPS, 1); // replay memsize once

void* pvData = pvAllocMemPageAligned (2 * lMemsize); // create a data buffer, 2 bytes per sample
vCalculate_or_Load_Data (pvData); // pvData must now be filled with data

// transfer the data to the on-board memory
spcm_dwDefTransfer_i64 (hDrv, SPC_BUF_DATA, SPCM_DIR_PCTOCARD, 0, pvData, 0, 2 * lMemsize);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// now we start the generation and wait for the interrupt that signalizes the end
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER | M2CMD_CARD_WAITREADY);
```

FIFO Single replay mode

The FIFO single mode does a continuous data replay using the on-board memory as a FIFO buffer and transferring data continuously from PC memory. One can generate the data on-line or load data continuously from disk.

Card mode

The card mode has to be set to the correct mode SPC_REP_FIFO_SINGLE.

| Register | Value | Direction | Description |
|---------------------|-------|------------|---|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode, a read command will return the currently used mode. |
| SPC_REP_FIFO_SINGLE | 800h | | Continuous data replay from PC memory. Complete on-board memory is used as FIFO buffer. |

Length of FIFO mode

In general FIFO mode can run forever until it is stopped by an explicit user command or one can program the total length of the transfer by two counters Loop and Segment size

| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_SEGMENTSIZE | 10010 | read/write | Length of segments to replay. |
| SPC_LOOPS | 10020 | read/write | Number of segments to replay in total. If set to zero the FIFO mode will run continuously until it is stopped by the user. |

The total amount of samples per channel that is replayed can be calculated by $[SPC_LOOPS * SPC_SEGMENTSIZE]$. Please stick to the below mentioned limitations of these registers.

Difference to standard single mode

The standard modes and the FIFO modes do not differ very much from the programming point of view. In fact one can even use the FIFO mode to get the same behavior as the standard mode. The buffer handling that is shown in the next chapter is the same for both modes.

Length of replay.

In standard mode the replay (memory size) length is defined before the start and is limited to the installed on-board memory whilst in FIFO mode the replay length can either be defined or it can run continuously until user stops it.

Example (FIFO replay)

The following example shows a simple FIFO single mode data replay setup with the data calculation placed somewhere else. To keep this example simple there is no error checking implemented. Please see in this example that data has to be calculated and transferred prior to the start of the output. The card start and the DMA transfer start cannot be done simultaneously.

```

spcm_dwSetParam_i32 (hDrv, SPC_CHENABLE, CHANNEL0);           // only one channel activated
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_FIFO_SINGLE); // set the FIFO single replay mode

// starting with firmware version V9 we can program the hardware buffer size to reduce the latency
spcm_dwGetParam_i32 (hDrv, SPC_PCVERSION, &lVersion);
if ((lVersion & 0xffff) >= 9)
{
    spcm_dwSetParam_i64 (stCard.hDrv, SPC_DATA_OUTBUFSIZE, 65536);
    spcm_dwSetParam_i32 (stCard.hDrv, SPC_M2CMD, M2CMD_CARD_WRITESETUP);
}

// in FIFO mode we need to define the buffer before starting the transfer
int16* pData = (int16*) pvAllocMemPageAligned (llBufsizeInSamples * 2); // assuming 2 byte per sample
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, 4096,
    (void*) pData, 0, 2 * llBufsizeInSamples);

// before start we once have to fill some data in for the start of the output
vCalcOrLoadData (&pData[0], 2 * llBufsizeInSamples);
spcm_dwSetParam_i64 (hDrv, SPC_DATA_AVAIL_CARD_LEN, 2 * llBufsizeInSamples);
dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// now the first <notifysize> bytes have been transferred to card and we start the output
dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER);

// we replay data in a loop. As we defined a notify size of 4k we'll get the data in >=4k chunks
llTotalBytes = 2 * llBufsizeInSamples;
while (!dwError)
{
    // read out the available bytes that are free again
    spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_USER_LEN, &llAvailBytes);
    spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_USER_POS, &llUserPosInBytes);

    // be sure not to make a rollover and limit the data to be processed
    if ((llUserPosInBytes + llAvailBytes) > (2 * llBufsizeInSamples))
        llAvailBytes = (2 * llBufsizeInSamples) - llUserPosInBytes;
    llTotalBytes += llAvailBytes;

    // generate some new data
    vCalcOrLoadData (&pData[llUserPosInBytes / 2], llAvailBytes);
    printf ("Currently Available: %lld, total: %lld\n", llAvailBytes, llTotalBytes);

    // now we mark the number of bytes that we just generated for replay and wait for the next free buffer
    spcm_dwSetParam_i64 (hDrv, SPC_DATA_AVAIL_CARD_LEN, llAvailBytes);
    dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_WAITDMA);
}

```

Limits of segment size, memory size

The maximum memory size parameter is only limited by the number of activated channels and by the amount of installed memory. Please keep in mind that each sample needs 2 bytes of memory to be stored.

Due to the internal organization of the card memory there is a certain stepsize when setting these values that has to be taken into account. The following table gives you an overview of all limits concerning memory size, segment size and loops. The table shows all values in relation to the installed memory size in samples. If more memory is installed the maximum memory size figures will increase according to the complete installed memory:

| Activated Channels | Used Mode | Memory size SPC_MEMSIZE | | | Segment size SPC_SEGMENTSIZE | | | Loops SPC_LOOPS | | |
|--------------------|-----------------|----------------------------|-------|------|---------------------------------|--------|------|--------------------|--------|------|
| | | Min | Max | Step | Min | Max | Step | Min | Max | Step |
| 1 channel | Standard Single | 8 | Mem | 8 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 8 | Mem | 8 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 8 | Mem | 8 | 8 | Mem/2 | 8 | not used | | |
| | Standard Gate | 8 | Mem | 8 | not used | | | not used | | |
| | FIFO Single | not used | | | 8 | 8G - 8 | 8 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 8 | Mem/2 | 8 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |
| 2 channels | Standard Single | 4 | Mem/2 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 4 | Mem/2 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 4 | Mem/2 | 4 | 4 | Mem/4 | 4 | not used | | |
| | Standard Gate | 4 | Mem/2 | 4 | not used | | | not used | | |
| | FIFO Single | not used | | | 4 | 8G - 4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 4 | Mem/4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |
| 4 channels | Standard Single | 4 | Mem/4 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 4 | Mem/4 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 4 | Mem/4 | 4 | 4 | Mem/8 | 4 | not used | | |
| | Standard Gate | 4 | Mem/4 | 4 | not used | | | not used | | |
| | FIFO Single | not used | | | 4 | 8G - 4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 4 | Mem/8 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |

All figures listed here are given in samples. An entry of [8k - 16] means [8 kSamples - 16] = [8192 - 16] = 8176 samples.

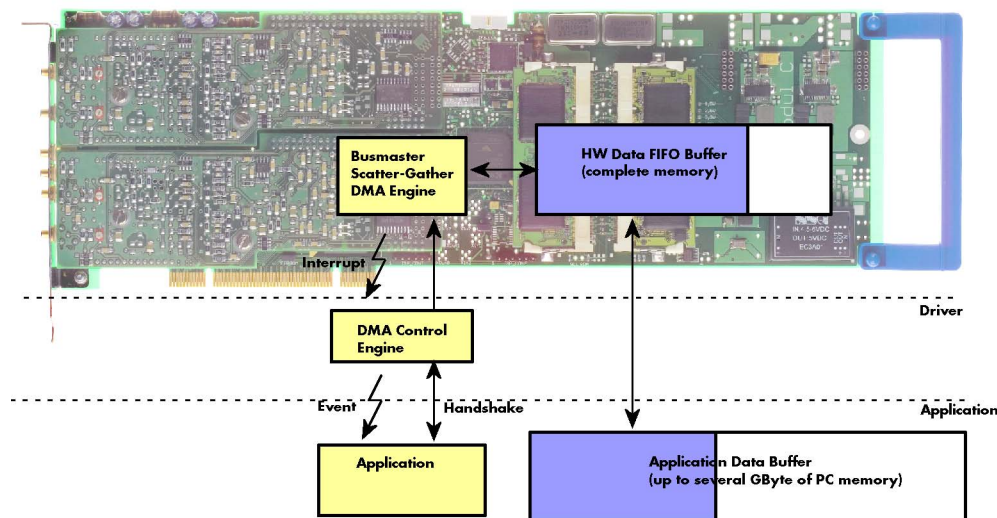
The given memory and memory / divider figures depend on the installed on-board memory as listed below:

| | Installed Memory | | | | | | |
|---------|------------------|------------|-------------|-------------|-------------|-------------|-------------|
| | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample |
| Mem | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample |
| Mem / 2 | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample |
| Mem / 4 | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample |
| Mem / 8 | 4 MSample | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample |

Please keep in mind that this table shows all values at once. Only the absolute maximum and minimum values are shown. There might be additional limitations. Which of these values is programmed depends on the used mode. Please read the detailed documentation of the mode.

Buffer handling

To handle the huge amount of data that can possibly be acquired with the M2i/M3i series cards, there is a very reliable two step buffer strategy set up. The on-board memory of the card can be completely used as a real FIFO buffer. In addition a part of the PC memory can be used as an additional software buffer. Transfer between hardware FIFO and software buffer is performed interrupt driven and automatically by the driver to get best performance. The following drawing will give you an overview of the structure of the data transfer handling:



A data buffer handshake is implemented in the driver which allows to run the card in different data transfer modes. The software transfer buffer is handled as one large buffer which is on the one side controlled by the driver and filled automatically by busmaster DMA from/to the hardware FIFO buffer and on the other hand it is handled by the user who set's parts of this software buffer available for the driver for further transfer. The handshake is fulfilled with the following 3 software registers:

| Register | Value | Direction | Description |
|-------------------------|-------|-----------|--|
| SPC_DATA_AVAIL_USER_LEN | 200 | read | Returns the number of currently to the user available bytes inside a sample data transfer. |
| SPC_DATA_AVAIL_USER_POS | 201 | read | Returns the position as byte index where the currently available data samples start. |
| SPC_DATA_AVAIL_CARD_LEN | 202 | write | Writes the number of bytes that the card can now use for sample data transfer again |

Internally the card handles two counters, a user counter and a card counter. Depending on the transfer direction the software registers have slightly different meanings:

| Transfer direction | Register | Direction | Description |
|--------------------|-------------------------|-----------|---|
| Write to card | SPC_DATA_AVAIL_USER_LEN | read | This register contains the currently available number of bytes that are free to write new data to the card. The user can now fill this amount of bytes with new data to be transferred. |
| | SPC_DATA_AVAIL_CARD_LEN | write | After filling an amount of the buffer with new data to transfer to card, the user tells the driver with this register that the amount of data is now ready to transfer. |
| Read from card | SPC_DATA_AVAIL_USER_LEN | read | This register contains the currently available number of bytes that are filled with newly transferred data. The user can now use this data for own purposes, copy it, write it to disk or start calculations with this data. |
| | SPC_DATA_AVAIL_CARD_LEN | write | After finishing the job with the new available data the user needs to tell the driver that this amount of bytes is again free for new data to be transferred. |
| Any direction | SPC_DATA_AVAIL_USER_POS | read | The register holds the current byte index position where the available bytes start. The register is just intended to help you and to avoid own position calculation |
| Any direction | SPC_FILLSIZEPROMILLE | read | The register holds the current fill size of the on-board memory (FIFO buffer) in promille (1/1000) of the full on-board memory. Please note that the hardware reports the fill size only in 1/16 parts of the full memory. The reported fill size is therefore only shown in $1000/16 = 63$ promille steps. |

Directly after start of transfer the SPC_DATA_AVAIL_USER_LEN is every time zero as no data is available for the user and the SPC_DATA_AVAIL_CARD_LEN is every time identical to the length of the defined buffer as the complete buffer is available for the card for transfer.

The counter that is holding the user buffer available bytes (SPC_DATA_AVAIL_USER_LEN) is sticking to the defined notify size at the DefTransfer call. Even when less bytes already have been transferred you won't get notice of it if the notify size is programmed to a higher value.



Remarks

- The transfer between hardware FIFO buffer and application buffer is done with scatter-gather DMA using a busmaster DMA controller located on the card. Even if the PC is busy with other jobs data is still transferred until the application data buffer is completely used.
- Even if application data buffer is completely used there's still the hardware FIFO buffer that can hold data until the complete on-board memory is used. Therefore a larger on-board memory will make the transfer more reliable against any PC dead times.
- As you see in the above picture data is directly transferred between application data buffer and on-board memory. Therefore it is absolutely critical to delete the application data buffer without stopping any DMA transfers that are running actually. It is also absolutely critical to define the application data buffer with an unmatching length as DMA can than try to access memory outside the application data

area.

- As shown in the drawing above the DMA control will announce new data to the application by sending an event. Waiting for an event is done internally inside the driver if the application calls one of the wait functions. Waiting for an event does not consume any CPU time and is therefore highly desirable if other threads do a lot of calculation work. However it is not necessary to use the wait functions and one can simply request the current status whenever the program has time to do so. When using this polling mode the announced available bytes still stick to the defined notify size!
- If the on-board FIFO buffer has an overrun (card to PC) or an underrun (PC to card) data transfer is stopped. However in case of transfer from card to PC there is still a lot of data in the on-board memory. Therefore the data transfer will continue until all data has been transferred although the status information already shows an overrun.
- Getting best bus transfer performance is done using a „continuous buffer“. This mode is explained in the appendix in greater detail.

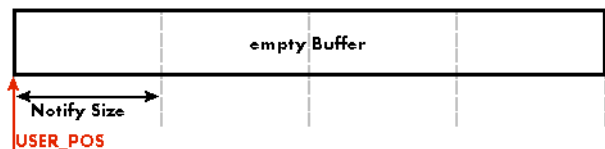


The Notify size sticks to the page size which is defined by the PC hardware and the operating system. Therefore the notify size must be a multiple of 4 kByte. For data transfer it may also be a fraction of 4k in the range of 16, 32, 64, 128, 256, 512, 1k or 2k. No other values are allowed. For ABA and timestamp the notify size can be 2k as a minimum. If you need to work with ABA or timestamp data in smaller chunks please use the polling mode as described later.

The following graphs will show the current buffer positions in different states of the transfer. The drawings have been made for the transfer from card to PC. However all the block handling is similar for the opposite direction, just the empty and the filled parts of the buffer are inverted.

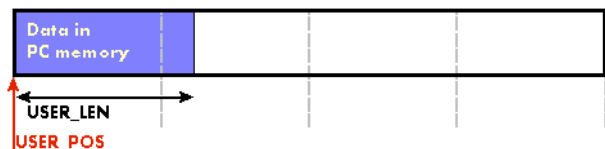
Step 1: Buffer definition

Directly after buffer definition the complete buffer is empty (card to PC) or completely filled (PC to card). In our example we have a notify size which is 1/4 of complete buffer memory to keep the example simple. In real world use it is recommended to set the notify size to a smaller stepsize.



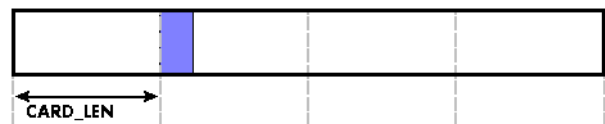
Step 2: Start and first data available

In between we have started the transfer and have waited for the first data to be available for the user. When there is at least one block of notify size in the memory we get an interrupt and can proceed with the data. Any data that already was transferred is announced. The USER_POS is still zero as we are right at the beginning of the complete transfer.



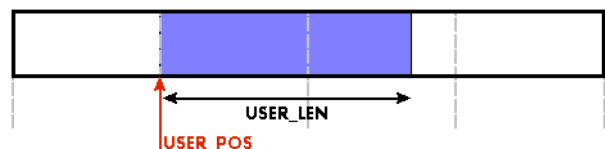
Step 3: set the first data available for card

Now the data can be processed. If transfer is going from card to PC that may be storing to hard disk or calculation of any figures. If transfer is going from PC to card that means we have to fill the available buffer again with data. After the amount of data that has been processed by the user application we set it available for the card and for the next step.



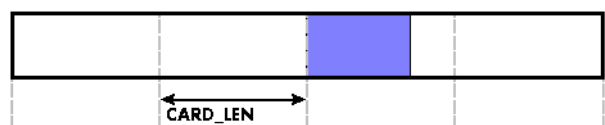
Step 4: next data available

After reaching the next border of the notify size we get the next part of the data buffer to be available. In our example at the time when reading the USER_LEN even some more data is already available. The user position will now be at the position of the previous set CARD_LEN.



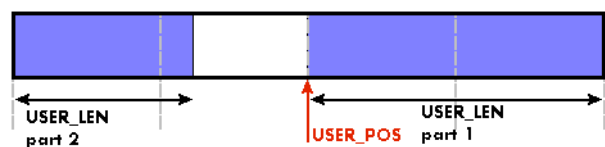
Step 5: set data available again

Again after processing the data we set it free for the card use. In our example we now make something else and don't react to the interrupt for a longer time. In the background the buffer is filled with more data.



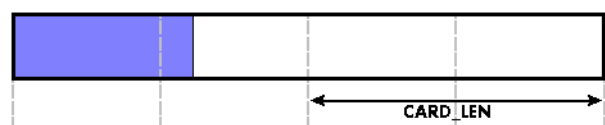
Step 6: roll over the end of buffer

Now nearly the complete buffer is filled. Please keep in mind that our current user position is still at the end of the data part that we processed and marked in step 4 and step 5. Therefore the data to process now is split in two parts. Part 1 is at the end of the buffer while part 2 is starting with address 0.



Step 7: set the rest of the buffer available

Feel free to process the complete data or just the part 1 until the end of the buffer as we do in this example. If you decide to process complete buffer please keep in mind the roll over at the end of the buffer.



This buffer handling can now continue endless as long as we manage to set the data available for the card fast enough. The USER_POS and USER_LEN for step 8 would now look exactly as the buffer shown in step 2.

Buffer handling example for transfer from card to PC (Data acquisition)

```

int8* pcData = (int8*) pvAllocMemPageAligned (llBufferSizeInBytes);

// we now define the transfer buffer with the minimum notify size of one page = 4 kByte
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_CARDTOPC, 4096, (void*) pcData, 0, llBufferSizeInBytes);

// we start the DMA transfer
dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA);

do
{
    if (!dwError)
    {
        // we wait for the next data to be available. After this call we get at least 4k of data to proceed
        dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_WAITDMA);

        // if there was no error we can proceed and read out the available bytes that are free again
        spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_USER_LEN, &llAvailBytes);
        spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_USER_POS, &llBytePos);

        printf ("We now have %lld new bytes available\n", llAvailBytes);
        printf ("The available data starts at position %lld\n", llBytePos);

        // we take care not to go across the end of the buffer, handling the wrap-around
        if ((llBytePos + llAvailBytes) >= llBufferSizeInBytes)
            llAvailBytes = llBufferSizeInBytes - llBytePos;

        // our do function gets a pointer to the start of the available data section and the length
        vDoSomething (&pcData[llBytePos], llAvailBytes);

        // the buffer section is now immediately set available for the card
        spcm_dwSetParam_i64 (hDrv, SPC_DATA_AVAIL_CARD_LEN, llAvailBytes);
    }
}
while (!dwError); // we loop forever if no error occurs

```

Buffer handling example for transfer from PC to card (Data generation)

```

int8* pcData = (int8*) pvAllocMemPageAligned (llBufferSizeInBytes);

// before starting transfer we first need to fill complete buffer memory with meaningful data
vDoGenerateData (&pcData[0], llBufferSizeInBytes);

// we now define the transfer buffer with the minimum notify size of one page = 4 kByte
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, 4096, (void*) pcData, 0, llBufferSizeInBytes);

// and transfer some data to the hardware buffer before the start of the card
spcm_dwSetParam_i32 (hDrv, SPC_DATA_AVAIL_CARD_LEN, llBufferSizeInBytes);
dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

do
{
    if (!dwError)
    {
        // if there was no error we can proceed and read out the current amount of available data
        spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_USER_LEN, &llAvailBytes);
        spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_USER_POS, &llBytePos);

        printf ("We now have %lld free bytes available\n", llAvailBytes);
        printf ("The available data starts at position %lld\n", llBytePos);

        // we take care not to go across the end of the buffer, handling the wrap-around
        if ((llBytePos + llAvailBytes) >= llBufferSizeInBytes)
            llAvailBytes = llBufferSizeInBytes - llBytePos;

        // our do function gets a pointer to the start of the available data section and the length
        vDoGenerateData (&pcData[llBytePos], llAvailBytes);

        // now we mark the number of bytes that we just generated for replay
        // and wait for the next free buffer
        spcm_dwSetParam_i64 (hDrv, SPC_DATA_AVAIL_CARD_LEN, llAvailBytes);
        dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_WAITDMA);
    }
}
while (!dwError); // we loop forever if no error occurs

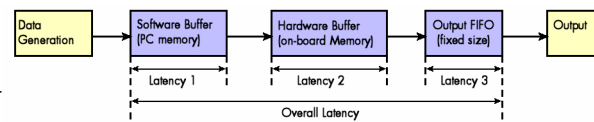
```

Please keep in mind that you are using a continuous buffer writing/reading that will start again at the zero position if the buffer length is reached. However the `DATA_AVAIL_USER_LEN` register will give you the complete amount of available bytes even if one part of the free area is at the end of the buffer and the second half at the beginning of the buffer.



Output latency

The card is designed to have a most stable and reliable continuous output in FIFO mode. Therefore as default the complete on-board memory is used for buffering data. This however means that you have quite a large latency when changing output data dynamically in reaction of - for example - some external events.



To have a smaller output latency when using dynamically changing data it is recommended that you use smaller buffers. The size of the software buffer is programmed as described above. The size of the hardware buffer can be programmed using a special register:

| Register | Value | Direction | Description |
|---------------------|-------|------------|--|
| SPC_DATA_OUTBUFSIZE | 209 | read/write | Programms the used hardware buffer size for output direction. The default value is the complete standard on-board memory. The output buffer size can be programmed in steps of factor two of the minimum size of 1k. Resulting in allowed settings of 1k, 2k, 4k, 8k, 16k, ... up to the installed on-board memory size |

This programmable functionality is available starting with firmware version V9.

When the hardware buffer is adjusted, this must be followed by a M2CMD_CARD_WRITESETUP command and done after defining the card mode but before defining the transfer buffers via the spcm_dwDefTransfer function and , as shown in the example below.

The size of the output FIFO is fixed to 16 kByte (Latency 3) and cannot be changed. If using a hardware buffer of 4 kByte (Latency 2) and a software buffer of 4 kByte (Latency 1) the total size of buffered data is hence 24 kByte. Please see the following table for some example output latency calculations, taking buffers and the clock rate into account:

| Configuration | Sampling rate | Software Buffer | | Hardware Buffer | | Output FIFO | | Overall Latency |
|--------------------|---------------|-----------------|------------|-----------------|-------------|-------------|---------|-----------------|
| | | Size | Latency | Size | Latency | Size | Latency | |
| 1 x 16 Bit Channel | 1 MS/s | 8 MByte | 4194.30 ms | 64 MByte | 33554.43 ms | 16 kByte | 8.19 ms | 37.8 s |
| ... | ... | 1 MByte | 524.29 ms | 1 MByte | 524.29 ms | 16 kByte | 8.19 ms | 1.1 s |
| ... | ... | 4 kByte | 2.05 ms | 4 kByte | 2.05 ms | 16 kByte | 8.19 ms | 12.3 ms |
| 1 x 16 Bit Channel | 50 MS/s | 8 MByte | 83.89 ms | 64 MByte | 671.09 ms | 16 kByte | 0.16 ms | 755.1 ms |
| ... | ... | 1 MByte | 10.48 ms | 1 MByte | 10.48 ms | 16 kByte | 0.16 ms | 21.1 ms |
| ... | ... | 4 kByte | 0.04 ms | 4 kByte | 0.04 ms | 16 kByte | 0.16 ms | 240.0 us |
| 4 x 16 Bit Channel | 1 MS/s | 8 MByte | 1048.58 ms | 64 MByte | 8388.61 ms | 16 kByte | 2.05 ms | 9.4 s |
| ... | ... | 1 MByte | 131.07 ms | 1 MByte | 131.07 ms | 16 kByte | 2.05 ms | 264.2 ms |
| ... | ... | 4 kByte | 0.53 ms | 4 kByte | 0.53 ms | 16 kByte | 2.05 ms | 3.1 ms |



Please keep in mind that lowering the output buffer size also means that the risk of a buffer underrun gets higher as less data is buffered on the hardware side. Therefore please be careful with selecting the correct hardware buffer size and do not make it smaller than absolutely necessary.

The above mentioned latency calculations are only an example on how to calculate the time. They're not tested in real life to run continuously with that sampling speed.

```

void* pvBuffer = NULL;
int64 llHWBufSize = KILO_B(64);
int64 llSWBufSize = KILO_B(128); // must be an integer multiple of llNotifysize
uint32 dwNotifysize = KILO_B(8);
uint32 dwErr;

// define card mode first
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_STD_SINGLE);

// secondly define the hardware buffer and write it to the hardware
spcm_dwSetParam_i64 (hDrv, SPC_DATA_OUTBUFSIZE, llHWBufSize);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_WRITESETUP);

// and then allocate and setup the software fifo buffer
pvBuffer = pvAllocMemPageAligned ((uint32) llSWBufSize);
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, dwNotifysize, pvBuffer, 0, llSWBufSize);

// --> now fill the buffer with initial data (not shown here)

spcm_dwSetParam_i64 (hDrv, SPC_DATA_AVAIL_CARD_LEN, llSWBufSize);

// now that SW-buffer is filled, we start the data transfer (replay itself is not started yet)
// and wait for the data to be transferred.
spcm_dwSetParam_i32 (stCard.hDrv, SPC_TIMEOUT, 1000);
dwErr = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

if (!dwErr)
{
    // please see FIFO replay examples for further details regarding the complete data transfer ...
}
  
```

Data organisation

Data is organized in a multiplexed way in the transfer buffer. If using 4 channels, data of the first activated channel of first module comes first, then data of first activated channel of second module, then second activated channel of first module and so on.

| Activated Channels | Ch0 | Ch1 | Ch2 | Ch3 | Samples ordering in buffer memory starting with data offset zero | | | | | | | | | | | | | | | | |
|--------------------|-----|-----|-----|-----|--|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
| 1 channel | X | | | | A0 | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | A13 | A14 | A15 | A16 |
| 1 channel | | X | | | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 |
| 1 channel | | | X | | C0 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 |
| 1 channel | | | | X | D0 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 | D11 | D12 | D13 | D14 | D15 | D16 |
| 2 channels | X | X | | | A0 | B0 | A1 | B1 | A2 | B2 | A3 | B3 | A4 | B4 | A5 | B5 | A6 | B6 | A7 | B7 | A8 |
| 2 channels | X | | X | | A0 | C0 | A1 | C1 | A2 | C2 | A3 | C3 | A4 | C4 | A5 | C5 | A6 | C6 | A7 | C7 | A8 |
| 2 channels | | X | | X | A0 | D0 | A1 | D1 | A2 | D2 | A3 | D3 | A4 | D4 | A5 | D5 | A6 | D6 | A7 | D7 | A8 |
| 2 channels | | X | X | | B0 | C0 | B1 | C1 | B2 | C2 | B3 | C3 | B4 | C4 | B5 | C5 | B6 | C6 | B7 | C7 | B8 |
| 2 channels | | X | | X | B0 | D0 | B1 | D1 | B2 | D2 | B3 | D3 | B4 | D4 | B5 | D5 | B6 | D6 | B7 | D7 | B8 |
| 2 channels | | | X | X | C0 | D0 | C1 | D1 | C2 | D2 | C3 | D3 | C4 | D4 | C5 | D5 | C6 | D6 | C7 | D7 | C8 |
| 4 channels | X | X | X | X | A0 | C0 | B0 | D0 | A1 | C1 | B1 | D1 | A2 | C2 | B2 | D2 | A3 | C3 | B3 | D3 | A4 |

The samples are re-named for better readability. A0 is sample 0 of channel 0, C4 is sample 4 of channel 2, and so on.

Sample format

The 14 bit D/A samples are stored in two's complement in the lower 14 bit of the 16 bit data word. 14 bit resolution means that data is ranging from -8192...to...+8191. In standard mode the upper two bits contain the sign extension allowing to directly use 16 bit integer values for the write data directly. If digital outputs are activated these outputs are stored in the two upper bits.

| Bit | Standard Mode | Digital outputs (option) enabled |
|-----|------------------|----------------------------------|
| D15 | DAx Bit 13 | Digital bit 1 of channel x |
| D14 | DAx Bit 13 | Digital bit 0 of channel x |
| D13 | DAx Bit 13 (MSB) | DAx Bit 13 (MSB) |
| D12 | DAx Bit 12 | DAx Bit 12 |
| D11 | DAx Bit 11 | DAx Bit 11 |
| D10 | DAx Bit 10 | DAx Bit 10 |
| D9 | DAx Bit 9 | DAx Bit 9 |
| D8 | DAx Bit 8 | DAx Bit 8 |
| D7 | DAx Bit 7 | DAx Bit 7 |
| D6 | DAx Bit 6 | DAx Bit 6 |
| D5 | DAx Bit 5 | DAx Bit 5 |
| D4 | DAx Bit 4 | DAx Bit 4 |
| D3 | DAx Bit 3 | DAx Bit 3 |
| D2 | DAx Bit 2 | DAx Bit 2 |
| D1 | DAx Bit 1 | DAx Bit 1 |
| D0 | DAx Bit 0 (LSB) | DAx Bit 0 (LSB) |

Hardware data conversion

The data conversion modes allow the conversion of input data in hardware. This is especially usefull when replaying previously recorded data of acquisition cards with either a higher 16bit or lower 12bit resolution. The conversion takes place in hardware and therefore avoids a possible time consuming shift in the user application software.

| Register | Value | Direction | Description |
|------------------------|--------|------------|---|
| SPC_AVAIDATACONVERSION | 201401 | read | Bitmask, in which all bits of the below mentioned data conversion modes are set, if available. |
| SPC_DATACONVERSION | 201400 | read/write | Defines the used hardware data conversion mode or reads out the actual selected one. |
| SPCM_DC_NONE | 0h | | No hardware data conversion will be done. |
| SPCM_DC_12BIT_TO_14BIT | 1h | | 12bit input data is assumed and samples will be logically shifted upwards to use available 14bit resolution. |
| SPCM_DC_16BIT_TO_14BIT | 2h | | 16bit input data is assumed and samples will be arithmetically shifted downwards to use available 14bit resolution. |

The data conversion modes require driver version V2.11 (or newer) and firmware version V18 (or newer). Please update your system to the newest versions to use this mode.



Clock generation

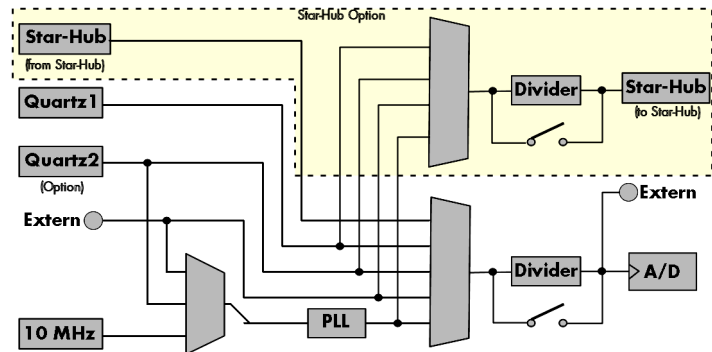
Overview

The different clock modes

The Spectrum M2i cards offer a wide variety of different clock modes to match all the customers needs. All of the clock modes are described in detail with programming examples in this chapter.

The figure is showing an overview of the complete engine used on all M2i cards for clock generation.

The purpose of this chapter is to give you a guide to the best matching clock settings for your specific application and needs.



Standard internal sample rate (PLL)

PLL with internal 10 MHz reference. This is the easiest and most common way to generate a sample rate with no need for additional external clock signals. The sample rate has a fine resolution. You can find details on the granularity of the clock in PLL mode in the technical data section of this manual.

Quartz1 with or without divider

This mode provides an internal sampling quartz clock with a dedicated divider. It's best suited for applications that need an even lower clock jitter than the PLL produces. The possible sample rates are restricted to the values of the divider. For details on the available divider values please see the according section in this chapter or take a look at the technical data section of this manual.

Quartz2 with or without PLL and/or with or without divider (optional)

This optional second Quartz2 is for special customer needs, either for a special direct sampling clock or as a very precise reference for the PLL. Please feel free to contact Spectrum for your special needs.

External reference clock

PLL with external 1 MHz to 125 MHz reference clock. This provides a very good clock accuracy if a stable external reference clock is used. It also allows the easy synchronization with an external source.

Direct external clock

Any clock can be fed in that matches the specification of the board. The external clock signal can be used to synchronize the board on a system clock or to feed in an exact matching sample rate.



Direct external clock is not available for M2i.49xx cards. Please use external reference clock mode instead.

External clock with divider

In addition to the direct external clocking it is also possible to use the externally fed in clock and divide it for generating a low-jitter sample rate of a slower speed than the external clock available.



Direct external clock with divider is not available for M2i.49xx cards. Please use external reference clock mode instead.

Synchronization clock (optional)

The star-hub option allows the synchronization of up to 16 cards of the M2i series from Spectrum with a minimal phase delay between the different cards. As this clock is also available at the dividers input, cards of the same or slower sampling speeds can be synchronized. For details on the synchronization option please take a look at the dedicated chapter in this manual.

Clock Mode Register

The selection of the different clock modes has to be done by the SPC_CLOCKMODE register. All available modes, can be read out by the help of the SPC_AVAIRCLOCKMODES register.

| Register | Value | Direction | Description |
|---------------------|-------|------------|--|
| SPC_AVAIRCLOCKMODES | 20201 | read | Bitmask, in which all bits of the below mentioned clock modes are set, if available. |
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode or reads out the actual selected one. |
| SPC_CM_INTPLL | 1 | | Enables internal PLL with 10 MHz internal reference for sample clock generation |
| SPC_CM_QUARTZ1 | 2 | | Enables Quartz1 for sample clock generation |
| SPC_CM_QUARTZ2 | 4 | | Enables optional Quartz2 for sample clock generation |
| SPC_CM_EXTERNAL | 8 | | Enables external clock input for direct sample clock generation |
| SPC_CM_EXTDIVIDER | 16 | | Enables external clock input for divided sample clock generation |
| SPC_CM_EXTREFCLOCK | 32 | | Enables internal PLL with external reference for sample clock generation |

The different clock modes and all other related or required register settings are described on the following pages.

Internally generated sample rate

Standard internal sampling clock (PLL)

The internal sampling clock is generated in default mode by a PLL and dividers out of an internal precise 10 MHz frequency reference. You can select the clock mode by the dedicated register shown in the table below:

| Register | Value | Direction | Description |
|---------------|-------|------------|---|
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode |
| SPC_CM_INTPLL | 1 | | Enables internal PLL with 10 MHz internal reference for sample clock generation |

In most cases the user does not have to care about how the desired sampling rate is generated by multiplying and dividing internally. You simply write the desired sample rate to the according register shown in the table below and the driver makes all the necessary calculations. If you want to make sure the sample rate has been set correctly you can also read out the register and the driver will give you back the sampling rate that is matching your desired one best.

| Register | Value | Direction | Description |
|----------------|-------|-----------|--|
| SPC_SAMPLERATE | 20000 | write | Defines the sample rate in Hz for internal sample rate generation. |
| | | read | Read out the internal sample rate that is nearest matching to the desired one. |

If a sampling rate is generated internally, you can additionally enable the clock output. The clock will be available on the external clock connector and can be used to synchronize external equipment with the board.

| Register | Value | Direction | Description |
|-----------------------|-------|------------|--|
| SPC_CLOCKOUT | 20110 | read/write | Enables clock output on external clock connector. On A/D and D/A cards only possible with internal clocking. |
| SPC_CLOCKOUTFREQUENCY | 20111 | read | Allows to read out the frequency of an internally synthesized clock present at the clock output. |

Example on writing and reading internal sampling rate

```

spcm_dwSetParam_i32 (hDrv, SPC_CLOCKMODE, SPC_CM_INTPLL); // Enables internal PLL mode
spcm_dwSetParam_i32 (hDrv, SPC_SAMPLERATE, 1000000); // Set internal sampling rate to 1 MHz
spcm_dwSetParam_i32 (hDrv, SPC_CLOCKOUT, 1); // enable the clock output of that 1 MHz clock
spcm_dwGetParam_i32 (hDrv, SPC_SAMPLERATE, &lSamplerate); // Read back the programmed sample rate and
printf („Sample rate = %d\n“, lSamplerate); // print it. Output should be „Sample rate = 1000000“

```

Minimum internal sample rate

The minimum internal sample rate on all M2i cards is limited to 1 kHz and the maximum sample rate depends on the specific type of board. The maximum sample rates for your type of card are shown in the tables below.

Maximum internal sampling rate in MS/s

| activated Channels | | | | M2i.6011 | M2i.6012 | M2i.6021 | M2i.6022 | M2i.6030 | M2i.6031 | M2i.6033 | M2i.6034 |
|--------------------|-----|-----|-----|------------------------------------|---------------------------------------|------------------------------------|---------------------------------------|----------------------------------|--------------------------------------|--------------------------------------|--|
| Ch0 | Ch1 | Ch2 | Ch3 | | | | | | | | |
| X | X | | | 20 MS/s 20 MS/s n.a. n.a. | 20 MS/s 20 MS/s 20 MS/s n.a. | 60 MS/s 60 MS/s n.a. n.a. | 60 MS/s 60 MS/s 60 MS/s n.a. | 125 MS/s n.a. n.a. n.a. | 125 MS/s 125 MS/s n.a. n.a. | 125 MS/s 125 MS/s n.a. n.a. | 125 MS/s 125 MS/s 125 MS/s 125 MS/s |
| X | X | | | 20 MS/s n.a. n.a. n.a. | 20 MS/s 20 MS/s 20 MS/s n.a. | 60 MS/s n.a. n.a. n.a. | 60 MS/s 60 MS/s 60 MS/s n.a. | n.a. n.a. n.a. n.a. | 125 MS/s n.a. n.a. n.a. | 62.5 MS/s n.a. n.a. n.a. | 62.5 MS/s 125 MS/s 125 MS/s 125 MS/s |
| X | X | X | | n.a. n.a. n.a. n.a. | 20 MS/s 20 MS/s 20 MS/s n.a. | n.a. n.a. n.a. n.a. | 60 MS/s 60 MS/s 60 MS/s n.a. | n.a. n.a. n.a. n.a. | n.a. n.a. n.a. n.a. | n.a. n.a. n.a. n.a. | 125 MS/s 125 MS/s 125 MS/s 62.5 MS/s |
| X | X | X | X | n.a. n.a. n.a. n.a. | 20 MS/s 20 MS/s 20 MS/s n.a. | n.a. n.a. n.a. n.a. | 60 MS/s 60 MS/s 60 MS/s n.a. | n.a. n.a. n.a. n.a. | n.a. n.a. n.a. n.a. | n.a. n.a. n.a. n.a. | 62.5 MS/s 62.5 MS/s 62.5 MS/s 62.5 MS/s |

Using plain Quartz1 without PLL

In some cases it is useful for the application not to have the on-board PLL activated. Although the PLL used on the Spectrum boards is a low-jitter version it still produces more clock jitter than a plain quartz oscillator. For these cases the Spectrum boards have the opportunity to switch off the PLL by software and use a simple clock divider.

| Register | Value | Direction | Description |
|----------------|-------|------------|---|
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode |
| SPC_CM_QUARTZ1 | 2 | | Enables Quartz1 for sample clock generation |

The Quartz1 used on the board is similar to the maximum sampling rate the board can achieve. As with internal PLL mode it's also possible to program the clock mode first, set a desired sampling rate with the SPC_SAMPLERATE register and to read it back. The driver will internally set the divider and find the closest matching sampling rate. The result will then again be the best matching sampling rate.

If a sampling rate is generated internally, you can additionally enable the clock output. The clock will be available on the external clock connector and can be used to synchronize external equipment with the board.

| Register | Value | Direction | Description |
|-----------------------|-------|------------|--|
| SPC_CLOCKOUT | 20110 | read/write | Enables clock output on external clock connector. On A/D and D/A cards only possible with internal clocking. |
| SPC_CLOCKOUTFREQUENCY | 20111 | read | Allows to read out the frequency of an internally synthesized clock present at the clock output. |

Using plain Quartz2 without PLL (optional)

In some cases it is necessary to use a special frequency for sampling rate generation. For these applications all cards of the M2i series can be equipped with a special customer quartz. Please contact Spectrum for details on available oscillators. If your card is equipped with a second oscillator you can enable it for sampling rate generation with the following register:

| Register | Value | Direction | Description |
|----------------|-------|------------|--|
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode |
| SPC_CM_QUARTZ2 | 4 | | Enables optional quartz2 for sample clock generation |

In addition to the direct usage of the second clock oscillator one can program the internal clock divider to use slower sampling rates. As with internal PLL mode it's also possible to program the clock mode first, set a desired sampling rate with the SPC_SAMPLERATE register and to read it back. The result will then again be the best matching sampling rate.

If a sampling rate is generated internally, you can additionally enable the clock output. The clock will be available on the external clock connector and can be used to synchronize external equipment with the board.

| Register | Value | Direction | Description |
|-----------------------|-------|------------|--|
| SPC_CLOCKOUT | 20110 | read/write | Enables clock output on external clock connector. On A/D and D/A cards only possible with internal clocking. |
| SPC_CLOCKOUTFREQUENCY | 20111 | read | Allows to read out the frequency of an internally synthesized clock present at the clock output. |

External reference clock

If you have an external clock generator with a extremely stable frequency, you can use it as a reference clock. You can connect it to the external clock connector and the PLL will be fed with this clock instead of the internal reference. The following table shows how to enable the reference clock mode:

| Register | Value | Direction | Description |
|--------------------|-------|------------|--|
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode |
| SPC_CM_EXTREFCLOCK | 32 | | Enables internal PLL with external reference for sample clock generation |

Due to the fact that the driver needs to know the external fed in frequency for an exact calculation of the sampling rate you must set the SPC_REFERENCECLOCK register accordingly as shown in the table below. The driver automatically then sets the PLL to achieve the desired sampling rate. Please be aware that the PLL has some internal limits and not all desired sampling rates may be reached with every reference clock.

| Register | Value | Direction | Description |
|--------------------|--|------------|---|
| SPC_REFERENCECLOCK | 20140 | read/write | Programs the external reference clock in the range from 1 MHz to 125 MHz. |
| | External sampling rate in Hz as an integer value | | You need to set up this register exactly to the frequency of the external fed in clock. |

Example of reference clock:

```

spcm_dwSetParam_i32 (hDrv, SPC_CLOCKMODE, SPC_CM_EXTREFCLOCK); // Set to reference clock mode
spcm_dwSetParam_i32 (hDrv, SPC_REFERENCECLOCK, 10000000); // Reference clock that is fed in is 10 MHz
spcm_dwSetParam_i32 (hDrv, SPC_SAMPLERATE, 25000000); // We want to have 25 MHz as sampling rate

```

The reference clock must be defined via the SPC_REFERENCECLOCK register prior to defining the sample rate via the SPC_SAMPLERATE register to allow the driver to calculate the proper clock settings correctly.



Termination of the clock input

If the external connector is used as an input, either for feeding in an external reference clock or for external clocking you can enable a 50 Ohm termination on the board. If the termination is disabled, the impedance is high. Please make sure that your source is capable of driving that current and that it still fulfills the clock input specification as given in the technical data section.

| Register | Value | Direction | Description |
|----------------|-------|------------|---|
| SPC_CLOCK50OHM | 20120 | read/write | A „1“ enables the 50 Ohm termination at the external clock connector. Only possible, when using the external connector as an input. |

External clocking

Direct external clock

An external clock can be fed in on the external clock connector of the board. This can be any clock, that matches the specification of the card. The external clock signal can be used to synchronize the card on a system clock or to feed in an exact matching sampling rate.

| Register | Value | Direction | Description |
|-----------------|-------|------------|---|
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode |
| SPC_CM_EXTERNAL | 8 | | Enables external clock input for direct sample clock generation |

The maximum values for the external clock is board dependant and shown in the table below.

Termination of the clock input

If the external connector is used as an input, either for feeding in an external reference clock or for external clocking you can enable a 50 Ohm termination on the board. If the termination is disabled, the impedance is high. Please make sure that your source is capable of driving that current and that it still fulfills the clock input specification as given in the technical data section.

| Register | Value | Direction | Description |
|----------------|-------|------------|---|
| SPC_CLOCK50OHM | 20120 | read/write | A „1“ enables the 50 Ohm termination at the external clock connector. Only possible, when using the external connector as an input. |

Minimum external sample rate

The minimum external sample rate can be as low as DC and the maximum sample rate depends on the specific type of board. The maximum sample rates for your type of board are shown in the tables below.

Maximum external sampling rate in MS/s

| activated Channels | | | | M2I.6011 | M2I.6012 | M2I.6021 | M2I.6022 | M2I.6030 | M2I.6031 | M2I.6033 | M2I.6034 |
|--------------------|-----|-----|-----|----------|----------|----------|----------|----------|----------|-----------|-----------|
| Ch0 | Ch1 | Ch2 | Ch3 | | | | | | | | |
| X | X | | | 20 MS/s | 20 MS/s | 60 MS/s | 60 MS/s | 125 MS/s | 125 MS/s | 125 MS/s | 125 MS/s |
| | | X | | 20 MS/s | 20 MS/s | 60 MS/s | 60 MS/s | n.a. | 125 MS/s | 125 MS/s | 125 MS/s |
| | | | X | n.a. | 20 MS/s | n.a. | 60 MS/s | n.a. | n.a. | n.a. | 125 MS/s |
| | | | | n.a. | 20 MS/s | n.a. | 60 MS/s | n.a. | n.a. | n.a. | 125 MS/s |
| X | X | X | | 20 MS/s | 20 MS/s | 60 MS/s | 60 MS/s | n.a. | 125 MS/s | 62.5 MS/s | 62.5 MS/s |
| X | | | | n.a. | 20 MS/s | n.a. | 60 MS/s | n.a. | n.a. | n.a. | 125 MS/s |
| X | | X | | n.a. | 20 MS/s | n.a. | 60 MS/s | n.a. | n.a. | n.a. | 125 MS/s |
| | X | X | | n.a. | 20 MS/s | n.a. | 60 MS/s | n.a. | n.a. | n.a. | 125 MS/s |
| | | X | X | n.a. | 20 MS/s | n.a. | 60 MS/s | n.a. | n.a. | n.a. | 125 MS/s |
| X | X | X | X | n.a. | 20 MS/s | n.a. | 60 MS/s | n.a. | n.a. | n.a. | 62.5 MS/s |



An external sample rate above the mentioned maximum can cause damage to the board.

The following table shows the available ranges when using external clocking:

| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_EXTERNRANGE | 20130 | read/write | Defines the range of the actual fed in external clock. Use one of the below mentioned ranges |
| EXRANGE_LOW | 64 | | External range for slower clocks |
| EXRANGE_HIGH | 128 | | External range for faster clocks |



The range must not be left by more than 5% when the board is running. Remember that the ranges depend on the activated channels as well, so a different board setup for external clocking must always include the related clock ranges.

This table below shows the ranges that are defined by the two range registers mentioned above. The range depends on the activated channels per module. For details about what channels of your specific type of board is located on which module, please take a look at the according introduction chapter. Please be sure to select the correct external range, as otherwise it is possible that the card will not run properly.

| Activated Channels on one module | For cards with 8 bit converter resolution | | For cards with 12, 14, 16 bit converter resolution | |
|-------------------------------------|---|--------------|--|--------------|
| | EXRANGE_LOW | EXRANGE_HIGH | EXRANGE_LOW | EXRANGE_HIGH |
| 1 | < 50.0 MHz | >= 50.0 MHz | < 50.0 MHz | >= 50.0 MHz |
| 2 | < 50.0 MHz | >= 50.0 MHz | < 25.0 MHz | >= 25.0 MHz |
| 4 | < 25.0 MHz | >= 25.0 MHz | < 12.5 MHz | >= 12.5 MHz |
| 8 | < 12.5 MHz | >= 12.5 MHz | < 6.0 MHz | >= 6.0 MHz |

How to read this table? If you have a card with a total number of four channels (available on two modules with two channels each), you have an external clock source with 30 MHz and you activate channel 0 and channel 2 (one channel per module), you will have to set the external range to EXRANGE_LOW. If you activate channel 0 and channel 1 on the same card and use the same 30 MHz external clock, you will have to set the external range EXRANGE_HIGH instead. Example:

```

spcm_dwSetParam_i32 (hDrv, SPC_CLOCKMODE, SPC_CM_EXTERNAL);           // activate ext. clock (which is e.g. 30 MHz)
spcm_dwSetParam_i32 (hDrv, SPC_CHENABLE, CHANNEL0 | CHANNEL1);        // activate two channels (assuming that they
                                                                           // are located on one module) you
spcm_dwSetParam_i32 (hDrv, SPC_EXTERNRANGE, EXRANGE_HIGH);            // set external range to EXRANGE_HIGH

```

Further external clock details

- When using the high clock range the external clock has to be stable, needs to be continuously and is not allowed to have gaps or fast changes in frequency.
- When using the high clock range there must be a valid external clock be present before the start command is given.
- The external clock is directly used to feed the converters (on analog boards) or to feed the input registers (on digital boards). Therefore the quality and jitter of this clock may improve or degrade the dynamic performance of the card depending on the quality of the provided clock.
- When using the low clock range the clock needn't to be continuously and may have gaps. When using a A/D card please keep in mind that most A/D converters need a stable clock and there might be false samples inbetween directly after a gap or after a fast clock frequency change. The quality of the analog samples may also be worse than with a continuous clock.

External clock with divider

In some cases it is necessary to generate a slower frequency for sampling rate generation, than the available external source delivers. For these applications one can use an external clock and divide it.

| Register | Value | Direction | Description |
|---------------|-------|------------|-----------------------------|
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode |

| | | |
|-------------------|----|--|
| SPC_CM_EXTDIVIDER | 16 | Enables external clock input for divided sample clock generation |
|-------------------|----|--|

The value for the clock divider must be written to the register shown in the table below:

| Register | Value | Direction | Description |
|--------------|-------|------------|--|
| SPC_CLOCKDIV | 20040 | read/write | Register for setting the clock divider. Values up to 8190 in steps of two are allowed. |

Please set the external clock range register matching your fed in clock.

Ranges for external sampling rate

Due to the internal structure of the board it is essential for the driver to know in which clock range the external clock is operating at the divider output. The external range register must be set according to the result of the clock that is fed in externally divided by the programmed clock divider.

The following table shows the available ranges when using external clocking:

| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_EXTERNRANGE | 20130 | read/write | Defines the range of the actual fed in external clock. Use one of the below mentioned ranges |
| EXRANGE_LOW | 64 | | External range for slower clocks |
| EXRANGE_HIGH | 128 | | External range for faster clocks |

The range must not be left by more than 5% when the board is running. Remember that the ranges depend on the activated channels as well, so a different board setup for external clocking must always include the related clock ranges.



This table below shows the ranges that are defined by the two range registers mentioned above. The range depends on the activated channels per module. For details about what channels of your specific type of board is located on which module, please take a look at the according introduction chapter. Please be sure to select the correct external range, as otherwise it is possible that the card will not run properly.

| Activated Channels on one module | For cards with 8 bit converter resolution | | For cards with 12, 14, 16 bit converter resolution | |
|-------------------------------------|---|--------------|--|--------------|
| | EXRANGE_LOW | EXRANGE_HIGH | EXRANGE_LOW | EXRANGE_HIGH |
| 1 | < 50.0 MHz | >= 50.0 MHz | < 50.0 MHz | >= 50.0 MHz |
| 2 | < 50.0 MHz | >= 50.0 MHz | < 25.0 MHz | >= 25.0 MHz |
| 4 | < 25.0 MHz | >= 25.0 MHz | < 12.5 MHz | >= 12.5 MHz |
| 8 | < 12.5 MHz | >= 12.5 MHz | < 6.0 MHz | >= 6.0 MHz |

How to read this table? If you have a card with a total number of four channels (available on two modules with two channels each), you have an external clock source with 30 MHz and you activate channel 0 and channel 2 (one channel per module), you will have to set the external range to EXRANGE_LOW. If you activate channel 0 and channel 1 on the same card and use the same 30 MHz external clock, you will have to set the external range EXRANGE_HIGH instead. Example:

```

spcm_dwSetParam_i32 (hDrv, SPC_CLOCKMODE, SPC_CM_EXTERNAL);           // activate ext. clock (which is e.g. 30 MHz)
spcm_dwSetParam_i32 (hDrv, SPC_CHENABLE, CHANNEL0 | CHANNEL1);        // activate two channels (assuming that they
// are located on one module) you
spcm_dwSetParam_i32 (hDrv, SPC_EXTERNRANGE, EXRANGE_HIGH);            // set external range to EXRANGE_HIGH

```

Further external clock details

- When using the high clock range the external clock has to be stable, needs to be continuously and is not allowed to have gaps or fast changes in frequency.
- When using the high clock range there must be a valid external clock be present before the start command is given.
- The external clock is directly used to feed the converters (on analog boards) or to feed the input registers (on digital boards). Therefore the quality and jitter of this clock may improve or degrade the dynamic performance of the card depending on the quality of the provided clock.
- When using the low clock range the clock needn't to be continuously and may have gaps. When using a A/D card please keep in mind that most A/D converters need a stable clock and there might be false samples inbetween directly after a gap or after a fast clock frequency change. The quality of the analog samples may also be worse than with a continuous clock.

Termination of the clock input

If the external connector is used as an input, either for feeding in an external reference clock or for external clocking you can enable a 50 Ohm termination on the board. If the termination is disabled, the impedance is high. Please make sure that your source is capable of driving that current and that it still fulfills the clock input specification as given in the technical data section.

| Register | Value | Direction | Description |
|----------------|-------|------------|---|
| SPC_CLOCK50OHM | 20120 | read/write | A „1“ enables the 50 Ohm termination at the external clock connector. Only possible, when using the external connector as an input. |

Trigger modes and appendant registers

General Description

The trigger modes of the Spectrum M2i series D/A cards are very extensive and give you the possibility to detect nearly any trigger event, you can think of. You can choose between seven external TTL trigger modes and software trigger.

Every analog Spectrum board has one dedicated SMB connector mounted in it's bracket for feeding in an external trigger signal or generating a trigger output of an internal trigger event. Due to the fact that only one connector is available for external trigger I/O, it is not possible to forward the fed in external trigger signal to another board. If this is however necessary, you need to split up the external trigger signal before.

Trigger Engine Overview

To extend trigger facilities of the various trigger sources/modes further on, the trigger engine of the Spectrum M2i series allows the logical combination of different trigger events by an AND-mask and an OR-mask.

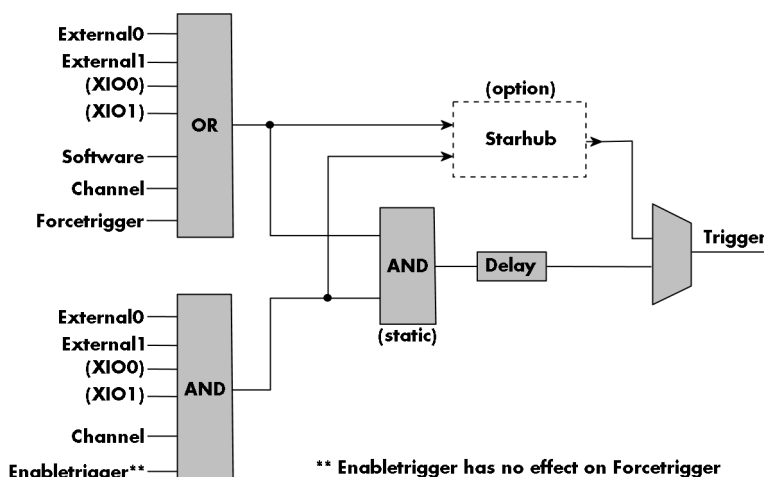
The Enable trigger allows the user to enable or disable all trigger sources (including channel trigger and external TTL trigger) with a single software command.

Channel trigger is only available on data acquisition cards.

When the card is waiting for a trigger event, either for a channel trigger or an external trigger, the force-trigger command allows to force a trigger event with a single software command.

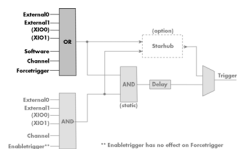
Before the trigger event is finally generated, it is wired through a programmable trigger delay.

All analog D/A and A/D cards have one external trigger input (External0) and digital i/o cards and pattern generators have one to two external trigger inputs (External0 and External1). In addition using the option BaseXIO it is possible to have two additional trigger inputs named XIO0 and XIO1 in the drawing.



Trigger masks

Trigger OR mask



The purpose of this passage is to explain the trigger OR mask (see left figure) and all the appendant software registers in detail.

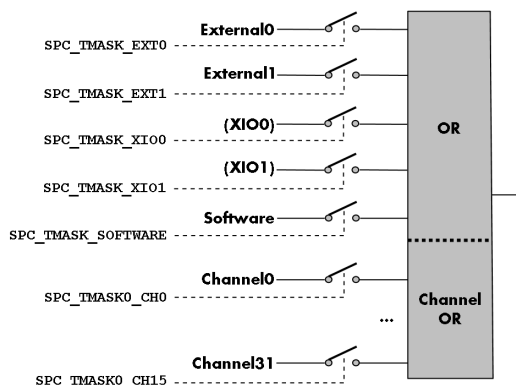
The OR mask shown in the overview before as one object, is separated into two parts: a general OR mask for external TTL trigger and software trigger and a channel OR mask.

Every trigger source of the M2i series cards is wired to one of the above mentioned OR masks. The user then can program which trigger source will be recognized, and which one won't.

This selection for the general mask is realized with the SPC_TRIG_ORMASK register in combination with constants for every possible trigger source.

This selection for the channel mask is realized with the SPC_TRIG_CH_ORMASK0 and the SPC_TRIG_CH_ORMASK1 register in combination with constants for every possible channel trigger source.

In either case the sources are coded as a bitfield, so that they can be combined by one access to the driver with the help of a bitwise OR.



The table below shows the relating register for the general OR mask and the possible constants that can be written to it.

| Register | Value | Direction | Description |
|----------------------|-------|------------|---|
| SPC_TRIG_AVAILORMASK | 40400 | read | Bitmask, in which all bits of the below mentioned sources for the OR mask are set, if available. |
| SPC_TRIG_ORMASK | 40410 | read/write | Defines the events included within the trigger OR mask of the card. |
| SPC_TMASK_NONE | 0 | | No trigger source selected |
| SPC_TMASK_SOFTWARE | 1h | | Enables the software trigger for the OR mask. The card will trigger immediately after start. |
| SPC_TMASK_EXT0 | 2h | | Enables the external trigger0 for the OR mask. The card will trigger when the programmed condition for this input is valid. |
| SPC_TMASK_EXT1 | 4h | | Enables the external trigger1 for the OR mask. This input is only available on digital cards. The card will trigger when the programmed condition for this input is valid. |
| SPC_TMASK_XIO0 | 100h | | Enables the extra TTL trigger 0 for the OR mask. On plain cards this input is only available if the option BaseXIO is installed. As part of the digitizerNETBOX this input is available as connector Trigger B. |
| SPC_TMASK_XIO1 | 200h | | Enables the extra TTL trigger 1 for the OR mask. This input is only available if the option BaseXIO is installed. |



Please note that as default the SPC_TRIG_ORMASK is set to SPC_TMASK_SOFTWARE. When not using any trigger mode requiring values in the SPC_TRIG_ORMASK register, this mask should explicitly cleared, as otherwise the software trigger will override other modes.

The following example shows, how to setup the OR mask, for an external TTL trigger. As an example a simple edge detection has been chosen. The explanation and a detailed description of the different trigger modes for the external TTL trigger inputs will be shown in the dedicated passage within this chapter.

```
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // Enable external trigger within the OR mask
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS); // Setting up external TTL trigger for rising edges
```

The table below is showing the registers for the channel OR mask and the possible constants that can be written to it.

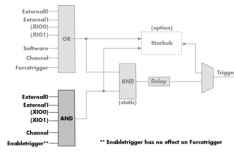
Please note that channel trigger sources are only available on data acquisition cards and not on pure generator cards. If you have purchased an arbitrary waveform generator or a pattern generator please just ignore this part.

| Register | Value | Direction | Description |
|--------------------------|-----------|------------|--|
| SPC_TRIG_CH_AVAILORMASK0 | 40450 | read | Bitmask, in which all bits of the below mentioned sources/channels (0...31) for the channel OR mask are set, if available. |
| SPC_TRIG_CH_AVAILORMASK1 | 40451 | read | Bitmask, in which all bits of the below mentioned sources/ channels (32...63) for the channel OR mask are set, if available. |
| SPC_TRIG_CH_ORMASK0 | 40460 | read/write | Includes the analog or digital channels (0...31) within the channel trigger OR mask of the card. |
| SPC_TRIG_CH_ORMASK1 | 40461 | read/write | Includes the analog or digital channels (32...63) within the channel trigger OR mask of the card. |
| SPC_TMASK0_CH0 | 1h | | Enables channel0 (channel32) for recognition within the channel OR mask. |
| SPC_TMASK0_CH1 | 2h | | Enables channel1 (channel33) for recognition within the channel OR mask. |
| SPC_TMASK0_CH2 | 4h | | Enables channel2 (channel34) for recognition within the channel OR mask. |
| SPC_TMASK0_CH3 | 8h | | Enables channel3 (channel35) for recognition within the channel OR mask. |
| ... | ... | | ... |
| SPC_TMASK0_CH28 | 10000000h | | Enables channel28 (channel60) for recognition within the channel OR mask. |
| SPC_TMASK0_CH29 | 20000000h | | Enables channel29 (channel61) for recognition within the channel OR mask. |
| SPC_TMASK0_CH30 | 40000000h | | Enables channel30 (channel62) for recognition within the channel OR mask. |
| SPC_TMASK0_CH31 | 80000000h | | Enables channel31 (channel63) for recognition within the channel OR mask. |

The following example shows, how to setup the OR mask, for an external TTL trigger. As an example a simple edge detection has been chosen. The explanation and a detailed description of the different trigger modes for the external TTL trigger inputs will be shown in the dedicated passage within this chapter.

```
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_NONE); // disable default software trigger
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_CH_ORMASK0, SPC_TMASK_CH0); // Enable channel0 trigger within the OR mask
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS); // Setting up external trigger for rising edges
```

Trigger AND mask



The purpose of this passage is to explain the trigger AND mask (see left figure) and all the appendant software registers in detail.

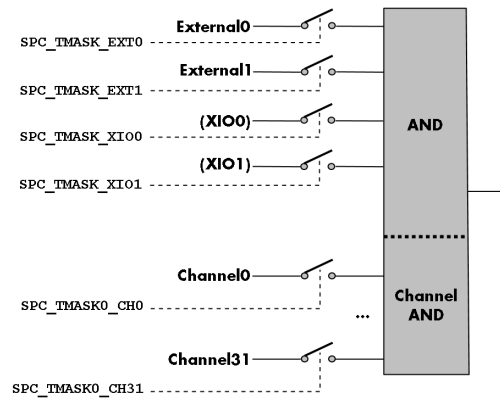
The AND mask shown in the overview before as one object, is separated into two parts: a general AND mask for external TTL trigger and software trigger and a channel AND mask.

Every trigger source of the M2i series cards except the software trigger is wired to one of the above mentioned AND masks. The user then can program which trigger source will be recognized, and which one won't.

This selection for the general mask is realized with the SPC_TRIG_ANDMASK register in combination with constants for every possible trigger source.

This selection for the channel mask is realized with the SPC_TRIG_CH_ANDMASK0 and the SPC_TRIG_CH_ANDMASK1 register in combination with constants for every possible channel trigger source. In either case the sources are coded as a bitfield, so that they can be combined by one access to the driver with the help of a bitwise OR.

The table below shows the relating register for the general AND mask and the possible constants that can be written to it.



| Register | Value | Direction | Description |
|-----------------------|-------|------------|--|
| SPC_TRIG_AVAILANDMASK | 40420 | read | Bitmask, in which all bits of the below mentioned sources for the AND mask are set, if available. |
| SPC_TRIG_ANDMASK | 40430 | read/write | Defines the events included within the trigger AND mask of the card. |
| SPC_TMASK_EXT0 | 2h | | Enables the external trigger0 for the AND mask. The card will trigger <u>when</u> the programmed condition for this input is valid. |
| SPC_TMASK_EXT1 | 4h | | Enables the external trigger1 for the AND mask. This input is only available on digital cards. The card will trigger when the programmed condition for this input is valid. |
| SPC_TMASK_XIO0 | 100h | | Enables the extra TTL trigger 0 for the AND mask. On plain cards this input is only available if the option BaseXIO is installed. As part of the digitizerNETBOX this input is available as connector Trigger B. |
| SPC_TMASK_XIO1 | 200h | | Enables the extra TTL trigger 1 for the AND mask. This input is only available if the option BaseXIO is installed. |

The following example shows, how to setup the AND mask, for an external TTL trigger. As an example a simple level detection has been chosen. The explanation and a detailed description of the different trigger modes for the external TTL trigger inputs will be shown in the dedicated passage within this chapter.

```

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_NONE); // disable default software trigger
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ANDMASK, SPC_TMASK_EXT0); // Enable external trigger within the AND mask
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_HIGH ); // Setting up external TTL trigger for HIGH level

```

The table below is showing the constants for the channel AND mask and all the constants for the different channels.

| Register | Value | Direction | Description |
|---------------------------|-----------|------------|---|
| SPC_TRIG_CH_AVAILANDASK0 | 40470 | read | Bitmask, in which all bits of the below mentioned sources/channels (0...31) for the channel AND mask are set, if available. |
| SPC_TRIG_CH_AVAILANDMASK1 | 40471 | read | Bitmask, in which all bits of the below mentioned sources/ channels (32...63) for the channel AND mask are set, if available. |
| SPC_TRIG_CH_ANDMASK0 | 40480 | read/write | Includes the analog or digital channels (0...31) within the channel trigger AND mask of the card. |
| SPC_TRIG_CH_ANDMASK1 | 40481 | read/write | Includes the analog or digital channels (32...63) within the channel trigger AND mask of the card. |
| SPC_TMASK0_CH0 | 1h | | Enables channel0 (channel32) for recognition within the channel AND mask. |
| SPC_TMASK0_CH1 | 2h | | Enables channel1 (channel33) for recognition within the channel AND mask. |
| SPC_TMASK0_CH2 | 4h | | Enables channel2 (channel34) for recognition within the channel AND mask. |
| SPC_TMASK0_CH3 | 8h | | Enables channel3 (channel35) for recognition within the channel AND mask. |
| ... | ... | ... | ... |
| SPC_TMASK0_CH28 | 10000000h | | Enables channel28 (channel60) for recognition within the channel AND mask. |
| SPC_TMASK0_CH29 | 20000000h | | Enables channel29 (channel61) for recognition within the channel AND mask. |
| SPC_TMASK0_CH30 | 40000000h | | Enables channel30 (channel62) for recognition within the channel AND mask. |
| SPC_TMASK0_CH31 | 80000000h | | Enables channel31 (channel63) for recognition within the channel AND mask. |

The following example shows how to setup the AND mask, for a channel trigger. As an example a simple level detection has been chosen.

The explanation and a detailed description of the different trigger modes for the channel trigger will be shown in the dedicated passage within this chapter.

```
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_NONE); // disable default software trigger
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_CH_ANDMASK0, SPC_TMASK_CH0); // Enable channel0 trigger within the AND mask
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_CH0_MODE, SPC_TM_HIGH); // Setting up ch0 trigger for HIGH levels
```

Software trigger

The software trigger is the easiest way of triggering any Spectrum board. The acquisition or replay of data will start immediately after the card is started and the trigger engine is armed. The resulting delay upon start includes the time the board needs for its setup and the time for recording the pre-trigger area (for acquisition cards).

For enabling the software trigger one simply has to include the software event within the trigger OR mask, as the following table is showing:



| Register | Value | Direction | Description |
|--------------------|-------|------------|---|
| SPC_TRIG_ORMASK | 40410 | read/write | Defines the events included within the trigger OR mask of the card. |
| SPC_TMASK_SOFTWARE | 1h | | Sets the trigger mode to software, so that the recording/replay starts immediately. |

Due to the fact that the software trigger is an internal trigger mode, you can optionally enable the external trigger output to generate a high active trigger signal, which indicates when the data acquisition or replay begins. This can be useful to synchronize external equipment with your Spectrum board.

| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_TRIG_OUTPUT | 40100 | read/write | Defines the data direction of the external trigger connector. |
| | 0 | | The trigger connector is not used and the line driver is disabled. |
| | 1 | | The trigger connector is used as an output that indicates a detected internal trigger event. |

Example for setting up the software trigger:

```
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_SOFTWARE); // Internal software trigger mode is used
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_OUTPUT, 1); // And the trigger output is enabled
```

Force- and Enable trigger

In addition to the software trigger (free run) it is also possible to force a trigger event by software while the board is waiting for a real physical trigger event. The forcetrigger command will only have any effect, when the board is waiting for a trigger event. The command for forcing a trigger event is shown in the table below.

Issuing the forcetrigger command will every time only generate one trigger event. If for example using Multiple Recording that will result in only one segment being acquired by forcetrigger. After execution of the forcetrigger command the trigger engine will fall back to the trigger mode that was originally programmed and will again wait for a trigger event.

| Register | Value | Direction | Description |
|-------------------------|-------|-----------|--|
| SPC_M2CMD | 100 | write | Command register of the M2i/M3i/M4i/M4x/M2p series cards. |
| M2CMD_CARD_FORCETRIGGER | 10h | | Forces a trigger event if the hardware is still waiting for a trigger event. |

The example shows, how to use the forcetrigger command:

```
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_FORCETRIGGER); // Force trigger is used.
```

It is also possible to enable (arm) or disable (disarm) the card's whole triggerengine by software. By default the trigger engine is disabled.

| Register | Value | Direction | Description |
|---------------------------|-------|-----------|--|
| SPC_M2CMD | 100 | write | Command register of the M2i/M3i/M4i/M4x/M2p series cards. |
| M2CMD_CARD_ENABLETRIGGER | 8h | | Enables the trigger engine. Any trigger event will now be recognized. |
| M2CMD_CARD_DISABLETRIGGER | 20h | | Disables the trigger engine. No trigger events will be recognized, except force trigger. |

The example shows, how to arm and disarm the card's trigger engine properly:

```
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_ENABLETRIGGER); // Trigger engine is armed.
...
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_DISABLETRIGGER); // Trigger engine is disarmed.
```

Delay trigger

All of the Spectrum M2i series cards allow the user to program an additional trigger delay. As shown in the trigger overview section, this delay is the last element in the trigger chain. Therefore the user does not have to care for the sources when programming the trigger delay. The following table shows the related register and the possible values. A value of 0 disables the extra delay. The resulting delays (due to the internal structure of the card) can be found in the technical data section of this manual.

| Register | Value | Direction | Description |
|---------------------|-----------|------------|---|
| SPC_TRIG_AVAILDELAY | 40800 | read | Contains the maximum available delay as a decimal integer value. |
| SPC_TRIG_DELAY | 40810 | read/write | Defines the delay for the detected trigger events. |
| | 0 | | No additional delay will be added. The resulting internal delay is mentioned in the technical data section. |
| | 0...65535 | | Defines the additional trigger delay in number of sample clocks. |

The example shows, how to use the delay trigger command:

```
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_DELAY, 2000); // A detected trigger event will be
// delayed for 2000 sample clocks.
```



Using the delay trigger does not affect the ratio between pre trigger and post trigger recorded number of samples, but only shifts the trigger event itself. For changing these values, please take a look in the relating chapter about „Acquisition Modes“.



Please note that the trigger delay setting is not used when synchronizing cards. If you need a trigger delay on synchronized systems it is necessary to program posttrigger, segmentsize and memsize to fulfill this task.

External TTL trigger

Enabling the external trigger input(s) is done, if you choose one of the following external trigger modes. The dedicated register for that operation is shown below.

| Register | Value | Direction | Description |
|----------------------------------|-----------|------------|--|
| SPC_TRIG_EXT_AVAILMODES | 40500 | read | Bitmask, in which all bits of the below mentioned modes for the external trigger are set, if available. |
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Defines the external TTL trigger mode for the external SMB connector (A/D and D/A boards only). On digital boards this defines the TTL trigger mode for the trigger input of the first module (Mod A). |
| SPC_TRIG_EXT1_MODE | 40511 | read/write | Defines the external TTL trigger mode for the trigger input of the second module (digital boards only). |
| SPC_TRIG_XIO0_MODE | 40560 | read/write | Defines the trigger mode for the extra TTL input 0. On plain cards this input is only available if the option BaseXIO is installed. As part of the digitizerNETBOX this input is available as connector Trigger B. |
| SPC_TRIG_XIO1_MODE | 40561 | read/write | Defines the trigger mode for the extra TTL input 1. These trigger inputs are only available, when option BaseXIO is installed. |
| SPC_TM_NONE | 0h | | Input is not used for trigger detection. This is as with the trigger masks another possibility for disabling TTL sources. |
| SPC_TM_POS | 1h | | Sets the trigger mode for external TTL trigger to detect positive edges. |
| SPC_TM_POS SPC_TM_PULSESTRETCH | 10000001h | | Sets the trigger mode for external TTL trigger to stretch and detect HIGH pulses. |
| SPC_TM_NEG | 2h | | Sets the trigger mode for external TTL trigger to detect negative edges |
| SPC_TM_NEG SPC_TM_PULSESTRETCH | 10000002h | | Sets the trigger mode for external TTL trigger to stretch and detect LOW pulses. |
| SPC_TM_BOTH | 4h | | Sets the trigger mode for external TTL trigger to detect positive and negative edges |
| SPC_TM_HIGH | 8h | | Sets the trigger mode for external TTL trigger to detect HIGH levels. |
| SPC_TM_LOW | 10h | | Sets the trigger mode for external TTL trigger to detect LOW levels. |
| SPC_TM_POS SPC_TM_PW_GREATER | 4000001h | | Sets the trigger mode for external TTL trigger to detect HIGH pulses that are longer than a programmed pulsewidth. |
| SPC_TM_POS SPC_TM_PW_SMALLER | 2000001h | | Sets the trigger mode for external TTL trigger to detect HIGH pulses that are shorter than a programmed pulsewidth. |
| SPC_TM_NEG SPC_TM_PW_GREATER | 4000002h | | Sets the trigger mode for external TTL trigger to detect LOW pulses that are longer than a programmed pulsewidth. |
| SPC_TM_NEG SPC_TM_PW_SMALLER | 2000002h | | Sets the trigger mode for external TTL trigger to detect LOW pulses that are shorter than a programmed pulsewidth. |



Using the SPC_TM_PULSESTRETCH mode requires driver version V2.11 (or newer) and firmware version V18 (or newer). Please update your system to the newest versions to use this mode.

For all external edge and level trigger modes, the OR mask must contain the corresponding input, as the following table shows:

| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_TRIG_ORMASK | 40410 | read/write | Defines the OR mask for the different trigger sources. |
| SPC_TMASK_EXT0 | 2h | | Enable external trigger input for the OR mask |
| SPC_TMASK_XIO0 | 100h | | Enable extra TTL input 0 for the OR mask. On plain cards this input is only available if the option BaseXIO is installed. As part of the digitizerNETBOX this input is available as connector Trigger B. |
| SPC_TMASK_XIO1 | 200h | | Enable extra TTL input 1 for the OR mask. These trigger inputs are only available, when option BaseXIO is installed. |

If you choose an external trigger mode the SPC_TRIGGEROUT register will be overwritten and the trigger connector will be used as an input any ways.

| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_TRIG_OUTPUT | 40100 | read/write | Enables the trigger output if internal trigger is detected |
| | X | | If external trigger modes are used, this register will have no effect. |

As the trigger connector is used as an input, you can decide whether the input is 50 Ohm terminated or not. If you enable the termination, please make sure, that your trigger source is capable to deliver the needed current. Please check carefully whether the source is able to fulfil the trigger input specification given in the technical data section. If termination is disabled, the input is at high impedance.

| Register | Value | Direction | Description |
|---------------|-------|------------|---|
| SPC_TRIG_TERM | 40110 | read/write | A „1“ sets the 50 Ohm termination, if the trigger connector is used as an input for external trigger signals. A „0“ sets the high impedance termination |

The following short example shows how to set up the board for external positive edge TTL trigger. The trigger input is 50 Ohm terminated. The different modes for external TTL trigger are to be detailed described in the next few passages.

```

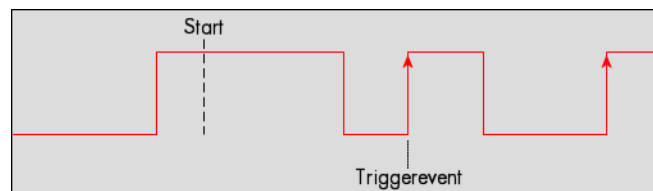
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS ); // Setting up external TTL
// trigger to detect rising edges
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_TERM, 1 ); // Enables the 50 Ohm input termination
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the OR mask

```

Edge and level triggers

Positive (rising) edge TTL trigger

This mode is for detecting the rising edges of an external TTL signal. The board will trigger on the first rising edge that is detected after starting the board. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again. This mode can be combined with the pulse stretch feature to detect pulses that are shorter than the sample period.



| Register | Value | Direction | Description |
|----------------------------------|-----------|------------|---|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board. |
| SPC_TM_POS | 1h | | Sets the trigger mode for external TTL trigger to detect positive edges. |
| SPC_TM_POS SPC_TM_PULSESTRETCH | 10000001h | | Sets the trigger mode for external TTL trigger to stretch and detect HIGH pulses. Not available on all cards, please check SPC_TRIG_EXT_AVAILMODES register for availability. |

Example on how to set up the board for positive TTL trigger:

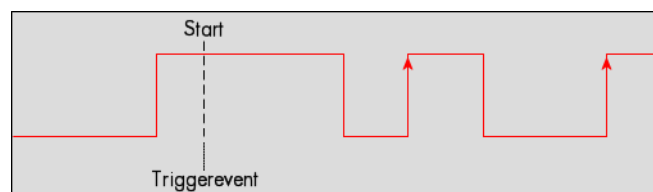
```

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS); // Set up ext. TTL trigger to detect positive edges

```

HIGH level TTL trigger

This mode is for detecting the HIGH levels of an external TTL signal. The board will trigger on the first HIGH level that is detected after starting the board. If this condition is fulfilled when the board is started, a trigger event will be detected. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.



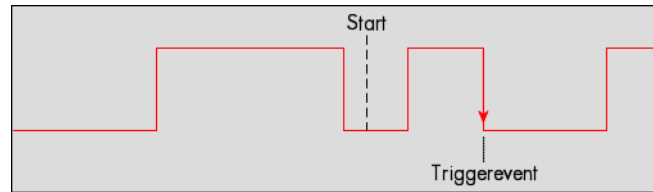
| Register | Value | Direction | Description |
|--------------------|-------|------------|---|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board. |

| | | |
|-------------|----|---|
| SPC_TM_HIGH | 8h | Sets the trigger mode for external TTL trigger to detect HIGH levels. |
|-------------|----|---|

Negative (falling) edge TTL trigger

This mode is for detecting the falling edges of an external TTL signal. The board will trigger on the first falling edge that is detected after starting the board. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.

This mode can be combined with the pulse stretch feature to detect pulses that are shorter than the sample period.

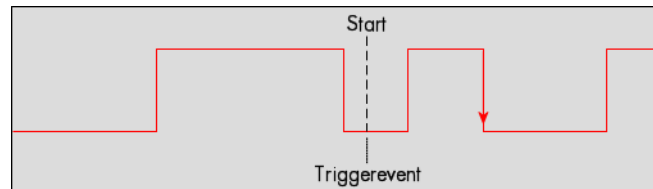


| Register | Value | Direction | Description |
|----------------------------------|-----------|------------|--|
| SPC_TRIG_EXTO_MODE | 40510 | read/write | Sets the external trigger mode for the board. |
| SPC_TM_NEG | 2h | | Sets the trigger mode for external TTL trigger to detect negative edges. |
| SPC_TM_NEG SPC_TM_PULSESTRETCH | 10000002h | | Sets the trigger mode for external TTL trigger to stretch and detect LOW pulses. Not available on all cards, please check SPC_TRIG_EXT_AVAILMODES register for availability. |

LOW level TTL trigger

This mode is for detecting the LOW levels of an external TTL signal. The board will trigger on the first LOW level that is detected after starting the board. If this condition is fulfilled when the board is started, a trigger event will be detected.

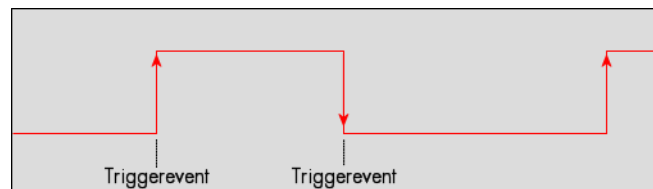
The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.



| Register | Value | Direction | Description |
|--------------------|-------|------------|--|
| SPC_TRIG_EXTO_MODE | 40510 | read/write | Sets the external trigger mode for the board. |
| SPC_TM_LOW | 10h | | Sets the trigger mode for external TTL trigger to detect LOW levels. |

Positive (rising) and negative (falling) edges TTL trigger

This mode is for detecting the rising and falling edges of an external TTL signal. The board will trigger on the first rising or falling edge that is detected after starting the board. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.

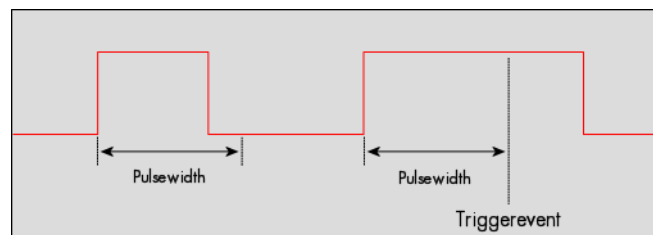


| Register | Value | Direction | Description |
|--------------------|-------|------------|---|
| SPC_TRIG_EXTO_MODE | 40510 | read/write | Sets the external trigger mode for the board. |
| SPC_TM_BOTH | 4h | | Sets the trigger mode for external TTL trigger to detect positive and negative edges. |

Pulsewidth triggers

TTL pulsewidth trigger for long HIGH pulses

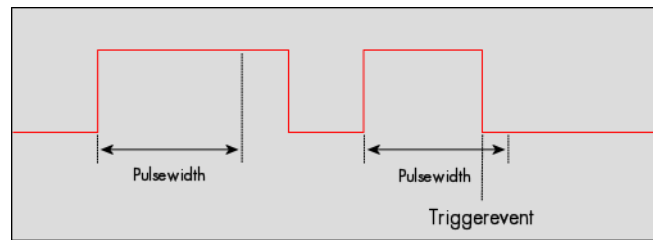
This mode is for detecting HIGH pulses of an external TTL signal that are longer than a programmed pulsewidth. If the pulse is shorter than the programmed pulsewidth, no trigger will be detected. The board will trigger on the first pulse matching the trigger condition after starting the board. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.



| Register | Value | Direction | set to | Value |
|--------------------------|-------|------------|----------------------------------|---------------|
| SPC_TRIG_EXTO_PULSEWIDTH | 44210 | read/write | Sets the pulsewidth in samples. | 2 up to 65535 |
| SPC_TRIG_EXTO_MODE | 40510 | read/write | (SPC_TM_POS SPC_TM_PW_GREATER) | 4000001h |

TTL pulsewidth trigger for short HIGH pulses

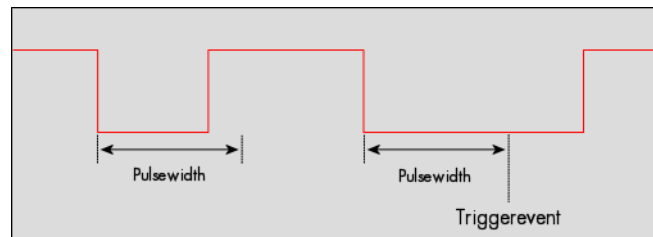
This mode is for detecting HIGH pulses of an external TTL signal that are shorter than a programmed pulsewidth. If the pulse is longer than the programmed pulsewidth, no trigger will be detected. The board will trigger on the first pulse matching the trigger condition after starting the board. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.



| Register | Value | Direction | set to | Value |
|--------------------------|-------|------------|----------------------------------|---------------|
| SPC_TRIG_EXT0_PULSEWIDTH | 44210 | read/write | Sets the pulsewidth in samples. | 2 up to 65535 |
| SPC_TRIG_EXT0_MODE | 40510 | read/write | (SPC_TM_POS SPC_TM_PW_SMALLER) | 2000001h |

TTL pulsewidth trigger for long LOW pulses

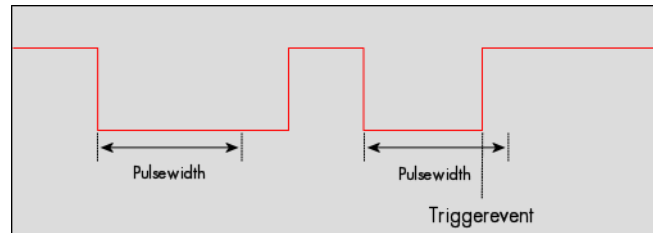
This mode is for detecting LOW pulses of an external TTL signal that are longer than a programmed pulsewidth. If the pulse is shorter than the programmed pulsewidth, no trigger will be detected. The board will trigger on the first pulse matching the trigger condition after starting the board. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.



| Register | Value | Direction | set to | Value |
|--------------------------|-------|------------|----------------------------------|---------------|
| SPC_TRIG_EXT0_PULSEWIDTH | 44210 | read/write | Sets the pulsewidth in samples. | 2 up to 65535 |
| SPC_TRIG_EXT0_MODE | 40510 | read/write | (SPC_TM_NEG SPC_TM_PW_GREATER) | 4000002h |

TTL pulsewidth trigger for short LOW pulses

This mode is for detecting LOW pulses of an external TTL signal that are shorter than a programmed pulsewidth. If the pulse is longer than the programmed pulsewidth, no trigger will be detected. The board will trigger on the first pulse matching the trigger condition after starting the board. The next trigger event will then be detected, if the actual recording/replay has finished and the board is armed and waiting for a trigger again.



| Register | Value | Direction | set to | Value |
|--------------------------|-------|------------|----------------------------------|---------------|
| SPC_TRIG_EXT0_PULSEWIDTH | 44210 | read/write | Sets the pulsewidth in samples. | 2 up to 65535 |
| SPC_TRIG_EXT0_MODE | 40510 | read/write | (SPC_TM_NEG SPC_TM_PW_SMALLER) | 2000002h |

The following example shows, how to setup the card for using external TTL pulse width trigger:

```

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_NEG | SPC_TM_PW_GREATER); // Setting up external TTL
// trigger to detect low pulses
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_PULSEWIDTH, 50); // that are longer than 50 samples.
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the OR mask

```

To find out what maximum pulsewidth (in samples) is available, please read out the register shown in the table below:

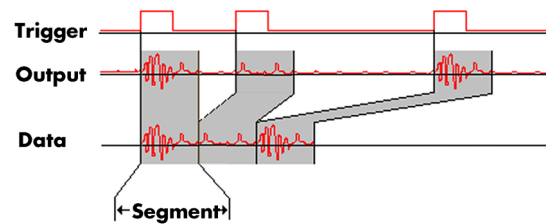
| Register | Value | Direction | Description |
|------------------------------|-------|-----------|--|
| SPC_TRIG_EXT_AVAILPULSEWIDTH | 44200 | read | Contains the maximum possible value for the external trigger pulsewidth counter. |

Mode Multiple Replay

The Multiple Replay mode allows the generation of data blocks with multiple trigger events without restarting the hardware.

The on-board memory will be divided into several segments of the same size. On each trigger event one segment of data will be replayed.

As this mode is totally controlled in hardware there is a very small re-arm time from end of one segment until the trigger detection is enabled again. You'll find that re-arm time in the technical data section of this manual.



The following table shows the register for defining the structure of the segments to be replayed with each trigger event.

| Register | Value | Direction | Description |
|-----------------|-------|------------|---|
| SPC_SEGMENTSIZE | 10010 | read/write | Size of one Multiple Replay segment: the total number of samples to be replayed per channel after detection of one trigger event. |

Trigger Modes

When using Multiple Recording all of the card's trigger modes can be used except the software trigger. For detailed information on the available trigger modes, please take a look at the relating chapter earlier in this manual.

Programming examples

The following example shows how to set up the card for Multiple Replay in standard mode.

```

spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_STD_MULTI); // Enables Standard Multiple Replay

spcm_dwSetParam_i64 (hDrv, SPC_SEGMENTSIZE, 1024); // Set the segment size to 1024 samples
spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, 4096); // Set the total memsize for recording to 4096 samples
// so that actually four segments will be replayed

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS); // Set trig mode to ext. TTL mode (rising edge)
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the trigger OR-mask

```

The following example shows how to set up the card for Multiple Replay in FIFO mode.

```

spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_FIFO_MULTI); // Enables FIFO Multiple Replay

spcm_dwSetParam_i64 (hDrv, SPC_SEGMENTSIZE, 2048); // Set the segment size to 2048 samples
spcm_dwSetParam_i64 (hDrv, SPC_LOOPS, 256); // 256 segments will be replayed

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_NEG); // Set trig mode to ext. TTL mode (falling edge)
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the trigger OR-mask

```

Replay modes

Standard Mode

With every detected trigger event one data block is replayed. The length of one multiple replay segment is set by the value of the segment size register SPC_SEGMENTSIZE. The total amount of samples to be replayed is defined by the memsize register.

Memsize must be set to a multiple of the segment size. The table below shows the register for enabling Multiple Recording. For detailed information on how to setup and start the standard replay mode please refer to the according chapter earlier in this manual.

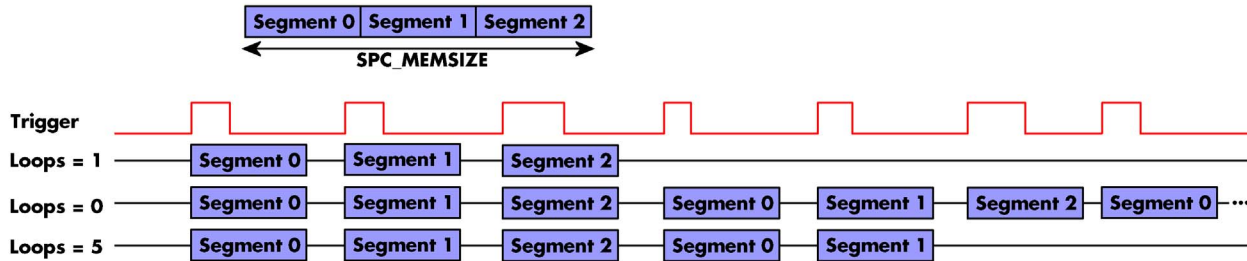
| Register | Value | Direction | Description |
|-------------------|-------|------------|--|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode |
| SPC_REP_STD_MULTI | 200h | | Enables Multiple Replay for standard replay. |

The total number of samples to be replayed from the on-board memory in standard mode is defined by the SPC_MEMSIZE register. When using the SPC_LOOPS parameter one can further program whether all segments should be replayed once or continuously or whether a dedicated number of segments should be replayed

| Register | Value | Direction | Description |
|-------------|-------|------------|--|
| SPC_MEMSIZE | 10000 | read/write | Defines the total number of samples to be replayed. |
| SPC_LOOPS | 10020 | read/write | When writing a 1 the complete memory is replayed once, when writing a zero the replay continues from the beginning forever. When writing a number >1 this number of segments is replayed until the card stops automatically. |

| | |
|----------------|---|
| 0 | Replay will be infinite until the user stops it. When replay reaches the end of programmed memory it will start from the beginning again. |
| 1 | The complete memory is replayed once. |
| 2 ... [4G - 1] | Defines the number of segments to be replayed. After replaying this number of segments the card will stop automatically. |

Replay modes with the use of SPC_LOOPS



FIFO Mode

The Multiple Replay in FIFO mode is similar to the Multiple Replay in standard mode. In contrast to the standard mode it is not necessary to program the number of samples to be replayed. The replay is running until the user stops it. The data is written block by block by the driver as described under single FIFO mode example earlier in this manual. These blocks can be online calculated or loaded from hard disk. This mode significantly reduces the amount of data to be transferred on the PCI bus as gaps with no significant output did not have to be transferred. This enables you to use faster sample rates than you would be able to in FIFO mode without Multiple Recording.

The table below shows the dedicated register for enabling Multiple Replay. For detailed information how to setup and start the board in FIFO mode please refer to the according chapter earlier in this manual.

| Register | Value | Direction | Description |
|--------------------|-------|------------|--|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode |
| SPC_REP_FIFO_MULTI | 1000h | | Enables Multiple Replay for FIFO mode. |

The number of segments to be replayed must be set separately with the register shown in the following table:

| Register | Value | Direction | Description |
|----------------|-------|------------|--|
| SPC_LOOPS | 10020 | read/write | Defines the number of segments to be replayed |
| 0 | | | Replay will be infinite until the user stops it. |
| 1 ... [4G - 1] | | | Defines the total segments to be replayed. |

Limits of segment size, memory size

The maximum memory size parameter is only limited by the number of activated channels and by the amount of installed memory. Please keep in mind that each sample needs 2 bytes of memory to be stored.

Due to the internal organization of the card memory there is a certain stepsize when setting these values that has to be taken into account. The following table gives you an overview of all limits concerning memory size, segment size and loops. The table shows all values in relation to the installed memory size in samples. If more memory is installed the maximum memory size figures will increase according to the complete installed memory:

| Activated Channels | Used Mode | Memory size SPC_MEMSIZE | | | Segment size SPC_SEGMENTSIZE | | | Loops SPC_LOOPS | | |
|--------------------|-----------------|----------------------------|-------|------|---------------------------------|--------|------|--------------------|--------|------|
| | | Min | Max | Step | Min | Max | Step | Min | Max | Step |
| 1 channel | Standard Single | 8 | Mem | 8 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 8 | Mem | 8 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 8 | Mem | 8 | 8 | Mem/2 | 8 | not used | | |
| | Standard Gate | 8 | Mem | 8 | not used | | | not used | | |
| | FIFO Single | not used | | | 8 | 8G - 8 | 8 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 8 | Mem/2 | 8 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |
| 2 channels | Standard Single | 4 | Mem/2 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 4 | Mem/2 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 4 | Mem/2 | 4 | 4 | Mem/4 | 4 | not used | | |
| | Standard Gate | 4 | Mem/2 | 4 | not used | | | not used | | |
| | FIFO Single | not used | | | 4 | 8G - 4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 4 | Mem/4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |
| 4 channels | Standard Single | 4 | Mem/4 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 4 | Mem/4 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 4 | Mem/4 | 4 | 4 | Mem/8 | 4 | not used | | |

| Activated Channels | Used Mode | Memory size SPC_MEMSIZE | | | Segment size SPC_SEGMENTSIZE | | | Loops SPC_LOOPS | | |
|--------------------|---------------|----------------------------|-------|------|---------------------------------|--------|------|--------------------|--------|------|
| | | Min | Max | Step | Min | Max | Step | Min | Max | Step |
| | Standard Gate | 4 | Mem/4 | 4 | not used | | | not used | | |
| | FIFO Single | not used | | | 4 | 8G - 4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 4 | Mem/8 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |

All figures listed here are given in samples. An entry of $[8k - 16]$ means $[8 \text{ kSamples} - 16] = [8192 - 16] = 8176$ samples.

The given memory and memory / divider figures depend on the installed on-board memory as listed below:

| | Installed Memory | | | | | | |
|---------|------------------|------------|-------------|-------------|-------------|-------------|-------------|
| | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample |
| Mem | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample |
| Mem / 2 | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample |
| Mem / 4 | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample |
| Mem / 8 | 4 MSample | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample |

Please keep in mind that this table shows all values at once. Only the absolute maximum and minimum values are shown. There might be additional limitations. Which of these values is programmed depends on the used mode. Please read the detailed documentation of the mode.

Programming the behaviour in pauses and after replay

Usually the used outputs of the analog generation boards are set to zero level after replay. This is in most cases adequate. In some cases it can be necessary to hold the last sample, to output the maximum positive level or maximum negative level after replay. The stoplevel will stay on the defined level until the next output has been made. With the following registers you can define the behaviour after replay:

| Register | Value | Direction | Description |
|-----------------------|--------|------------|---|
| SPC_CH0_STOPLEVEL | 206020 | read/write | Defines the behavior after replay for channel 0 |
| SPC_CH1_STOPLEVEL | 206021 | read/write | Defines the behavior after replay for channel 1 |
| SPC_CH2_STOPLEVEL | 206022 | read/write | Defines the behavior after replay for channel 2 |
| SPC_CH3_STOPLEVEL | 206023 | read/write | Defines the behavior after replay for channel 3 |
| SPCM_STOPLVL_ZERO | 16 | | Defines the analog output to enter zero level (D/A converter is fed with digital zero value) |
| SPCM_STOPLVL_LOW | 2 | | Defines the analog output to enter maximum negative level (D/A converter is fed with most negative level) |
| SPCM_STOPLVL_HIGH | 4 | | Defines the analog output to enter maximum positive level (D/A converter is fed with most positive level) |
| SPCM_STOPLVL_HOLDLAST | 8 | | Holds the last replayed sample on the analog output |

All outputs that are not activated for replay, will keep the programmed stoplevel also while the replay is in progress.



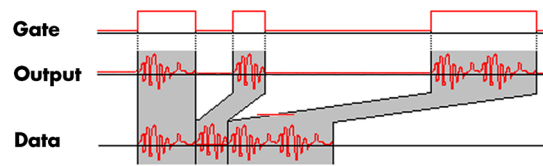
Because the STOPLEVEL registers impact the digital samples fed to the D/A converter, the output is still shifted by the programmed output offset, as described before.

Mode Gated Replay

The Gated Replay mode allows the data generation controlled by an external or an internal gate signal. Data will only be replayed if the programmed gate condition is true.

This chapter will explain all the necessary software register to set up the card for Gated Replay properly.

The section on the allowed trigger modes deals with detailed description on the different trigger events and the resulting gates.



Generation Modes

Standard Mode

Data will be replayed as long as the gate signal fulfils the programmed gate condition. At the end of the gate interval the replay will be stopped and the card will pause until another gates signal appears. If loops (SPC_LOOPS) is set to 1 the card stops immediately as soon as the total amount of data (SPC_MEMSIZE) has been replayed. In that case the last gate segment is ended by the expiring memory size counter and not by the gate end signal. If loops is set to zero the Gated Replay mode will run in a continuous loop until explicitly stopped by user. If the replay reaches the end of the programmed memory it will start again at the beginning with no gap in between. If setting loops to a number larger than 1 this number of complete gates will be replayed and the card stopped afterwards automatically.

The table below shows the register for enabling Gated Sampling. For detailed information on how to setup and start the standard acquisition mode please refer to the according chapter earlier in this manual.

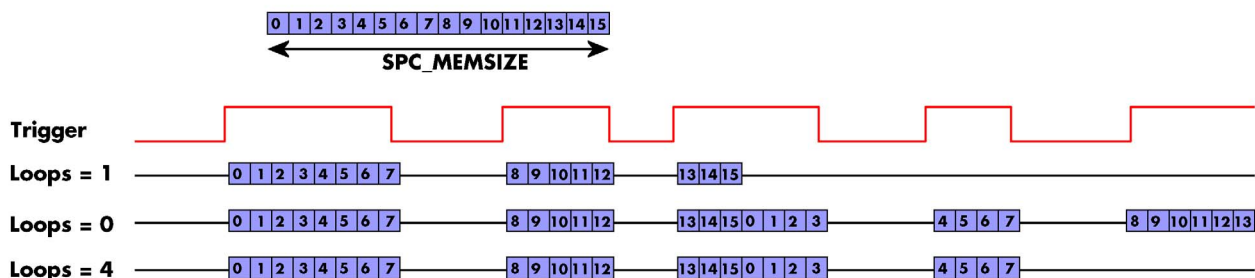
| Register | Value | Direction | Description |
|------------------|-------|------------|--|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode |
| SPC_REP_STD_GATE | 400h | | Enables Gated Sampling for standard acquisition. |

The total number of samples to be replayed from the on-board memory in standard mode is defined by the SPC_MEMSIZE register.

| Register | Value | Direction | Description |
|----------------|-------|------------|---|
| SPC_MEMSIZE | 10000 | read/write | Defines the total number of samples to be replayed. |
| SPC_LOOPS | 10020 | read/write | Defines the number of gates to be replayed |
| 0 | | | Replay will be infinite until the user stops it. When replay reaches the end of programmed memory it will start from the beginning with no gap. |
| 1 | | | The complete memory is replayed once. The last gate segment is cut off when end of memory is reached. |
| 2 ... [4G - 1] | | | Defines the number of gate segments to be replayed. |

Examples of Standard Gated Replay with the use of SPC LOOPS parameter

To keep the diagram easy to read there's no delay shown in here and there's also only a very small number of samples shown. Any further restrictions are described later in this chapter.



FIFO Mode

The Gated Replay in FIFO mode is similar to the Gated Replay in standard mode. The replay can either run until the user stops it by software (infinite replay, loops = 0) or until a programmed number of gates has been played (loops = 1). The data is written continuously by the driver and can be either online calculated or loaded from hard disk. The table below shows the dedicated register for enabling Gated Sampling in FIFO mode. For detailed information how to setup and start the card in FIFO mode please refer to the according chapter earlier in this manual.

| Register | Value | Direction | Description |
|-------------------|-------|------------|-------------------------------------|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode |
| SPC_REP_FIFO_GATE | 2000h | | Enables Gated Replay with FIFO mode |

The number of gates to be replayed must be set separately with the register shown in the following table:

| Register | Value | Direction | Description |
|-----------------|-------|------------|---|
| SPC_LOOPS | 10020 | read/write | Defines the number of gates to be replayed |
| 0 | | | Replay will be infinite until the user stops it or an underrun occurs |
| 1 [4G - 1] | | | Defines the total gates to be replayed. |

Limits of segment size, memory size

The maximum memory size parameter is only limited by the number of activated channels and by the amount of installed memory. Please keep in mind that each sample needs 2 bytes of memory to be stored.

Due to the internal organization of the card memory there is a certain stepsize when setting these values that has to be taken into account. The following table gives you an overview of all limits concerning memory size, segment size and loops. The table shows all values in relation to the installed memory size in samples. If more memory is installed the maximum memory size figures will increase according to the complete installed memory:

| Activated Channels | Used Mode | Memory size SPC_MEMSIZE | | | Segment size SPC_SEGMENTSIZE | | | Loops SPC_LOOPS | | |
|--------------------|-----------------|----------------------------|-------|------|---------------------------------|--------|------|--------------------|--------|------|
| | | Min | Max | Step | Min | Max | Step | Min | Max | Step |
| 1 channel | Standard Single | 8 | Mem | 8 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 8 | Mem | 8 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 8 | Mem | 8 | 8 | Mem/2 | 8 | not used | | |
| | Standard Gate | 8 | Mem | 8 | not used | | | not used | | |
| | FIFO Single | not used | | | 8 | 8G - 8 | 8 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 8 | Mem/2 | 8 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |
| 2 channels | Standard Single | 4 | Mem/2 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 4 | Mem/2 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 4 | Mem/2 | 4 | 4 | Mem/4 | 4 | not used | | |
| | Standard Gate | 4 | Mem/2 | 4 | not used | | | not used | | |
| | FIFO Single | not used | | | 4 | 8G - 4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 4 | Mem/4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |
| 4 channels | Standard Single | 4 | Mem/4 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Single Restart | 4 | Mem/4 | 4 | not used | | | 0 (∞) | 4G - 1 | 1 |
| | Standard Multi | 4 | Mem/4 | 4 | 4 | Mem/8 | 4 | not used | | |
| | Standard Gate | 4 | Mem/4 | 4 | not used | | | not used | | |
| | FIFO Single | not used | | | 4 | 8G - 4 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Multi | not used | | | 4 | Mem/8 | 4 | 0 (∞) | 4G - 1 | 1 |
| | FIFO Gate | not used | | | not used | | | 0 (∞) | 4G - 1 | 1 |

All figures listed here are given in samples. An entry of [8k - 16] means [8 kSamples - 16] = [8192 - 16] = 8176 samples.

The given memory and memory / divider figures depend on the installed on-board memory as listed below:

| | 32 MSample | 64 MSample | 128 MSample | Installed Memory | | | | 256 MSample | 512 MSample | 1 GSample | 2 GSample |
|---------|------------|------------|-------------|------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Mem | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample |
| Mem / 2 | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample |
| Mem / 4 | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample |
| Mem / 8 | 4 MSample | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample |

Please keep in mind that this table shows all values at once. Only the absolute maximum and minimum values are shown. There might be additional limitations. Which of these values is programmed depends on the used mode. Please read the detailed documentation of the mode.

Allowed trigger modes

Edge and level triggers

For all external edge and level trigger modes, the OR mask must contain the corresponding input, as the following table shows:

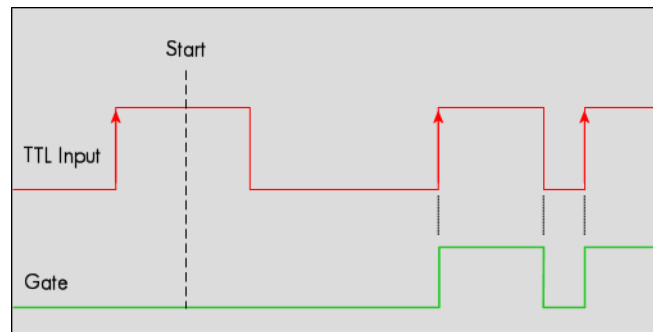
| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_TRIG_ORMASK | 40410 | read/write | Defines the OR mask for the different trigger sources. |
| SPC_TMASK_EXT0 | 2h | | Enable external trigger input for the OR mask |
| SPC_TMASK_XIO0 | 100h | | Enable extra TTL input 0 for the OR mask. On plain cards this input is only available if the option BaseXIO is installed. As part of the digitizerNETBOX this input is available as connector Trigger B. |
| SPC_TMASK_XIO1 | 200h | | Enable extra TTL input 1 for the OR mask. These trigger inputs are only available, when option BaseXIO is installed. |

Positive TTL single edge trigger

This mode is for detecting the rising edges of an external TTL signal. The gate will start on rising edges that are detected after starting the board.

As this mode is purely edge-triggered, the high level at the cards start time, does not trigger the board.

With the next falling edge the gate will be stopped.



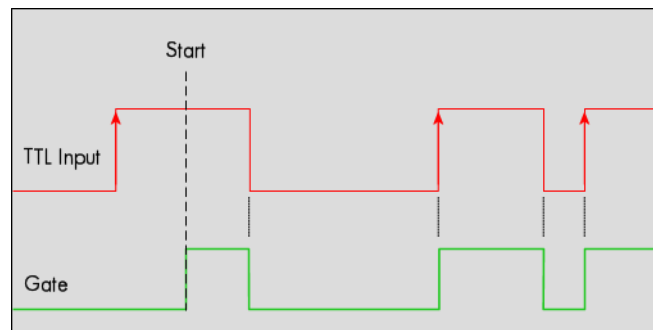
| Register | Value | Direction | Description |
|--------------------|-------|------------|---|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board |
| SPC_TM_POS | 1h | | Sets the trigger mode for external TTL trigger to detect positive edges |

HIGH TTL level trigger

This mode is for detecting the high levels of an external TTL signal. The gate will start on high levels that are detected after starting the board acquisition/generation.

As this mode is purely level-triggered, the high level at the cards start time, does trigger the board.

With the next low level the gate will be stopped.



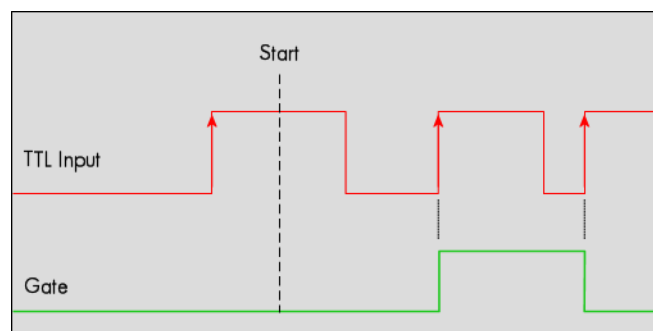
| Register | Value | Direction | Description |
|--------------------|-------|------------|---|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board |
| SPC_TM_HIGH | 8h | | Sets the trigger mode for external TTL trigger to detect high levels. |

Positive TTL double edge trigger

This mode is for detecting the rising edges of an external TTL signal. The gate will start on the first rising edge that is detected after starting the board.

As this mode is purely edge-triggered, the high level at the cards start time, does not trigger the board.

The gate will stop on the second rising edge that is detected.



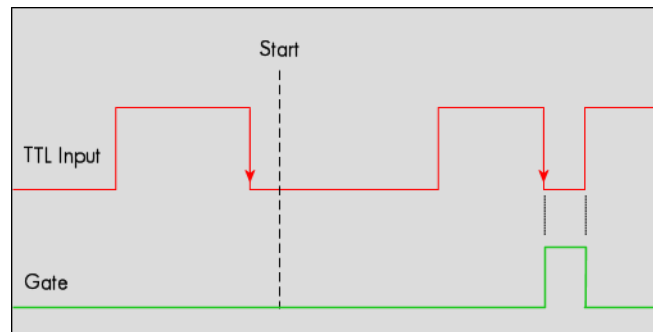
| Register | Value | Direction | Description |
|--------------------------------|-----------|------------|--|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board |
| SPC_TM_POS SPC_TM_DOUBLEEDGE | 08000001h | | Sets the gate mode for external TTL trigger to start and stop on positive edges. |

Negative TTL single edge trigger

This mode is for detecting the falling edges of an external TTL signal. The gate will start on falling edges that are detected after starting the board.

As this mode is purely edge-triggered, the low level at the cards start time, does not trigger the board.

With the next rising edge the gate will be stopped.



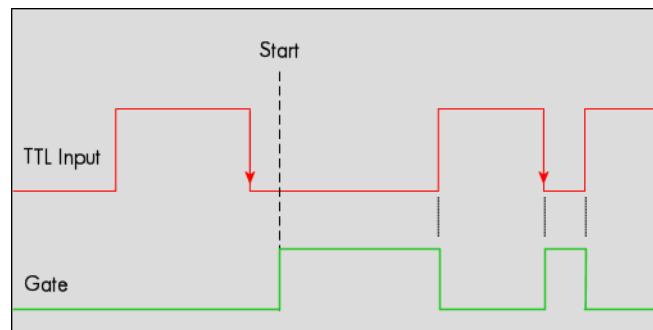
| Register | Value | Direction | Description |
|--------------------|-------|------------|--|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board |
| SPC_TM_NEG | 2h | | Sets the trigger mode for external TTL trigger to detect negative edges. |

LOW TTL level trigger

This mode is for detecting the low levels of an external TTL signal. The gate will start on low levels that are detected after starting the board.

As this mode is purely level-triggered, the low level at the cards start time, does trigger the board.

With the next high level the gate will be stopped.



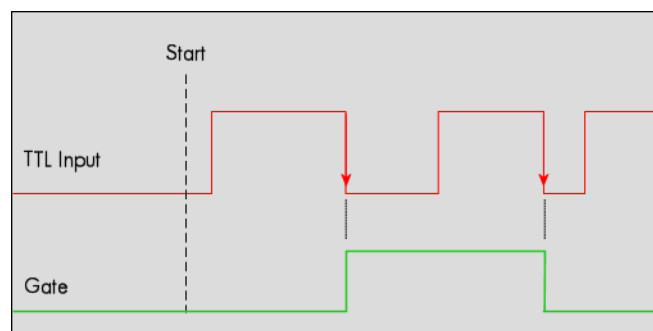
| Register | Value | Direction | Description |
|--------------------|-------|------------|--|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board |
| SPC_TM_LOW | 10h | | Sets the trigger mode for external TTL trigger to detect low levels. |

Negative TTL double edge trigger

This mode is for detecting the falling edges of an external TTL signal. The gate will start on the first falling edge that is detected after starting the board.

As this mode is purely edge-triggered, the low level at the cards start time, does not trigger the board.

The gate will stop on the second falling edge that is detected.



| Register | Value | Direction | Description |
|--------------------------------|-----------|------------|---|
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the external trigger mode for the board |
| SPC_TM_NEG SPC_TM_DOUBLEEDGE | 08000002h | | Sets the gate mode for external TTL trigger to start and stop on negative edges |

Pulsewidth triggers

For all external edge and level trigger modes, the OR mask must contain the corresponding input, as the following table shows:

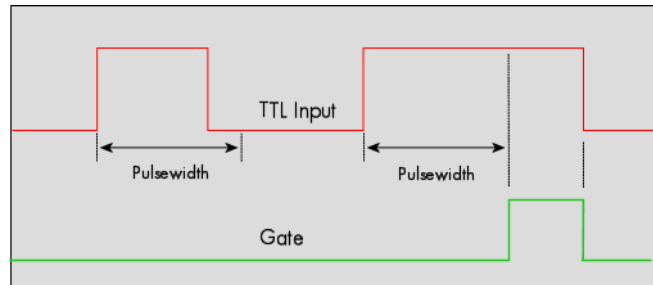
| Register | Value | Direction | Description |
|-----------------|-------|------------|--|
| SPC_TRIG_ORMASK | 40410 | read/write | Defines the OR mask for the different trigger sources. |
| SPC_TMASK_EXT0 | 2h | | Enable external trigger input for the OR mask |
| SPC_TMASK_XIO0 | 100h | | Enable extra TTL input 0 for the OR mask. On plain cards this input is only available if the option BaseXIO is installed. As part of the digitizerNETBOX this input is available as connector Trigger B. |
| SPC_TMASK_XIO1 | 200h | | Enable extra TTL input 1 for the OR mask. These trigger inputs are only available, when option BaseXIO is installed. |

TTL pulsewidth trigger for long HIGH pulses

This mode is for detecting a rising edge of an external TTL signal followed by a HIGH pulse that are longer than a programmed pulsewidth. If the pulse is shorter than the programmed pulsewidth, no trigger will be detected.

The gate will start on the first pulse matching the trigger condition after starting the board.

The gate will stop with the next falling edge.



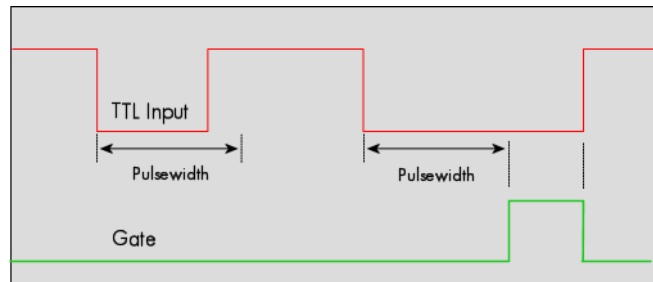
| Register | Value | Direction | Description |
|----------------------------------|----------|------------|--|
| SPC_TRIG_EXT0_PULSEWIDTH | 44210 | read/write | Sets the pulsewidth in samples. Values from 2 to 65535 are allowed. |
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the trigger mode for the board. |
| (SPC_TM_POS SPC_TM_PW_GREATER) | 4000001h | | Sets the trigger mode for external TTL trigger to detect HIGH pulses that are longer than a programmed pulsewidth. |

TTL pulsewidth trigger for long LOW pulses

This mode is for detecting a falling edge of an external TTL signal followed by a LOW pulse that are longer than a programmed pulsewidth. If the pulse is shorter than the programmed pulsewidth, no trigger will be detected.

The gate will start on the first pulse matching the trigger condition after starting the board.

The gate will stop with the next rising edge.



| Register | Value | Direction | Description |
|----------------------------------|----------|------------|---|
| SPC_TRIG_EXT0_PULSEWIDTH | 44210 | read/write | Sets the pulsewidth in samples. Values from 2 to 65535 are allowed. |
| SPC_TRIG_EXT0_MODE | 40510 | read/write | Sets the trigger mode for the board. |
| (SPC_TM_NEG SPC_TM_PW_GREATER) | 4000002h | | Sets the trigger mode for external TTL trigger to detect LOW pulses that are longer than a programmed pulsewidth. |

```

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_NEG | SPC_TM_PW_GREATER); // Setting up external TTL
                                                                    // trigger to detect low pulses
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_PULSEWIDTH, 50); // that are longer than 50 samples.
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the OR mask

```

Programming examples

The following examples shows how to set up the card for Gated Replay in standard mode for Gated Replay in FIFO mode.

```
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_STD_GATE); // Enables Standard Gated Replay

spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, 8192); // Set the total memsize for replay to 8192 samples

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS); // Set triggermode to ext. TTL rising edge
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the trigger OR-mask
```

```
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_FIFO_GATE); // Enables FIFO Gated Replay

pcm_dwSetParam_i64 (hDrv, SPC_LOOP, 1024); // 1024 gates will be replayed

spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_NEG); // Set triggermode to ext. TTL falling edge
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the trigger OR-mask
```

Programming the behaviour in pauses and after replay

Usually the used outputs of the analog generation boards are set to zero level after replay. This is in most cases adequate. In some cases it can be necessary to hold the last sample, to output the maximum positive level or maximum negative level after replay. The stoplevel will stay on the defined level until the next output has been made. With the following registers you can define the behaviour after replay:

| Register | Value | Direction | Description |
|-----------------------|--------|------------|---|
| SPC_CH0_STOPLEVEL | 206020 | read/write | Defines the behavior after replay for channel 0 |
| SPC_CH1_STOPLEVEL | 206021 | read/write | Defines the behavior after replay for channel 1 |
| SPC_CH2_STOPLEVEL | 206022 | read/write | Defines the behavior after replay for channel 2 |
| SPC_CH3_STOPLEVEL | 206023 | read/write | Defines the behavior after replay for channel 3 |
| SPCM_STOPLVL_ZERO | 16 | | Defines the analog output to enter zero level (D/A converter is fed with digital zero value) |
| SPCM_STOPLVL_LOW | 2 | | Defines the analog output to enter maximum negative level (D/A converter is fed with most negative level) |
| SPCM_STOPLVL_HIGH | 4 | | Defines the analog output to enter maximum positive level (D/A converter is fed with most positive level) |
| SPCM_STOPLVL_HOLDLAST | 8 | | Holds the last replayed sample on the analog output |

All outputs that are not activated for replay, will keep the programmed stoplevel also while the replay is in progress.



Because the STOPLEVEL registers impact the digital samples fed to the D/A converter, the output is still shifted by the programmed output offset, as described before.

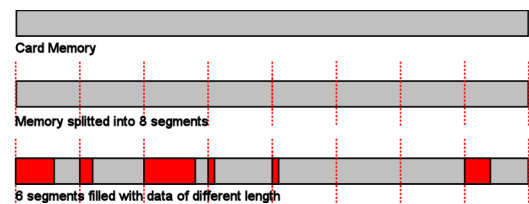
Sequence Replay Mode

The sequence replay mode is a special firmware mode that allows to program an output sequence by defining one or more sequences each associated with a certain memory pattern. Therefore the user is provided with two different memories, one for the sequence steps and one for the data patterns. The separated sequence memory can hold different sequence steps (the actual number depends on the hardware and can be found in the technical data section). Each step itself contains information about how often it should be repeated in a loop, which step will be next and on what condition the change will happen. To define the pattern for the steps, the on-board memory is split up into several segments of different length. The switch over from one segment to the other is seamless, without any missing samples or spikes. The powerful sequence mode option adds a huge variety of different application areas to Spectrum's generator cards.

Theory of operation

Define segments in data memory

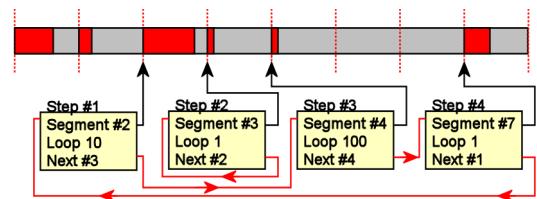
The complete installed on-board memory of the card is divided into a user definable number of segments. Each segment space has the same length limiting the maximum length of one data segment to $[\text{Installed Memory}] / [\text{Number of Segments}]$. Each data segment can be filled by the user with patterns of different lengths or can even be left completely empty if unused:



In our example we see the complete installed card memory is being split into 8 segments and 6 of these segments are actually filled with data sequences of different length afterwards (indicated in red). Two of these segments are not needed for the assumed sequence and therefore left empty as an example. Due to the fact that each sequence step can be associated with any of the data segments, it is also possible to use one data segment in multiple steps or to just once upload the data for multiple sequences, and just change the order of the sequence.

Define steps in sequence memory

The sequence memory defines a number of data loop steps that are executed step by step either linear or interrupted by waiting for trigger event. The first step that is entered after a card start is separately defined by software. When being entered, each step first repeats the associated data segment the number times defined by its loop parameter. Afterwards the sequencer will either automatically proceed either unconditionally or check for a trigger event as a condition to change over to the next step, which is defined by the steps next parameter. This next segment can be the same segment again performing an endless loop or the beginning of the sequence to repeat the sequence until being stopped by the user. Additionally a step can also be defined to be the last step in a sequence such that the card is stopped afterwards.



In our example 4 steps have been defined. Three of them (Step #1, Step #3, Step #4) perform an endless loop that will be repeated continuously. The output of the card will then be 10 times data segment #2, 100 times data segment #4, 1 time data segment #7 and then starting over with 10 times data segment #2 and so on...

In this first simple example the sequence consisting of the three steps is once defined prior to the card start and not changed during runtime, therefore the shown Step #2 is not used here. There will be an extra passage later, that shows how the sequence memory can be updated or modified even during runtime, whilst the replay is in progress.

Programming

Programming of the sequence mode is done using the known driver interface with the addition of a few new registers.

Gathering information

If the sequence mode is installed on the card, the different details and limits of the sequence programming can be read out:

| Register | Value | Direction | Description |
|--------------------|-------|-----------|--|
| SPC_PCIFEATURES | 2120 | read only | PCI feature register. Holds the installed features and options as a bit field. The return value must be masked out with one of the masks below to get information about one certain feature. |
| SPCM_FEAT_SEQUENCE | 1000h | | Replay sequence mode available (only available for arbitrary generator and digital I/O cards). |

| Register | Value | Direction | Description |
|-----------------------------|--------|-----------|---|
| SPC_SEQMODE_AVAILMAXSEGMENT | 349900 | read only | Returns the maximum number of segments the memory can be divided into. Please note that only dividers with a power of 2 are possible return values. |
| SPC_SEQMODE_AVAILMAXSTEPS | 349901 | read only | Returns the maximum number of sequence steps that can be used on this card. |
| SPC_SEQMODE_AVAILMAXLOOP | 349902 | read only | Returns the maximum number of loops that can be programmed for a step. |
| SPC_SEQMODE_AVAILFEATURES | 349903 | read only | Returns the available features for each sequence step as shown below: |

| | | |
|----------------------|-----------|--|
| SPCSEQ_ENDLOOPONTRIG | 40000000h | The step runs endless until a trigger is received. If no trigger has been detected, the step will enter itself again, counting down its own loops and check for a trigger again. For a minimum reaction time on an external trigger event it is good practice to set the loop parameter to 1 in the step checking for the trigger. |
| SPCSEQ_END | 80000000h | This sequence step is the end of the sequence. The card is stopped somewhere inside this step. |

Setting up the registers

Define the card mode

To enable the sequencer the card mode needs to be set appropriately first:

| Register | Value | Direction | Description |
|----------------------|--------|------------|--|
| SPC_CARDMODE | 9500 | read/write | Defines the used operating mode. |
| SPC_REP_STD_SEQUENCE | 40000h | | Data generation from on-board memory, by splitting the memory into several segments and replaying the data using a programmable order coming from a special sequence memory. |

Prepare the data memory

Setting up the segmentation of the on-board data memory is done by using the following registers:

| Register | Value | Direction | Description |
|--------------------------|--------|------------|---|
| SPC_SEQMODE_MAXSEGMENTS | 349910 | read/write | Programs the number of segments the on-board memory should be divided into. If changing the number of segments all information that has been stored before is lost and all sequence data and all sequence setup has to be written again. Only a power of two is allowed, but not all of the segments must be actually used in the sequence. If reading this register the number of segments the memory is currently divided into is returned. |
| SPC_SEQMODE_WRITESEGMENT | 349920 | read/write | Defines the current segment to be addressed by the user. Must be programmed prior to changing any segment parameters. |
| SPC_SEQMODE_SEGMENTSIZE | 349940 | read/write | Defines the number of valid/to be replayed samples for the current selected memory segment. |

Due to the internal organization of the card memory there is a certain minimum, maximum and stepsize when setting the segmentsize for the sequence memory. The following table gives you an overview of all limits. The table shows all values in relation to the installed memory size in samples. If more memory is installed the maximum memory size figures will increase according to the complete installed memory:

For analog generator cards

| Activated Channels | For cards with 14 bit converter resolution Pattern size for register SPC_SEQMODE_SEGMENTSIZE | | | For cards with 8 bit converter resolution Pattern size for currently register SPC_SEQMODE_SEGMENTSIZE | | |
|--------------------|--|-----------------------------------|------|---|-----------------------------------|------|
| | Min | Max | Step | Min | Max | Step |
| 1 channel | 32 | (Mem/1) / SPC_SEQMODE_MAXSEGMENTS | 8 | 48 | (Mem/1) / SPC_SEQMODE_MAXSEGMENTS | 16 |
| 2 channels | 32 | (Mem/2) / SPC_SEQMODE_MAXSEGMENTS | 8 | 48 | (Mem/2) / SPC_SEQMODE_MAXSEGMENTS | 16 |
| 4 channels | 32 | (Mem/4) / SPC_SEQMODE_MAXSEGMENTS | 8 | 48 | (Mem/4) / SPC_SEQMODE_MAXSEGMENTS | 16 |

For Digital I/O cards

| Activated Channels | For cards with 8 bit converter resolution Pattern size for currently selected segment SPC_SEQMODE_SEGMENTSIZ | | |
|--------------------|--|-----------------------------------|------|
| | Min | Max | Step |
| 1 | Not allwed | | |
| 2 | | | |
| 4 | | | |
| 8 | 48 | (Mem/1) / SPC_SEQMODE_MAXSEGMENTS | 16 |
| 16 | 32 | (Mem/2) / SPC_SEQMODE_MAXSEGMENTS | 8 |
| 32 | 32 | (Mem/4) / SPC_SEQMODE_MAXSEGMENTS | 4 |
| 64 | 32 | (Mem/8) / SPC_SEQMODE_MAXSEGMENTS | 4 |

All figures listed here are given in samples. An entry of [8k - 16] means $[8 \text{ kSamples} - 16] = [8192 - 16] = 8176$ samples. The given memory and memory / divider figures depend on the installed on-board memory as listed below:

| | Installed Memory | | | | | | | |
|---------|------------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|
| | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample | 4 GSample |
| Mem | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample | 4 GSample |
| Mem / 2 | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample | 2 GSample |
| Mem / 4 | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample | 1 GSample |
| Mem / 8 | 4 MSample | 8 MSample | 16 MSample | 32 MSample | 64 MSample | 128 MSample | 256 MSample | 512 MSample |

Definition of the transfer buffer

The data transfer itself is done using the standard data transfer commands, with the exception that the buffer type and the direction is fixed in combination with the sequence mode. The definition of the buffer is done with the `spcm_dwDefTransfer` function as explained in an earlier chapter.

```
uint32_stdcall spcm_dwDefTransfer_i64 (// Defines the transfer buffer by using 64 bit unsigned integer values
    drv_handle hDevice,           // handle to an already opened device
    uint32 dwBufType,             // fixed SPCM_BUF_DATA (segment memory is always in on-board memory)
    uint32 dwDirection,           // fixed SPCM_DIR_PCTOCARD (only available for replay cards)
    uint32 dwNotifySize,          // number of bytes after which an event is sent (0=end of transfer)
    void* pvDataBuffer,           // pointer to the data buffer
    uint64 qwBrdOffs,             // offset for transfer in relation to the currently selected segment
    uint64 qwTransferLen);        // buffer length for the currently selected segment
```

The programming examples further below will show the setup and also some examples of data transfer.

Set up the sequence memory

Sequence steps are programmed using a dedicated register for each step. Please note that the register has to be written with 64 bit of data to cover all settings. It is possible to either use raw 64 bit access or multiplexed 64 bit access (2 times 32 bit data). The masks mentioned in the table below are 32 bit masks only, so that they can be used for 64 bit and 32 bit accesses.

| Register | Value | Direction | Description |
|--|-----------|------------|--|
| SPC_SEQMODE_STEPMEM0 | 340000 | read/write | First address (sequence step 0) of the 64 bit organized sequence memory. |
| ... | ... | ... | ... |
| SPC_SEQMODE_STEPMEM0 + ReturnValue[SPC_SEQMODE_AVAILMAXSTEPS - 1] | 340511 | read/write | Writes the sequence step 511, as an example. The maximum number of steps should be read out by using the SPC_SEQMODE_AVAILMAXSTEPS register as described above. |
| Lower 32 bit: | | | |
| SPCSEQ_SEGMENTMASK | 0000FFFFh | | Associates the current sequence step with one of the memory segments. |
| SPCSEQ_NEXTSTEPMASK | FFFF0000h | | Defines the next step in the sequence. |
| Upper 32 bit: | | | |
| SPCSEQ_LOOPMASK | 000FFFFh | | Defines how often the memory segment associated with the current step will be repeated before the next step condition will be evaluated. |
| SPCSEQ_ENDLOOPALWAYS | 0h | | Unconditionally change to the next step, if defined loops for the current segment have been replayed. |
| SPCSEQ_ENDLOOPONTRIG | 40000000h | | Feature flag that marks the step to conditionally change to the next step on a trigger condition. The occurrence of a trigger event is repeatedly checked each time the defined loops for the current segment have been replayed. A temporarily valid trigger condition will be stored until evaluation at the end of the step. |
| SPCSEQ_END | 80000000h | | Feature flag that marks the current step to be the last in the sequence. The stop itself is not sample accurate. Therefore it is best practice when using the SPCSEQ_END marker, to use one of the available segments as a dummy stop segment, set the loop parameter to 1 and pre-fill the complete memory segment with data samples, that hold the same pattern as the one defined by the SPC_STOPLEVEL. For details on „Programming the behaviour after output“ please see the according chapter in this manual. |

The start step register allows to define which of the set up steps is used first after card start. Therefore is possible to upload multiple sequences prior to the start and switch between these sequences by using a simple command, setting a different starting point:

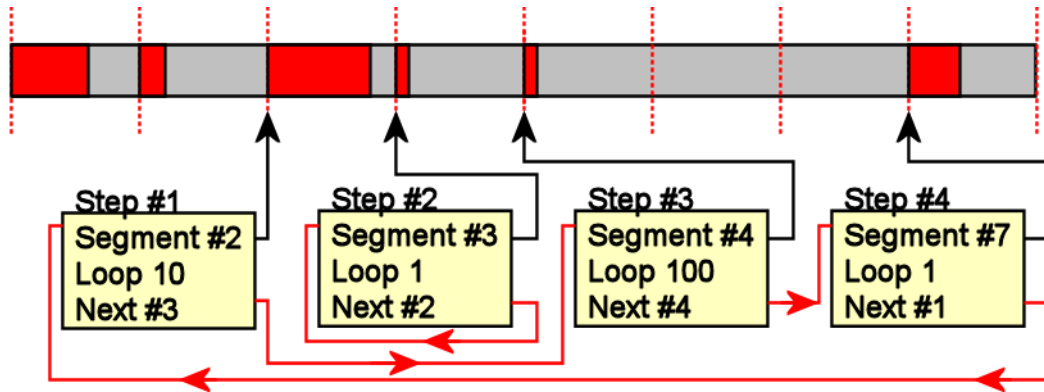
| Register | Value | Direction | Description |
|-----------------------|--------|------------|---|
| SPC_SEQMODE_STARTSTEP | 349930 | read/write | Defines which of all defined steps in the sequence memory will be used first directly after the card start. |



Due to the internal structure of the sequencer, the delay between a trigger event and the change in the sequence, when using the SPCSEQ_ENDLOOPONTRIG feature, is not a fixed value but rather varies with the current fill-size of the Output FIFO. Please see „Output latency“ section in this manual for the size of the Output FIFO on your card.

Changing sequences or step parameters during runtime

Due to the strict separation of the two memory areas it is also possible to change the sequence memory during runtime. If we look again on the example sequence below, we can see that there is an unused step #2:



In our example 3 steps have been defined, prior to the card start, and these at first are not changed. Additionally Step#2 is set up to repeat itself, but due to the defined start step it is normally not used. Due to the nature of the sequence memory (read-before-write) it is possible to write to any step register in the sequence memory during runtime without corrupting the sequence memory. By addressing a certain step and changing for example its next parameter, it is possible switch between two sequences by software. Because the user does not know what sequence is currently replayed, one cannot leave the „current“ step but instead has to address one certain step and therefore defines an exit/change state.

Assuming in the example above, that we change the next parameter of Step#4 from Next=1 to Next=2, the infinitely executed 3-step sequence that is used as default after card start will be left the next time that the replay finishes the last sample of the pattern associated with Step#4 (which in this case is Segment#7), will then jump to step #2 and seamlessly continue replaying with the first sample off the associated segment #3. As step #2 links back to itself it will generate data segment #3 in an endless loop until being either stopped by a software command or another change in the sequence is applied.

Any of the three step parameters „Next“, „Segment“ and „Loop“ of any step in the sequence memory can be changed during runtime, without corruption the sequence memory. However once a step is entered, it will first execute the current parameters such as replay the associated pattern and repeating it the programmed number of times.

Changing data patterns during runtime

In addition to the possible runtime changes within the sequence memory as described above, it is also possible to change the parts of the pattern memory.



However since the data memory's nature is not „read-before-write“, the user must take care not to change the content of the memory segments, which are used within the currently active sequence.

Changing the data pattern can be useful in applications, where the data for the next test needs to be updated based on results from the currently running test. Remember to update the sequence step entries if the segment length has changed, so that the driver can automatically re-calculate the internal start-addresses of the segments.

Synchronization



Please note that the sequence mode is NOT synchronized using the star-hub. This also relates to generator-NETBOX products with an internal star-hub. Using sequence mode together with star-hub, it is still possible to synchronize the clock and the start of the cards. However it is neither possible to synchronize any changes inside the step memory nor to synchronize software commands that change the step memory order nor to synchronize a trigger that ends a steps loop.

Programming example

The following example shows a very simple sequence as an example. Only two segments are used, the first is replayed 10 times and then unconditionally left and replay switches over to the second segment. This segment is repeated until a trigger event is detected by the card. After the trigger has been detected the sequence starts over again ... until the card is stopped.

```
// Setup of channel enable, output conditioning as well as trigger setup not shown for simplicity

#define MAX_SEGMENTS      2 // only 2 segments used here for simplicity
int32 lBytesPerSample;

// Read out used bytes per sample
spcm_dwGetParam_i32 (hDrv, SPC_MIINST_BYTESPERSAMPLE, &lBytesPerSample);

// Setting up the card mode
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REP_STD_SEQUENCE); // enable sequence mode
spcm_dwSetParam_i32 (hDrv, SPC_SEQMODE_MAXSEGMENTS, 2); // Divide on-board mem in two parts
spcm_dwSetParam_i32 (hDrv, SPC_SEQMODE_STARTSTEP, 0); // Step#0 is the first step after card start

// Setting up the data memory and transfer data
spcm_dwSetParam_i32 (hDrv, SPC_SEQMODE_WRITESEGMENT, 0); // set current configuration switch to segment 0
spcm_dwSetParam_i32 (hDrv, SPC_SEQMODE_SEGMENTSIZE, 1024); // define size of current segment 0

// it is assumed, that the Buffer memory has been allocated and is already filled with valid data
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, 0, pData, 0, 1024 * lBytesPerSample);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// Setting up the data memory and transfer data
spcm_dwSetParam_i32 (hDrv, SPC_SEQMODE_WRITESEGMENT, 1); // set current configuration switch to segment 1
spcm_dwSetParam_i32 (hDrv, SPC_SEQMODE_SEGMENTSIZE, 512); // define size of current segment 1

// it is assumed, that the Buffer memory has been allocated and is already filled with valid data
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, 0, pData, 0, 512 * lBytesPerSample);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// Setting up the sequence memory (Only two steps used here as an example)
l1Step = 0; // current step is Step#0
l1Segment = 0; // associated with data memory segment 0
l1Loop = 10; // Pattern will be repeated 10 times
l1Next = 1; // Next step is Step#1
l1Condition = SPCSEQ_ENDLOOPALWAYS; // Unconditionally leave current step

// combine all the parameters to one int64 bit value
l1Value = (l1Condition << 32) | (l1Loop << 32) | (l1Next << 16) | (l1Segment);
spcm_dwSetParam_i64 (hDrv, SPC_SEQMODE_STEPMEM0 + l1Step, l1Value);

l1Step = 1; // current step is Step#1
l1Segment = 1; // associated with data memory segment 1
l1Loop = 1; // Pattern will be repeated once before condition is checked
l1Next = 0; // Next step is Step#0
l1Condition = SPCSEQ_ENDLOOPONTRIG; // Repeat current step until a trigger has occurred

l1Value = (l1Condition << 32) | (l1Loop << 32) | (l1Next << 16) | (l1Segment);
spcm_dwSetParam_i64 (hDrv, SPC_SEQMODE_STEPMEM0 + l1Step, l1Value);

// Start the card
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER);

// ... wait here or do something else ...

// Stop the card
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_STOP);
```

Option Star-Hub

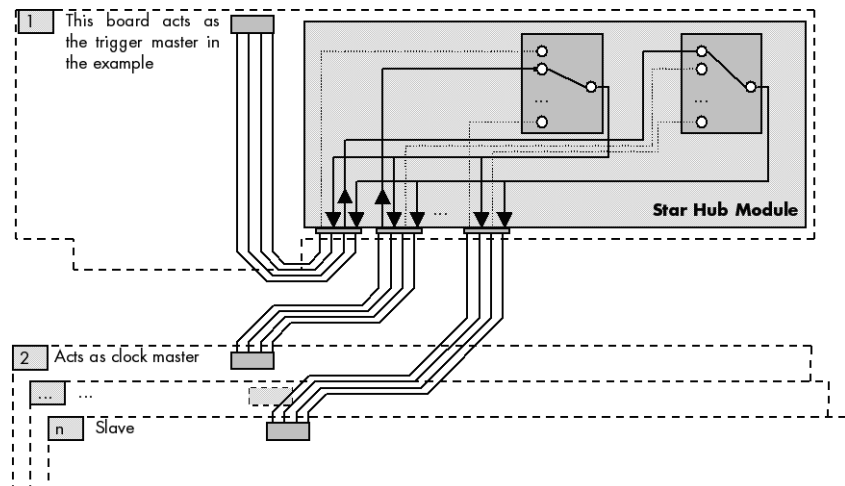
Star-Hub introduction

The purpose of the Star-Hub is to extend the number of channels available for acquisition or generation by interconnecting multiple cards and running them simultaneously. It is even possible to interconnect multiple systems using the system Star-Hubs described further below.

The Star-Hub option allows to synchronize several cards of the M2i series that are mounted within one host system (PC). Two different versions are available: a small version with 5 connectors (option SH5) for synchronizing up to five cards and a big version with 16 connectors (option SH16) for synchronizing up to 16 cards.

Both versions are implemented as a piggy-back module that is mounted to one of the cards. For details on how to install several cards including the one carrying the Star-Hub module, please refer to the section on hardware installation.

Either which of the two available Star-Hub options is used, there will be no phase delay between the sampling clocks of the synchronized cards and either no delay between the trigger events, if all synchronized cards run with the same sampling rate. Any one of the synchronized cards can be used as a clock master and besides any card can be part of the trigger generation.



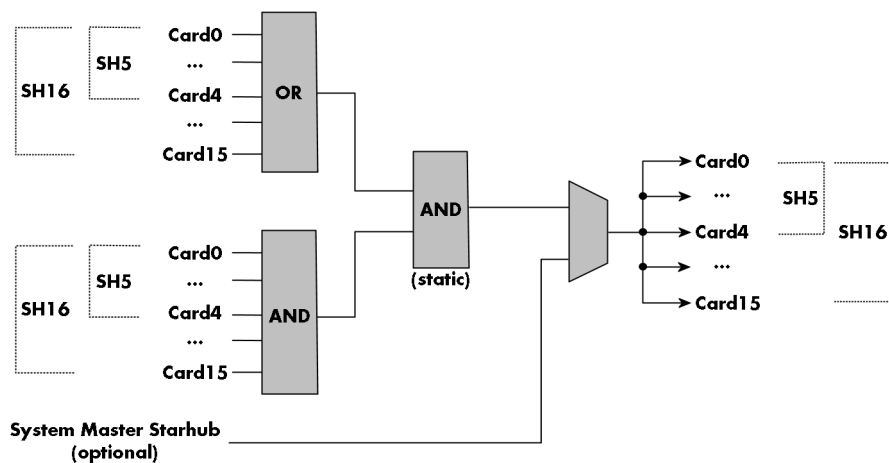
When accessing a digitizerNETBOX multiple digitizer modules are internally synchronized using a Star-Hub also. Synchronization of the cards and accessing the Star-Hub is done in the very exact way like a Star-Hub that is installed on a plug-in card.

Star-Hub trigger engine

The trigger bus between an M2i card and the Star-Hub option consists of three lines. Two of them send the trigger information from the card's trigger engine to the Star-Hub and one line receives the resulting trigger from the Star-Hub.

While the returned trigger is identical for all synchronized cards, the sent out trigger of every single card depends on their trigger settings.

Two lines are used to send the trigger from the card to the Star-Hub to provide the possibility to use the same OR/AND conjunctions for the resulting synchronization trigger like on a card that runs on its own.



By this separation all OR masks of all synchronized cards are therefore extended to one big OR mask, while all AND masks of the synchronized cards are extended to one overall AND mask. This allows to combine the various trigger sources of all synchronized cards with AND and OR conditions and so to create highly complex trigger conditions that will certainly suit your application's needs.

For details on the card's trigger engine and the usage of the OR/AND trigger masks please refer to the relating section of this manual.

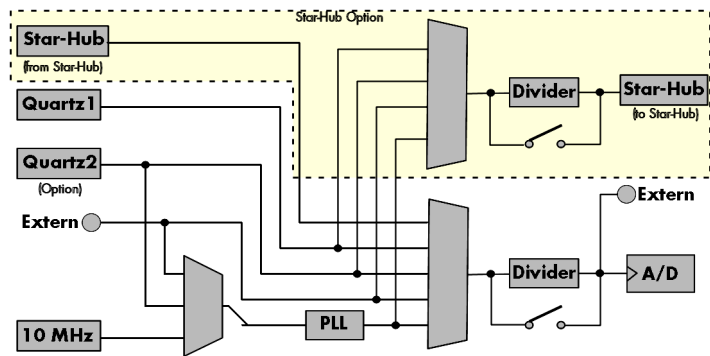
As an option it is also possible to synchronize multiple host systems each containing one Star-Hub module. These system slaves then will simply listen on the trigger line from the system master and distribute it to the connected cards. As this multi-system synchronization comes with some limits on certain settings and also needs some special attention on synchronizing the application software as well, it is therefore described in a separate section later in this manual.

Star-Hub clock engine

One of the cards can be the clock master for the complete system. This can be any card of the system even one card that does not contain the Star-Hub. As shown in the drawing on the right the clock master can use any of its clock sources to be broadcasted to all other cards.

All cards including the clock master itself receive the distributed clock with equal phase information. This makes sure that there is no phase delay between the cards running with the same speed.

Each slave card can use an additional divider on the received Star-Hub clock. This allows to synchronize fast and slow cards in one system.



Software Interface

The software interface is similar to the card software interface that is explained earlier in this manual. The same functions and some of the registers are used with the Star-Hub. The Star-Hub is accessed using its own handle which has some extra commands for synchronization setup. All card functions are programmed directly on card as before. There are only a few commands that need to be programmed directly to the Star-Hub for synchronization.

The software interface as well as the hardware supports multiple Star-Hubs in one system. Each set of cards connected by a Star-Hub then runs totally independent. It is also possible to mix cards that are connected with the Star-Hub with other cards that run independent in one system.

Star-Hub Initialization

The interconnection between the Star-Hubs is probed at driver load time and does not need to be programmed separately. Instead the cards can be accessed using a logical index. This card index is only based on the ordering of the cards in the system and is not influenced by the current cabling. It is even possible to change the cable connections between two system starts without changing the logical card order that is used for Star-Hub programming.

The Star-Hub initialization must be done AFTER initialization of all cards in the system. Otherwise the inter-connection won't be received properly.



The Star-Hubs are accessed using a special device name „sync“ followed by the index of the star-hub to access. The Star-Hub is handled completely like a physical card allowing all functions based on the handle like the card itself.

Example with 4 cards and one Star-Hub (no error checking to keep example simple)

```
drv_handle hSync;
drv_handle hCard[4];

for (i = 0; i < 4; i++)
{
    sprintf (s, "/dev/spcm%d", i);
    hCard[i] = spcm_hOpen (s);
}
hSync = spcm_hOpen ("sync0");

...

spcm_vClose (hSync);
for (i = 0; i < 4; i++)
    spcm_vClose (hCard[i]);
```

Example for a digitizerNETBOX with two internal digitizer/generator modules, This example is also suitable for accessing a remote server

with two cards installed:

```
drv_handle hSync;
drv_handle hCard[2];

for (i = 0; i < 2; i++)
{
    sprintf (s, "TCPIP::192.168.169.14::INST%d::INSTR", i);
    hCard[i] = spcm_hOpen (s);
}
hSync = spcm_hOpen ("sync0");

...

spcm_vClose (hSync);
for (i = 0; i < 2; i++)
    spcm_vClose (hCard[i]);
```

When opening the Star-Hub the cable interconnection is checked. The Star-Hub may return an error if it sees internal cabling problems or if the connection between Star-Hub and the card that holds the Star-Hub is broken. It can't identify broken connections between Star-Hub and other cards as it doesn't know that there has to be a connection.

The synchronization setup is done using bit masks where one bit stands for one recognized card. All cards that are connected with a Star-Hub are internally numbered beginning with 0. The number of connected cards as well as the connections of the star-hub can be read out after initialization. For each card that is connected to the star-hub one can read the index of that card:

| Register | Value | Direction | Description |
|-----------------------------|-------|-----------|---|
| SPC_SYNC_READ_NUMCONNECTORS | 48991 | read | Number of connectors that the Star-Hub offers at max. (available with driver V5.6 or newer) |
| SPC_SYNC_READ_SYNCCOUNT | 48990 | read | Number of cards that are connected to this Star-Hub |
| SPC_SYNC_READ_CARDIDX0 | 49000 | read | Index of card that is connected to star-hub logical index 0 (mask 0x0001) |
| SPC_SYNC_READ_CARDIDX1 | 49001 | read | Index of card that is connected to star-hub logical index 1 (mask 0x0002) |
| ... | | read | ... |
| SPC_SYNC_READ_CARDIDX7 | 49007 | read | Index of card that is connected to star-hub logical index 7 (mask 0x0080) |
| SPC_SYNC_READ_CARDIDX8 | 49008 | read | M2i only: Index of card that is connected to star-hub logical index 8 (mask 0x0100) |
| ... | | read | ... |
| SPC_SYNC_READ_CARDIDX15 | 49015 | read | M2i only: Index of card that is connected to star-hub logical index 15 (mask 0x8000) |
| SPC_SYNC_READ_CABLECON0 | | read | Returns the index of the cable connection that is used for the logical connection 0. The cable connections can be seen printed on the PCB of the star-hub. Use these cable connection information in case that there are hardware failures with the star-hub cabling. |
| ... | 49100 | read | ... |
| SPC_SYNC_READ_CABLECON15 | 49115 | read | Returns the index of the cable connection that is used for the logical connection 15. |

In standard systems where all cards are connected to one star-hub reading the star-hub logical index will simply return the index of the card again. This results in bit 0 of star-hub mask being 1 when doing the setup for card 0, bit 1 in star-hub mask being 1 when setting up card 1 and so on. On such systems it is sufficient to read out the SPC_SYNC_READ_SYNCCOUNT register to check whether the star-hub has found the expected number of cards to be connected.

```
spcm_dwGetParam_i32 (hSync, SPC_SYNC_READ_SYNCCOUNT, &lSyncCount);
for (i = 0; i < lSyncCount; i++)
{
    spcm_dwGetParam_i32 (hSync, SPC_SYNC_READ_CARDIDX0 + i, &lCardIdx);
    printf ("star-hub logical index %d is connected with card %d\n", i, lCardIdx);
}
```

In case of 4 cards in one system and all are connected with the star-hub this program excerpt will return:

```
star-hub logical index 0 is connected with card 0
star-hub logical index 1 is connected with card 1
star-hub logical index 2 is connected with card 2
star-hub logical index 3 is connected with card 3
```

Let's see a more complex example with two Star-Hubs and one independent card in one system. Star-Hub A connects card 2, card 4 and card 5. Star-Hub B connects card 0 and card 3. Card 1 is running completely independent and is not synchronized at all:

| card | Star-Hub connection | card handle | star-hub handle | card index in star-hub | mask for this card in star-hub |
|--------|---------------------|-------------|-----------------|------------------------|--------------------------------|
| card 0 | - | /dev/spcm0 | | 0 (of star-hub B) | 0x0001 |
| card 1 | - | /dev/spcm1 | | | - |
| card 2 | star-hub A | /dev/spcm2 | sync0 | 0 (of star-hub A) | 0x0001 |
| card 3 | star-hub B | /dev/spcm3 | sync1 | 1 (of star-hub B) | 0x0002 |
| card 4 | - | /dev/spcm4 | | 1 (of star-hub A) | 0x0002 |
| card 5 | - | /dev/spcm5 | | 2 (of star-hub A) | 0x0004 |

Now the program has to check both star-hubs:

```
for (j = 0; j < lStarhubCount; j++)
{
    spcm_dwGetParam_i32 (hSync[j], SPC_SYNC_READ_SYNC_COUNT, &lSyncCount);
    for (i = 0; i < lSyncCount; i++)
    {
        spcm_dwGetParam_i32 (hSync[j], SPC_SYNC_READ_CARDIDX0 + i, &lCardIdx);
        printf ("star-hub %c logical index %d is connected with card %d\n", (!j ? 'A' : 'B'), i, lCardIdx);
    }
    printf ("\n");
}
```

In case of the above mentioned cabling this program excerpt will return:

```
star-hub A logical index 0 is connected with card 2
star-hub A logical index 1 is connected with card 4
star-hub A logical index 2 is connected with card 5

star-hub B logical index 0 is connected with card 0
star-hub B logical index 1 is connected with card 3
```

For the following examples we will assume that 4 cards in one system are all connected to one star-hub to keep things easier.

Setup of Synchronization and Clock

The synchronization setup only requires two additional registers to enable the cards that are synchronized in the next run and to select a clock master for the next run.

| Register | Value | Direction | Description |
|---------------------|-------|------------|--|
| SPC_SYNC_ENABLEMASK | 49200 | read/write | Mask of all cards that are enabled for the synchronization |

The enable mask is based on the logical index explained above. It is possible to just select a couple of cards for the synchronization. All other cards then will run independently. Please be sure to always enable the card on which the star-hub is located as this one is a must for the synchronization.

| Register | Value | Direction | Description |
|------------------|-------|------------|--|
| SPC_SYNC_CLKMASK | 49220 | read/write | Mask of the card that is the clock master, only one bit is allowed to be set |

One of the enabled cards must be selected to be the clock master for the complete system. If you intend to run cards with different clock speeds the clock master must have the highest clock as all other cards will derive their clock by dividing the master clock. The locally selected clock source from the clock master is routed throughout the complete synchronized system.

When using external clock please be sure that the external clock stays within all limits of all synchronized cards. Please take special care regarding the minimum and maximum frequencies as offending these may damage components on the cards!



In our example we synchronize all four cards and select card number 2 to be the clock master:

```
spcm_dwSetParam_i32 (hSync, SPC_SYNC_ENABLEMASK, 0x000F); // all 4 cards are masked
spcm_dwSetParam_i32 (hSync, SPC_SYNC_CLKMASK, 0x0004); // card 2 is selected as clock master

// set the clock master to 1 MS/s internal clock
spcm_dwSetParam_i32 (hCard[2], SPC_CLOCKMODE, SPC_CM_INTPLL);
spcm_dwSetParam_i32 (hCard[2], SPC_SAMPLERATE, MEGA(1));

// set all the slaves to run synchronously with 1 MS/s
spcm_dwSetParam_i32 (hCard[0], SPC_SAMPLERATE, MEGA(1));
spcm_dwSetParam_i32 (hCard[1], SPC_SAMPLERATE, MEGA(1));
spcm_dwSetParam_i32 (hCard[3], SPC_SAMPLERATE, MEGA(1));
```

When running the slave cards with a divided clock it is simply necessary to write the desired sampling rate to this card. The synchronization will automatically calculate the matching divider and set up all details internally:

```
// set the clock master to 1 MS/s internal clock
spcm_dwSetParam_i32 (hCard[2], SPC_CLOCKMODE, SPC_CM_INTPLL);
spcm_dwSetParam_i32 (hCard[2], SPC_SAMPLERATE, MEGA(1));

// set all the slaves to run with 100 kS/s only
spcm_dwSetParam_i32 (hCard[0], SPC_SAMPLERATE, KILO(100));
spcm_dwSetParam_i32 (hCard[1], SPC_SAMPLERATE, KILO(100));
spcm_dwSetParam_i32 (hCard[3], SPC_SAMPLERATE, KILO(100));
```



The slaves can only run with a sampling rate divided from the master clock using a divider up to 8190 in steps of two. Values that are not matching will be calculated to the nearest matching value on start of the synchronization.

Setup of Trigger

Setting up the trigger does not need any further steps of synchronization setup. Simply all trigger settings of all cards that have been enabled for synchronization are connected together. All trigger sources and all trigger modes can be used on synchronization as well.

Having positive edge of external trigger on card 0 to be the trigger source for the complete system needs the following setup:

```
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_ORMASK, SPC_TM_MASK_EXT0);
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_EXT0_MODE, SPC_TM_POS);

spcm_dwSetParam_i32 (hCard[1], SPC_TRIG_ORMASK, SPC_TM_NONE);
spcm_dwSetParam_i32 (hCard[2], SPC_TRIG_ORMASK, SPC_TM_NONE);
spcm_dwSetParam_i32 (hCard[3], SPC_TRIG_ORMASK, SPC_TM_NONE);
```

Assuming that the 4 cards are analog data acquisition cards with 4 channels each we can simply setup a synchronous system with all channels of all cards being trigger source. The following setup will show how to set up all trigger events of all channels to be OR connected. If any of the channels will now have a signal above the programmed trigger level the complete system will do an acquisition:

```
for (i = 0; i < lSyncCount; i++)
{
    int32 lAllChannels = (SPC_TM_MASK0_CH0 | SPC_TM_MASK0_CH1 | SPC_TM_MASK0_CH2 | SPC_TM_MASK0_CH3);
    spcm_dwSetParam_i32 (hCard[i], SPC_TRIG_CH_ORMASK0, lAllChannels);
    for (j = 0; j < 2; j++)
    {
        // set all channels to trigger on positive edge crossing trigger level 100
        spcm_dwSetParam_i32 (hCard[i], SPC_TRIG_CH0_MODE + j, SPC_TM_POS);
        spcm_dwSetParam_i32 (hCard[i], SPC_TRIG_CH0_LEVEL0 + j, 100);
    }
}
```

Trigger Delay on synchronized cards



Please note that the trigger delay setting is not used when synchronizing cards. If you need a trigger delay on synchronized systems it is necessary to program posttrigger, segmentsize and memsize to fulfill this task.

Run the synchronized cards

Running of the cards is very simple. The star-hub acts as one big card containing all synchronized cards. All card commands have to be omitted directly to the star-hub which will check the setup, do the synchronization and distribute the commands in the correct order to all synchronized cards. The same card commands can be used that are also possible for single cards:

| Register | Value | Direction | Description |
|---------------------------|-------|------------|---|
| SPC_M2CMD | 100 | write only | Executes a command for the card or data transfer |
| M2CMD_CARD_RESET | 1h | | Performs a hard and software reset of the card as explained further above |
| M2CMD_CARD_WRITESSETUP | 2h | | Writes the current setup to the card without starting the hardware. This command may be useful if changing some internal settings like clock frequency and enabling outputs. |
| M2CMD_CARD_START | 4h | | Starts the card with all selected settings. This command automatically writes all settings to the card if any of the settings has been changed since the last one was written. After card has been started none of the settings can be changed while the card is running. |
| M2CMD_CARD_ENABLETRIGGER | 8h | | The trigger detection is enabled. This command can be either send together with the start command to enable trigger immediately or in a second call after some external hardware has been started. |
| M2CMD_CARD_FORCETRIGGER | 10h | | This command forces a trigger even if none has been detected so far. Sending this command together with the start command is similar to using the software trigger. |
| M2CMD_CARD_DISABLETRIGGER | 20h | | The trigger detection is disabled. All further trigger events are ignored until the trigger detection is again enabled. When starting the card the trigger detection is started disabled. |
| M2CMD_CARD_STOP | 40h | | Stops the current run of the card. If the card is not running this command has no effect. |

All other commands and settings need to be send directly to the card that it refers to.

This example shows the complete setup and synchronization start for our four cards:

```

spcm_dwSetParam_i32 (hSync, SPC_SYNC_ENABLEMASK, 0x000F); // all 4 cards are masked
spcm_dwSetParam_i32 (hSync, SPC_SYNC_CLKMASK, 0x0004); // card 2 is selected as clock master

// to keep it easy we set all card to the same clock and disable trigger
for (i = 0; i < 4; i++)
{
    spcm_dwSetParam_i32 (hCard[i], SPC_CLOCKMODE, SPC_CM_INTPLL);
    spcm_dwSetParam_i32 (hCard[i], SPC_SAMPLERATE, MEGA(1));
    spcm_dwSetParam_i32 (hCard[i], SPC_TRIG_ORMASK, SPC_TM_NONE);
}

// card 0 is trigger master and waits for external positive edge
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_ORMASK, SPC_TM_MASK_EXT0);
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_EXT0_MODE, SPC_TM_POS);

// start the cards and wait for them a maximum of 1 second to be ready
spcm_dwSetParam_i32 (hSync, SPC_TIMEOUT, 1000);
spcm_dwSetParam_i32 (hSync, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER);
if (spcm_dwSetParam_i32 (hSync, SPC_M2CMD, M2CMD_CARD_WAITREADY) == ERR_TIMEOUT)
    printf ("Timeout occurred - no trigger received within time\n")

```

Using one of the wait commands for the Star-Hub will return as soon as the card holding the Star-Hub has reached this state. However when synchronizing cards with different sampling rates or different memory sizes there may be other cards that still haven't reached this level.



Error Handling

The Star-Hub error handling is similar to the card error handling and uses the function `spcm_dwGetErrorInfo_i32`. Please see the example in the card error handling chapter to see how the error handling is done.

Excluding cards from trigger synchronization

When synchronizing cards with the Star-Hub option it is possible and most likely to synchronize clock and trigger. For some applications it can be useful to synchronize the sampling clock only for one or multiple cards. This can be useful, when acquisition cards are synchronized together with one or multiple generation cards. When these cards are used to feed a DUT (device under test) with signals and the result/reaction is to be recorded, it is often necessary that the generation is in progress before the acquisition can begin.

For such applications it is possible to exclude one or multiple of the synchronized cards from receiving the Star-Hub trigger:

| Register | Value | Direction | Description |
|--------------------------|-------|------------|--|
| SPC_SYNC_NOTRIGSYNCKMASK | 49210 | read/write | Bitmask that defines which of the connected cards is using its own trigger engine as trigger source instead of using the synchronization trigger. If set to 1, a card only uses the synchronization clock, when set to 0 the card uses also the synchronization trigger. By default this mask is set to 0 for all cards. |

The following example shows, how to exclude certain cards from receiving the synchronization trigger:

```

spcm_dwSetParam_i32 (hSync, SPC_SYNC_NOTRIGSYNCKMASK, 0x00000005); // Exclude cards 0 and 2 from sync trigger

```

By default all cards that are enabled for synchronization are set to take part in clock and trigger synchronization.



SH-Direct: using the Star-Hub clock directly without synchronization

Starting with driver version 1.26 build 1754 it is possible to use the clock from the Star-Hub just like an external clock and running one or more cards totally independent of the synchronized card. The mode is by example useful if one has one or more output cards that run continuously in a loop and are synchronized with Star-Hub and in addition to this one or more acquisition cards should make multiple acquisitions but using the same clock.

For all M2i cards it is also possible to run the „slave“ cards with a divided clock. Therefore please program a desired divided sampling rate in the `SPC_SAMPLERATE` register (example: running the Star-Hub card with 10 MS/s and the independent cards with 1 MS/s). The sampling rate is automatically adjusted by the driver to the next matching value.

What is necessary?

- All cards need to be connected to the Star-Hub
- The card(s) that should run independently can not hold the Star-Hub
- The card(s) with the Star-Hub must be setup to synchronization even if it's only one card
- The synchronized card(s) have to be started prior to the card(s) that run with the direct Star-Hub clock

Setup

At first all cards that should run synchronized with the Star-Hub are set-up exactly as explained before. The card(s) that should run independently and use the Star-Hub clock need to use the following clock mode:

| Register | Value | Direction | Description |
|-----------------|-------|------------|---|
| SPC_CLOCKMODE | 20200 | read/write | Defines the used clock mode |
| SPC_CM_SHDIRECT | 128 | | Uses the clock from the Star-Hub as if this was an external clock |



When using SH_Direct mode, the register call to SPC_CLOCKMODE enabling this mode must be written before initiating a card start command to any of the connected cards. Also it is not allowed to be modified later in the programming sequence to prevent the driver from calculating wrong sample rates.

Example

In this example we have one generator card with the Star-Hub mounted running in a continuous loop and one acquisition card running independently using the SH-Direct clock.

```
// setup of the generator card
spcm_dwSetParam_i32 (hCard[0], SPC_CARDMODE, SPC_REC_STD_SINGLE);
spcm_dwSetParam_i32 (hCard[0], SPC_LOOPS, 0); // infinite data replay
spcm_dwSetParam_i32 (hCard[0], SPC_CLOCKMODE, SPC_CM_INTPLL);
spcm_dwSetParam_i32 (hCard[0], SPC_SAMPLERATE, MEGA(1));
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_ORMASK, SPC_TM_SOFTWARE);

spcm_dwSetParam_i32 (hSync, SPC_SYNC_ENABLEMASK, 0x0001); // card 0 is the generator card
spcm_dwSetParam_i32 (hSync, SPC_SYNC_CLKMASK, 0x0001); // only for M2i/M3i cards: set ClkMask

// Setup of the acquisition card (waiting for external trigger)
spcm_dwSetParam_i32 (hCard[1], SPC_CARDMODE, SPC_REC_STD_SINGLE);
spcm_dwSetParam_i32 (hCard[1], SPC_CLOCKMODE, SPC_CM_SHDIRECT);
spcm_dwSetParam_i32 (hCard[1], SPC_SAMPLERATE, MEGA(1));
spcm_dwSetParam_i32 (hCard[1], SPC_TRIG_ORMASK, SPC_TMASK_EXT0);
spcm_dwSetParam_i32 (hCard[1], SPC_TRIG_EXT0_MODE, SPC_TM_POS);

// now start the generator card (sync!) first and then the acquisition card
spcm_dwSetParam_i32 (hSync, SPC_TIMEOUT, 1000);
spcm_dwSetParam_i32 (hSync, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER);

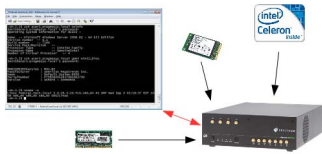
// start first acquisition
spcm_dwSetParam_i32 (hCard[1], SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER | M2CMD_CARD_WAITREADY);

// process data

// start next acquisition
spcm_dwSetParam_i32 (hCard[1], SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER | M2CMD_CARD_WAITREADY);

// process data
```

Option Embedded Server



The option turns the digitizerNETBOX/generatorNETBOX in a powerful PC that allows to run own programs on a small and remote data acquisition system. The digitizerNETBOX/generatorNETBOX is enhanced by more memory, a powerful CPU, a freely accessible internal SSD and a remote software development access method.

The digitizerNETBOX/generatorNETBOX can either run connected to LAN or it can run totally independent, storing/replaying data to/from the internal SSD. The original digitizerNETBOX/generatorNETBOX remote instrument functionality is still 100% available. Running the embedded server option it is possible to pre-calculate results based on the acquired data, pre-calculate generator data, store acquisitions locally and to transfer just the required data or results parts in a client-server based software structure. A different example for the digitizerNETBOX embedded server is surveillance/logger application which can run totally independent for days and send notification emails only over LAN or offloads stored data as soon as it's connected again.

Access to the embedded server is done through a standard text based Linux shell based on the ssh secure shell.

Accessing the Embedded Server

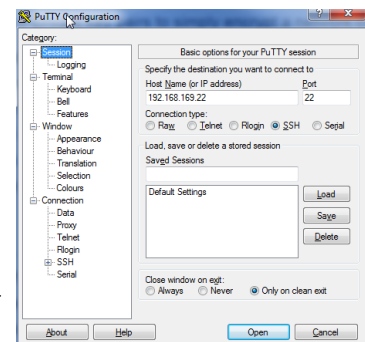
Access to the Embedded Server is only available if that particular option is installed. As this option is a combination of hardware features and software access a later update with that options needs some factory work. As long as no one uses the embedded server connection and no programs are placed in the autostart folder, the digitizerNETBOX/generatorNETBOX will behave just like a standard digitizerNETBOX or generatorNETBOX and can be used as a remote LXI device.

SSH Connection

The embedded server is accessed using a standard SSH (secure shell) connection. Please install a SSH client on your working system and connect to the digitizerNETBOX/generatorNETBOX IP address (found in the control center) using port 22. Any SSH compatible client will do the job.

An example for a Windows based SSH client is PuTTY which shown on the right.

You may enter the login parameters here also and save a session for faster access.



Login

Login is done using a separate user space with some restricted access to the system. A login as root isn't possible due to security and system stability reasons. Please use the following default user settings:

| | |
|----------|----------|
| Username | embedded |
| Password | embedded |

After first login you should immediately change the password to a personal one using the command „passwd“. Please keep in mind that it is possible to reset the password using the web interface of the digitizerNETBOX/generatorNETBOX. To fully secure access to the digitizerNETBOX/generatorNETBOX it is necessary to give a password to the web interface setup.

Mounting network folders

Network folders can be mounted and unmounted using the standard Linux mount/unmount command. Please note that you need root rights to do a mounting/unmounting of a network folder. You get root rights for this command by using the „sudo“ command which gives you root rights for some dedicated commands.

Mounting a test folder from a Windows server with active directory may look like this:

```
cd
mkdir tmp
sudo mount -t cifs //192.168.169.123/tmp tmp -o user=YourUsername,domain=YourDomain,password=YourPassword
```

You may unmount the folder again with:

```
sudo umount tmp
```

Access to the /etc/fstab table is not available.

Access to NTP (Network Time Protocol)

You access NTP with (requires firmware version V34 or newer):

```
sudo /usr/sbin/sntp -s de.pool.ntp.org
```

Editors

As a default there are two standard editors installed on the system:

- GNU nano
- vim

Installing packages

Any matching RPM modules can be installed to the system using root rights and the rpm packet manager:

```
sudo rpm -ihv mypackage.rpm
```

Programming

For general information on programming of the internal Spectrum cards please have a look through the complete manual. Programming the cards inside the Embedded Server is 100% similar to programming of the cards of any other host system.

Accessing the cards

Depending on the type of digitizerNETBOX/generatorNETBOX that you have there might be one or two cards installed in the system. If two cards are installed then there is also a Star-Hub installed. Please refer to the chapter „Introduction - Internal Digitizer Modules“ or „Introduction - Internal Generator Modules“ respectively to see how many digitizers are installed in your digitizerNETBOX/generatorNETBOX and whether a starhub is present or not.

As an example, for a DN2.491-16 you will find the information that you have 2 cards M2i.4912-exp and one Star-Hub installed. Accessing these components is done with the following handles:

```
1st card: „/dev/spcm0“  
2nd card: „/dev/spcm1“  
Star-Hub: „sync0“
```

Examples

The home folder „examples-cpp“ contains all Linux based examples that are currently available. Please use and modify these examples for your own programs as you like.

The sub-folder „netbox_embedded_server“ contains some additional examples for using the embedded server features. The following examples are available:

Client/Server

A simple example showing the communication over TCP/IP between the digitizerNETBOX/generatorNETBOX (server) and the host PC (client). The server is running an acquisition in FIFO Multiple Recording mode and calculates minimum and maximum value from every block. These results are then sent to the client program for further processing. In our example the results are simply printed to console.

Please change the TCP/IP settings inside the client program to your local settings to get it running.

simple_rec_fifo_mail

This example will run a FIFO multi acquisition and send a mail for each acquired segment as a SBenchó - compatible binary file and text header for that file. The example can easily be modified and used as a base for a monitoring application.

Please be sure to change the email settings to a server and port settings that is available on your system.

Please keep in mind that a high trigger frequency will flood your mailserver with emails which might trigger some spam detection mechanisms. You should therefore use this example only with single trigger events.

dbus

This is an example on how to connect to the digitizerNETBOX/generatorNETBOX internal signals (currently only LAN state).

Autostart

All executable files in the autostart folder will automatically be executed on system start-up. Please place any program in here that should run automatically after powering the system. It is requested to use the „fork()“ command to continue a program or a service in the background if multiple commands should be running.

The autoastart feature can be turned off using the web interface in case that some failing program prevents the machine from starting.

LEDs

The digitizerNETBOX/generatorNETBOX LEDs can be accessed using the special system command „netbox_led_client“. Calling this system command from inside a C++ program is shown in the client-server example.

The following commands will manipulate the Arm/Trig and Connected LEDs on the frontplate:

```
system ("netbox_led_client armgreen=1");  
system ("netbox_led_client armgreen=0");  
system ("netbox_led_client connngreen=1");  
system ("netbox_led_client connngreen=0");
```

Appendix

Error Codes

The following error codes could occur when a driver function has been called. Please check carefully the allowed setup for the register and change the settings to run the program.

| error name | value (hex) | value (dec.) | error description |
|----------------------|-------------|--------------|--|
| ERR_OK | 0h | 0 | Execution OK, no error. |
| ERR_INIT | 1h | 1 | An error occurred when initializing the given card. Either the card has already been opened by another process or an hardware error occurred. |
| ERR_TYP | 3h | 3 | Initialization only: The type of board is unknown. This is a critical error. Please check whether the board is correctly plugged in the slot and whether you have the latest driver version. |
| ERR_FNCNOTSUPPORTED | 4h | 4 | This function is not supported by the hardware version. |
| ERR_BRDREMAP | 5h | 5 | The board index re map table in the registry is wrong. Either delete this table or check it carefully for double values. |
| ERR_KERNELVERSION | 6h | 6 | The version of the kernel driver is not matching the version of the DLL. Please do a complete re-installation of the hardware driver. This error normally only occurs if someone copies the driver library and the kernel driver manually. |
| ERR_HWRVRVERSION | 7h | 7 | The hardware needs a newer driver version to run properly. Please install the driver that was delivered together with the card. |
| ERR_ADRRANGE | 8h | 8 | One of the address ranges is disabled (fatal error), can only occur under Linux. |
| ERR_INVALIDHANDLE | 9h | 9 | The used handle is not valid. |
| ERR_BOARDNOTFOUND | Ah | 10 | A card with the given name has not been found. |
| ERR_BOARDINUSE | Bh | 11 | A card with given name is already in use by another application. |
| ERR_EXPHW64BITADR | Ch | 12 | Express hardware version not able to handle 64 bit addressing -> update needed. |
| ERR_FWVERSION | Dh | 13 | Firmware versions of synchronized cards or for this driver do not match -> update needed. |
| ERR_SYNCPROTOCOL | Eh | 14 | Synchronization protocol versions of synchronized cards do not match -> update needed |
| ERR_LASTERR | 10h | 16 | Old error waiting to be read. Please read the full error information before proceeding. The driver is locked until the error information has been read. |
| ERR_BOARDINUSE | 11h | 17 | Board is already used by another application. It is not possible to use one hardware from two different programs at the same time. |
| ERR_ABORT | 20h | 32 | Abort of wait function. This return value just tells that the function has been aborted from another thread. The driver library is not locked if this error occurs. |
| ERR_BOARDLOCKED | 30h | 48 | The card is already in access and therefore locked by another process. It is not possible to access one card through multiple processes. Only one process can access a specific card at the time. |
| ERR_DEVICE_MAPPING | 32h | 50 | The device is mapped to an invalid device. The device mapping can be accessed via the Control Center. |
| ERR_NETWORKSETUP | 40h | 64 | The network setup of a digitizerNETBOX has failed. |
| ERR_NETWORKTRANSFER | 41h | 65 | The network data transfer from/to a digitizerNETBOX has failed. |
| ERR_FWPOWERCYCLE | 42h | 66 | Power cycle (PC off/on) is needed to update the card's firmware (a simple OS reboot is not sufficient !) |
| ERR_NETWORKTIMEOUT | 43h | 67 | A network timeout has occurred. |
| ERR_BUFFERSIZE | 44h | 68 | The buffer size is not sufficient (too small). |
| ERR_RESTRICTEDACCESS | 45h | 69 | The access to the card has been intentionally restricted. |
| ERR_INVALIDPARAM | 46h | 70 | An invalid parameter has been used for a certain function. |
| ERR_TEMPERATURE | 47h | 71 | The temperature of at least one of the card's sensors measures a temperature, that is too high for the hardware. |
| ERR_REG | 100h | 256 | The register is not valid for this type of board. |
| ERR_VALUE | 101h | 257 | The value for this register is not in a valid range. The allowed values and ranges are listed in the board specific documentation. |
| ERR_FEATURE | 102h | 258 | Feature (option) is not installed on this board. It's not possible to access this feature if it's not installed. |
| ERR_SEQUENCE | 103h | 259 | Command sequence is not allowed. Please check the manual carefully to see which command sequences are possible. |
| ERR_READABORT | 104h | 260 | Data read is not allowed after aborting the data acquisition. |
| ERR_NOACCESS | 105h | 261 | Access to this register is denied. This register is not accessible for users. |
| ERR_TIMEOUT | 107h | 263 | A timeout occurred while waiting for an interrupt. This error does not lock the driver. |
| ERR_CALTYPE | 108h | 264 | The access to the register is only allowed with one 64 bit access but not with the multiplexed 32 bit (high and low double word) version. |
| ERR_EXCEEDSINT32 | 109h | 265 | The return value is int32 but the software register exceeds the 32 bit integer range. Use double int32 or int64 accesses instead, to get correct return values. |
| ERR_NOWRITEALLOWED | 10Ah | 266 | The register that should be written is a read-only register. No write accesses are allowed. |
| ERR_SETUP | 10Bh | 267 | The programmed setup for the card is not valid. The error register will show you which setting generates the error message. This error is returned if the card is started or the setup is written. |
| ERR_CLOCKNOTLOCKED | 10Ch | 268 | Synchronization to external clock failed: no signal connected or signal not stable. Please check external clock or try to use a different sampling clock to make the PLL locking easier. |
| ERR_MEMINIT | 10Dh | 269 | On-board memory initialization error. Power cycle the PC and try another PCIe slot (if possible). In case that the error persists, please contact Spectrum support for further assistance. |
| ERR_POWERSUPPLY | 10Eh | 270 | On-board power supply error. Power cycle the PC and try another PCIe slot (if possible). In case that the error persists, please contact Spectrum support for further assistance. |
| ERR_ADCCOMMUNICATION | 10Fh | 271 | Communication with ADC failed. Power cycle the PC and try another PCIe slot (if possible). In case that the error persists, please contact Spectrum support for further assistance. |
| ERR_CHANNEL | 110h | 272 | The channel number may not be accessed on the board: Either it is not a valid channel number or the channel is not accessible due to the current setup (e.g. Only channel 0 is accessible in interface mode) |
| ERR_NOTIFYSIZE | 111h | 273 | The notify size of the last spcm_dwDeflTransfer call is not valid. The notify size must be a multiple of the page size of 4096. For data transfer it may also be a fraction of 4k in the range of 16, 32, 64, 128, 256, 512, 1k or 2k. For ABA and timestamp the notify size can be 2k as a minimum. |
| ERR_RUNNING | 120h | 288 | The board is still running, this function is not available now or this register is not accessible now. |
| ERR_ADJUST | 130h | 304 | Automatic card calibration has reported an error. Please check the card inputs. |
| ERR_PRETRIGGERLEN | 140h | 320 | The calculated pretrigger size (resulting from the user defined posttrigger values) exceeds the allowed limit. |
| ERR_DIRMISMATCH | 141h | 321 | The direction of card and memory transfer mismatch. In normal operation mode it is not possible to transfer data from PC memory to card if the card is an acquisition card nor it is possible to transfer data from card to PC memory if the card is a generation card. |
| ERR_POSTEXCDSEGMENT | 142h | 322 | The posttrigger value exceeds the programmed segment size in multiple recording/ABA mode. A delay of the multiple recording segments is only possible by using the delay trigger! |
| ERR_SEGMENTINMEM | 143h | 323 | Memsizes is not a multiple of segment size when using Multiple Recording/Replay or ABA mode. The programmed segment size must match the programmed memory size. |
| ERR_MULTIPLEPW | 144h | 324 | Multiple pulsewidth counters used but card only supports one at the time. |

| error name | value (hex) | value (dec.) | error description |
|---------------------|-------------|--------------|---|
| ERR_NOCHANNELPWOR | 145h | 325 | The channel pulsewidth on this card can't be used together with the OR conjunction. Please use the AND conjunction of the channel trigger sources. |
| ERR_ANDORMASKOVRLAP | 146h | 326 | Trigger AND mask and OR mask overlap in at least one channel. Each trigger source can only be used either in the AND mask or in the OR mask, no source can be used for both. |
| ERR_ANDMASKEDGE | 147h | 327 | One channel is activated for trigger detection in the AND mask but has been programmed to a trigger mode using an edge trigger. The AND mask can only work with level trigger modes. |
| ERR_ORMASKLEVEL | 148h | 328 | One channel is activated for trigger detection in the OR mask but has been programmed to a trigger mode using a level trigger. The OR mask can only work together with edge trigger modes. |
| ERR_EDGEPERMOD | 149h | 329 | This card is only capable to have one programmed trigger edge for each module that is installed. It is not possible to mix different trigger edges on one module. |
| ERR_DOLEVELMINDIFF | 14Ah | 330 | The minimum difference between low output level and high output level is not reached. |
| ERR_STARHUBENABLE | 14Bh | 331 | The card holding the star-hub must be enabled when doing synchronization. |
| ERR_PATPWSMALLEDGE | 14Ch | 332 | Combination of pattern with pulsewidth smaller and edge is not allowed. |
| ERR_PCICHECKSUM | 203h | 515 | The check sum of the card information has failed. This could be a critical hardware failure. Restart the system and check the connection of the card in the slot. |
| ERR_MEMALLOC | 205h | 517 | Internal memory allocation failed. Please restart the system and be sure that there is enough free memory. |
| ERR_EEPROMLOAD | 206h | 518 | Timeout occurred while loading information from the on-board EEPROM. This could be a critical hardware failure. Please restart the system and check the PCI connector. |
| ERR_CARDNOSUPPORT | 207h | 519 | The card that has been found in the system seems to be a valid Spectrum card of a type that is supported by the driver but the driver did not find this special type internally. Please get the latest driver from www.spectrum-instrumentation.com and install this one. |
| ERR_CONFIGACCESS | 208h | 520 | Internal error occurred during config writes or reads. Please contact Spectrum support for further assistance. |
| ERR_FIFOHWVERRUN | 301h | 769 | Hardware buffer overrun in FIFO mode. The complete on-board memory has been filled with data and data wasn't transferred fast enough to PC memory. If acquisition speed is smaller than the theoretical bus transfer speed please check the application buffer and try to improve the handling of this one. |
| ERR_FIFOFINISHED | 302h | 770 | FIFO transfer has been finished, programmed data length has been transferred completely. |
| ERR_TIMESTAMP_SYNC | 310h | 784 | Synchronization to timestamp reference clock failed. Please check the connection and the signal levels of the reference clock input. |
| ERR_STARHUB | 320h | 800 | The auto routing function of the Star-Hub initialization has failed. Please check whether all cables are mounted correctly. |
| ERR_INTERNAL_ERROR | FFFFh | 65535 | Internal hardware error detected. Please check for driver and firmware update of the card. |

Spectrum Knowledge Base

You will also find additional help and information in our knowledge base available on our website:

<https://spectrum-instrumentation.com/en/knowledge-base-overview>

Details on M2i cards clock and trigger I/O section

The SMB clock and trigger I/O connectors of the M2i cards from Spectrum are protected against over voltage conditions.

For this purpose clamping diodes of the types 1N4148 are used. Both I/O lines are internally clamped to signal ground and to a specific clamping voltage named V_{t*} for the trigger and V_{c*} for the clock line. So when connecting sources with a higher level than the clamping voltage plus the forward voltage of typically 0.6...0.7 V will be the resulting maximum high-level level.

The maximum forward current limit for the used 1N4148 diodes is 100 mA.

When connecting a high performance clock or trigger source with the card's clock or trigger inputs, with logic high levels above the clamping voltage please make sure to not exceed the current limit of the clamping diodes.

This can most easily be ensured, when using the card's 50 Ohm termination and a series resistor of 33 Ohm up to 47 Ohm on the clock or trigger source.

To avoid floating levels with unconnected inputs, a pull up resistor of 4.7 kOhm to 3,3V is used on each line.

The following table shows the values for the both clamping voltages V_{t*} and V_{c*} :

| Card series | Base Hardware Version | V_{t*} | V_{c*} | Trigger input 5.0 V tolerant | Clock input 5.0 V tolerant |
|--------------|-----------------------|----------|----------|------------------------------|----------------------------|
| M2i.xxxx | ≤ V20 | 3.3 V | 3.3 V | no | no |
| M2i.xxxx | > V20 | 5.0 V | 3.3 V | yes | no |
| M2i.xxxx-exp | > V20 | 5.0 V | 3.3 V | yes | no |



For details on how to read out the base hardware version from the driver or where to find that information on the cards type plate please look up the relating sections in this manual.

