M2p.75xx-x4

Fast digital I/O board
with TTL levels
for PCI Express bus

Hardware Manual
Software Driver Manual

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(c) Spectrum GmbH
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Introduction

Preface

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

In addition, this guide takes you through the process of installing your board 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 board and the related driver. The reader of this manual will be able to integrate the board in any PC system with one of the supported bus and operating systems.

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.

Overview

M2p cards for PCI Express (PCIe)

The M2p generation is the fast streaming general purpose platform from Spectrum. The ½ length PCIe cards are available in different speed grades and resolutions with best performance.

The cards have been optimized for fast data transfer and allow to read data for online analysis or offline storage with more than 700 MB/s using the PCI Express x4 Gen 1 bus interface. Mechanically the card family needs x4, x8 or x16 lane PCI Express connectors with any PCI Express generation. Electrically the card can handle smaller number of PCI Express lanes with reduced transfer speed.

When using high sampling rates the 1 GByte standard on-board memory (512 MSamples for cards with 16 bit resolution) is sufficient to acquire up to several seconds of high-speed data. The M2p cards are carefully designed and offer an optimized clock section, a wide range of trigger possibilities, new and improved features, easy usability and programming as well as an outstanding software support.

The PCI Express bus was first introduced in 2004. In today’s standard PC there are usually two to six slots available for instrumentation boards. Special industrial PCs offer up to a maximum of 16 slots. The PCI Express Gen1 standard theoretically delivers up to 4 GByte/s data transfer rate per x16 slot. The Spectrum M2p boards are available as PCI Express x4 (four lane) Gen1, 1/2 length card.

Within this document the name M2p or M2p.xxxx is used as a synonym for the PCI Express version with the full name of M2p.xxxx-x4 to enhance readability. The exact order information can be found in the related passage in this manual.

General Information

The M2p.75xx series of fast digital I/O boards for PCI Express allow for acquisition/generation of data on up to 32 channels with a maximum sampling/output rate of 125 MS/s. All digital32 I/O lines can be programmed for either input or output.

The multi-purpose lines allow for up to 4 logic triggers and can also be used for status output (run, arm, trigger etc.), as marker outputs and also as asynchronous control for external equipment.

The 1 GByte on-board memory can be used as waveform storage for replay or acquisition buffer or as a FIFO buffer continuously streaming data via the PCIe interface. It can completely be used by the current active channels. Due to the high transfer speed of the used PCIe x4 interface, data can continuously be streamed over the PCIe bus from/to the PC memory or from/to hard disk, even when having all 32 channels active.

Several boards of the M2p.xxxx series may be connected together by the internal standard synchronisation bus to work with the same time base.

Application examples: Recording/Replay of digital data, test pattern generation, chip test, system test, pattern recognition, laboratory, development.
**Different models of the M2p.75xx series**

The following overview shows the different available models of the M2p.75xx series. They differ in the number of available channels and maximum update rates. You can also see the model dependent location of the input connectors.

- **M2p.7515-x4**

![M2p.7515-x4 Image]

**Additional options**

**Star-Hub**

The star hub module allows the synchronization of either up to six or up to sixteen M2p cards. It is even possible to synchronize cards of different families of M2p series cards with each other.

Two different mechanical versions of the star-hub module allowing the synchronization of up to 16 cards are available. A version that is mounted on top of the carrier card as a piggy-back module (option SH6tm or SH16tm) extending the width of the card to two slots.

The second version (option SH6ex or SH16ex) is mounted behind the card and extends the M2p base card to a 3/4 length PCI Express card. Therefore it requires the availability of a 3/4 length slot in the system but does not need the width of an additional slot.

The module acts as a star hub for clock and trigger signals. Each board is connected with a small cable of the same length, even the master board. That minimizes the clock skew between the different cards. The picture shows the extension module mounted on the base board schematically without any cables to achieve a better visibility.

The carrier card acts as the clock master and the same or any other card can be the trigger master. All trigger modes that are available on a single card are also available if the synchronization star-hub is used.

The cable connection of the boards is automatically recognized and checked by the driver when initializing the star-hub module. So no care must be taken on how to cable the cards. The star-hub module itself is handled as an additional device just like any other card and the programming consists of only a few additional commands.
The Spectrum type plate

The Spectrum type plate, which consists of the following components, can be found on all of our boards. 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 board type, consisting of the two letters describing the bus (in this case M2p.xxxx-x4 for the PCI Express x4 bus) and the model number.

2. The size of the on-board installed memory in MSample or GSample. In this example there are 512 MS (1 GByte = 1024 MByte) installed.

3. The serial number of your Spectrum board. Every board has a unique serial number.

4. A list of the installed options. A complete list of all available options is shown in the order information. In this example no additional options are installed.

5. The base card version, consisting of the printed circuit board (PCB) version, the hardware version and the firmware version.

6. The version of the analog/digital front-end module, consisting of the printed circuit board (PCB) version, the hardware version and the firmware version (if available). If no programmable device is located on the module, the firmware field is left empty.

7. The date of production, consisting of the calendar week and the year.

8. The version of the extension module (such as a star-hub) if one is installed, consisting of the printed circuit board (PCB) version, the hardware version and the firmware version. If no extension module is installed this part is left empty.

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 Diagrams**

**M2p.75xx Block Diagram**
Technical Data

Power Up
Data channels direction after power up: input (high impedance)
Clock and trigger output after power up: disabled

Digital Data Inputs
Direction: software programmable
Acquisition channel selection: software programmable
Sampling clock edge: rising or falling edge (see clock section for details)
Logic type: software programmable
Input transition rise or fall rate: \(\leq 10\,\text{ns/V}\)
Input Impedance: software programmable
110 \(\Omega\) / 50 \(\Omega\) || 15 \(\text{pF}\)
110 \(\Omega\) termination voltage:
Low: \(\leq 0.8\,\text{V}\)
High: \(\geq 2.0\,\text{V}\)
Absolute maximum Input levels:
Low: \(\geq -0.5\,\text{V}\)
High: \(\leq 7.0\,\text{V}\)
Input current sink: no termination
Low: \(-5.0\,\mu\text{A}\) (0.0 \(\text{V}\))
High: \(+5.0\,\mu\text{A}\) (3.3 \(\text{V}\)), \(+20.0\,\mu\text{A}\) (5.0 \(\text{V}\))

Direction: software programmable
Replay channel selection: software programmable
Update clock edge: rising or falling edge (see clock section for details)
Logic type: 3.3V LVTTL
Typical output levels:
Low: 0.2 \(\text{V}\)
High: 2.8 \(\text{V}\)
Output max current load:
Low: 64 mA
High: -32 mA
Output levels at max load:
Low: \(< 0.5\,\text{V}\)
High: \(> 2.0\,\text{V}\)
Output Impedance (typical): ca. 7 \(\Omega\)
Stop level: Tristate, Low, High, Hold Last, Custom Value

Data format:
Std., Startreset: 64 bit counter, increments with sample clock (reset manually or on start)
RefClock: 40 bit lower counter (increments with sample clock, reset with RefClock)

Available trigger modes: External, Software, Or/And, Delay
Trigger edge: Rising edge, falling edge or both edges
Trigger pulse width: 0 to [4G - 1] samples in steps of 1 sample
Trigger delay: 0 to [4G - 1] samples in steps of 1 samples
Trigger holdoff (for Multi, ABA, Gate): 0 to [4G - 1] samples in steps of 1 samples
Pretrigger at Multi, ABA, Gate, FIFO: 8 up to [32 kSamples / number of active channels] in steps of 8
Posttrigger: 8 up to [8G - 4] samples in steps of 8 (defining pretrigger in standard scope mode)
Memory depth: 16 up to [installed memory / number of active channels] samples in steps of 8
Multiple Recording/ABA segment size: 8 up to [installed memory / number of active channels] samples in steps of 8
Internal/External trigger accuracy: 1 sample (sampled with programmed clock edge, see clock section for details)
Timetag mode: Standard, Startreset, external reference clock on X1 (e.g. PPS from GPS, IRIG-B)
Data format: Std., Startreset: 64 bit counter, increments with sample clock (reset manually or on start)
Extra data: none, acquisition of X0/X1/X2/X3 inputs at trigger time, trigger source (for OR trigger)
Size per stamp: 128 bit = 16 bytes

External trigger sources:
X0, X1, X2, X3
External trigger logic type: 3.3V LVTTL (5V TTL tolerant)
Input transition rise or fall rate: \(\leq 10\,\text{ns/V}\)
110 \(\Omega\) termination voltage: 2.25 \(\text{V}\)
Standard input levels:
Low: \(\leq 0.8\,\text{V}\)
High: \(\geq 2.0\,\text{V}\)
Absolute maximum Input levels:
Low: \(\geq -0.5\,\text{V}\)
High: \(\leq 7.0\,\text{V}\)
Input current sink: no termination
Low: \(-5.0\,\mu\text{A}\) (0.0 \(\text{V}\))
High: \(+5.0\,\mu\text{A}\) (3.3 \(\text{V}\)), \(+20.0\,\mu\text{A}\) (5.0 \(\text{V}\))
Minimum external trigger pulse width: \(\geq 2\) samples
Multi Purpose I/O lines

Number of multi purpose input/output lines: four, named X0, X1, X2, X3

**Multi Purpose line**
- Input: available signal types: software programmable
- Input: logic type: Asynchronous Digital-In, Timestamp Reference Clock, Logic trigger
- Input: transition rate: 3.3V (LVTTL), 5V TTL tolerant
- Input: impedance: ≤ 10 nS/V
- Input: standard levels: Low: ≤ 0.8 V, High: > 2.0 V
- Input: maximum levels: Low: > -0.5 V, High: ≤ 7.0 V
- Input: current sink: no termination
- Output: available signal types: software programmable
- Output: logic type: 3.3V (LVTTL)
- Output: typical levels: High: 2.8 V
- Output: maximum bandwidth: 125 MHz
- Output: levels at max load: Low: < 0.5 V, High: > 2.0 V
- Output: update rate: software programmable
- Clock: Modes: software programmable
- Clock: Active clock edge: rising or falling edge
- Clock: Internal clock range: 1 kS/s to 125 MS/s
- Clock: Accuracy after warm-up: ≤ ±1.0 ppm (at time of calibration in production)
- Clock: Aging: ≤ ±0.5 ppm / year
- Clock: PLL clock setup granularity: 1 Hz
- Clock: External reference clock range: 128 kHz up to 125 MHz
- Clock: Direct external clock to internal clock delay: 5 ns
- Clock: Direct external clock range: DC to 125 MHz
- Clock: Direct clock minimum LOW/HIGH time: 1 ns
- Clock: Clock type: 3.3V (LVTTL)
- Clock: Transition rate: ≤ 10 nS/V
- Clock: Termination: 50 Ω
- Clock: Levels at max load: Low: < 0.5 V, High: > 2.0 V
- Clock: Impedance: ca. 7 Ω
- Clock: Clock multiplier: N being a multiplier [1, 2, 3, 4, 5, ... Max] of the card with the currently slowest sampling clock.

Connectors

Digital Inputs/Outputs
- 40 pole half pitch (Hirose FX2 series)
- Connector on card: Hirose FX2B-40PA-1.27SHL
- Flat ribbon cable connector: Hirose FX2B-40SA-1.27SHL

Environmental and Physical Details

- **Dimension (Single Card)**
  - Type: M2p.59xx, M2p.75xx series
  - Weight: maximum 215 g
  - Dimensions: 8 channel AWG or High power AWG
- **Dimension (all other single boards)**
  - Weight: M2p.65x8, M2p.65x11, M2p.65x6 series: maximum 195 g
- **Dimension (with SH6ex or SH16ex installed)**
  - Weight: M2p.65x3, M2p.65x8 series: maximum 305 g
- **Dimension (with DigSMB or DigFX2 installed)**
  - Weight: (Star-Hub Option SH6ex, SH16tm) including 6 sync cables: 65 g
  - Weight: (Star-Hub Option SH16ex, SH16tm) including 16 sync cables: 90 g
- **Weight (Option DigSMB)**
  - Maximum: 50 g
- **Weight (Option DigFX2)**
  - Maximum: 60 g
- **Operating temperature**
  - Range: 0 °C to 40 °C
- **Storage temperature**
  - Range: -10 °C to 70 °C
- **Humidity**
  - Range: 10% to 90%
- **Volume weight of packing**
  - 1 or 2 cards: 4 kgs

Dimension of packing: 470 mm x 250 mm x 130 cm

Volume of packing: 1 or 2 cards: 4 kgs
PCI Express specific details

- **PCIe slot type**: x4, Generation 1
- **PCIe slot compatibility (physical)**: x4, x8, x16
- **PCIe slot compatibility (electrical)**: x1, x2, x4, x8, x16 with Generation 1, Generation 2, Generation 3, Generation 4
- **Sustained streaming mode**
  - (Card-to-System: M2p.59xx or M2p.75xx)
  - Sustained streaming mode
  - (System-to-Card: M2p.65xx or M2p.75xx)

**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

**Power Consumption**

<table>
<thead>
<tr>
<th></th>
<th>3.3V</th>
<th>12V</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2p.75xx</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**MTBF**

- **MTBF**: TBD hours

**Clock to data timing**

The setup and hold times as well as any delays relate to the output clock. Please be sure to meet this timing constraints if feeding in external clock. All timings shown here are in relation to the programmed clock edge (rising or falling). The illustration on the right shows the relation to the rising edge as an example.

For detailed information on the different modes for external clocking please refer to the dedicated chapter in the hardware manual for the boards of the M2p.75xx series.

### Input Timing

- **Clock Input to Clock Output (single card)**: 
  - $t_{d}$: 9.3 ns
  - Internal Clocking: n.a.
- **Clock In to Clock Out (Star-Hub connected)**: 
  - $t_{d}$: TBD
  - $t_{d}$: 2.0 ns
  - Internal Clocking: n.a.
- **Data/Trigger Output**
  - $t_{d1}$: 0.0 ns
  - $t_{d2}$: 2.0 ns
  - Internal Clocking: 0.0 ns
- **Data/Trigger Input**
  - $t_{d1}$: 6.1 ns
  - $t_{d2}$: 3.5 ns
  - Internal Clocking: 6.1 ns

When using external clock, a delayed clock signal is generated on the Clock Output pin. The timing data in relation to this delayed clock output is identical to the timing when using internal clocking. It is therefore strongly recommended that you use the delay clock output for clocking any external devices.
Order Information

M2p Order Information

The card is delivered with 1 GByte on-board memory and supports standard acquisition and replay (scope, single-shot, loop, single restart), FIFO acquisition/replay (streaming), Multiple Recording/Replay, Gated Sampling/Replay, Timestamps and Sequence Mode. Operating system drivers for Windows/Linux 32 bit and 64 bit, examples for C/C++, LabVIEW (Windows), MATLAB (Windows and Linux), .NET, Delphi, Java, Python and a Base license of the oscilloscope software SBench 6 are included.

One digital connecting cable Cab-d40-idc-100 is included in the delivery for every digital connection (each 16 channels).

<table>
<thead>
<tr>
<th>PCIe Express x4</th>
<th>Order no.</th>
<th>Input</th>
<th>Output</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2p.7515-x4</td>
<td>32 Channels</td>
<td>32 Channels</td>
<td>125 MS/s</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Options</th>
<th>Order no.</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2p.xxxx-SH6ex (1)</td>
<td>Synchronization Star-Hub for up to 6 cards incl. cables, only one slot width, card length 245 mm</td>
<td></td>
</tr>
<tr>
<td>M2p.xxxx-SH6tm (1)</td>
<td>Synchronization Star-Hub for up to 6 cards incl. cables, two slots width, standard card length</td>
<td></td>
</tr>
<tr>
<td>M2p.xxxx-SH16ex (1)</td>
<td>Synchronization Star-Hub for up to 16 cards incl. cables, only one slot width, card length 245 mm</td>
<td></td>
</tr>
<tr>
<td>M2p.xxxx-SH16tm (1)</td>
<td>Synchronization Star-Hub for up to 16 cards incl. cables, two slots width, standard card length</td>
<td></td>
</tr>
<tr>
<td>M2p.upgrade</td>
<td>Upgrade for M2p.xxxx: Later installation of options Star-Hub</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cables</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cab-d40-idc-100</td>
<td>Flat-ribbon cable to 2x20 pole IDC, 100 cm</td>
</tr>
<tr>
<td>Cab-d40-d40-100</td>
<td>Flat-ribbon cable to 40 pole FX2, 100 cm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Software SBench6</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBench6</td>
<td>Base version included in delivery. Supports standard mode for one card</td>
</tr>
<tr>
<td>SBench6-Pro</td>
<td>Professional version for one card. FIFO mode, export/import, calculation functions</td>
</tr>
<tr>
<td>SBench6-Multi</td>
<td>Option multiple cards: Needs SBench6-Pro. Handles multiple synchronized cards in one system.</td>
</tr>
<tr>
<td>Volume Licenses</td>
<td>Please ask Spectrum for details.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Software Options</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP-RServer</td>
<td>Remote Server Software Package - LAN remote access for M2i/M3i/M4i/M4x/M2p cards</td>
</tr>
<tr>
<td>SP-SCAPP</td>
<td>Spectrum’s CUDA Access for Parallel Processing - SDK for direct data transfer between Spectrum card and CUDA GPU. Includes RDMA activation and examples.</td>
</tr>
</tbody>
</table>

(1): Just one of the options can be installed on a card at a time.
(2): Third party product with warranty differing from our export conditions. No volume rebate possible.
Hardware Installation

ESD Precautions

All Spectrum boards contain electronic components that can be damaged by electrostatic discharge (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.

Sources of noise

Noise sensitive analog devices, such as analog acquisition and generator boards should be placed physically as far away from any noise producing source (like e.g. the power supply) as possible. It should especially be avoided to place the board in the slot directly adjacent to another fast board like e.g. a graphics controller.

Cooling Precautions

The boards of the M2p.xxxx-x4 series operate with components having very high power consumption at high speeds. For this reason it is absolutely required to cool the boards sufficiently.

For all M2p cards it is absolutely mandatory to have installed cooling fans specifically providing a stream of air across the board’s surface.

- Make absolutely sure, that the on-board heat sink on the M2p card is not blocked by PC internal cabling or any other means.
- Ensure that there is plenty of space around the PC chassis fan’s intake and exhaust vents, both inside and outside the chassis.
- If your chassis includes fan filters, make sure that these are regularly cleaned.
- Set the rotation speed for all chassis fans and especially those providing air for the PCIe cards to highest setting in the BIOS/UEFI.
- Whenever possible leave the slot adjacent to the M2p card empty. This allows for best possible air flow over the card’s surface.
- If you do need to to use any adjacent slots, preferably install cards, that grant the most clearance between the devices, such as low-profile adapters.
- If available install filler panels with ventilation holes for all unused PCI or PCI Express slots to allow for additional air flow for the M2p cards and serve as an additional outtake.

For all M2p cards requiring an additional slot for its heat-sink, the supplied ventilation PCIe bracket must be installed for the slot used by the heat-sink, to allow for proper air move over the heat-sink and out of the PC chassis..

Connector Handling Precautions

The connectors used on this product are designed for high signal quality and good shielding. Due to the limited space on the front-panel they have to be as small as possible to fit the needed signal connections on the front panel. Therefore these connectors are vulnerable to mechanical damages when used not properly. Especially SMB and MMCX connectors may be broken when not operated correctly.

Always dismount the connections by operating the connector itself and not the cable. Always move the cable connector in a straight line from the board connector. Do not cant the connector when opening the connection. A broken connector can only be replaced in factory and is not covered by warranty.
**M2p PCIe Cards**

**System Requirements**
All Spectrum M2p.xxxx-x4 instrumentation cards are compliant to the PCI Express 1.0 standard and require in general one free 1/2 length PCI Express slot. This can mechanically either be a x4, x8 or x16 slot, electrically all lane widths are supported, be it x1, x4, x8 or x16. Some older x16 PCIe slots are for the use of graphic cards only and can not be used for other cards.

**Installing the M2p board in the system**

**Installing a single board without any options**
Before installing the board you first need to unscrew and remove the dedicated blind-bracket usually mounted to cover unused slots of your PC. Please keep the screw in reach to fasten your Spectrum card afterwards. All Spectrum M2p cards mechanically require one PCI Express x4, x8 or x16 slot (electrically either x1, x4, x8 or x16). Now insert the board slowly into your computer. This is done best with one hand each at both fronts of the board. After the insertion of the board fasten the screw of the bracket carefully, without overdoing.

⚠️ Please take special care to not bend the card in any direction while inserting it into the system. A bending of the card may damage the PCB totally and is not covered by the standard warranty.

⚠️ Please be very careful when inserting the board in the slot, as most of the mainboards are mounted with spacers and therefore might be damaged if they are exposed to high pressure.

**Installing the M2p.xxxx-x4 PCI Express card in a PCIe x4, x8 or x16 slot**

**Additional notes on the M2p cards PCIe x16 slot retention**
All M2p-xxx-x4 cards do have an additional PCIe retention hook (hockey stick) added to the PCB.

That allows the card to be additionally locked when being installed into a PCIe x16 slot.

⚠️ When installing the card in a x16 slot, make sure that the locking mechanism of the slots properly lock in place with the retention hook.
In the case that there are any components on the mainboard in the way of the retention hook when installing the card in an x4 or x8 slot, you can remove the hook by carefully breaking it off at its perforation line.

**Additional notes for M2p main cards with heat-sink requiring two slots**

Some M2p cards are equipped with a heat-sink, that requires one additional slot space into the slot right of the main card’s bracket, on „component side“ of the main PCIe card.

With these cards, an additional ventilation bracket is delivered with the card, that must be mounted for that particular slot, to ensure that there is sufficient air-flow over the card’s heat-sink and out of the system.

Simply replace the existing blind-bracket usually mounted to cover unused slots of your PC with the supplied bracket.

**Installing a board with digital inputs/outputs mounted on an extra bracket**

Before installing the board you first need to unscrew and remove the dedicated blind-bracket usually mounted to cover unused slots of your PC. Please keep the screw in reach to fasten your Spectrum card afterwards. All Spectrum M2p cards mechanically require one PCI Express x4, x8 or x16 slot (electrically either x1, x4, x8 or x16). Now insert the board with it’s attached extra bracket slowly into your computer. This is done best with one hand each at both fronts of the board.

Please take special care to not bend the card in any direction while inserting it into the system. A bending of the card may damage the PCB totally and is not covered by the standard warranty.

Please be very carefully when inserting the board in the PCI slot, as most of the mainboards are mounted with spacers and therefore might be damaged they are exposed to high pressure.

After the board’s insertion fasten the screws of both brackets carefully, without overdoing. The figure shows an example of a board with two installed front-end modules and the option -DigFX2. The same procedure applies for option -DigSMB.
Installing multiple boards synchronized by star-hub option

Hooking up the boards
Before mounting several synchronized boards for a multi channel system into the PC you can hook up the cards with their synchronisation cables first. If there is enough space in your computer’s case (e.g. a big tower case) you can also mount the boards first and hook them up afterwards. Spectrum ships the card carrying the star-hub option together with the needed amount of synchronisation cables. All of them are matched to the same length, to achieve a zero clock delay between the cards.

Only use the included flat ribbon cables.

All of the cards, including the one that carries the star-hub piggy-back module, must be wired to the star-hub as the figure is showing as an example for four synchronized boards.

It does not matter which of the available connectors on the star-hub module you use for which board. The software driver will detect the types and order of the synchronized boards automatically.

All of the synchronization cables are secured against wrong plugging, but nonetheless you should take care to have the pin 1 markers on the connector and on the cable on the same side, as the figure on the right is showing.

Mounting the wired boards
Before installing the cards you first need to unscrew and remove the dedicated blind-brackets usually mounted to cover unused slots of your PC. Please keep the screws in reach to fasten your Spectrum cards afterwards.

Spectrum M2p cards with the option „M2p.xxxx-SH6tm“ or „M2p.xxxx-SH16tm“ installed require two slots with ½ PCIe length, whilst M2p cards with the option „M2p.xxxx-SH6ex“ or „M2p.xxxx-SH16ex“ installed require one single ¾ PCIe length PCIe slot.

Now insert the cards slowly into your computer. This is done best with one hand each at both fronts of the board.

⚠️ While inserting the board take care not to tilt the retainer in the track. Please take especial care to not bend the card in any direction while inserting it in the system. A bending of the card may damage the PCB totally and is not covered by the standard warranty.

⚠️ Please be very careful when inserting the cards in the slots, as most of the mainboards are mounted with spacers and therefore might be damaged if they are exposed to high pressure.
**Software Driver Installation**

Before using the board, a driver must be installed that matches the operating system.

**Since driver V3.33 (released on install-disk V3.48 in August 2017) the installation is done via an installer executable rather than manually via the Windows Device Manager. The steps for manually installing a card has since been moved to a separate application note „AN008 - Legacy Windows Driver Installation“.

This new installer is common on all currently supported Windows platforms (Windows 7, Windows 8 and Windows 10) both 32bit and 64bit. The driver from the USB-Stick supports all cards of the M2i/M3i, M4i/M4x and M2p series, meaning that you can use the same driver for all cards of these families.

**Windows**

**Before installation**

When you install a card for the very first time, Windows will discover the new hardware and might try to search the Microsoft Website for available matching driver modules.

Prior to running the Spectrum installer, the card will appear in the Windows device manager as a generalized card, shown here is the device manager of a Windows 10 as an example.

- M2i and M3i cards will be shown as „DPIO module“
- M4i, M4x and M2p cards will be shown as „PCI Data Acquisition and Signal Processing Controller“

**Running the driver Installer**

Simply run the installer supplied on the USB-Stick (..Driver\windows“ folder or downloadable from www.spectrum-instrumentation.com
After installation
After running the Spectrum driver installer, the card will appear in the Windows device manager with its name matching the card series.

The card is now ready to be used.
**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 upon special request. Please send an email to Support@spec.de to receive the kernel driver sources. 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_stdc++6.so` - supporting libstdc++.so.6 on 32 bit systems
- `spcm_linux_64bit_stdc++6.so` - supporting libstdc++.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 CD 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 (0x402a000)
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 Overview

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 CD 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 CD or on the website.

Card Control Center

A special card control center is available on CD 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 CD 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. There 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:

```c
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 the 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/M3i 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 form 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 \(2 \text{ channels} \times 2 \text{ Bytes/Sample} \times 28000000\) = 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 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.
Software Accessing the hardware with SBench 6

Firmware upgrade

One of the major features of the card control center is the ability to update the card’s firmware by an easy-to-use software. The latest firmware revisions can be found in the download section of our homepage under http://www.spectrum-instrumentation.com.

A new firmware version is provided there as an installer, that copies the latest firmware to your system. All files are located in a dedicated subfolder „FirmwareUpdate“ that will be created inside the Spectrum installation folder. Under Windows this folder by default has been created in the standard program installation directory.

Please do the following steps when wanting to update the firmware of your M2i/M3i/M4i/M4x/M2p card:

- Download the latest software driver for your operating system provided on the Spectrum homepage.
- Install the new driver as described in the driver install section of your hardware manual or install manual. All manuals can also be found on the Spectrum homepage in the literature download section.
- Download and run the latest Spectrum Control Center installer.
- Download the installer for the new firmware version.
- Start the installer and follow the instructions given there.
- Start the card control center, select the „card“ tab, select the card from the listbox and press the „firmware update“ button on the right side.

The dialog then will inform you about the currently installed firmware version for the different cards on the card and the new versions that are available. All devices that will be affected with the update are marked as „update needed“. Simply start the update or cancel the operation now, as a running update cannot be aborted.

Please keep in mind that you have to start the update for each card installed in your system separately. Select one card after the other from the listbox and press the „firmware update“ button. The firmware installer on the other hand only needs to be started once prior to the update.

Do not abort or shut down the computer while the firmware update is in progress. After a successful update please shut down your PC completely. The re-powering is required to finally activate the new firmware version of your Spectrum card.

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 CD 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 CD 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 CD 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:

```c
#include "dlltyp.h"     // 1st include
#include "regs.h"       // 2nd include
#include "spcm_drv.h"   // 3rd include
#include "spcerr.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 CD 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 CD 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 your 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.
**Software C/C++ Driver Interface**

**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 CD 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_bccppb.lib that is delivered together with the drivers. The library file can be found on the CD 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:

```makefile
COMPILER =   gcc
EXECUTABLE = test_prog
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:

```c
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:

```c
hDLL = LoadLibrary ("spcm_win64.dll"); // Modified: Load the 64 bit version of the Spcm driver here
pf_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.

### 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.

<table>
<thead>
<tr>
<th>Declaration</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>int8</td>
<td>8 bit signed integer (range from -128 to +127)</td>
</tr>
<tr>
<td>int16</td>
<td>16 bit signed integer (range from -32768 to 32767)</td>
</tr>
<tr>
<td>int32</td>
<td>32 bit signed integer (range from -2147483648 to 2147483647)</td>
</tr>
<tr>
<td>int64</td>
<td>64 bit signed integer (full range)</td>
</tr>
<tr>
<td>drv_handle</td>
<td>handle to driver, implementation depends on operating system platform</td>
</tr>
</tbody>
</table>

### 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.

```c
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

```c
drv_handle hDrv; // returns the handle to the opended 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

```c
drv_handle hDrv; // returns the handle to the opended driver or NULL in case of error
hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INST0::INSTR"); // string to the driver to open
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:

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

Example:

```c
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

```c
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
```

Example:

```c
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 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

```c
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
```

```c
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
```

```c
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
```
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 port 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:

<table>
<thead>
<tr>
<th>Internal register</th>
<th>read/write</th>
<th>Function type</th>
<th>Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 bit register</td>
<td>read</td>
<td>spcm_dwGetParam_i32</td>
<td>value is returned as 32 bit integer in plValue</td>
</tr>
<tr>
<td>32 bit register</td>
<td>read</td>
<td>spcm_dwGetParam_i64</td>
<td>value is returned as 64 bit integer in pllValue</td>
</tr>
<tr>
<td>32 bit register</td>
<td>read</td>
<td>spcm_dwGetParam_i64m</td>
<td>value is returned as 64 bit integer, the lower part in pllValueLow, the upper part in pllValueHigh. The upper part can be ignored as it’s only a sign extension</td>
</tr>
<tr>
<td>32 bit register</td>
<td>write</td>
<td>spcm_dwSetParam_i32</td>
<td>32 bit value can be directly written</td>
</tr>
<tr>
<td>32 bit register</td>
<td>write</td>
<td>spcm_dwSetParam_i64</td>
<td>64 bit value can be directly written, please be sure not to exceed the valid register value range</td>
</tr>
<tr>
<td>32 bit register</td>
<td>write</td>
<td>spcm_dwSetParam_i64m</td>
<td>64 bit value is written as pllValue, the value pllValueHigh needs to contain the sign extension of this value. In case of pllValueLow being a value &gt;= 0 pllValueHigh can be 0, in case of pllValueLow being a value &lt; 0 pllValueHigh has to be -1</td>
</tr>
<tr>
<td>64 bit register</td>
<td>read</td>
<td>spcm_dwGetParam_i32</td>
<td>If the internal register has a value that is inside the 32 bit integer range [2G up to (2G - 1)] the value is returned normally. If the internal register exceeds this size an error code ERR_EXCEEDSINT32 is returned. As an example: reading back the installed memory will work as long as this memory is &lt; 2 GByte. If the installed memory is &gt;= 2 GByte the function will return an error.</td>
</tr>
<tr>
<td>64 bit register</td>
<td>read</td>
<td>spcm_dwGetParam_i64</td>
<td>value is returned as 64 bit integer value in pllValue independent of the value of the internal register</td>
</tr>
<tr>
<td>64 bit register</td>
<td>read</td>
<td>spcm_dwGetParam_i64m</td>
<td>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 pllValueLow contains the 32 bit value and the upper part pllValueHigh can be ignored. If the internal value exceeds the 32 bit range it is absolutely necessary to take both value parts into account</td>
</tr>
<tr>
<td>64 bit register</td>
<td>write</td>
<td>spcm_dwSetParam_i32</td>
<td>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.</td>
</tr>
<tr>
<td>64 bit register</td>
<td>write</td>
<td>spcm_dwSetParam_i64</td>
<td>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.</td>
</tr>
<tr>
<td>64 bit register</td>
<td>write</td>
<td>spcm_dwSetParam_i64m</td>
<td>the value has to be split into two parts. Be sure to fill the upper part pllValueHigh 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</td>
</tr>
</tbody>
</table>

**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.

```c
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 SPCM_BUF_XXXX
void** ppvDataBuffer, // address of available data buffer
uint64* ppleContBuflen); // 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 SPCM_BUF_XXXX
void** ppvDataBuffer, // address of available data buffer
uint32* ppleContBuflenH), // high part of length of available continuous buffer
uint32* ppleContBuflenL); // 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**

```c
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
dwBufType,              // type of the buffer to define as listed above under SPCM_BUF_XXXX
dwDirection,            // the transfer direction as defined above
dwNotifySize,           // no. of bytes after which an event is sent (0=end of transfer)
pvDataBuffer,           // pointer to the data buffer
dwBrdOffsH,             // high part of offset in board memory
dwTransferLenH,         // high part of transfer buffer length
dwTransferLenL);        // low part of transfer 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:**

```c
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
”);
```

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_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 ERRORTEXTLEN 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**

```c
uint32 _stdcall spcm_dwGetErrorInfo_i32 ( //get the error info on the last error
    drv_handle  hDevice,                // handle to an already opened device
    pdwErrorReg,              // address of the error register (can be zero if not of interest)
    piErrorValue,             // address of the error value (can be zero if not of interest)
    pszErrorTextBuffer [ERRORTEXTLEN]); // text buffer for text error
```
Example:

```c
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:

```pascal
// ----- 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:

```pascal
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 SpeErr.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 CD. 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:

```pascal
uses Windows, Messages, SysUtils, Classes, Graphics, Controls, Forms, Dialogs, StdCtrls, ExtCtrls,
     SpcRegs, SpcErr, spcm_win32;
```
Examples
Examples for Delphi can be found on CD 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 class Regs
                {
                    public const int M2CMD_CARD_WRITESETUP = unchecked ((int)0x00000002);
                    ...
                    // ----- 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);
                    // ----- open remote card ----- 
                    hDevice = Drv.spcm_hOpen("TCPIP::192.168.169.14::INST0::INSTR");
                    
                    // ----- open remote card ----- 
                    hDevice = Drv.spcm_hOpen("TCPIP::192.168.169.14::INST0::INSTR");
                    
                    // ----- 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:

```c++
// ----- 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:

```c++
// ----- open remote card ----- 
```

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:

```csharp
' ----- open card ----- 
hDevice = Drv.spcm_hOpen("/dev/spcm0") If (hDevice = 0) Then 
    Console.WriteLine("Error: Could not open card") 
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:

```csharp
' ----- open remote card ----- 
hDevice = Drv.spcm_hOpen("TCPPIP::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 „Add Reference“. After this all functions and constants of the driver object are available.

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

```csharp
// ----- open card ----- 
```

Example for digitizerNETBOX/generatorNETBOX and remotely installed cards:

```csharp
' ----- open remote card ----- 
hDevice = Drv.spcm_hOpen("TCPPIP::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 pyspcm 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 pyspcm.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:

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

# load spc_mOpen 
spc_mOpen = get attr (spcmDll, "spc_mOpen@4") 
spc_mOpen.argtype = [c_char_p]
spc_mOpen.re type = drv_handle

# load spc_vClose 
spc_vClose = get attr (spcmDll, "spc_vClose@4")
spc_vClose.argtype = [drv_handle]
spc_vClose.re type = None

# load spc_dwGetErrorInfo 
spc_dwGetErrorInfo_i32 = get attr (spcmDll, "spc_dwGetErrorInfo_i32@16")
spc_dwGetErrorInfo_i32.argtype = [drv_handle, ptr32, ptr32, c_char_p]
spc_dwGetErrorInfo_i32.re type = uint32

# load spc_dwGetParam_i32 
spc_dwGetParam_i32 = get attr (spcmDll, "spc_dwGetParam_i32@12")
spc_dwGetParam_i32.argtype = [drv_handle, int32, ptr32]
spc_dwGetParam_i32.re type = uint32

# load spc_dwGetParam_i64 
spc_dwGetParam_i64 = get attr (spcmDll, "spc_dwGetParam_i64@12")
spc_dwGetParam_i64.argtype = [drv_handle, int64]
spc_dwGetParam_i64.re type = uint32

# load spc_dwSetParam_i32 
spc_dwSetParam_i32 = get attr (spcmDll, "spc_dwSetParam_i32@12")
spc_dwSetParam_i32.argtype = [drv_handle, int32, int32]
spc_dwSetParam_i32.re type = uint32

# load spc_dwSetParam_i64 
spc_dwSetParam_i64 = get attr (spcmDll, "spc_dwSetParam_i64@12")
spc_dwSetParam_i64.argtype = [drv_handle, int32, int32]
spc_dwSetParam_i64.re type = uint32

# load spc_dwDefTransfer_i64 
spc_dwDefTransfer_i64 = get attr (spcmDll, "spc_dwDefTransfer_i64@36")
spc_dwDefTransfer_i64.argtype = [drv_handle, uint32, uint32, uint32, c_void_p, uint64, uint64]
spc_dwDefTransfer_i64.re type = 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 spc_mOpen 
spc_mOpen = get attr (spcmDll, "spc_mOpen")
spc_mOpen.argtype = [c_char_p]
spc_mOpen.re type = 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 = 0x0000000001l                   # hardware reset
M2CMD_CARD_WRISETUP = 0x0000000002l                 # write setup only
M2CMD_CARD_START = 0x0000000004l                    # start of card (including writesetup)
M2CMD_CARD_ENABLETRIGGER = 0x0000000008l           # 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 CD 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 CD 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 CD 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 usage 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 CD 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 usage of the MATLAB drivers for this card.

SCAPP – CUDA GPU based data processing

SCAPP – CUDA GPU based data processing

Spectrum’s CUDA Access for Parallel Processing

Modern GPUs (Graphic Processing Units) are designed to handle a large number of parallel operations. While a CPU offers only a few cores for parallel calculations, a GPU can offer thousands of cores. This computing capabilities can be used for calculations using the Nvidia CUDA interface. Since bus bandwidth and CPU power are often a bottleneck in calculations, CUDA Remote Direct Memory Access (RDMA) can be used to directly transfer data from/to a Spectrum Digitizer/Generator to/from a GPU card for processing, thus avoiding the transfer of raw data to the host memory and benefiting from the computational power of the GPU.

For applications requiring high performance signal and data processing Spectrum offers SCAPP (Spectrum’s CUDA Access for Parallel Processing). The SCAPP SDK allows a direct link between Spectrum digitizers or generators and CUDA based GPU cards. Once in the GPU users can harness the processing power of the GPU’s multiple (up to 5000) processing cores and large (up to 24 GB) memories. SCAPP uses an RDMA (Linux only) process to send data to the digitizers full PCIe transfer speed to the GPU card. The SDK includes a set of examples for interaction between the digitizer or generator and the GPU card and another set of CUDA parallel processing examples with easy building blocks for basic functions like filtering, averaging, data de-multiplexing, data conversion or FFT. All the software is based on C/C++ and can easily be implemented, expanded and modified with normal programming skills.

Please follow the description in the SCAPP manual for installation and usage of the SCAPP drivers for this card.
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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>w</td>
<td>Command register of the board.</td>
</tr>
<tr>
<td>M2CMD_CARD_START</td>
<td>4h</td>
<td></td>
<td>Starts the board with the current register settings.</td>
</tr>
<tr>
<td>M2CMD_CARD_STOP</td>
<td>40h</td>
<td></td>
<td>Stops the board manually.</td>
</tr>
</tbody>
</table>

Any constants that can be used to program the register directly are shown inserted beneath the register table.

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

```c
#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)
    {
        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;
    }
    return -1;
}
```
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.

Open/Close Example

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
hDrv = spcm_hOpen ("TCPIP::192.168.169.14::INST0::INSTR");  // Opens the remote board #0
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.
Programming the Board

Gathering information from the card

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

```c
char szErrorText[ERRORTEXTLEN];

spcm_dwGetParam_i64 (hDrv, SPC_SAMPLERATE, 1000000);                        // correct command
spcm_dwGetParam_i64 (hDrv, SPC_MEMSIZE, -345);                              // faulty command
spcm_dwGetParam_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:

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

spcm_dwGetParam_i64 (hDrv, SPC_SAMPLERATE, 1000000);                        // correct command
spcm_dwGetParam_i64 (hDrv, SPC_MEMSIZE, -345);                              // faulty command
spcm_dwGetParam_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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PCITYP</td>
<td>2000</td>
<td>read</td>
<td>Type of board as listed in the table below.</td>
</tr>
</tbody>
</table>

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 an indication for the used bus type.
Gathering information from the card
Programming the Board

Hardware and PCB version

Since all of the boards from Spectrum are modular boards, they consist of one base board and one piggy-back front-end module 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.

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:
Programming the Board

Gathering information from the card

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

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_FW_MODEXTRA</td>
<td>210050</td>
<td>read</td>
<td>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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_FW_POWER</td>
<td>210060</td>
<td>read</td>
<td>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.</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PCIDATE</td>
<td>2020</td>
<td>read</td>
<td>Production date: week in bits 31 to 16, year in bits 15 to 0</td>
</tr>
</tbody>
</table>

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

```c
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CALIBDATE</td>
<td>2035</td>
<td>read</td>
<td>Last calibration date: week in bits 31 to 16, year in bit 15 to 0</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PCISERIALNO</td>
<td>2030</td>
<td>read</td>
<td>Serial number of the board</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PCISAMPLERATE</td>
<td>2100</td>
<td>read</td>
<td>Maximum sampling rate in Hz as a 64 bit integer value</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PCIMEMSIZE</td>
<td>2110</td>
<td>read _i32</td>
<td>Installed memory in bytes as a 32 bit integer value. Maximum return value will be 1 GByte. If more memory is installed this function will return the error code ERR_EXCEEDINT32.</td>
</tr>
<tr>
<td>SPC_PCIMEMSIZE</td>
<td>2110</td>
<td>read _i64</td>
<td>Installed memory in bytes as a 64 bit integer value.</td>
</tr>
</tbody>
</table>

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

```c
spcm_dwGetParam_i164 (hDrv, SPC_PCIMEMSIZE, &lCustomMod);
printf ("Custom modification no. %d is installed.", lCustomMod);
```

The following example demonstrates how to read out the information about one feature. (12, 14 or 16 bit board), on any 8 bit card memory in MSamples is similar to memory in MBytes.

```c
if (lCustomMod != 0)
    lCustomMod = (lFeatures >> 28) & 0xF;
```

### 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_FEAT_MUL</td>
<td>1h</td>
<td>read</td>
<td>Is set if the feature Multiple Recording / Multiple Replay is available.</td>
</tr>
<tr>
<td>SPCM_FEAT_GATE</td>
<td>2h</td>
<td>read</td>
<td>Is set if the feature Gated Sampling / Gated Replay is available.</td>
</tr>
<tr>
<td>SPCM_FEAT_DIGITAL</td>
<td>4h</td>
<td>read</td>
<td>Is set if the feature Digital Inputs / Digital Outputs is available.</td>
</tr>
<tr>
<td>SPCM_FEAT_TIMESTAMP</td>
<td>8h</td>
<td>read</td>
<td>Is set if the feature Timestamp is available.</td>
</tr>
<tr>
<td>SPCM_FEAT_STARHUB</td>
<td>20h</td>
<td>read</td>
<td>Is set on the card, that carries the star-hub extension or piggy-back module for synchronizing up to 6 cards (M2p).</td>
</tr>
<tr>
<td>SPCM_FEAT_STARHUB</td>
<td>20h</td>
<td>read</td>
<td>Is set on the card, that carries the star-hub extension or piggy-back module for synchronizing up to 8 cards (M4i).</td>
</tr>
<tr>
<td>SPCM_FEAT_CAPTURE</td>
<td>100h</td>
<td>read</td>
<td>Is set if the extra BaseXIO option is installed. The lines can be used for asynchronous digital I/O, extra trigger or time-stamp reference signal input.</td>
</tr>
<tr>
<td>SPCM_FEAT_AMPLIFIER_10V</td>
<td>200h</td>
<td>read</td>
<td>Arbitrary Waveform Generators only: card has additional set of calibration values for amplifier card.</td>
</tr>
<tr>
<td>SPCM_FEAT_STARHUBSYSTMSTR</td>
<td>400h</td>
<td>read</td>
<td>Is set in the card that carries a System StarHub Master card to connect multiple systems (M2).</td>
</tr>
<tr>
<td>SPCM_FEAT_DIFFMODE</td>
<td>800h</td>
<td>read</td>
<td>M2: 32x32 series only: card has option -diff installed for combining two SE channels to one differential channel.</td>
</tr>
<tr>
<td>SPCM_FEAT_SEQUENCE</td>
<td>1000h</td>
<td>read</td>
<td>Only available for output cards or I/O cards: Replay sequence module available.</td>
</tr>
<tr>
<td>SPCM_FEAT_AMPLMODULE_10V</td>
<td>2000h</td>
<td>read</td>
<td>Is set on the card that has a special amplifier module for mounted (M2i:60xx/81xx only).</td>
</tr>
<tr>
<td>SPCM_FEAT_STARHUBSYSSAVE</td>
<td>4000h</td>
<td>read</td>
<td>Is set in the card that carries a System StarHub Slave module to connect with System StarHub master systems (M2).</td>
</tr>
<tr>
<td>SPCM_FEAT_NETBOX</td>
<td>8000h</td>
<td>read</td>
<td>The card is physically mounted within a digitizerNETBOX or generatorNETBOX.</td>
</tr>
<tr>
<td>SPCM_FEAT_REMOTESERVER</td>
<td>10000h</td>
<td>read</td>
<td>Support for the Spectrum Remote Server option is installed on this card.</td>
</tr>
<tr>
<td>SPCM_FEAT_SCAPP</td>
<td>20000h</td>
<td>read</td>
<td>Support for the SCAPP option allowing CUDA RDMA access to supported graphics cards for GPU calculations (M4i and M2p).</td>
</tr>
<tr>
<td>SPCM_FEAT_DIG16_5MB</td>
<td>40000h</td>
<td>read</td>
<td>M2p: Set if option M2p:5xxx-Dig16MB is installed, adding 16 additional digital I/Os via SMB connectors.</td>
</tr>
<tr>
<td>SPCM_FEAT_DIG16_FX2</td>
<td>80000h</td>
<td>read</td>
<td>M2p: Set if option M2p:xxxx-DigFX2 is installed, adding 16 additional digital I/Os via FX2 multipin connectors.</td>
</tr>
<tr>
<td>SPCM_FEAT_DIGITALBWFILTER</td>
<td>100000h</td>
<td>read</td>
<td>A digital (baseca) bandwidth filter is available that can be globally enabled/disabled for all channels.</td>
</tr>
<tr>
<td>SPCM_FEAT_CUSTOMMOD_MASK</td>
<td>0x0000000h</td>
<td>read</td>
<td>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.</td>
</tr>
</tbody>
</table>

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

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

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

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

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**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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PCIEXTFEATURES</td>
<td>2121</td>
<td>read</td>
<td>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.</td>
</tr>
</tbody>
</table>

**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:

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

**Function type of the card**

This register register returns the basic type of the card:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_FNCTYPE</td>
<td>2001</td>
<td>read</td>
<td>Gives information about what type of card it is.</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_GETDRVTYP</td>
<td>1220</td>
<td>read</td>
<td>Gives information about what type of driver is actually used.</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_GETDRIVERVERSION</td>
<td>1200</td>
<td>read</td>
<td>Gives information about the driver library version.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Driver Major Version</th>
<th>Driver Minor Version</th>
<th>Driver Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Bit wide: bit 24 to bit 31</td>
<td>8 Bit wide: bit 16 to bit 23</td>
<td>16 Bit wide: bit 0 to bit 15</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_GETKERNELVERSION</td>
<td>1210</td>
<td>read</td>
<td>Gives information about the kernel driver version.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Driver Major Version</th>
<th>Driver Minor Version</th>
<th>Driver Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 bit wide, bit 24 to bit 31</td>
<td>8 bit wide, bit 16 to bit 23</td>
<td>16 bit wide, bit 0 to bit 15</td>
</tr>
</tbody>
</table>

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

```c
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

Custom modifications
Since all of the boards from Spectrum are modular boards, they consist of one base board and one piggy-back front-end module 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_CUSTOMMOD</td>
<td>3130</td>
<td>read</td>
<td>Dedicated feature register used to mark special custom modifications of the base card and/or the front-end module and/or the Star-Hub module. This is only used if the card has been specially customized. Please refer to the extra documentation for the meaning of the custom modifications. This register is supported for all M4i, M4x, M2p and digitizerNETBOX/generatorNETBOX based upon these series.</td>
</tr>
<tr>
<td>SPCM_CUSTOMMOD_BASE_MASK</td>
<td>000000FFh</td>
<td>Mask</td>
<td>Mask for the custom modification of the base card.</td>
</tr>
<tr>
<td>SPCM_CUSTOMMOD_MODULE_MASK</td>
<td>0000FF00h</td>
<td>Mask</td>
<td>Mask for the custom modification of the front-end module(s).</td>
</tr>
<tr>
<td>SPCM_CUSTOMMOD_STARHUB_MASK</td>
<td>00000000h</td>
<td>Mask</td>
<td>Mask out custom modification of the Star-Hub module.</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>w</td>
<td>Command register of the board</td>
</tr>
<tr>
<td>M2CMD_CARD_RESET</td>
<td>1h</td>
<td></td>
<td>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.</td>
</tr>
</tbody>
</table>
Digital I/O channels

Channel Selection

One key setting that influences nearly all other possible settings is the channel enable register. An unique feature of the Spectrum boards is the possibility to program the data width. The complete on-board memory can then be used by samples with the actual data width.

This description shows you the channel enable register for the complete board family. However your specific board may have less inputs/outputs bits depending on the board type you purchased does not allow you to set the maximum number of bits shown here. The channel enable register is set as a 64 bit wide bitfield coping all possible channel enable combination.

<table>
<thead>
<tr>
<th>Register</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CHENABLE</td>
<td>Sets/reads out the channel enable mask for the up to 64 channels as a bitfield</td>
</tr>
</tbody>
</table>

As 64 bit wide constants are not supported by all compilers, the channel enable register is one exception to all the constant based registers mentioned throughout the other parts of the manual.

The following tables shows all allowed settings for the channel enable register for:

<table>
<thead>
<tr>
<th>Number of activated digital channels</th>
<th>Value as hex</th>
<th>Recorded/replayed channel numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>X</td>
<td>000000000000FFFFh</td>
<td>D15...D0</td>
</tr>
<tr>
<td>X</td>
<td>00000000FFFFFFFFh</td>
<td>D31...D0</td>
</tr>
</tbody>
</table>

**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.

Settings of the I/O lines

Settings for the inputs

All inputs of Spectrum’s digital boards can be terminated wordwise with 110 Ohm by software programming. If you do so, please make sure that your signal source is able to deliver the higher output currents. If no termination is used, the inputs have an impedance of several Kilohm.

The following table shows the corresponding register to set the input termination.

<table>
<thead>
<tr>
<th>Register</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_110OHM0</td>
<td>30060 read/write A 1 sets the 110 ohm termination for the channels D15...D0. A 0 sets the termination to high impedance.</td>
</tr>
<tr>
<td>SPC_110OHM1</td>
<td>30160 read/write A 1 sets the 110 ohm termination for the channels D31...D16. A 0 sets the termination to high impedance.</td>
</tr>
</tbody>
</table>
Levels on unused outputs

If a sample width lower than 32 bit is used for generating data, the unused output lines of the lowest 16 bit output connector are set to high-impedance (tristate).

Programming the behavior in pauses and after replay

Usually the used outputs of the digital I/O boards are set to logical 0 after replay. This is in most cases adequate as many pattern generators generate signals with a relation to the system ground. In some cases it can be necessary to hold the last sample, to output logical 1 or to switch outputs to a high impedance 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 behavior after replay:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CH0_STOPLEVEL</td>
<td>206020</td>
<td>read/write</td>
<td>Defines the behavior after replay for outputs D15...D0</td>
</tr>
<tr>
<td>SPC_CH1_STOPLEVEL</td>
<td>206021</td>
<td>read/write</td>
<td>Defines the behavior after replay for outputs D31...D16</td>
</tr>
<tr>
<td>SPCM_STOPVL_TRISTATE</td>
<td>1</td>
<td>read/write</td>
<td>Defines outputs to enter high-impedance state (tristate)</td>
</tr>
<tr>
<td>SPCM_STOPVL_LOW</td>
<td>2</td>
<td>read/write</td>
<td>Defines outputs to enter logical 0 state</td>
</tr>
<tr>
<td>SPCM_STOPVL_HIGH</td>
<td>4</td>
<td>read/write</td>
<td>Defines outputs to enter logical 1 state</td>
</tr>
<tr>
<td>SPCM_STOPVL_HOLDLAST</td>
<td>8</td>
<td></td>
<td>Holds the last replayed sample</td>
</tr>
<tr>
<td>SPCM_STOPVL_CUSTOM</td>
<td>32</td>
<td></td>
<td>Allows to define a 16bit wide custom level per channel for the digital output to enter in pauses. The sample format is exactly the same as during replay.</td>
</tr>
</tbody>
</table>

When using SPCM_STOPVL_CUSTOM, the sample value for the pauses must be defined via the following registers:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CH0_CUSTOM_STOP</td>
<td>206050</td>
<td>read/write</td>
<td>Defines the custom stop level for channels D15...D0 when using SPCM_STOPVL_CUSTOM.</td>
</tr>
<tr>
<td>SPC_CH1_CUSTOM_STOP</td>
<td>206051</td>
<td>read/write</td>
<td>Defines the custom stop level for channels D31...D16 when using SPCM_STOPVL_CUSTOM.</td>
</tr>
</tbody>
</table>

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

Example showing how to set a custom stoplevel for channel 0:

```c
// enable the use of custom stop level and use raw value 10487 as stop value
spcm_dwSetParam_i32(stCard.hDrv, SPC_CH0_STOPLEVEL, SPCM_STOPVL_CUSTOM);
spcm_dwSetParam_i32(stCard.hDrv, SPC_CH0_CUSTOM_STOP, 10487);  
```

Read out of input features

The digital inputs 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 input features settings that are available throughout all Spectrum digital I/O and logic analyzer cards. Some of these features are not installed on your specific hardware.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_READDFEATURES</td>
<td>3103</td>
<td>read</td>
<td>Returns a bit map with the available features of the digital input path. The possible return values are listed below.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_DI_TERM</td>
<td>000000001h</td>
<td>Programmable input termination available</td>
</tr>
<tr>
<td>SPCM_DI_SE</td>
<td>000000002h</td>
<td>Input is single-ended. If available together with SPC_DI_DIFF: input type is software selectable.</td>
</tr>
<tr>
<td>SPCM_DI_DIFF</td>
<td>000000004h</td>
<td>Input is differential. If available together with SPC_DI_SE: input type is software selectable.</td>
</tr>
<tr>
<td>SPCM_DI_PROGTHRESHOLD</td>
<td>000000008h</td>
<td>Input offset programmable in per cent of input range</td>
</tr>
<tr>
<td>SPCM_DI_HIGHIMP</td>
<td>00000010h</td>
<td>High impedance input is available. If available together with SPCM_DI_TERM: input impedance is software selectable.</td>
</tr>
<tr>
<td>SPCM_DI_LOWIMP</td>
<td>00000020h</td>
<td>Low impedance input is available. If available together with SPC_DI_TERM: input impedance is software selectable.</td>
</tr>
<tr>
<td>SPCM_DI_INDIVPULSEWIDTH</td>
<td>00010000h</td>
<td>Trigger pulsewidth is individually per channel programmable</td>
</tr>
<tr>
<td>SPCM_DI_IOCHANNEL</td>
<td>00200000h</td>
<td>The input channel is connected with a digital output (DO) channel (digital I/O cards only)</td>
</tr>
</tbody>
</table>

Read out of output features

The digital 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 digital I/O and pattern generator cards. Some of these features are not installed on your specific hardware.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_READDOFEATURES</td>
<td>3104</td>
<td>Returns a bit map with the available features of the digital output path.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The possible return values are listed below.</td>
</tr>
<tr>
<td>SPCM_DO_SE</td>
<td>00000002h</td>
<td>Output is single-ended. If available together with SPCM_DO_DIFF, output type is software selectable.</td>
</tr>
<tr>
<td>SPCM_DO_DIFF</td>
<td>00000004h</td>
<td>Output is differential. If available together with SPCM_DO_SE, output type is software selectable.</td>
</tr>
<tr>
<td>SPCM_DO_PROGSTOPEVEL</td>
<td>00000008h</td>
<td>The output level between segments of generated data is programmable.</td>
</tr>
<tr>
<td>SPCM_DO_PROGOUTLEVELS</td>
<td>00000010h</td>
<td>Software programmable output levels (low + high) are available.</td>
</tr>
<tr>
<td>SPCM_DO_ENABLEMASK</td>
<td>00000020h</td>
<td>An individual enable mask for each output channel is available.</td>
</tr>
<tr>
<td>SPCM_DO_IOCHANNEL</td>
<td>00000040h</td>
<td>The output channel is connected with a digital input (DI) channel (digital I/O cards only).</td>
</tr>
</tbody>
</table>
Acquisition 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode, a read command will return the currently used mode.</td>
</tr>
<tr>
<td>SPC_AVAILCARDMODES</td>
<td>9501</td>
<td>read</td>
<td>Returns a bitmap with all available modes on your card. The modes are listed below.</td>
</tr>
</tbody>
</table>

Acquisition modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Value</th>
<th>Available on</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_REC_STD_SINGLE</td>
<td>1h</td>
<td>all cards</td>
<td>Data acquisition to on-board memory for one single trigger event.</td>
</tr>
<tr>
<td>SPC_REC_STD_MULTI</td>
<td>2h</td>
<td>all cards</td>
<td>Data acquisition to on-board memory for multiple trigger events. Each recorded segment has the same size. This mode is described in greater detail in a special chapter about the Multiple Recording option.</td>
</tr>
<tr>
<td>SPC_REC_STD_GATE</td>
<td>4h</td>
<td>all cards</td>
<td>Data acquisition to on-board memory using an external Gate signal. Acquisition is only done as long as the gate signal has a programmed level. The mode is described in greater detail in a special chapter about the Gated Sampling option.</td>
</tr>
<tr>
<td>SPC_REC_STD_ABA</td>
<td>8h</td>
<td>digitizer only</td>
<td>Data acquisition to on-board memory for multiple trigger events. While the multiple trigger events are stored with programmed sampling rate the inputs are sampled continuously with a slower sampling speed. The mode is described in a special chapter about ABA mode option.</td>
</tr>
<tr>
<td>SPC_REC_STD_SEGSTATS</td>
<td>10000h</td>
<td>M4i/M4x.2xxx M4i/M4x.44xx DN2/DN6.2xx DN2/DN6.44x digitizer only</td>
<td>Data acquisition to on-board memory for multiple trigger events, using Block/Segment Statistic Module (FPGA firmware Option).</td>
</tr>
<tr>
<td>SPC_REC_STD_AVERAGE</td>
<td>20000h</td>
<td>M4i/M4x.2xxx M4i/M4x.44xx DN2/DN6.2xx DN2/DN6.44x digitizer only</td>
<td>Data acquisition to on-board memory for multiple trigger events, using Block Average Module (FPGA firmware Option).</td>
</tr>
<tr>
<td>SPC_REC_STD_BOXCAR</td>
<td>800000h</td>
<td>M4i/M4x.44xx DN2/DN6.44x digitizer only</td>
<td>Enables Boxcar Averaging for standard acquisition. Requires digitizer module with firmware version V29 or newer.</td>
</tr>
<tr>
<td>SPC_REC_FIFO_SINGLE</td>
<td>10h</td>
<td>all cards</td>
<td>Continuous data acquisition for one single trigger event. The on-board memory is used completely as FIFO buffer.</td>
</tr>
<tr>
<td>SPC_REC_FIFO_MULTI</td>
<td>20h</td>
<td>all cards</td>
<td>Continuous data acquisition for multiple trigger events.</td>
</tr>
<tr>
<td>SPC_REC_FIFO_GATE</td>
<td>40h</td>
<td>all cards</td>
<td>Continuous data acquisition using an external gate signal.</td>
</tr>
<tr>
<td>SPC_REC_FIFO_ABA</td>
<td>80h</td>
<td>digitizer only</td>
<td>Continuous data acquisition for multiple trigger events together with continuous data acquisition with a slower sampling clock.</td>
</tr>
<tr>
<td>SPC_REC_FIFO_SEGSTATS</td>
<td>100000h</td>
<td>M4i/M4x.2xxx M4i/M4x.44xx DN2/DN6.2xx DN2/DN6.44x digitizer only</td>
<td>Enables Block/Segment Statistic for FIFO acquisition (FPGA firmware Option).</td>
</tr>
<tr>
<td>SPC_REC_FIFO_AVERAGE</td>
<td>200000h</td>
<td>M4i/M4x.2xxx M4i/M4x.44xx DN2/DN6.2xx DN2/DN6.44x digitizer only</td>
<td>Enables Block Averaging for FIFO acquisition (FPGA firmware Option).</td>
</tr>
<tr>
<td>SPC_REC_FIFO_BOXCAR</td>
<td>1000000h</td>
<td>M4i/M4x.44xx DN2/DN6.44x digitizer only</td>
<td>Enables Boxcar Averaging for FIFO acquisition. Requires digitizer module firmware version V29 or newer.</td>
</tr>
<tr>
<td>SPC_REC_FIFO_SINGLE_MONITOR</td>
<td>2000000h</td>
<td>digitizer only</td>
<td>Combination of SPC_REC_FIFO_SINGLE mode with additional slower sampling clock data stream for monitoring purposes (same as A-data of SPC_REC_FIFO_ABA mode).</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>write only</td>
<td>Executes a command for the card or data transfer.</td>
</tr>
</tbody>
</table>

Card execution commands

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.

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.

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:

```c
// card is started and trigger detection is enabled immediately
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_RESET | 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_M2CMD, M2CMD_CARD_WAITTRIGGER, 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\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_M2CMD, M2CMD_CARD_WAITREADY);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_WAITREADY);
printf("Card has stopped now\n\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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2STATUS</td>
<td>110</td>
<td>read only</td>
<td>Reads out the current status information</td>
</tr>
<tr>
<td>M2STAT_CARD_PRETRIGGER</td>
<td>1h</td>
<td>Acquisition modes only: the first pretrigger area has been filled. In Multi/ABA/Gated acquisition this status is set only for the first segment and will be cleared at the end of the acquisition.</td>
<td></td>
</tr>
<tr>
<td>M2STAT_CARD_TRIGGER</td>
<td>2h</td>
<td>The first trigger has been detected</td>
<td></td>
</tr>
<tr>
<td>M2STAT_CARD_READY</td>
<td>4h</td>
<td>The card has finished its run and is ready</td>
<td></td>
</tr>
<tr>
<td>M2STAT_CARD_SEGMENT_PRETRG</td>
<td>8h</td>
<td>This flag will be set for each completed pretrigger area including the first one of a Single acquisition. Additionally for a Multi/ABA/Gated acquisition of M4i/M4x/M2p only, this flag will be set when the pretrigger area of a segment has been filled and will be cleared in between segments.</td>
<td></td>
</tr>
</tbody>
</table>

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 spc_m_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
dwBufType,              // type of the buffer to define as listed below under SPCM_BUF_XXXX
dwDirection,            // the transfer direction as defined below
void* pvDataBuffer,           // pointer to the data buffer
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:

<table>
<thead>
<tr>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_BUF_DATA</td>
<td>Buffer is used for transfer of standard sample data</td>
</tr>
<tr>
<td>SPCM_BUF_ABA</td>
<td>Buffer is used to read out slow ABA data. Details on this mode are described in the chapter about the ABA mode option.</td>
</tr>
<tr>
<td>SPCM_BUF_TIMESTAMP</td>
<td>Buffer is used to read out timestamp information. Details on this mode are described in the chapter about the timestamp option.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Direction Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_DIR_PCTOCARD</td>
<td>Transfer is done from PC memory to on-board memory of card</td>
</tr>
<tr>
<td>SPCM_DIR_CARDTOPC</td>
<td>Transfer is done from card on-board memory to PC memory</td>
</tr>
<tr>
<td>SPCM_DIR_CARDTOGPU</td>
<td>RDMA transfer from card memory to GPU memory, SCAPP option needed, Linux only</td>
</tr>
<tr>
<td>SPCM_DIR_GPUTOCARD</td>
<td>RDMA transfer from GPU memory to card memory, SCAPP option needed, Linux only</td>
</tr>
</tbody>
</table>

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 `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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_MEMTEST</td>
<td>200700</td>
<td>read/write</td>
<td>Writing a 1 activates the memory test mode, no commands are then processed. Writing a 0 deactivates the memory test mode again.</td>
</tr>
</tbody>
</table>
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.

```c
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:

<table>
<thead>
<tr>
<th>Buffer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_BUF_DATA</td>
<td>Buffer is used for transfer of standard sample data</td>
</tr>
<tr>
<td>SPCM_BUF_ABA</td>
<td>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.</td>
</tr>
<tr>
<td>SPCM_BUF_TIMESTAMP</td>
<td>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.</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>write only</td>
<td>Executes a command for the card or data transfer</td>
</tr>
<tr>
<td>M2CMD_DATA_STARTDMA</td>
<td>10000h</td>
<td>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</td>
<td></td>
</tr>
<tr>
<td>M2CMD_DATA_WAITDMA</td>
<td>20000h</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>M2CMD_DATA_STOPDMA</td>
<td>40000h</td>
<td>Stops a running DMA transfer. Data is invalid afterwards.</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2STATUS</td>
<td>110</td>
<td>read only</td>
<td>Reads out the current status information</td>
</tr>
<tr>
<td>M2STAT_DATA_BLOCKREADY</td>
<td>100h</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>M2STAT_DATA_END</td>
<td>200h</td>
<td>The data transfer has completed. This status information will only occur if the notify size is set to zero.</td>
<td></td>
</tr>
<tr>
<td>M2STAT_DATA_OVERRUN</td>
<td>400h</td>
<td>The data transfer had an overrun (acquisition) or underrun (replay) while doing FIFO transfer.</td>
<td></td>
</tr>
<tr>
<td>M2STAT_DATA_ERROR</td>
<td>800h</td>
<td>An internal error occurred while doing data transfer.</td>
<td></td>
</tr>
</tbody>
</table>

Example of data transfer

```c
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 | M2CMD_DATA_WAITDMA);
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 acquisition mode

The standard single mode is the easiest and mostly used mode to acquire analog data with a Spectrum acquisition card. In standard single recording mode the card is working totally independent from the PC, after the card setup is done. The advantage of the Spectrum boards is that regardless to the system usage the card will sample with equidistant time intervals. The sampled and converted data is stored in the on-board memory and is held there for being read out after the acquisition. This mode allows sampling at very high conversion rates without the need to transfer the data into the memory of the host system at high speed. After the recording is done, the data can be read out by the user and is transferred via the bus into PC memory.

This standard recording mode is the most common mode for all analog and digital acquisition and oscilloscope boards. The data is written to a programmed amount of the on-board memory (memsize). That part of memory is used as a ring buffer, and recording is done continuously until a trigger event is detected. After the trigger event, a certain programmable amount of data is recorded (post trigger) and then the recording finishes. Due to the continuous ring buffer recording, there are also samples prior to the trigger event in the memory (pretrigger).

When the card is started the pre trigger area is filled up with data first. While doing this the board’s trigger detection is not armed. If you use a huge pre trigger size and a slow sample rate it can take some time after starting the board before a trigger event will be detected.

Card mode
The card mode has to be set to the correct mode SPC_REC_STD_SINGLE.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode, a read command will return the currently used mode.</td>
</tr>
<tr>
<td>SPC_REC_STD_SINGLE</td>
<td>1h</td>
<td></td>
<td>Data acquisition to on-board memory for one single trigger event.</td>
</tr>
</tbody>
</table>

Memory, Pre- and Posttrigger
At first you have to define, how many samples are to be recorded at all and how many of them should be acquired after the trigger event has been detected.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_MEMSIZE</td>
<td>10000</td>
<td>read/write</td>
<td>Sets the memory size in samples per channel.</td>
</tr>
<tr>
<td>SPC_POSTTRIGGER</td>
<td>10100</td>
<td>read/write</td>
<td>Sets the number of samples to be recorded per channel after the trigger event has been detected.</td>
</tr>
</tbody>
</table>

You can access these settings by the register SPC_MEMSIZE, which sets the total amount of data that is recorded, and the register SPC_POSTTRIGGER, that defines the number of samples to be recorded after the trigger event has been detected. The size of the pretrigger results on the simple formula:

pretrigger = memsize - posttrigger

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

Example
The following example shows a simple standard single mode data acquisition setup with the read out of data afterwards. To keep this example simple there is no error checking implemented.

```c
int32 lMemsize = 16384; // recording length is set to 16 kSamples
spcm_dwSetParam_i32 (hDrv, SPC_CHENABLE, CHANNEL0); // only one channel activated
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REC_STD_SINGLE); // set the standard single recording mode
spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, lMemsize); // recording length
spcm_dwSetParam_i64 (hDrv, SPC_POSTTRIGGER, 8192); // samples to acquire after trigger = 8k

// now we start the acquisition and wait for the interrupt that signalsize the end
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER | M2CMD_CARD_WAITREADY);
void* pvData = pvAllocMemPageAligned (2 * lMemsize); // assuming 2 bytes per sample

// read out the data
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_CARDTOPC , 0, pvData, 0, 2 * lMemsize);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);
```
**FIFO Single acquisition mode**

The FIFO single mode does a continuous data acquisition using the on-board memory as a FIFO buffer and transferring data continuously to PC memory. One can make on-line calculations with the acquired data, store the data continuously to disk for later use or even have a data logger functionality with on-line data display.

**Card mode**

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

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode, a read command will return the currently used mode.</td>
</tr>
<tr>
<td>SPC_REC_FIFO_SINGLE</td>
<td>10h</td>
<td>Continuous data acquisition to PC memory. Complete on-board memory is used as FIFO buffer.</td>
<td></td>
</tr>
</tbody>
</table>

**Length and Pretrigger**

Even in FIFO mode it is possible to program a pretrigger area. 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PRETRIGGER</td>
<td>10030</td>
<td>read/write</td>
<td>Programs the number of samples to be acquired before the trigger event detection</td>
</tr>
<tr>
<td>SPC_SEGMENTSIZE</td>
<td>10010</td>
<td>read/write</td>
<td>Length of segments to acquire.</td>
</tr>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>Number of segments to acquire in total. If set to zero the FIFO mode will run continuously until it is stopped by the user.</td>
</tr>
</tbody>
</table>

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

**Difference to standard single acquisition mode**

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

**Pretrigger**

When doing standard single acquisition memory is used as a circular buffer and the pre trigger can be up to the [installed memory] - [minimum post trigger]. Compared to this the pre trigger in FIFO mode is limited by a special pre trigger FIFO and hence considerably shorter.

**Length of acquisition**

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

**Example FIFO acquisition**

The following example shows a simple FIFO single mode data acquisition setup with the read out of data afterwards. To keep this example simple there is no error checking implemented.

```c
spcm_dwSetParam_i32 (hDrv, SPC_CHENABLE, CHANNEL0);                      // only one channel activated
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REC_FIFO_SINGLE);           // set the FIFO single recording mode
spcm_dwSetParam_i64 (hDrv, SPC_PRETRIGGER, 1024);                        // 1 kSample of data before trigger

// in FIFO mode we need to define the buffer before starting the transfer
void* pvData = pvAllocMemPageAligned (llBufsizeInSamples * 2);            // 2 bytes per sample
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_CARDTOPC, 4096, pvData, 0, 2 * llBufsizeInSamples);

// now we start the acquisition and wait for the first block
dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER);  
dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// we acquire data in a loop. As we defined a notify size of 4k we'll get the data in >=4k chunks
llTotalBytes = 0;
while (!dwError)
{
    dwError = spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_USER_LEN, &llAvailBytes); // read out the available bytes
    llTotalBytes += llAvailBytes;
    // here is the right position to do something with the data (printf is limited to 32 bit variables)
    printf("Currently Available: %lld, total: %lld\n", llAvailBytes, llTotalBytes);
    // now we free the number of bytes and wait for the next buffer
    spcm_dwGetParam_i64 (hDrv, SPC_DATA_AVAIL_CARD_LEN, llAvailBytes);
    dwError = spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_WAITDMA);
}
```

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The maximum memory size parameter is only limited by the number of activated channels and by the amount of installed memory. Minimum memory size as well as minimum and maximum post trigger limits are independent of the activated channels or the installed memory.

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 pre trigger, post trigger, 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.

All figures listed here are given in samples. An entry of [8G - 16] means [8 GSamples - 16] = 8,589,934,576 samples.

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

<table>
<thead>
<tr>
<th>Installed Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>512 MSample</td>
</tr>
<tr>
<td>256 MSample</td>
</tr>
</tbody>
</table>

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 are 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 M4i/M4x/M2p 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:

![Diagram of data transfer handling]

Although an M4i is shown here, this applies to M4x and M2p cards as well. 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 sets parts of this software buffer available for the driver for further transfer. The handshake is fulfilled with the following 3 software registers:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_DATA_AVAIL_USER_LEN</td>
<td>200</td>
<td>read</td>
<td>Returns the number of currently to the user available bytes inside a sample data transfer.</td>
</tr>
<tr>
<td>SPC_DATA_AVAIL_USER_POS</td>
<td>201</td>
<td>read</td>
<td>Returns the position as byte index where the currently available data samples start.</td>
</tr>
<tr>
<td>SPC_DATA_AVAIL_CARD_LEN</td>
<td>202</td>
<td>write</td>
<td>Writes the number of bytes that the card can now use for sample data transfer again.</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Transfer direction</th>
<th>Register</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write to card</td>
<td>SPC_DATA_AVAIL_USER_LEN</td>
<td>read</td>
<td>Returns 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.</td>
</tr>
<tr>
<td></td>
<td>SPC_DATA_AVAIL_CARD_LEN</td>
<td>write</td>
<td>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.</td>
</tr>
<tr>
<td>Read from card</td>
<td>SPC_DATA_AVAIL_USER_LEN</td>
<td>read</td>
<td>Returns 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.</td>
</tr>
<tr>
<td></td>
<td>SPC_DATA_AVAIL_CARD_LEN</td>
<td>write</td>
<td>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.</td>
</tr>
<tr>
<td>Any direction</td>
<td>SPC_DATA_AVAIL_USER_POS</td>
<td>read</td>
<td>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.</td>
</tr>
<tr>
<td>Any direction</td>
<td>SPC_FILLSIZEPROMILLE</td>
<td>read</td>
<td>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.</td>
</tr>
</tbody>
</table>

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 related to the notify size at the DefTransfer call. Even when less bytes already have been transferred you won’t get notice of it in case 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 buffer.

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Buffer handling

Acquisition modes

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.

For very small notify sizes, getting best bus transfer performance could be improved by 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)

```c
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, SPCM_BUF_DATA, SPCM_DIR_CARDTOPC, SPCM_DIR_PCTOCARD, 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, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, 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, SPCM_DATA_AVAIL_USER_LEN, &llAvailBytes);
        printf ("We now have %lld new bytes available\n", llAvailBytes);
        printf ("The available data starts at position %lld\n", llBytesPos);
        // we take care not to go across the end of the buffer, handling the wrap-around
        if ((llBytesPos + llAvailBytes) >= llBufferSizeInBytes)
            llAvailBytes = llBufferSizeInBytes - llBytesPos;
        // our do function gets a pointer to the start of the available data section and the length
        vDoSomething (pcData[llBytesPos], llAvailBytes);
        // the buffer section is now immediately set available for the card
        spcm_dwSetParam_i32 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, M2CMD_DATA_WAITDMA);
}while (!dwError); // we loop forever if no error occurs
```

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

```c
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, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, 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, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, M2CMD_DATA_STARTDMA, M2CMD_DATA_WAITDMA);
        printf ("We now have %lld free bytes available\n", llAvailBytes);
        printf ("The available data starts at position %lld\n", llBytesPos);
        // we take care not to go across the end of the buffer, handling the wrap-around
        if ((llBytesPos + llAvailBytes) >= llBufferSizeInBytes)
            llAvailBytes = llBufferSizeInBytes - llBytesPos;
        // our do function gets a pointer to the start of the available data section and the length
        vDoGenerateData (pcData[llBytesPos], llAvailBytes);
        // now we mark the number of bytes that we just generated for replay
        // and wait for the next free buffer
        spcm_dwSetParam_i32 (hDrv, SPCM_BUF_DATA, SPCM_DIR_PCTOCARD, M2CMD_DATA_STARTDMA, 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.
Data organisation

Data is organized in a multiplexed way in the transfer buffer, as shown in the following table.

<table>
<thead>
<tr>
<th>Sample width</th>
<th>Samples ordering in buffer memory starting with data offset zero</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 bit (D15...D0)</td>
<td>B0 A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18 A19</td>
</tr>
<tr>
<td>16 bit (D31...D16)</td>
<td>B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12 B13 B14 B15 B16 B17 B18 B19</td>
</tr>
<tr>
<td>32 bit</td>
<td>A0 B0 A1 B1 A2 B2 A3 B3 A4 B4 A5 B5 A6 B6 A7 B7 A8 B8 A9 B9</td>
</tr>
</tbody>
</table>

The samples are re-named for better readability:

- **A0**: bits (D15...D0) of sample 0 when generating 16 bit and 32 bit
- **B0**: bits (D31...D16) of sample 0 when generating 16 bit and 32 bit.

Sample format

All samples are stored in memory as 16 bit integer values. The following table shows the sample format for the 75xx series cards.

<table>
<thead>
<tr>
<th>Bit</th>
<th>16 channels</th>
<th>32 channels (alternating 16bit sample order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D15</td>
<td>N Sample Bit 15 (MSB)</td>
<td>N Sample Bit 15</td>
</tr>
<tr>
<td>D14</td>
<td>N Sample Bit 14</td>
<td>N Sample Bit 14</td>
</tr>
<tr>
<td>D13</td>
<td>N Sample Bit 13</td>
<td>N Sample Bit 13</td>
</tr>
<tr>
<td>D12</td>
<td>N Sample Bit 12</td>
<td>N Sample Bit 12</td>
</tr>
<tr>
<td>D11</td>
<td>N Sample Bit 11</td>
<td>N Sample Bit 11</td>
</tr>
<tr>
<td>D10</td>
<td>N Sample Bit 10</td>
<td>N Sample Bit 10</td>
</tr>
<tr>
<td>D9</td>
<td>N Sample Bit 9</td>
<td>N Sample Bit 9</td>
</tr>
<tr>
<td>D8</td>
<td>N Sample Bit 8</td>
<td>N Sample Bit 8</td>
</tr>
<tr>
<td>D7</td>
<td>N Sample Bit 7</td>
<td>N Sample Bit 7</td>
</tr>
<tr>
<td>D6</td>
<td>N Sample Bit 6</td>
<td>N Sample Bit 6</td>
</tr>
<tr>
<td>D5</td>
<td>N Sample Bit 5</td>
<td>N Sample Bit 5</td>
</tr>
<tr>
<td>D4</td>
<td>N Sample Bit 4</td>
<td>N Sample Bit 4</td>
</tr>
<tr>
<td>D3</td>
<td>N Sample Bit 3</td>
<td>N Sample Bit 3</td>
</tr>
<tr>
<td>D2</td>
<td>N Sample Bit 2</td>
<td>N Sample Bit 2</td>
</tr>
<tr>
<td>D1</td>
<td>N Sample Bit 1</td>
<td>N Sample Bit 1</td>
</tr>
<tr>
<td>D0</td>
<td>N Sample Bit 0 (LSB)</td>
<td>N Sample Bit 0 (LSB)</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode, a read command will return the currently used mode.</td>
</tr>
<tr>
<td>SPC_AVAILCARDMDE</td>
<td>9501</td>
<td>read</td>
<td>Returns a bitmap with all available modes on your card. The modes are listed below.</td>
</tr>
</tbody>
</table>

Replay modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_REP_STD_SINGLE</td>
<td>100h</td>
<td>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.</td>
</tr>
<tr>
<td>SPC_REP_STD_MULTI</td>
<td>200h</td>
<td>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.</td>
</tr>
<tr>
<td>SPC_REP_STD_GATE</td>
<td>400h</td>
<td>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.</td>
</tr>
<tr>
<td>SPC_REP_STD_SINGLERESTART</td>
<td>8000h</td>
<td>Data generation from on-board memory. The programmed memory is repeated once after each single trigger event.</td>
</tr>
<tr>
<td>SPC_REP_STD_SEQUENCE</td>
<td>40000h</td>
<td>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.</td>
</tr>
<tr>
<td>SPC_REP_FIFO_SINGLE</td>
<td>800h</td>
<td>Continuous data generation after one single trigger event. The on-board memory is used completely as FIFO buffer.</td>
</tr>
<tr>
<td>SPC_REP_FIFO_MULTI</td>
<td>1000h</td>
<td>Continuous data generation after multiple trigger events. The on-board memory is used completely as FIFO buffer.</td>
</tr>
<tr>
<td>SPC_REP_FIFO_GATE</td>
<td>2000h</td>
<td>Continuous data generation using an external gate signal. The on-board memory is used completely as FIFO buffer.</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>write only</td>
<td>Executes a command for the card or data transfer.</td>
</tr>
</tbody>
</table>
### Card execution commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2CMD_CARD_RESET</td>
<td>1h</td>
<td>Performs a hard and software reset of the card as explained further above.</td>
</tr>
<tr>
<td>M2CMD_CARD_WRITESETUP</td>
<td>2h</td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_START</td>
<td>4h</td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_ENABLETRIGGER</td>
<td>8h</td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_FORCETRIGGER</td>
<td>10h</td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_DISABLETRIGGER</td>
<td>20h</td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_STOP</td>
<td>40h</td>
<td>Stops the current run of the card. If the card is not running this command has no effect.</td>
</tr>
</tbody>
</table>

### 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.

<table>
<thead>
<tr>
<th>Command</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2CMD_CARD_WAITPREFULL</td>
<td>1000h</td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_WAITTRIGGER</td>
<td>2000h</td>
<td>Waits until the first trigger event has been detected by the card. If using a mode with multiple trigger events like Multi Recording or Gated Sampling there only the first trigger detection will generate an interrupt for this wait command.</td>
</tr>
<tr>
<td>M2CMD_CARD_WAITREADY</td>
<td>4000h</td>
<td>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.</td>
</tr>
</tbody>
</table>

### 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.

### Example for card control:

```c
// 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!
    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\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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2STATUS</td>
<td>110</td>
<td>read only</td>
<td>Reads out the current status information</td>
</tr>
<tr>
<td>M2STAT_CARD_PRETRIGGER</td>
<td>1h</td>
<td></td>
<td>Acquisition modes only: the first pretrigger area has been filled. In Multi/ABA/Gated acquisition this status is set only for the first segment and will be cleared at the end of the acquisition.</td>
</tr>
<tr>
<td>M2STAT_CARD_TRIGGER</td>
<td>2h</td>
<td></td>
<td>The first trigger has been detected</td>
</tr>
</tbody>
</table>

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.
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.

```c
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*       pvDataBuffer,           // 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:

<table>
<thead>
<tr>
<th>Buffer Type</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_BUF_DATA</td>
<td>1000</td>
<td>Buffer is used for transfer of standard sample data</td>
</tr>
<tr>
<td>SPCM_BUF_ABA</td>
<td>2000</td>
<td>Buffer is used to read out slow ABA data. Details on this mode are described in the chapter about the ABA mode option</td>
</tr>
<tr>
<td>SPCM_BUF_TIMESTAMP</td>
<td>3000</td>
<td>Buffer is used to read out timestamp information. Details on this mode are described in the chapter about the timestamp option</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Direction Type</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_DIR_PCTOCARD</td>
<td>0</td>
<td>Transfer is done from PC memory to on-board memory of card</td>
</tr>
<tr>
<td>SPCM_DIR_CARDTOPC</td>
<td>1</td>
<td>Transfer is done from card on-board memory to PC memory</td>
</tr>
<tr>
<td>SPCM_DIR_CARDTOGPU</td>
<td>2</td>
<td>RDMA transfer from card memory to GPU memory, SCAPP option needed, Linux only</td>
</tr>
<tr>
<td>SPCM_DIR_GPUTOCARD</td>
<td>3</td>
<td>RDMA transfer from GPU memory to card memory, SCAPP option needed, Linux only</td>
</tr>
</tbody>
</table>

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 `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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_MEMTEST</td>
<td>200700</td>
<td>read/write</td>
<td>Writing a 1 activates the memory test mode, no commands are then processed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Writing a 0 deactivates the memory test mode again.</td>
</tr>
</tbody>
</table>
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.

```c
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.

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

- **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:

- **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 an 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

```c
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode, a read command will return the currently used mode.</td>
</tr>
<tr>
<td>SPC_REP_STD_SINGLE</td>
<td>100h</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>SPC_REP_STD_SINGLESTART</td>
<td>8000h</td>
<td></td>
<td>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.</td>
</tr>
</tbody>
</table>

**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.

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

The maximum memsize that can be use 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 on 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 stopps 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

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPC REP STD SINGLE</strong></td>
<td>Replay starts with the first trigger event and then the programmed data is replayed in a continuous loop until stopped by the user.</td>
</tr>
<tr>
<td><strong>SPC REP STD SINGLERESTART</strong></td>
<td>The programmed memory is replayed once on every trigger event. This continues until stopped by the user.</td>
</tr>
<tr>
<td><strong>SPC REP STD SINGLERESTART</strong></td>
<td>The programmed memory is replayed once on every trigger event. This continues until stopped by the user.</td>
</tr>
</tbody>
</table>

### Continuous marker output

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

The marker output will generate a TTL pulse on one of the multi-purpose I/O lines. The pulse length is of ½ of programmed memory. The marker output is enabled using the dedicated multi-purpose I/O line setup that is described later in this manual. Please see the chapter „Multi Purpose I/O Lines“ in the trigger section to find more information.
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.

```c
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, SPCM_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.

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

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

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SEGMENTSIZE</td>
<td>10010</td>
<td>read/write</td>
<td>Length of segments to replay.</td>
</tr>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>Number of segments to replay in total. If set to zero the FIFO mode will run continuously until it is stopped by the user.</td>
</tr>
</tbody>
</table>

The total amount of samples per channel that is replayed can be calculated by \([\text{SPC_LOOPs} \times \text{SPC_SEGMENTSIZE}]\). 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.

```c
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

// 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;
    llotalBytes += 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);
}
```

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**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.

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:

<table>
<thead>
<tr>
<th>Activated Channels</th>
<th>Used Mode</th>
<th>Memory size SPC_MEMSIZE</th>
<th>Segment size SPC_SEGMENTSIZE</th>
<th>Loops SPC_LOOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Step</td>
</tr>
<tr>
<td>16 channels</td>
<td>Standard Single 16 Mem 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>Single Restart 16 Mem 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>Standard Multi 16 Mem 8</td>
<td>Mem/2</td>
<td>8</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>Standard Gate 16 Mem 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>FIFO Single 8</td>
<td>8</td>
<td>0 (c)</td>
<td>4G</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi 8</td>
<td>Mem/2</td>
<td>8</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
<tr>
<td>32 channels</td>
<td>Standard Single 16 Mem/2 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>Single Restart 16 Mem/2 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>Standard Multi 16 Mem/2 8</td>
<td>Mem/4</td>
<td>8</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>Standard Gate 16 Mem/2 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>FIFO Single 8</td>
<td>8</td>
<td>0 (c)</td>
<td>4G</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi 8</td>
<td>Mem/4</td>
<td>8</td>
<td>0 (c)</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate 8</td>
<td>not used</td>
<td>8192</td>
<td>0 (c)</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Installed Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>512 MSample</td>
</tr>
<tr>
<td>Mem</td>
</tr>
<tr>
<td>Mem / 2</td>
</tr>
<tr>
<td>Mem / 4</td>
</tr>
</tbody>
</table>

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 M4i/M4x/M2p 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:

Although an M4i is shown here, this applies to M4x and M2p cards as well. 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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_DATA_AVAIL_USER_LEN</td>
<td>200</td>
<td>read</td>
<td>Returns the number of currently to the user available bytes inside a sample data transfer.</td>
</tr>
<tr>
<td>SPC_DATA_AVAIL_USER_POS</td>
<td>201</td>
<td>read</td>
<td>Returns the position as byte index where the currently available data samples start.</td>
</tr>
<tr>
<td>SPC_DATA_AVAIL_CARD_LEN</td>
<td>202</td>
<td>write</td>
<td>Writes the number of bytes that the card can now use for sample data transfer again.</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Transfer direction</th>
<th>Register</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write to card</td>
<td>SPC_DATA_AVAIL_USER_LEN</td>
<td>read</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>SPC_DATA_AVAIL_CARD_LEN</td>
<td>write</td>
<td>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.</td>
</tr>
<tr>
<td>Read from card</td>
<td>SPC_DATA_AVAIL_USER_LEN</td>
<td>read</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>SPC_DATA_AVAIL_CARD_LEN</td>
<td>write</td>
<td>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.</td>
</tr>
<tr>
<td>Any direction</td>
<td>SPC_DATA_AVAIL_USER_POS</td>
<td>read</td>
<td>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.</td>
</tr>
<tr>
<td>Any direction</td>
<td>SPC_FILL_SIZE_PROMILLE</td>
<td>read</td>
<td>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.</td>
</tr>
</tbody>
</table>

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 related to the notify size at the DefTransfer call. Even when less bytes already have been transferred you won’t get notice of it in case 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

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Buffer handling

Generation modes

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.
  • For very small notify sizes, getting best bus transfer performance could be improved by 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)

```c
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, SPCM_M2CMD, SPCM_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, SPCM_M2CMD, SPCM_DATA_WAITDMA);
    // if there was no error we can proceed and read out the available bytes that are free again
    spcm_dwGetParam_i64 (hDrv, SPCM_DATA_AVAIL_USER_LEN, &llAvailBytes);
    spcm_dwGetParam_i64 (hDrv, SPCM_DATA_AVAIL_USER_POS, &llBytePos);
    printf ("We now have %lld new bytes available\n", llAvailBytes);
    printf ("The available data starts at position %lld\n", llBytesPos);
    // 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[llBytesPos], llAvailBytes);
    // the buffer section is now immediately set available for the card
    spcm_dwSetParam_i64 (hDrv, SPCM_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)

```c
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, SPCM_M2CMD, SPCM_DATA_AVAIL_CARD_LEN, llBufferSizeInBytes);
dwError = spcm_dwSetParam_i32 (hDrv, SPCM_M2CMD, SPCM_DATA_STARTDMA | SPCM_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, SPCM_DATA_AVAIL_USER_LEN, &llAvailBytes);
    spcm_dwGetParam_i64 (hDrv, SPCM_DATA_AVAIL_USER_POS, &llBytePos);
    printf ("We now have %lld free bytes available\n", llAvailBytes);
    printf ("The available data starts at position %lld\n", llBytesPos);
    // 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[llBytesPos], 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, SPCM_DATA_AVAIL_CARD_LEN, llAvailBytes);
    dwError = spcm_dwSetParam_i32 (hDrv, SPCM_M2CMD, SPCM_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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Read/Write</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_DATA_OUTBUFSIZE</td>
<td>209</td>
<td>read/write</td>
<td>Programs the used hardware buffer size for output direction. The default value is the complete standard on-board memory (which is 1 GByte). 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.</td>
</tr>
</tbody>
</table>

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 96 kByte (Latency 3) and cannot be changed. If using a hardware buffer of 64 kByte (Latency 2) and a software buffer of 64 kByte (Latency 1), the total size of buffered data is hence 224 kByte. Please see the following table for some example output latency calculations, taking buffers and the clock rate into account:

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Sampling rate</th>
<th>Software Buffer</th>
<th>Hardware Buffer</th>
<th>Output FIFO</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Size</td>
<td>Size</td>
<td>Size (max)</td>
<td>Latency</td>
</tr>
<tr>
<td>D/A: 1 x 16 Bit Channel</td>
<td>125 MS/s</td>
<td>8 MByte</td>
<td>8 MByte</td>
<td>64 kB</td>
<td>0.52 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67.11 ms</td>
<td>67.11 ms</td>
<td>132 kB</td>
<td>0.79 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.39 ms</td>
<td>8.39 ms</td>
<td>132 kB</td>
<td>17.0 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>0.79 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.52 ms</td>
<td>0.52 ms</td>
<td>132 kB</td>
<td>1.8 ms</td>
</tr>
<tr>
<td>Digital I/O: 16 channels</td>
<td>...</td>
<td>8 MByte</td>
<td>8 MByte</td>
<td>64 kB</td>
<td>0.52 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67.11 ms</td>
<td>67.11 ms</td>
<td>132 kB</td>
<td>0.79 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.39 ms</td>
<td>8.39 ms</td>
<td>132 kB</td>
<td>17.0 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>0.79 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.52 ms</td>
<td>0.52 ms</td>
<td>132 kB</td>
<td>1.8 ms</td>
</tr>
<tr>
<td>D/A: 1 x 16 Bit Channel</td>
<td>40 MS/s</td>
<td>8 MByte</td>
<td>8 MByte</td>
<td>64 kB</td>
<td>0.52 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>209.72 ms</td>
<td>209.72 ms</td>
<td>132 kB</td>
<td>2.46 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 MByte</td>
<td>1 MByte</td>
<td>132 kB</td>
<td>2.46 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26.21 ms</td>
<td>26.21 ms</td>
<td>132 kB</td>
<td>5.7 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>1.8 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.64 ms</td>
<td>1.64 ms</td>
<td>132 kB</td>
<td>5.7 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>1.8 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>1.8 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.52 ms</td>
<td>0.52 ms</td>
<td>132 kB</td>
<td>1.8 ms</td>
</tr>
<tr>
<td>Digital I/O: 16 channels</td>
<td>...</td>
<td>8 MByte</td>
<td>8 MByte</td>
<td>64 kB</td>
<td>0.52 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>838.86 ms</td>
<td>838.86 ms</td>
<td>132 kB</td>
<td>9.83 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 MByte</td>
<td>1 MByte</td>
<td>132 kB</td>
<td>9.83 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>104.86 ms</td>
<td>104.86 ms</td>
<td>132 kB</td>
<td>21.9 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>9.83 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.55 ms</td>
<td>6.55 ms</td>
<td>132 kB</td>
<td>22.9 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>9.83 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.82 ms</td>
<td>0.82 ms</td>
<td>132 kB</td>
<td>2.9 ms</td>
</tr>
<tr>
<td>D/A: 8 x 16 Bit Channels</td>
<td>10 MS/s</td>
<td>8 MByte</td>
<td>8 MByte</td>
<td>64 kB</td>
<td>0.52 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>104.86 ms</td>
<td>104.86 ms</td>
<td>132 kB</td>
<td>1.23 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 MByte</td>
<td>1 MByte</td>
<td>132 kB</td>
<td>1.23 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.11 ms</td>
<td>13.11 ms</td>
<td>132 kB</td>
<td>27.4 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 kB</td>
<td>64 kB</td>
<td>132 kB</td>
<td>1.23 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.82 ms</td>
<td>0.82 ms</td>
<td>132 kB</td>
<td>2.9 ms</td>
</tr>
</tbody>
</table>

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.

```c
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_DATA_OUTBUFSIZE, llHWBufSize);

// 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, as shown in the following table.

<table>
<thead>
<tr>
<th>Sample width</th>
<th>Samples ordering in buffer memory starting with data offset zero</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 bit (D15...D0)</td>
<td>A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15 A16 A17 A18 A19</td>
</tr>
<tr>
<td>16 bit (D31...D16)</td>
<td>B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12 B13 B14 B15 B16 B17 B18 B19</td>
</tr>
<tr>
<td>32 bit</td>
<td>A0 B0 A1 B1 A2 B2 A3 B3 A4 B4 A5 B5 A6 B6 A7 B7 A8 B8 A9 B9</td>
</tr>
</tbody>
</table>

The samples are re-named for better readability:

- A0: bits (D15...D0) of sample 0 when generating 16 bit and 32 bit
- B0: bits (D31...D16) of sample 0 when generating 16 bit and 32 bit.

Sample format

All samples are stored in memory as 16 bit integer values. The following table shows the sample format for the 75xx series cards.

<table>
<thead>
<tr>
<th>Bit</th>
<th>16 channels (alternating 16 bit sample order)</th>
<th>32 channels (alternating 16 bit sample order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D15</td>
<td>N Sample Bit 15 (MSB)</td>
<td>N Sample Bit 15</td>
</tr>
<tr>
<td>D14</td>
<td>N Sample Bit 14</td>
<td>N Sample Bit 14</td>
</tr>
<tr>
<td>D13</td>
<td>N Sample Bit 13</td>
<td>N Sample Bit 13</td>
</tr>
<tr>
<td>D12</td>
<td>N Sample Bit 12</td>
<td>N Sample Bit 12</td>
</tr>
<tr>
<td>D11</td>
<td>N Sample Bit 11</td>
<td>N Sample Bit 11</td>
</tr>
<tr>
<td>D10</td>
<td>N Sample Bit 10</td>
<td>N Sample Bit 10</td>
</tr>
<tr>
<td>D9</td>
<td>N Sample Bit 9</td>
<td>N Sample Bit 9</td>
</tr>
<tr>
<td>D8</td>
<td>N Sample Bit 8</td>
<td>N Sample Bit 8</td>
</tr>
<tr>
<td>D7</td>
<td>N Sample Bit 7</td>
<td>N Sample Bit 7</td>
</tr>
<tr>
<td>D6</td>
<td>N Sample Bit 6</td>
<td>N Sample Bit 6</td>
</tr>
<tr>
<td>D5</td>
<td>N Sample Bit 5</td>
<td>N Sample Bit 5</td>
</tr>
<tr>
<td>D4</td>
<td>N Sample Bit 4</td>
<td>N Sample Bit 4</td>
</tr>
<tr>
<td>D3</td>
<td>N Sample Bit 3</td>
<td>N Sample Bit 3</td>
</tr>
<tr>
<td>D2</td>
<td>N Sample Bit 2</td>
<td>N Sample Bit 2</td>
</tr>
<tr>
<td>D1</td>
<td>N Sample Bit 1</td>
<td>N Sample Bit 1</td>
</tr>
<tr>
<td>D0</td>
<td>N Sample Bit 0 (LSB)</td>
<td>N Sample Bit 0 (LSB)</td>
</tr>
</tbody>
</table>

(c) Spectrum GmbH
Overview

The Spectrum M2p PCI Express (PCIe) 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 the M2p digital I/O 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.

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_AVAILCLOCKMODES register.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_AVAILCLOCKMODES</td>
<td>20201</td>
<td>read</td>
<td>Bitmask, in which all bits of the below mentioned clock modes are set, if available.</td>
</tr>
<tr>
<td>SPC_CLOCKMODE</td>
<td>20200</td>
<td>read/write</td>
<td>Defines the used clock mode or reads out the actual selected one.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CM_INTPLL</td>
<td>1</td>
<td>Enables internal PLL with 20 MHz internal reference for sample clock generation.</td>
<td></td>
</tr>
<tr>
<td>SPC_CM_EXTERNAL</td>
<td>8</td>
<td>Enables external clock input for direct sample clock generation.</td>
<td></td>
</tr>
<tr>
<td>SPC_CM_EXTREFCLOCK</td>
<td>32</td>
<td>Enables internal PLL with external reference for sample clock generation.</td>
<td></td>
</tr>
</tbody>
</table>

The different clock modes and all other related or required register settings are described on the following pages.

The different clock modes

Standard internal sample rate (PLL with internal 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 very fine resolution, low jitter and a high accuracy. The on-board oscillator acts as a reference to the internal PLL. The specification is found in the technical data section of this manual.

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.

External reference 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. The external clock is divided/multiplied using a PLL allowing a wide range of external clock modes.

Synchronization Clock (option Star-Hub)
The Star-Hub option allows the synchronization of up to 16 cards of the M2p series from Spectrum with a minimal phase delay between the different cards. The clock is distributed from the master card to all connected cards. As this clock is also available at the PLL input, cards of the same or slower sampling speeds can be synchronized with different sample rates when using the PLL. For details on the synchronization option please take a look at the dedicated chapter in this manual.

Standard internal sampling clock (PLL)
The internal sampling clock is generated in default mode by a programmable high precision quartz. You need to select the clock mode by the dedicated register shown in the table below:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CLOCKMODE</td>
<td>20200</td>
<td>read/write</td>
<td>Defines the used clock mode</td>
</tr>
<tr>
<td>SPC_CM_INTPLL</td>
<td>1</td>
<td>Enables internal programmable high precision quartz for sample clock generation</td>
<td></td>
</tr>
</tbody>
</table>

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.

Independent of the used clock source it is possible to enable the clock output. The clock will be available on the external clock output connector and can be used to synchronize external equipment with the board.

Example on writing and reading internal sampling rate

Maximum and minimum internal sampling rate

The minimum and the maximum internal sampling rates depend on the specific type of board. Both values can be found in the technical data section of this manual.

Clock Edge Selection

The clock that is used to clock in the data to the capture flip flops (acquisition direction) or clock out the data from the output flip flops (replay direction) can be chosen to update the data only on the rising edge or the falling edge:

Example of clock edge selection:

Clock Delay (acquisition only)

The clock that is used to clock in the data to the capture flip flops can be delayed in very fine steps to further ease synchronous data capture in addition to the possibility to change the capture edge of the clock between rising and falling edge. The clock delay can be defined using the following register:

Example of clock delay:

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**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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CLOCKMODE</td>
<td>20200</td>
<td>r/w</td>
<td>Defines the used clock mode</td>
</tr>
<tr>
<td>SPC_CM_EXTERNAL</td>
<td>8</td>
<td></td>
<td>Enables external clock input for direct sample clock generation</td>
</tr>
</tbody>
</table>

The maximum values for the external clock is board dependent and shown in the technical data section.

**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 110 Ohm termination on the board. If the termination is disabled, the impedance is several Kiloohm. 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CLOCK110OHM</td>
<td>20120</td>
<td>r/w</td>
<td>A “1” enables the 110 Ohm termination at the external clock input</td>
</tr>
</tbody>
</table>

**Clock Edge Selection**

The clock that is used to clock in the data to the capture flip flops (acquisition direction) or clock out the data from the output flip flops (replay direction) can be chosen to update the data only on the rising edge or the falling edge:

Examples of clock edge selection:

```c
spcm_dwSetParam_i32 (hDrv, SPC_CLOCK_EDGE, SPCM_FALLING_EDGE); // capture data on falling edge
```

**Clock Delay (acquisition only)**

The clock that is used to clock in the data to the capture flip flops can be delayed in very fine steps to further ease synchronous data capture in addition to the possibility to change the capture edge of the clock between rising and falling edge. The clock delay can be defined using the following register:

Examples of clock delay:

```c
spcm_dwSetParam_i32 (hDrv, SPC_CLOCKMODE, SPC_CM_EXTERNALS); // Set to external clock mode
spcm_dwSetParam_i64 (hDrv, SPC_CLOCK_DELAY, 350); // additionally delay clock by 35 ps
```

**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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CLOCKMODE</td>
<td>20200</td>
<td>r/w</td>
<td>Defines the used clock mode</td>
</tr>
<tr>
<td>SPC_CM_EXTREFCLOCK</td>
<td>32</td>
<td></td>
<td>Enables internal PLL with external reference for sample clock generation</td>
</tr>
</tbody>
</table>
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.

### Example of reference clock:

```c
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 110 Ohm termination on the board. If the termination is disabled, the impedance is several Kiloohm. 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.

### Clock Edge Selection

The clock that is used to clock in the data to the capture flip flops (acquisition direction) or clock out the data from the output flip flops (replay direction) can be chosen to update the data only on the rising edge or the falling edge:

#### Example of clock edge selection:

```c
spcm_dwSetParam_i32 (hDrv, SPC_CLOCK_EDGE, SPCM_FALLING_EDGE); // capture data on falling edge
```

### Clock Delay (acquisition only)

The clock that is used to clock in the data to the capture flip flops can be delayed in very fine steps to further ease synchronous data capture in addition to the possibility to change the capture edge of the clock between rising and falling edge. The clock delay can be defined using the following register:

#### Example of clock delay:

```c
spcm_dwSetParam_i32 (hDrv, SPC_CLOCKMODE, SPC_CM_EXTERNAL0); // Set to external clock mode
spcm_dwSetParam_i64 (hDrv, SPC_CLOCK_DELAY, 350); // additionally delay clock by 35 ps
```
General Description

The trigger modes of the Spectrum M2p series digital I/O cards are quite flexible and give you the possibility to detect many trigger events that you can think of.

You can choose between various external trigger modes and sources including software and channel trigger, depending on your type of board. All of the trigger modes can be independently set for each logic trigger input resulting in a even bigger variety of modes. This chapter is about to explain all of the different trigger modes and setting up the card’s registers for the desired mode.

Trigger Engine Overview

The trigger engine of the M2p card series allows to combine several different trigger sources with OR and AND combination, with a trigger delay or even with an OR combination across several cards when using the Star-Hub option. The above drawing gives a complete overview of the trigger engine and shows all possible features that are available.

On digital I/O cards each has four multi purpose inputs/outputs, that can be used as logic (TTL) trigger sources. These lines can also be software programmed to either inputs or outputs some extended status signals.

The Enable trigger allows the user to enable or disable all trigger sources with a single software command. The enable trigger command will not work on force trigger.

When the card is waiting for a trigger event on an external trigger line the force trigger command allows to force a trigger event with a single software command. The force trigger overrides the enable trigger command.

Before the trigger event is finally generated, it is wired through a programmable trigger delay. This trigger delay will also work when used in a synchronized system thus allowing each card to individually delay its trigger recognition.
**Trigger masks**

**Trigger OR mask**

The purpose of this passage is to explain the trigger OR mask and all the related software registers in detail.

The OR mask shown in the overview allows combination of the four logic trigger and software trigger.

Every trigger source of the M2p series cards is wired to the above mentioned OR mask. The user then can program which trigger source will be recognized, and which one won’t.

This selection for the mask is realized with the SPC_TRIG_ORMASK register in combination with constants for every possible 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_AVAILORMASK</td>
<td>40400</td>
<td>read</td>
<td>Bitmask, in which all bits of the below mentioned sources for the OR mask are set, if available.</td>
</tr>
<tr>
<td>SPC_TRIG_ORMASK</td>
<td>40410</td>
<td>read/write</td>
<td>Defines the events included within the trigger OR mask of the card.</td>
</tr>
<tr>
<td>SPC_TMASK_NONE</td>
<td>0h</td>
<td></td>
<td>No trigger source selected</td>
</tr>
<tr>
<td>SPC_TMASK_SOFTWARE</td>
<td>1h</td>
<td></td>
<td>Enables the software trigger for the OR mask. The card will trigger immediately after start.</td>
</tr>
<tr>
<td>SPC_TMASK_EXT0</td>
<td>2h</td>
<td></td>
<td>Enables the X0 (logic) trigger for the OR mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
<tr>
<td>SPC_TMASK_EXT1</td>
<td>4h</td>
<td></td>
<td>Enables the X1 (logic) trigger for the OR mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
<tr>
<td>SPC_TMASK_EXT2</td>
<td>8h</td>
<td></td>
<td>Enables the X2 (logic) trigger for the OR mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
<tr>
<td>SPC_TMASK_EXT3</td>
<td>10h</td>
<td></td>
<td>Enables the X3 (logic) trigger for the OR mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
</tbody>
</table>

**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, otherwise the software trigger will override other modes.**

The following example shows, how to setup the OR mask, for the two external trigger inputs, ORing them together. When using just a single trigger, only this particular trigger must be used in the OR mask register, respectively. As an example a simple edge detection has been chosen for Ext1 input and a window edge detection has been chosen for Ext0 input. The explanation and a detailed description of the different trigger modes for the external trigger inputs will be shown in the dedicated passage within this chapter.

```c
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS); // Setting up X0 logic trigger for positive edges
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT1_MODE, SPC_TM_NEG); // Setting up X1 logic trigger for falling edges

// Enable both external triggers within the OR mask, by ORing the mask flags together
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT1 | SPC_TMASK_EXT0);
```
**Trigger AND mask**

The purpose of this passage is to explain the trigger AND mask and all the related software registers in detail.

The AND mask shown in the overview allows combination of the four logic trigger and the enable trigger.

Every trigger source of the M2p 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 this mask is realized with the SPC_TRIG_ANDMASK register in combination with constants for every possible trigger source.

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 combining the different constants.

The table below shows the relating register for the general AND mask and the possible constants that can be written to it.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_AVAILANDMASK</td>
<td>40420</td>
<td>read</td>
<td>Bitmask, in which all bits of the below mentioned sources for the AND mask are set, if available.</td>
</tr>
<tr>
<td>SPC_TRIG_ANDMASK</td>
<td>40430</td>
<td>read/write</td>
<td>Defines the events included within the trigger AND mask of the card.</td>
</tr>
<tr>
<td>SPC_TMASK_NONE</td>
<td>0</td>
<td>read</td>
<td>No trigger source selected</td>
</tr>
<tr>
<td>SPC_TMASK_EXT0</td>
<td>2h</td>
<td>read</td>
<td>Enables the X0 (logic) trigger for the AND mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
<tr>
<td>SPC_TMASK_EXT1</td>
<td>4h</td>
<td>read</td>
<td>Enables the X1 (logic) trigger for the AND mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
<tr>
<td>SPC_TMASK_EXT2</td>
<td>8h</td>
<td>read</td>
<td>Enables the X2 (logic) trigger for the AND mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
<tr>
<td>SPC_TMASK_EXT3</td>
<td>10h</td>
<td>read</td>
<td>Enables the X3 (logic) trigger for the AND mask. The card will trigger if the programmed condition for this input is valid.</td>
</tr>
</tbody>
</table>

The following example shows, how to setup the AND mask, for an external trigger. As an example a simple high level detection has been chosen. When multiple external triggers shall be combined by AND, both of the external sources must be included in the AND mask register, similar to the OR mask example shown before. The explanation and a detailed description of the different trigger modes for the external trigger inputs will be shown in the dedicated passage within this chapter.

```c
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_HIGH);  // Setting up X0 for HIGH level
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_NONE);  // disable default software trigger
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ANDMASK, SPC_TMASK_EXT0);  // include EXT0 into AND mask
```
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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_ORMASK</td>
<td>40410</td>
<td>read/write</td>
<td>Defines the events included within the trigger OR mask of the card.</td>
</tr>
<tr>
<td>SPC_TMASK_SOFTWARE</td>
<td>1h</td>
<td></td>
<td>Sets the trigger mode to software, so that the recording/replay starts immediately.</td>
</tr>
</tbody>
</table>

Example for setting up the software trigger:

```c
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_SOFTWARE); // Internal software trigger mode is used
```

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>write</td>
<td>Command register of the M2i/M3i/M4i/M4x/M2p series cards.</td>
</tr>
<tr>
<td>M2CMD_CARD_FORCETRIGGER</td>
<td>10h</td>
<td></td>
<td>Forces a trigger event if the hardware is still waiting for a trigger event.</td>
</tr>
</tbody>
</table>

The example shows, how to use the forcetrigger command:

```c
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 trigger engine by software. By default the trigger engine is disabled.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>write</td>
<td>Command register of the M2i/M3i/M4i/M4x/M2p series cards.</td>
</tr>
<tr>
<td>M2CMD_CARD_ENABLETRIGGER</td>
<td>8h</td>
<td></td>
<td>Enables the trigger engine. Any trigger event will now be recognized.</td>
</tr>
<tr>
<td>M2CMD_CARD_DISABLETRIGGER</td>
<td>20h</td>
<td></td>
<td>Disables the trigger engine. No trigger events will be recognized, except force trigger.</td>
</tr>
</tbody>
</table>

The example shows, how to arm and disarm the card’s trigger engine properly:

```c
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.
```
Trigger delay

All of the Spectrum M2p 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.

As shown in the overview the trigger delay is located after the star-hub connection meaning that every M2p card being synchronized can still have its own trigger delay programmed. The Star-Hub will combine the original trigger events before the result is being delayed.

The delay is programmed in samples. The resulting time delay will therefore be \( \text{Programmed Delay} / \text{Sampling Rate} \).

The following table shows the related register and the possible values. A value of 0 disables the trigger delay.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_AVAILDELAY</td>
<td>40800</td>
<td>read</td>
<td>Contains the maximum available delay as a decimal integer value.</td>
</tr>
<tr>
<td>SPC_TRIG_DELAY</td>
<td>40810</td>
<td>read/write</td>
<td>Defines the delay for the detected trigger events.</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>No additional delay will be added.</td>
</tr>
<tr>
<td>1…[4G -1] in steps of 1</td>
<td></td>
<td></td>
<td>Defines the additional trigger delay in number of sample clocks. The trigger delay can be programmed up to ((4 \text{ GSamples - 1}) = 4294967295). The stepsize is 1 samples for 16 bit cards.</td>
</tr>
</tbody>
</table>

The example shows, how to use the trigger delay command:

```c
spcm_dwSetParam_i64 (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 „.

Trigger holdoff

All the cards of the Spectrum M2p series allow the user to program a trigger holdoff time when using one of the segmented acquisition or generation modes, such as Multiple Recording/Multiple Replay, ABA Mode (analog acquisition cards only) or Gated Sampling/Gated Replay. This can be useful when observing and analyzing certain signals that are packeted or bursty in nature.

Using a trigger holdoff will result in an artificially inserted dead-time after each posttrigger area, in which the trigger engine will reject all detected trigger events. The holdoff value is programmed in samples and the resulting holdoff time will therefore be \( \text{Programmed Delay} / \text{Sampling Rate} \).

The following table shows the related register and the possible values. A value of 0 disables the trigger holdoff.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_AVAILHOLDOFF</td>
<td>40802</td>
<td>read</td>
<td>Contains the maximum available holdoff as a decimal integer value.</td>
</tr>
<tr>
<td>SPC_TRIG_HOLDOFF</td>
<td>40811</td>
<td>read/write</td>
<td>Defines the trigger holdoff for the card's trigger engine for segmented modes (Mult, ABA, Gate).</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>No additional holdoff will be added.</td>
</tr>
<tr>
<td>1…[4G -1] in steps of 1</td>
<td></td>
<td></td>
<td>Defines the trigger holdoff in number of sample clocks. The trigger holdoff can be programmed up to ((4 \text{ GSamples - 1}) = 4294967295). The stepsize is 1 samples for 16 bit cards.</td>
</tr>
</tbody>
</table>

The example shows, how to use the trigger holdoff command:

```c
spcm_dwSetParam_i64 (hDrv, SPC_TRIG_HOLDOFF, 2000); // A trigger holdoff is set to 2000
```
**External logic trigger (X0, X1, X2, X3)**

The four multi purpose I/O lines of the M2p digital I/O cards can be set up as logic (TTL) triggers.

The external logic triggers can be easily combined with each other.

The programming of the masks is shown in the chapters above.

### Trigger Mode

Please find the main external (analog) trigger input modes below. A detailed description of the modes follows in the next chapters.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_ORMASK</td>
<td>40410</td>
<td>read/write</td>
<td>Defines the OR mask for the different trigger sources.</td>
</tr>
<tr>
<td>SPC_TRIG_ANDMASK</td>
<td>40430</td>
<td>read/write</td>
<td>Defines the events included within the trigger AND mask of the card.</td>
</tr>
<tr>
<td>SPC_MASK_EXT0</td>
<td>4h</td>
<td></td>
<td>Enable logic trigger X0 input for the OR mask</td>
</tr>
<tr>
<td>SPC_MASK_EXT1</td>
<td>4h</td>
<td></td>
<td>Enable logic trigger X1 input for the OR mask</td>
</tr>
<tr>
<td>SPC_MASK_EXT2</td>
<td>8h</td>
<td></td>
<td>Enable logic trigger X2 input for the OR mask</td>
</tr>
<tr>
<td>SPC_MASK_EXT3</td>
<td>10h</td>
<td></td>
<td>Enable logic trigger X3 input for the OR mask</td>
</tr>
</tbody>
</table>

For all external edge and level trigger modes, at least one of the masks must contain the corresponding input, as the following table shows:
Detailed description of the logic trigger modes

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.

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.

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.

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.
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT0_MODE</td>
<td>40510</td>
<td>read/write</td>
<td>SPC_TM_BOTH</td>
<td>4h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT0_PULSEWIDTH</td>
<td>44210</td>
<td>read/write</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_PULSEWIDTH</td>
<td>44211</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_PULSEWIDTH</td>
<td>44212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_PULSEWIDTH</td>
<td>44213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT0_MODE</td>
<td>40510</td>
<td></td>
<td>[SPC_TM_POS</td>
<td>SPC_TM_PW_GREATER]</td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT0_PULSEWIDTH</td>
<td>44210</td>
<td>read/write</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_PULSEWIDTH</td>
<td>44211</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_PULSEWIDTH</td>
<td>44212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_PULSEWIDTH</td>
<td>44213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT0_MODE</td>
<td>40510</td>
<td></td>
<td>[SPC_TM_POS</td>
<td>SPC_TM_PW_SMALLER]</td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**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.

![Diagram of TTL pulsewidth trigger for long LOW pulses]

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT0_PULSEWIDTH</td>
<td>44210</td>
<td>read/write</td>
<td>Sets the pulsewidth in samples</td>
<td>2 up to [4G -1]</td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_PULSEWIDTH</td>
<td>44211</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_PULSEWIDTH</td>
<td>44212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_PULSEWIDTH</td>
<td>44213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT0_MODE</td>
<td>40510</td>
<td>read/write</td>
<td>(SPC_TM_NEG</td>
<td>SPC_TM_PW_GREATER)</td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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.

![Diagram of TTL pulsewidth trigger for short LOW pulses]

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT0_PULSEWIDTH</td>
<td>44210</td>
<td>read/write</td>
<td>Sets the pulsewidth in samples</td>
<td>2 up to [4G -1]</td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_PULSEWIDTH</td>
<td>44211</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_PULSEWIDTH</td>
<td>44212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_PULSEWIDTH</td>
<td>44213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT0_MODE</td>
<td>40510</td>
<td>read/write</td>
<td>(SPC_TM_NEG</td>
<td>SPC_TM_PW_SMALLER)</td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following example shows, how to setup the card for using external TTL pulse width trigger on EXT1 (X1) input:

```c
// Setting up external X1 TTL trigger to detect low pulses that are longer than 50 samples ...
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT1_MODE, SPC_TM_NEG | SPC_TM_PW_GREATER);
spcm_dwSetParam_i64 (hDrv, SPC_TRIG_EXTI_PULSEWIDTH , 50);
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT1); // ... and enable it in OR mask
```

To find out what maximum pulsewidth (in samples) is available, please read out the register shown in the table below:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_AVAILPULSEWIDTH</td>
<td>44201</td>
<td>read</td>
<td>Contains the maximum possible value for the external trigger pulsewidth counter. Valid for all of the external trigger sources.</td>
</tr>
</tbody>
</table>
Multi Purpose I/O Lines

On-board I/O lines (X0, X1, X2, X3)

The digital I/O cards of the M2p series have four multi purpose I/O lines (X0, X1, X2, X3). These lines can be used for a wide variety of functions to help the interconnection with external equipment.

The functionality of these multi purpose lines can be software programmed and each of these lines can either be used for input or output.

The multi purpose I/O lines may be used as status outputs such as trigger output or internal arm/run as well as for asynchronous I/O to control external equipment.

All four lines can also be used as logic trigger inputs, as described in the external trigger chapter.

The multi purpose I/O lines are available on the two multi-pin connectors, with the exact pinning described in the appendix. As default these lines are switched off.

Please be careful when programming these lines as an output whilst maybe still being connected with an external signal source, as that may damage components either on the external equipment or on the card itself.

Programming the behavior

Each multi purpose I/O line can be individually programmed. Please check the available modes by reading the SPCM_X0_AVAILMODES, SPCM_X1_AVAILMODES, SPCM_X2_AVAILMODES and SPCM_X3_AVAILMODES register first. The available modes may differ from card to card and may be enhanced with new driver/firmware versions to come.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPCM_X0_AVAILMODES</td>
<td>600300</td>
<td>read</td>
<td>Bitmask with all bits of the below mentioned modes showing the available modes for (X0)</td>
</tr>
<tr>
<td>SPCM_X1_AVAILMODES</td>
<td>600301</td>
<td>read</td>
<td>Bitmask with all bits of the below mentioned modes showing the available modes for (X1)</td>
</tr>
<tr>
<td>SPCM_X2_AVAILMODES</td>
<td>600302</td>
<td>read</td>
<td>Bitmask with all bits of the below mentioned modes showing the available modes for (X2)</td>
</tr>
<tr>
<td>SPCM_X3_AVAILMODES</td>
<td>600303</td>
<td>read</td>
<td>Bitmask with all bits of the below mentioned modes showing the available modes for (X3)</td>
</tr>
<tr>
<td>SPCM_X0_MODE</td>
<td>600200</td>
<td>read/write</td>
<td>Defines the mode for (X0). Only one mode selection is possible to be set at a time</td>
</tr>
<tr>
<td>SPCM_X1_MODE</td>
<td>600201</td>
<td>read/write</td>
<td>Defines the mode for (X1). Only one mode selection is possible to be set at a time</td>
</tr>
<tr>
<td>SPCM_X2_MODE</td>
<td>600202</td>
<td>read/write</td>
<td>Defines the mode for (X2). Only one mode selection is possible to be set at a time</td>
</tr>
<tr>
<td>SPCM_X3_MODE</td>
<td>600203</td>
<td>read/write</td>
<td>Defines the mode for (X3). Only one mode selection is possible to be set at a time</td>
</tr>
<tr>
<td>SPCM_XMODE_DISABLE</td>
<td>00000000h</td>
<td></td>
<td>No mode selected. Output is tristate (default setup)</td>
</tr>
<tr>
<td>SPCM_XMODE_ASYNCIN</td>
<td>00000001h</td>
<td></td>
<td>Connector is programmed for asynchronous input. Use SPCM_XX_ASYNCIO to read data asynchronous as shown in the passage below.</td>
</tr>
<tr>
<td>SPCM_XMODEASYNCOUT</td>
<td>00000002h</td>
<td></td>
<td>Connector is programmed for asynchronous output. Use SPCM_XXASYNCIO to write data asynchronous as shown in the passage below.</td>
</tr>
<tr>
<td>SPCM_XMODE_DIGIN</td>
<td>00000004h</td>
<td></td>
<td>A/D cards only. Connector is programmed for synchronous digital input. For each analog channel, one digital channel X1/X2/X3 is integrated into the ADC data stream. Depending on the ADC resolution of your card the resulting merged samples can have different formats. Please check the „Sample format“ chapter and the following passage on „Synchronous digital inputs“ for more details. Please note that automatic sign extension of analog data is ineffective as soon as one digital input line is activated and the software must properly mask out the digital bits.</td>
</tr>
<tr>
<td>SPCM_XMODE_TRIGIN</td>
<td>00000010h</td>
<td></td>
<td>Connector is programmed as additional TTL trigger input. X1/X2/X3 are available as Ext1/Ext2/Ext3 trigger input. Please be sure to also set the corresponding trigger OR/AND masks to use this trigger input for trigger detection.</td>
</tr>
<tr>
<td>SPCM_XMODE_DIGOUT</td>
<td>00000008h</td>
<td></td>
<td>D/A cards only. Connector is programmed for synchronous digital output. Digital channels can be „included“ within the analog samples and synchronously replayed along. Requires additional MODE bits to be set along with this flag, as explained later on.</td>
</tr>
<tr>
<td>SPCM_XMODE_TRIGOUT</td>
<td>00000020h</td>
<td></td>
<td>Connector is programmed as trigger output and shows the trigger detection. The trigger output goes HIGH as soon as the trigger is recognized. After end of acquisition it is LOW again. In Multiple Record/Graded Sampling/ABA mode it goes LOW after the acquisition of the current segment stops. In standard FIFO mode the trigger output is HIGH until FIFO mode is stopped.</td>
</tr>
<tr>
<td>SPCM_XMODE_RUNSTATE</td>
<td>00000100h</td>
<td></td>
<td>Connector shows the current run state of the card. If acquisition/output is running the signal is HIGH. If card has stopped the signal is LOW.</td>
</tr>
<tr>
<td>SPCM_XMODE_ARMSTATE</td>
<td>00000200h</td>
<td></td>
<td>Connector shows the current ARM state of the card. If the card is armed and ready to receive a trigger the signal is HIGH. If the card is not running or the card is still acquiring pretrigger data or the trigger has already been detected, the signal is LOW.</td>
</tr>
<tr>
<td>SPCM_XMODE_CONTOUTMARK</td>
<td>00002000h</td>
<td></td>
<td>D/A cards only. Outputs a HIGH pulse as continuous marker signal for continuous replay mode. The marker signal length is ½ of the programmed memory size.</td>
</tr>
<tr>
<td>SPCM_XMODE_SYSCLKOUT</td>
<td>00004000h</td>
<td></td>
<td>Output of internal FPGA system clock. The system clock is always an even division of the current sampling clock.</td>
</tr>
</tbody>
</table>
On-board I/O lines (X0, X1, X2, X3) Multi Purpose I/O Lines

**Please note that a change to the SPCM_X0_MODE, SPCM_X1_MODE, SPCM_X2_MODE or SPCM_X3_MODE will only be updated with the next call to either the M2CMD_CARD_START or M2CMD_CARD_WRITESETUP register. For further details please see the relating chapter on the M2CMD_CARD registers.**

**Asynchronous I/O**

To use asynchronous I/O on the multi purpose I/O lines it is first necessary to switch these lines to the desired asynchronous mode by programming the above explained mode registers. As a special feature asynchronous input can also be read if the mode is set to trigger input or digital input.

**Example of asynchronous write and read.** We write a high pulse on output X2 and wait for a high level answer on input X1:

```c
spcm_dwSetParam_i32 (hDrv, SPCM_X0_MODE, SPCM_XMODE_ASYNCIN);   // X0 set to asynchronous input
spcm_dwSetParam_i32 (hDrv, SPCM_X1_MODE, SPCM_XMODEASYNCIN);     // X1 set to asynchronous input
spcm_dwSetParam_i32 (hDrv, SPCM_X2_MODE, SPCM_XMODEASYNCOUT);    // X2 set to asynchronous output
spcm_dwSetParam_i32 (hDrv, SPCM_X3_MODE, SPCM_XMODEASYNCOUT);    // X3 set to trigger output
spcm_dwSetParam_i32 (hDrv, M2CMD_CARD, M2CMD_CARD_WRITESETUP);  // make modes effective

do {
    spcm_dwGetParam_i32 (hDrv, SPCM_X0_ASYNCIO, &iAsyncIn);     // read input in a loop
    if (iAsyncIn & 2) == 0);                                   // until X1 is going to high level
}
```

**Special behavior of trigger output**

As the driver of the M2p series is the same as the driver for the M2i series and some old software may rely on register structure of the M2i card series, there is a special compatible trigger output register that will work according to the M2i series style and output a trigger signal on the two outputs that are located, where the M2i digital I/O cards have had their respective trigger output on every connector.

It is not recommended to use this register unless you’re converting M2i software to the M2p card series:

**The SPC_TRIG_OUTPUT register overrides the multi purpose I/O settings done by SPCM_X0_MODE and SPCM_X2_MODE and vice versa. Do not use both methods together from within one program.**
Mode Multiple Recording

The Multiple Recording mode allows the acquisition 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. Each segment will be filled with data when a trigger event occurs (acquisition mode).

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 recorded with each trigger event.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_POSTTRIGGER</td>
<td>10100</td>
<td>read/write</td>
<td>Acquisition only: defines the number of samples to be recorded per channel after the trigger event.</td>
</tr>
<tr>
<td>SPC_SEGMENTSIZE</td>
<td>10010</td>
<td>read/write</td>
<td>Size of one Multiple Recording segment: the total number of samples to be recorded per channel after detection of one trigger event including the time recorded before the trigger (pre trigger).</td>
</tr>
</tbody>
</table>

Each segment in acquisition mode can consist of pretrigger and/or posttrigger samples. The user always has to set the total segment size and the posttrigger, while the pretrigger is calculated within the driver with the formula: \[\text{pretrigger} = \text{segment size} - \text{posttrigger}\].

When using Multiple Recording the maximum pretrigger is limited depending on the number of active channels. When the calculated value exceeds that limit, the driver will return the error ERR_PRETRIGGERLEN.

Please have a look at the table further below to see the maximum pretrigger length that is possible.

Recording modes

Standard Mode

With every detected trigger event one data block is filled with data. The length of one multiple recording segment is set by the value of the segment size register SPC_SEGMENTSIZE. The total amount of samples to be recorded 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 acquisition mode please refer to the according chapter earlier in this manual.

The total number of samples to be recorded to the on-board memory in Standard Mode is defined by the SPC_MEMSIZE register.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode</td>
</tr>
<tr>
<td>SPC_REC_STD_MULTI</td>
<td>2</td>
<td></td>
<td>Enables Multiple Recording for standard acquisition.</td>
</tr>
</tbody>
</table>

FIFO Mode

The Multiple Recording in FIFO Mode is similar to the Multiple Recording in Standard Mode. In contrast to the standard mode it is not necessary to program the number of samples to be recorded. The acquisition is running until the user stops it. The data is read block by block by the driver as described under FIFO single mode example earlier in this manual. These blocks are online available for further data processing by the user program. This mode significantly reduces the amount of data to be transferred on the PCI bus as gaps of no interest do 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 advantage of Multiple Recording in FIFO mode is that you can stream data online to the host system. You can make real-time data processing or store a huge amount of data to the hard disk. The table below shows the dedicated register for enabling Multiple Recording. For detailed information how to setup and start the board in FIFO mode please refer to the according chapter earlier in this manual.

The number of segments to be recorded must be set separately with the register shown in the following table:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode</td>
</tr>
<tr>
<td>SPC_REC_FIFO_MULTI</td>
<td>32</td>
<td></td>
<td>Enables Multiple Recording for FIFO acquisition.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>Defines the number of segments to be recorded</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>Recording will be infinite until the user stops it</td>
</tr>
<tr>
<td>1... [4G - 1]</td>
<td></td>
<td></td>
<td>Defines the total segments to be recorded</td>
</tr>
</tbody>
</table>
Limits of pre trigger, post trigger, memory size

The maximum memory size parameter is only limited by the number of activated channels and by the amount of installed memory. Minimum memory size as well as minimum and maximum post trigger limits are independent of the activated channels or the installed memory.

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 pre trigger, post trigger, 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.

<table>
<thead>
<tr>
<th>Activated Channels</th>
<th>Used Mode</th>
<th>Memory size</th>
<th>Pre trigger</th>
<th>Post trigger</th>
<th>Segment size</th>
<th>Loops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SPC_MEMSIZE</td>
<td>SPC_PRETRIGGER</td>
<td>SPC_POSTTRIGGER</td>
<td>SPC_SEGMENTSIZE</td>
<td>SPC_LOOPS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Step</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>16 Ch</td>
<td>Standard Single</td>
<td>16 Mem</td>
<td>8</td>
<td>Mem - 8</td>
<td>8</td>
<td>8G - B</td>
</tr>
<tr>
<td></td>
<td>Standard Multi</td>
<td>16 Mem</td>
<td>8</td>
<td>32k</td>
<td>8</td>
<td>Mem - 8</td>
</tr>
<tr>
<td></td>
<td>Standard Gate</td>
<td>16 Mem</td>
<td>8</td>
<td>32k</td>
<td>8</td>
<td>Mem - 8</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>32k</td>
<td>8</td>
<td>not used</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi</td>
<td>not used</td>
<td>8</td>
<td>32k</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate</td>
<td>not used</td>
<td>8</td>
<td>32k</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>32 Ch</td>
<td>Standard Single</td>
<td>16 Mem/2</td>
<td>8</td>
<td>Mem/2 - 8</td>
<td>8</td>
<td>8G - B</td>
</tr>
<tr>
<td></td>
<td>Standard Multi</td>
<td>16 Mem/2</td>
<td>8</td>
<td>16k</td>
<td>8</td>
<td>Mem/2 - 8</td>
</tr>
<tr>
<td></td>
<td>Standard Gate</td>
<td>16 Mem/2</td>
<td>8</td>
<td>16k</td>
<td>8</td>
<td>Mem/2 - 8</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>16k</td>
<td>8</td>
<td>not used</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi</td>
<td>not used</td>
<td>8</td>
<td>16k</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate</td>
<td>not used</td>
<td>8</td>
<td>16k</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

All figures listed here are given in samples. An entry of [8G - 16] means [8 GSamples - 16] = 8,589,934,576 samples.

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

<table>
<thead>
<tr>
<th>Installed Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>512 MSample</td>
</tr>
<tr>
<td>256 MSample</td>
</tr>
</tbody>
</table>

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 are programmed depends on the used mode. Please read the detailed documentation of the mode.

Multiple Recording and Timestamps

Multiple Recording is well matching with the timestamp option. If timestamp recording is activated each trigger event and therefore each Multiple Recording segment will get timestamped as shown in the drawing on the right.

Please keep in mind that the trigger events are timestamped, not the beginning of the acquisition. The first sample that is available is at the time position of [Timestamp - Pretrigger].

The programming details of the timestamp option is explained in an extra chapter.

Trigger Modes

When using Multiple Recording all of the card’s trigger modes can be used including the software trigger. For detailed information on the available trigger modes, please take a look at the relating chapter earlier in this manual.
**Trigger Counter**

The number of acquired trigger events in Multiple Recording mode is counted in hardware and can be read out while the acquisition is running or after the acquisition has finished. The trigger events are counted both in standard mode as well as in FIFO mode.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIGGERCOUNTER</td>
<td>200905</td>
<td>read</td>
<td>Returns the number of trigger events that has been acquired since the acquisition start. The internal trigger counter has 48 bits. It is therefore necessary to read out the trigger counter value with 64 bit access or 2 x 32 bit access if the number of trigger events exceed the 32 bit range.</td>
</tr>
</tbody>
</table>

The trigger counter feature needs at least driver version V2.17 and firmware version V20 (M2i series), V10 (M3i series), V6 (M4i/M4x series) or V1 (M2p series). Please update the driver and the card firmware to these versions to use this feature. Trying to use this feature without the proper firmware version will issue a driver error.

Using the trigger counter information one can determine how many Multiple Recording segments have been acquired and can perform a memory flush by issuing Force trigger commands to read out all data. This is helpful if the number of trigger events is not known at the start of the acquisition. In that case one will do the following steps:

- Program the maximum number of segments that one expects or use the FIFO mode with unlimited segments
- Set a timeout to be sure that there are no more trigger events acquired. Alternatively one can manually proceed as soon as it is clear from the application that all trigger events have been acquired
- Read out the number of acquired trigger segments
- Issue a number of Force Trigger commands to fill the complete memory (standard mode) or to transfer the last FIFO block that contains valid data segments
- Use the trigger counter value to split the acquired data into valid data with a real trigger event and invalid data with a force trigger event.
Programming examples

The following example shows how to set up the card for Multiple Recording in standard mode.

```c
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REC_STD_MULTI); // Enables Standard Multiple Recording
spcm_dwSetParam_i64 (hDrv, SPC_SEGMENTSIZE, 1024); // Set the segment size to 1024 samples
spcm_dwSetParam_i64 (hDrv, SPC_POSTTRIGGER, 768); // Set the posttrigger to 768 samples and therefore
// the pretrigger will be 256 samples
spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, 4096); // Set the total memsize for recording to 4096 samples
// so that actually four segments will be recorded
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS); // Set triggermode 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 Recording in FIFO mode.

```c
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REC_FIFO_MULTI); // Enables FIFO Multiple Recording
spcm_dwSetParam_i64 (hDrv, SPC_SEGMENTSIZE, 2048); // Set the segment size to 2048 samples
spcm_dwSetParam_i64 (hDrv, SPC_POSTTRIGGER, 1920); // Set the posttrigger to 1920 samples and therefore
// the pretrigger will be 128 samples
spcm_dwSetParam_i64 (hDrv, SPC_LOOPS, 256); // 256 segments will be recorded
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_NEG); // Set triggermode to ext. TTL mode (falling edge)
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0); // and enable it within the trigger OR-mask
```
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SEGMENTSIZE</td>
<td>10010</td>
<td>read/write</td>
<td>Size of one Multiple Replay segment: the total number of samples to be replayed per channel after detection of one trigger event.</td>
</tr>
</tbody>
</table>

Trigger Modes

When using Multiple Recording all of the card’s trigger modes can be used including 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_MEMSIZE, 4096);  // 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
```

(c) Spectrum GmbH
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode</td>
</tr>
<tr>
<td>SPC_REP_STD_MULTI</td>
<td>200h</td>
<td></td>
<td>Enables Multiple Replay for standard replay.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_MEMSIZE</td>
<td>10000</td>
<td>read/write</td>
<td>Defines the total number of samples to be replayed.</td>
</tr>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>When writing a 1 the complete memory is replayed once, when writing a zero the replay continues from the beginning forever.</td>
</tr>
</tbody>
</table>

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.

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 then 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode</td>
</tr>
<tr>
<td>SPC_REP_FIFO_MULTI</td>
<td>1000h</td>
<td></td>
<td>Enables Multiple Replay for FIFO mode.</td>
</tr>
</tbody>
</table>

The number of segments to be replayed must be set separately with the register shown in the following table:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>Defines the number of segments to be replayed</td>
</tr>
</tbody>
</table>

0: Replay will be infinite until the user stops it.
1... [4G - 1]: Defines the total segments to be replayed.

Fifo replay mode with the use of SPC_LOOPS

<table>
<thead>
<tr>
<th>Trigger</th>
<th>Loops = 3</th>
<th>Segment 0</th>
<th>Segment 1</th>
<th>Segment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loops = 0</td>
<td>Segment 0</td>
<td>Segment 1</td>
<td>Segment 2</td>
<td></td>
</tr>
<tr>
<td>Loops = 5</td>
<td>Segment 0</td>
<td>Segment 1</td>
<td>Segment 2</td>
<td>Segment 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trigger</th>
<th>Loops = 3</th>
<th>Segment 0</th>
<th>Segment 1</th>
<th>Segment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loops = 0</td>
<td>Segment 0</td>
<td>Segment 1</td>
<td>Segment 2</td>
<td>Segment 0</td>
</tr>
<tr>
<td>Loops = 5</td>
<td>Segment 0</td>
<td>Segment 1</td>
<td>Segment 2</td>
<td>Segment 1</td>
</tr>
</tbody>
</table>
**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.

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:

<table>
<thead>
<tr>
<th>Activated Channels</th>
<th>Used Mode</th>
<th>Memory size SPC_MEMSIZE</th>
<th>Segment size SPC_SEGMENTSIZE</th>
<th>Loops SPC_LOOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Step</td>
</tr>
<tr>
<td>16 channels</td>
<td>Standard Single</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Single Restart</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Multi</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Gate</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>9G - 8</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi</td>
<td>not used</td>
<td>8</td>
<td>Mem/2</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate</td>
<td>not used</td>
<td>not used</td>
<td>not used</td>
</tr>
<tr>
<td>32 channels</td>
<td>Standard Single</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Single Restart</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Multi</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Gate</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>9G - 8</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi</td>
<td>not used</td>
<td>8</td>
<td>Mem/4</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate</td>
<td>not used</td>
<td>not used</td>
<td>not used</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Installed Memory</th>
<th>512 MSample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mem</td>
<td>512 MSample</td>
</tr>
<tr>
<td>Mem / 2</td>
<td>256 MSample</td>
</tr>
<tr>
<td>Mem / 4</td>
<td>128 MSample</td>
</tr>
</tbody>
</table>

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 behavior in pauses and after replay

Usually the used outputs of the digital I/O boards are set to logical 0 after replay. This is in most cases adequate as many pattern generators generate signals with a relation to the system ground. In some cases it can be necessary to hold the last sample, to output logical 1 or to switch outputs to a high impedance 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 behavior after replay:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC.CH0_STOPLEVEL</td>
<td>206020</td>
<td>read/write</td>
<td>Defines the behavior after replay for outputs D15...D0</td>
</tr>
<tr>
<td>SPC.CH1_STOPLEVEL</td>
<td>206021</td>
<td>read/write</td>
<td>Defines the behavior after replay for outputs D31...D16</td>
</tr>
<tr>
<td>SPCM_STOPVL_TRISTATE</td>
<td>1</td>
<td></td>
<td>Defines outputs to enter high-impedance state (tristate)</td>
</tr>
<tr>
<td>SPCM_STOPVL_LOW</td>
<td>2</td>
<td></td>
<td>Defines outputs to enter logical 0 state</td>
</tr>
<tr>
<td>SPCM_STOPVL_HIGH</td>
<td>4</td>
<td></td>
<td>Defines outputs to enter logical 1 state</td>
</tr>
<tr>
<td>SPCM_STOPVL_HOLDLAST</td>
<td>8</td>
<td></td>
<td>Holds the last replayed sample</td>
</tr>
<tr>
<td>SPCM_STOPVL_CUSTOM</td>
<td>32</td>
<td></td>
<td>Allows to define a 16bit wide custom level per channel for the digital output to enter in pauses. The sample format is exactly the same as during replay.</td>
</tr>
</tbody>
</table>

When using SPCM_STOPVL_CUSTOM, the sample value for the pauses must be defined via the following registers:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC.CH0_CUSTOM_STOP</td>
<td>206050</td>
<td>read/write</td>
<td>Defines the custom stop level for channels D15...D0 when using SPCM_STOPVL_CUSTOM.</td>
</tr>
<tr>
<td>SPC.CH1_CUSTOM_STOP</td>
<td>206051</td>
<td>read/write</td>
<td>Defines the custom stop level for channels D31...D16 when using SPCM_STOPVL_CUSTOM.</td>
</tr>
</tbody>
</table>

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

Example showing how to set a custom stoplevel for channel 0:

```c
// enable the use of custom stop level and use raw value 10487 as stop value
spcm_dwSetParam_i32(stCard.hDrv, SPC.CH0_STOPLEVEL, SPCM_STOPVL_CUSTOM);
spcm_dwSetParam_i32(stCard.hDrv, SPC.CH0_CUSTOM_STOP, 10487);
```
Mode Gated Sampling

The Gated Sampling mode allows the data acquisition controlled by an external or an internal gate signal. Data will only be recorded if the programmed gate condition is true. When using the Gated Sampling acquisition mode it is in addition also possible to program a pre- and/or posttrigger for recording samples prior to and/or after the valid gate.

This chapter will explain all the necessary software register to set up the card for Gated Sampling properly.

The section on the allowed trigger modes deals with detailed description on the different trigger events and the resulting gates.

When using Gated Sampling the maximum pretrigger is limited as shown in the technical data section. When the programmed value exceeds that limit, the driver will return the error ERR_PRETRIGGERLEN.

### Acquisition modes

#### Standard Mode

Data will be recorded as long as the gate signal fulfills the programmed gate condition. At the end of the gate interval the recording will be stopped and the card will pause until another gates signal appears. If the total amount of data to acquire has been reached, the card stops immediately. For that reason the last gate segment is ended by the expiring memory size counter and not by the gate end signal. The total amount of samples to be recorded can be defined by the memsize register. 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.

The number of gates to be recorded must be set separately with the register shown in the following table:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_MEMSIZE</td>
<td>10000</td>
<td>read/write</td>
<td>Defines the total number of samples to be recorded per channel.</td>
</tr>
</tbody>
</table>

#### FIFO Mode

The Gated Sampling in FIFO Mode is similar to the Gated Sampling in Standard Mode. In contrast to the Standard Mode you cannot program a certain total amount of samples to be recorded, but two other end conditions can be set instead. The acquisition can either run until the user stops it by software (infinite recording), or until a programmed number of gates has been recorded. The data is read continuously by the driver. This data is online available for further data processing by the user program. The advantage of Gated Sampling in FIFO mode is that you can stream data online to the host system with a lower average data rate than in conventional FIFO mode without Gated Sampling. You can make real-time data processing or store a huge amount of data to the 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.

The number of gates to be recorded must be set separately with the register shown in the following table:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>Defines the number of gates to be recorded.</td>
</tr>
</tbody>
</table>

![Diagram of Gated Sampling](image)
**Limits of pre trigger, post trigger, memory size**

The maximum memory size parameter is only limited by the number of activated channels and by the amount of installed memory. Minimum memory size as well as minimum and maximum post trigger limits are independent of the activated channels or the installed memory.

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 pre trigger, post trigger, 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.

<table>
<thead>
<tr>
<th>Activated Channels</th>
<th>Used Mode</th>
<th>Memory size</th>
<th>Pre trigger limits</th>
<th>Post trigger limits</th>
<th>Segment size limits</th>
<th>Loops limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SPC_MEMSIZE</td>
<td>SPC_PRETRIGGER</td>
<td>SPC_POSTTRIGGER</td>
<td>SPC_SEGMENTSIZE</td>
<td>SPC_LOOPS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Step</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>16 Ch</td>
<td>Standard Single</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
<td>B</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>Mem</td>
<td>8</td>
<td>B</td>
<td>32k</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>Mem</td>
<td>8</td>
<td>B</td>
<td>32k</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>32k</td>
<td>8</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not used</td>
<td>8</td>
<td>32k</td>
<td>8</td>
<td>B</td>
</tr>
<tr>
<td>32 Ch</td>
<td>Standard Single</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
<td>B</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
<td>B</td>
<td>16k</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>16k</td>
<td>8</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not used</td>
<td>8</td>
<td>16k</td>
<td>8</td>
<td>B</td>
</tr>
</tbody>
</table>

All figures listed here are given in samples. An entry of \([BG - 16]\) means \([8 GSamples - 16] = 8,589,934,576\) samples.

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

<table>
<thead>
<tr>
<th>Installed Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>512 MSample</td>
</tr>
<tr>
<td>256 MSample</td>
</tr>
</tbody>
</table>

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 are programmed depends on the used mode. Please read the detailed documentation of the mode.

**Gate-End Alignment**

Due to the structure of the on-board memory, the length of a gate will be rounded up until the next card specific alignment:

<table>
<thead>
<tr>
<th>Active Channels</th>
<th>M2i + M2i-exp</th>
<th>M4i + M4x</th>
<th>M2p</th>
</tr>
</thead>
<tbody>
<tr>
<td>8Bit</td>
<td>12/14/16 bit</td>
<td>8Bit</td>
<td>14/16 bit</td>
</tr>
<tr>
<td>1 channel</td>
<td>4 Samples</td>
<td>2 Samples</td>
<td>32 Samples</td>
</tr>
<tr>
<td>2 channels</td>
<td>2 Samples</td>
<td>1 Samples</td>
<td>16 Samples</td>
</tr>
<tr>
<td>4 channels</td>
<td>1 Sample</td>
<td>1 Samples</td>
<td>8 Samples</td>
</tr>
<tr>
<td>8 channels</td>
<td>--</td>
<td>1 Samples</td>
<td>--</td>
</tr>
<tr>
<td>16 channels</td>
<td>--</td>
<td>1 Samples</td>
<td>--</td>
</tr>
<tr>
<td>32 channels</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

So in case of a M4i.22xx card with 8Bit samples and one active channel, the gate-end can only stop at 32Sample boundaries, so that up to 31 more samples can be recorded until the post-trigger starts. The timestamps themselves are not affected by this alignment.
Gated Sampling and Timestamps

Gated Sampling and the timestamp mode fit very good together. If timestamp recording is activated each gate will get timestamped as shown in the drawing on the right. Both, beginning and end of the gate interval, are timestamped. Each gate segment will therefore produce two timestamps (\text{Timestamp1} and \text{Timestamp2}) showing start of the gate interval and end of the gate interval. By taking both timestamps into account one can read out the time position of each gate as well as the length in samples. There is no other way to examine the length of each gate segment than reading out the timestamps.

Please keep in mind that the gate signals are timestamped, not the beginning and end of the acquisition. The first sample that is available is at the time position of \([\text{Timestamp1} - \text{Pretrigger}]\). The length of the gate segment is \([\text{Timestamp2} - \text{Timestamp1} + \text{Alignment} + \text{Pretrigger} + \text{Posttrigger}]\). The last sample of the gate segment is at the position \([\text{Timestamp2} + \text{Alignment} + \text{Posttrigger}]\). When using the standard gate mode the end of recording is defined by the expiring memsize counter. In standard gate mode there will be an additional timestamp for the last gate segment, when the maximum memsize is reached!

The programming details of the timestamp mode are explained in an extra chapter.

Trigger

Detailed description of the logic gate trigger modes

Positive TTL 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{SPC_TRIG_EXT1_MODE}</td>
<td>40511</td>
<td>read/write</td>
<td>\text{SPC_TM_POS}</td>
<td>1h</td>
</tr>
<tr>
<td>\text{SPC_TRIG_EXT2_MODE}</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\text{SPC_TRIG_EXT3_MODE}</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{SPC_TRIG_EXT1_MODE}</td>
<td>40511</td>
<td>read/write</td>
<td>\text{SPC_TM_HIGH}</td>
<td>8h</td>
</tr>
<tr>
<td>\text{SPC_TRIG_EXT2_MODE}</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\text{SPC_TRIG_EXT3_MODE}</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trigger Mode Gated Sampling

Negative TTL 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td>read/write</td>
<td>SPC_TM_NEG</td>
<td>2h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td>read/write</td>
<td>SPC_TM_LOW</td>
<td>10h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_PULSEWIDTH</td>
<td>44211</td>
<td>read/write</td>
<td>SPC_TM_POS</td>
<td>2 up to [4G -1]</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_PULSEWIDTH</td>
<td>44212</td>
<td></td>
<td>SPC_TM_PW_GREATER</td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_PULSEWIDTH</td>
<td>44213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td>read/write</td>
<td>SPC_TM_POS</td>
<td>4000001h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td>SPC_TM_PW_GREATER</td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.

### Programming examples

The following example shows how to setup the card for using external TTL pulse width trigger on EXT1 (X1) input:

```c
// Setting up external X1 TTL trigger to detect low pulses that are longer than 50 samples ...
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT1_MODE, SPC_TM_NEG | SPC_TM_PW_GREATER);
spcm_dwSetParam_i64 (hDrv, SPC_TRIG_EXT1_PULSEWIDTH, 50);
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT1); // ... and enable it in OR mask
```

### Programming examples

The following examples shows how to set up the card for Gated Sampling in standard mode and for Gated Sampling in FIFO mode.

```c
// Enables Standard Gated Sampling
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REC_STD_GATE);

// Set the pretrigger to 256 samples
spcm_dwSetParam_i32 (hDrv, PRETRIGGER, 256);

// Set the posttrigger to 2048 samples
spcm_dwSetParam_i32 (hDrv, POSTTRIGGER, 2048);

// Set the total memsize for recording to 8192 samples
spcm_dwSetParam_i32 (hDrv, SPC_MEMSIZE, 8192);

// Enables FIFO Gated Sampling
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REC_FIFO_GATE);

// Set the pretrigger to 128 samples
spcm_dwSetParam_i32 (hDrv, PRETRIGGER, 128);

// Set the posttrigger to 512 samples
spcm_dwSetParam_i32 (hDrv, POSTTRIGGER, 512);

// 1024 gates will be recorded
spcm_dwSetParam_i32 (hDrv, SPC_LOOP, 1024);

// Set triggermode to ext. TTL mode (rising edge)
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_POS);

// Set trigger level to +1500 mV
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_LEVEL0, 1500);

// and enable it within the trigger OR-mask
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0);

// Set triggermode to ext. TTL mode (falling edge)
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_MODE, SPC_TM_NEG);

// Set trigger level to -1500 mV
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT0_LEVEL0, -1500);

// and enable it within the trigger OR-mask
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT0);
```
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 fulfills 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.

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode</td>
</tr>
<tr>
<td>SPC_REP_STD_GATE</td>
<td>400h</td>
<td></td>
<td>Enables Gated Sampling for standard acquisition.</td>
</tr>
</tbody>
</table>

The total number of samples to be replayed from the on-board memory in standard mode is defined by the SPC_MEMSIZE register.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_MEMSIZE</td>
<td>10000</td>
<td>read/write</td>
<td>Defines the total number of samples to be replayed.</td>
</tr>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>Defines the number of gates to be replayed.</td>
</tr>
</tbody>
</table>

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.

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>read/write</td>
<td>Defines the used operating mode</td>
</tr>
<tr>
<td>SPC_REP_FIFO_GATE</td>
<td>2000h</td>
<td></td>
<td>Enables Gated Replay with FIFO mode.</td>
</tr>
</tbody>
</table>

The number of gates to be replayed must be set separately with the register shown in the following table:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_LOOPS</td>
<td>10020</td>
<td>read/write</td>
<td>Defines the number of gates to be replayed.</td>
</tr>
</tbody>
</table>
Examples of Fifo 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.

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.

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:

<table>
<thead>
<tr>
<th>Activated Channels</th>
<th>Used Mode</th>
<th>Memory size</th>
<th>Segment size</th>
<th>Loops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SPC_MEMSIZE</td>
<td>SPC_SEGMENTSIZE</td>
<td>SPC_LOOPS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Step</td>
</tr>
<tr>
<td>16 channels</td>
<td>Standard Single</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Single Restart</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Multi</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Gate</td>
<td>16</td>
<td>Mem</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>BG - 8</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi</td>
<td>not used</td>
<td>8</td>
<td>Mem/2</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate</td>
<td>not used</td>
<td>8</td>
<td>not used</td>
</tr>
<tr>
<td>32 channels</td>
<td>Standard Single</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Single Restart</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Multi</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Standard Gate</td>
<td>16</td>
<td>Mem/2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>FIFO Single</td>
<td>not used</td>
<td>8</td>
<td>BG - 8</td>
</tr>
<tr>
<td></td>
<td>FIFO Multi</td>
<td>not used</td>
<td>8</td>
<td>Mem/4</td>
</tr>
<tr>
<td></td>
<td>FIFO Gate</td>
<td>not used</td>
<td>8</td>
<td>not used</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Installed Memory</th>
<th>Mem</th>
<th>Mem / 2</th>
<th>Mem / 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>512 MSample</td>
<td>512 MSample</td>
<td>256 MSample</td>
<td>128 MSample</td>
</tr>
</tbody>
</table>

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.
Trigger

**Detailed description of the logic gate trigger modes**

**Positive TTL 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td>read/write</td>
<td>SPC_TM_POS</td>
<td>1h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td>read/write</td>
<td>SPC_TM_HIGH</td>
<td>8h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Negative TTL 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td>read/write</td>
<td>SPC_TM_NEG</td>
<td>2h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td>read/write</td>
<td>SPC_TM_LOW</td>
<td>10h</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_PULSEWIDTH</td>
<td>44211</td>
<td>read/write</td>
<td>SPC_TM_PULSEWIDTH</td>
<td>2 up to [4G -1]</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_PULSEWIDTH</td>
<td>44212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_PULSEWIDTH</td>
<td>44213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td></td>
<td>(SPC_TM_POS</td>
<td>SPC_TM_PW_GREATER)</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>set to</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_TRIG_EXT1_PULSEWIDTH</td>
<td>44211</td>
<td>read/write</td>
<td>SPC_TM_PULSEWIDTH</td>
<td>2 up to [4G -1]</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_PULSEWIDTH</td>
<td>44212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_PULSEWIDTH</td>
<td>44213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT1_MODE</td>
<td>40511</td>
<td></td>
<td>(SPC_TM_NEG</td>
<td>SPC_TM_PW_GREATER)</td>
</tr>
<tr>
<td>SPC_TRIG_EXT2_MODE</td>
<td>40512</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_TRIG_EXT3_MODE</td>
<td>40513</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following example shows, how to setup the card for using external TTL pulse width trigger on EXT1 (X1) input:

// Setting up external X1 TTL trigger to detect low pulses that are longer than 50 samples ...  
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_EXT1_MODE, SPC_TM_NEG | SPC_TM_PW_GREATER);  
spcm_dwSetParam_i64 (hDrv, SPC_TRIG_EXT1_PULSEWIDTH, 50);  
spcm_dwSetParam_i32 (hDrv, SPC_TRIG_ORMASK, SPC_TMASK_EXT1); // ... and enable it in OR mask
**Programming examples**

The following examples show how to set up the card for Gated Replay in standard mode for Gated Replay in FIFO mode.

```c
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
```

```c
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 behavior in pauses and after replay**

Usually the used outputs of the digital I/O boards are set to logical 0 after replay. This is in most cases adequate as many pattern generators generate signals with a relation to the system ground. In some cases it can be necessary to hold the last sample, to output logical 1 or to switch outputs to a high impedance 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 behavior after replay:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CH0_STOPLEVEL</td>
<td>206020</td>
<td>read/write</td>
<td>Defines the behavior after replay for outputs D15..D0</td>
</tr>
<tr>
<td>SPC_CH1_STOPLEVEL</td>
<td>206021</td>
<td>read/write</td>
<td>Defines the behavior after replay for outputs D31..D16</td>
</tr>
<tr>
<td>SPCM_STOPVL_TRISTATE</td>
<td>1</td>
<td></td>
<td>Defines outputs to enter high-impedance state (tristate)</td>
</tr>
<tr>
<td>SPCM_STOPVL_LOW</td>
<td>2</td>
<td></td>
<td>Defines outputs to enter logical 0 state</td>
</tr>
<tr>
<td>SPCM_STOPVL_HIGH</td>
<td>4</td>
<td></td>
<td>Defines outputs to enter logical 1 state</td>
</tr>
<tr>
<td>SPCM_STOPVL_HOLDLAST</td>
<td>8</td>
<td></td>
<td>Holds the last replayed sample</td>
</tr>
<tr>
<td>SPCM_STOPVL_CUSTOM</td>
<td>32</td>
<td></td>
<td>Allows to define a 16bit wide custom level per channel for the digital output to enter in pauses. The sample format is exactly the same as during replay.</td>
</tr>
</tbody>
</table>

When using SPCM_STOPVL_CUSTOM, the sample value for the pauses must be defined via the following registers:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CH0_CUSTOM_STOP</td>
<td>206050</td>
<td>read/write</td>
<td>Defines the custom stop level for channels D15..D0 when using SPCM_STOPVL_CUSTOM.</td>
</tr>
<tr>
<td>SPC_CH1_CUSTOM_STOP</td>
<td>206051</td>
<td>read/write</td>
<td>Defines the custom stop level for channels D31..D16 when using SPCM_STOPVL_CUSTOM.</td>
</tr>
</tbody>
</table>

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

Example showing how to set a custom stoplevel for channel 0:

```c
// enable the use of custom stop level and use raw value 10487 as stop value
spcm_dwSetParam_i32 (stCard.hDrv, SPC_CH0_STOPLEVEL, SPCM_STOPVL_CUSTOM);
spcm_dwSetParam_i32 (stCard.hDrv, SPC_CH0_CUSTOM_STOP, 10487);
```
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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_PCIFEATURES</td>
<td>2120</td>
<td>PCI feature register. Holds the installed features and options as a bit field.</td>
</tr>
<tr>
<td>SPMC_FEATURE_SEQUENCE</td>
<td>1000h</td>
<td>Replay sequence mode available (only available for arbitrary generator and digital I/O cards)</td>
</tr>
</tbody>
</table>

Register

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SEQMODE_AVAILMAXSEGMENT</td>
<td>349900</td>
<td>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.</td>
</tr>
<tr>
<td>SPC_SEQMODE_AVAILMAXSTEPS</td>
<td>349901</td>
<td>Returns the maximum number of sequence steps that can be used on this card.</td>
</tr>
<tr>
<td>SPC_SEQMODE_AVAILMAXLOOP</td>
<td>349902</td>
<td>Returns the maximum number of loops that can be programmed for a step.</td>
</tr>
<tr>
<td>SPC_SEQMODE_AVAILFEATURES</td>
<td>349903</td>
<td>Returns the available features for each sequence step as shown below.</td>
</tr>
</tbody>
</table>

Setting up the registers

Define the card mode

To enable the sequencer the card mode needs to be set appropriately first:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDMODE</td>
<td>9500</td>
<td>Defines the used operating mode.</td>
</tr>
<tr>
<td>SPC_SEQREP_STD_SEQUENCE</td>
<td>40000h</td>
<td>Data generation from onboard memory, by splitting the memory into several segments and replaying the data using a programmable order coming from a special sequence memory.</td>
</tr>
</tbody>
</table>

Prepare the data memory

Setting up the segmentation of the on-board data memory is done by using the following registers:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SEQMODE_MAXSEGMENTS</td>
<td>349910</td>
<td>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.</td>
</tr>
<tr>
<td>SPC_SEQMODE_WRITESEGMENT</td>
<td>349920</td>
<td>Defines the current segment to be addressed by the user. Must be programmed prior to changing any segment parameters.</td>
</tr>
<tr>
<td>SPC_SEQMODE_SEGMENTSIZE</td>
<td>349940</td>
<td>Defines the number of valid/to be replayed samples for the current selected memory segment.</td>
</tr>
</tbody>
</table>

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:

Limits and step sizes for the segment memory

<table>
<thead>
<tr>
<th>Activated Channels</th>
<th>analog generator (D/A) cards with 16 bit converter resolution</th>
<th>Digital I/O cards</th>
<th>Pattern size for register</th>
<th>Pattern size for register</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPC_SEQMODE_MAXSEGMENTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPC_SEQMODE_SEGMENTSIZE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 channel</td>
<td>32 ([Mem/1] / SPC_SEQMODE_MAXSEGMENTS)</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 channel</td>
<td>32 ([Mem/2] / SPC_SEQMODE_MAXSEGMENTS)</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 channel</td>
<td>32 ([Mem/4] / SPC_SEQMODE_MAXSEGMENTS)</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 channel</td>
<td>32 ([Mem/8] / SPC_SEQMODE_MAXSEGMENTS)</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 channel</td>
<td>32 ([Mem/16] / SPC_SEQMODE_MAXSEGMENTS)</td>
<td>32 ([Mem/1] / SPC_SEQMODE_MAXSEGMENTS) 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 channel</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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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.

The programming examples further below will show the setup and also some examples of data transfer.

Set up the sequence (step) 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SEQMODE_STEPMEM0</td>
<td>340000</td>
<td>read/write</td>
<td>First address (sequence step 0) of the 64 bit organized sequence memory.</td>
</tr>
<tr>
<td>SPC_SEQMODE_STEPMEM0 + 4095</td>
<td>344095</td>
<td>read/write</td>
<td>Writes the sequence step 4095, as an example. The maximum number of steps should be read out by using the SPC_SEQMODE_AVAILMAXSTEPS register as described above.</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SEQMODE_STARTSTEP</td>
<td>349930</td>
<td>read/write</td>
<td>Defines which of all defined steps in the sequence memory will be used first directly after the card start.</td>
</tr>
</tbody>
</table>

Read out the currently replayed sequence step

In case one wants to change the sequence on the fly or one needs to know which part of the sequence is currently replayed. It is possible to read out the number of the sequence step that is currently at the output connector of the card. This could be extremely useful if external equipment has to be changed after a dedicated sequence has been replayed or if the AWG is changing between different patterns in automatic test environment.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SEQMODE_STATUS</td>
<td>349950</td>
<td>read</td>
<td>Number of the sequence step that is currently replayed.</td>
</tr>
</tbody>
</table>

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 again ... until the card is stopped.

```c
#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_CARMODE, 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); // Step0 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);

// 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);

// combine all the parameters to one int64 bit value
lValue = (lCondition << 32) | (lLoop << 32) | (lNext << 16) | (lSegment);
spcm_dwSetParam_i64 (hDrv, SPC_SEQMODE_STEPMEM0 + lStep, lValue);

// Start the card
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, 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.

The Star-Hub option allows to synchronize several M2p cards that are mounted within one host system (PC) and is part of the digitizerNETBOX and generatorNETBOX products, that include more than one digitizer/generator module.

Two different sized Star-Hub versions are available: a small version with 6 connectors (options SH6ex or SH6tm) for synchronizing up to six cards and a bigger version with 16 connectors (options SH16ex or SH16tm) for synchronizing up to sixteen cards.

The M2p Star-Hub allows synchronizing cards of the same family as well as different families of the M2p series with each other.

Both sizes versions are implemented as either a piggy-back module that is mounted on top of one of the cards (options SH6tm or SH16tm), or as an extension (SH6ex or SH16ex). 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 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. The card holding the Star-Hub is automatically also the clock master. Any one of the synchronized cards can be part of the trigger generation.

**Star-Hub trigger engine**

The trigger bus between an M2p card and the Star-Hub option consists of several lines. Some of them send the trigger information from the card’s trigger engine to the Star-Hub and some receive the resulting trigger from the Star-Hub. All trigger events from the different cards connected can be combined logically by either OR or a logical AND within the Star-Hub.

While the returned trigger is identical for all synchronized cards, the sent out trigger of every single card depends on their respective trigger settings.

**Star-Hub clock engine**

The card holding the Star-Hub is the clock master for the complete system. If you need to feed in an external clock to a synchronized system the clock has to be connected to the master card. Slave cards cannot generate a Star-Hub system clock. As shown in the drawing on the right, the clock master can use either its on-board reference, an external reference or directly distribute the external fed in clock input to be broadcast 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.

**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 interconnection 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)

```c
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:

```c
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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SYNC_READ_NUMCONNECTORS</td>
<td>48991</td>
<td>read</td>
<td>Number of connectors that the Star-Hub offers at max. (available with driver V5.6 or newer)</td>
</tr>
<tr>
<td>SPC_SYNC_READ_SYNCCOUNT</td>
<td>48990</td>
<td>read</td>
<td>Number of cards that are connected to this Star-Hub</td>
</tr>
<tr>
<td>SPC_SYNC_READ_CARDIDX0</td>
<td>49000</td>
<td>read</td>
<td>Index of card that is connected to star-hub logical index 0 (mask 0x0001)</td>
</tr>
<tr>
<td>SPC_SYNC_READ_CARDIDX1</td>
<td>49001</td>
<td>read</td>
<td>Index of card that is connected to star-hub logical index 1 (mask 0x0002)</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_SYNC_READ_CARDIDX7</td>
<td>49007</td>
<td>read</td>
<td>Index of card that is connected to star-hub logical index 7 (mask 0x0080)</td>
</tr>
<tr>
<td>SPC_SYNC_READ_CARDIDX8</td>
<td>49008</td>
<td>read</td>
<td>M2i only: Index of card that is connected to star-hub logical index 8 (mask 0x0100)</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPC_SYNC_READ_CARDIDX15</td>
<td>49015</td>
<td>read</td>
<td>M2i only: Index of card that is connected to star-hub logical index 15 (mask 0x8000)</td>
</tr>
<tr>
<td>SPC_SYNC_READ_CABLECON0</td>
<td></td>
<td>read</td>
<td>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.</td>
</tr>
<tr>
<td>...</td>
<td>49100</td>
<td>read</td>
<td></td>
</tr>
<tr>
<td>SPC_SYNC_READ_CABLECON15</td>
<td>49115</td>
<td>read</td>
<td>Returns the index of the cable connection that is used for the logical connection 15.</td>
</tr>
</tbody>
</table>

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.

```c
spcm_dwGetParam_i32 (hSync, SPC_SYNC_READ_SYNCCOUNT, &iSyncCount);
for (i = 0; i < iSyncCount; 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:

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:

```c
for (j = 0; j < lStarhubCount; j++)
{
    spcm_dwGetParam_i32 (hSync[j], SPC_SYNC_READ_SYNCCOUNT, &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:

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

The synchronization setup only requires one additional register to enable the cards that are synchronized in the next run.

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_SYNC_ENABLEMASK</td>
<td>49200</td>
<td>read/write</td>
<td>Mask of all cards that are enabled for the synchronization</td>
</tr>
</tbody>
</table>

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.
In our example we synchronize all four cards. The star-hub is located on card #2 and is therefore the clock master.

**Limits of Clock for synchronized cards**

Using the M2p Star-Hub, it is possible to have synchronized cards run with different sample rates, as long as both of the following conditions are met for all cards connected to the Star-Hub and enabled for synchronization:

1) The sample rate of each card can be derived by integer division \((1/N_i)\) from the card with the fastest programmed sample rate.

2) The sample rate of each card can be derived by integer multiplication \((*M_i)\) of the card with the slowest programmed sample rate.

Both \(N\) and \(M\) must be an integer of 1 or greater, keeping the resulting sample rates within their allowed limits.

**Example 1: Valid setup**

- Samplerate\([\text{card0}]\) = 100 MSp/s
- Samplerate\([\text{card1}]\) = 25 MSp/s
- Samplerate\([\text{card2}]\) = 5 MSp/s

This setup is perfectly valid, as 100 MSp/s/25 MSp/s = 4 and 100 MSp/s/5 MSp/s = 20 and also 5 * 5 MSp/s = 25 MSp/s

**Example 2: Invalid setup**

- Samplerate\([\text{card0}]\) = 100 MSp/s
- Samplerate\([\text{card1}]\) = 25 MSp/s
- Samplerate\([\text{card2}]\) = 10 MSp/s

This setup is not valid, although the first condition of 100 MSp/s/25 MSp/s = 4 and 100 MSp/s/10 MSp/s = 20 is met. But the second condition is violated, as a non-integer would be required: 2.5 * 10 MSp/s = 25 MSp/s.

**Example 3: Invalid setup**

- Samplerate\([\text{card0}]\) = 100 MSp/s
- Samplerate\([\text{card1}]\) = 30 MSp/s
- Samplerate\([\text{card2}]\) = 10 MSp/s

This setup is not valid, although now the second condition is met, since a integer works: 3 * 10 MSp/s = 30 MSp/s but the first requirement is now violated, since 100 MSp/s/30 MSp/s = 3.33, which is not an integer.

**Example 4: Valid setup**

- Samplerate\([\text{card0}]\) = 100 MSp/s
- Samplerate\([\text{card1}]\) = 20 MSp/s
- Samplerate\([\text{card2}]\) = 10 MSp/s

This setup is perfectly valid again, as 100 MSp/s/20 MSp/s = 5 and 100 MSp/s/10 MSp/s = 10 and also 2 * 10 MSp/s = 20 MSp/s

**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:

```c
spcm_dwSetParam_i32 (hSync, SPC_SYNC_ENABLEMASK, 0x000F); // all 4 cards are masked
// set the clock master to 100 MS/s internal clock
spcm_dwSetParam_i32 (hCard[2], SPC_CLOCKMODE, SPC_CM_INTPLL);
spcm_dwSetParam_i32 (hCard[2], SPC_SAMPLEATE, MEGA(100));
// set all the slaves to run synchronously with 100 MS/s
spcm_dwSetParam_i32 (hCard[0], SPC_SAMPLEATE, MEGA(100));
spcm_dwSetParam_i32 (hCard[1], SPC_SAMPLEATE, MEGA(100));
spcm_dwSetParam_i32 (hCard[3], SPC_SAMPLEATE, MEGA(100));
```
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:

```c
for (i = 0; i < lSyncCount; i++)
{
  int32 lAllChannels = (SPC_TMASK0_CH0 | SPC_TMASK0_CH1 | SPC_TMASK_CH2 | SPC_TMASK_CH3);
  spcm_dwSetParam_i32 (hCard[i], SPC_TRIG_CH0.ORMASK0, lAllChannels);
  spcm_dwSetParam_i32 (hCard[i], SPC_TRIG_CH0.LEVEL0 + j, 100);
}
```

### 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:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_M2CMD</td>
<td>100</td>
<td>write only</td>
<td>Executes a command for the card or data transfer</td>
</tr>
<tr>
<td>M2CMD_CARD_RESET</td>
<td>1h</td>
<td></td>
<td>Performs a hard and software reset of the card as explained further above</td>
</tr>
<tr>
<td>M2CMD_CARD_WRITESETUP</td>
<td>2h</td>
<td></td>
<td>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</td>
</tr>
<tr>
<td>M2CMD_CARD_START</td>
<td>4h</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_ENABLETRIGGER</td>
<td>8h</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_FORCETRIGGER</td>
<td>10h</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_DISABLETRIGGER</td>
<td>20h</td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>M2CMD_CARD_STOP</td>
<td>40h</td>
<td></td>
<td>Stops the current run of the card. If the card is not running this command has no effect.</td>
</tr>
</tbody>
</table>

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:

```c
spcm_dwSetParam_i32 (hSync, SPC_SYNC_ENABLEMASK, 0x000F); // all 4 cards are masked
```

```
for (i = 0; i < 4; i++)
{
  spcm_dwSetParam_i32 (hCard[i], SPC_CLOCKMODE, SPC_CM_INTPLL);
  spcm_dwSetParam_i32 (hCard[i], SPC_SAMPLERATE, MEGA(100));
}
```

```
// card 0 is trigger master and waits for external positive edge
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_ORMASK, SPC_TM_NONE);
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_EXT0_MODE, SPC_TM_POS);
```

```
// to keep it easy we set all card to the same clock and disable trigger
for (i = 0; i < lSyncCount; i++)
{
  spcm_dwSetParam_i32 (hCard[i], SPC_CLOCKMODE, SPC_CM_INTPLL);
  spcm_dwSetParam_i32 (hCard[i], SPC_SAMPLERATE, MEGA(100));
}
```

```
// card 0 is trigger master and waits for external positive edge
spcm_dwSetParam_i32 (hCard[0], SPC_TRIG_ORMASK, SPC_TM_NONE);
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);
if (spcm_dwSetParam_i32 (hSync, SPC_M2CMD, M2CMD_CARD_START | M2CMD_CARD_ENABLETRIGGER) != ERR_TIMEOUT)
  printf ("Timeout occured - 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 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_dwGetErrInfo_i32. Please see the example in the card error handling chapter to see how the error handling is done.
Option Remote Server

Introduction

Using the Spectrum Remote Server (order code SPc-RServer) it is possible to access the M2i/M3i/M4i/M4x/M2p card(s) installed in one PC (server) from another PC (client) via local area network (LAN), similar to using a digitizerNETBOX or generatorNETBOX.

It is possible to use different operating systems on both server and client. For example the Remote Server is running on a Linux system and the client is accessing them from a Windows system.

The Remote Server software requires, that the option „SPc-RServer“ is installed on at least one card installed within the server side PC. You can either check this with the Control Center in the "Installed Card features" node or by reading out the feature register, as described in the „Installed features and options“ passage, earlier in this manual.

To run the Remote Server software, it is required to have least version 3.18 of the Spectrum SPCM driver installed. Additionally at least on one card in the server PC the feature flag SPCM_FEAT_REMOTESERVER must be set.

Installing and starting the Remote Server

Windows

Windows users find the Control Center installer on the USB-Stick under „Install\win\spcm_remote_install.exe“. After the installation has finished there will be a new start menu entry in the Folder "Spectrum GmbH" to start the Remote Server. To start the Remote Server automatically after login, just copy this shortcut to the Autostart directory.

Linux

Linux users find the versions of the installer for the different StdC libraries under under /Install/linux/spcm_control_center/ as RPM packages.

To start the Remote Server type "spcm_remote_server" (without quotation marks). To start the Remote Server automatically after login, add the following line to the .bashrc or .profile file (depending on the used Linux distribution) in the user’s home directory:

`spcm_remote_server&`

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 one's own specific application:

```c
#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 to 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.

**Accessing remote cards**

To detect remote card(s) from the client PC, start the Spectrum Control Center on the client and click "Netbox Discovery". All discovered cards will be listed under the "Remote" node.

Using remote cards instead of using local ones is as easy as using a digitizerNETBOX and only requires a few lines of code to be changed compared to using local cards.

Instead of opening two locally installed cards like this:

```c
hDrv0 = spcm_hOpen("/dev/spcm0"); // open local card spcm0
hDrv1 = spcm_hOpen("/dev/spcm1"); // open local card spcm1
```

one would call `spcm_hOpen()` with a VISA string as a parameter instead:

```c
hDrv0 = spcm_hOpen("TCPIP::192.168.1.2::inst0::INSTR"); // open card spcm0 on a Remote Server PC
hDrv1 = spcm_hOpen("TCPIP::192.168.1.2::inst1::INSTR"); // open card spcm1 on a Remote Server PC
```

to open cards on the Remote Server PC with the IP address 192.168.1.2. The driver will take care of all the network communication.
### 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.

<table>
<thead>
<tr>
<th>error name</th>
<th>value (hex)</th>
<th>value (dec.)</th>
<th>error description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERR_OK</td>
<td>0h</td>
<td>0</td>
<td>Execution OK, no error.</td>
</tr>
<tr>
<td>ERR_INIT</td>
<td>1h</td>
<td>1</td>
<td>An error occurred when initializing the given card. Either the card has already been opened by another process or an hardware error occurred.</td>
</tr>
<tr>
<td>ERR_TYP</td>
<td>3h</td>
<td>3</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_FNCNOTSUPPORTED</td>
<td>4h</td>
<td>4</td>
<td>This function is not supported by the hardware version.</td>
</tr>
<tr>
<td>ERR_BRDREMAP</td>
<td>5h</td>
<td>5</td>
<td>The board index map table in the registry is wrong. Either delete this table or check it carefully for double values.</td>
</tr>
<tr>
<td>ERR_KERNVER</td>
<td>6h</td>
<td>6</td>
<td>The version of the kernel driver is not matching the version of the DLL. Please do a complete re-installation of the hard- ware driver. This error normally only occurs if someone copies the driver library and the kernel driver manually.</td>
</tr>
<tr>
<td>ERR_FWDRVERSION</td>
<td>7h</td>
<td>7</td>
<td>The hardware needs a newer driver version to run properly. Please install the driver that was delivered together with the card.</td>
</tr>
<tr>
<td>ERR_ADRRANGE</td>
<td>8h</td>
<td>8</td>
<td>One of the address ranges is disabled (fatal error), can only occur under Linux.</td>
</tr>
<tr>
<td>ERR_INVALIDHANDLE</td>
<td>9h</td>
<td>9</td>
<td>The used handle is not valid.</td>
</tr>
<tr>
<td>ERR_BOARDNOTFOUND</td>
<td>Ah</td>
<td>10</td>
<td>A card with the given name has not been found.</td>
</tr>
<tr>
<td>ERR_BOARDINUSE</td>
<td>Bh</td>
<td>11</td>
<td>A card with given name is already in use by another application.</td>
</tr>
<tr>
<td>ERR_EXHYHVS48BITADR</td>
<td>Ch</td>
<td>12</td>
<td>Express hardware version not able to handle 64 bit addressing -&gt; update needed.</td>
</tr>
<tr>
<td>ERR_FWVERS</td>
<td>Dh</td>
<td>13</td>
<td>Firmware versions of synchronized cards or for this driver do not match -&gt; update needed.</td>
</tr>
<tr>
<td>ERR_SYNCPROTOCOL</td>
<td>Eh</td>
<td>14</td>
<td>Synchronization protocol versions of synchronized cards do not match -&gt; update needed.</td>
</tr>
<tr>
<td>ERR_LASTERR</td>
<td>10h</td>
<td>16</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_BOARDINUSE</td>
<td>11h</td>
<td>17</td>
<td>Board is already used by another application. It is not possible to use one hardware from different programs at the same time.</td>
</tr>
<tr>
<td>ERR_ABORT</td>
<td>20h</td>
<td>32</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_BOARDLOCKED</td>
<td>30h</td>
<td>48</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_DEVICE_MAPPING</td>
<td>32h</td>
<td>50</td>
<td>The device is mapped to an invalid device. The device mapping can be accessed via the Control Center.</td>
</tr>
<tr>
<td>ERR_NETWORKSETUP</td>
<td>40h</td>
<td>64</td>
<td>The network setup of a digitizerNETBOX has failed.</td>
</tr>
<tr>
<td>ERR_NETWORKTRANSFER</td>
<td>41h</td>
<td>65</td>
<td>The network data transfer from/to a digitizerNETBOX has failed.</td>
</tr>
<tr>
<td>ERR_FWPOWERCYCLE</td>
<td>42h</td>
<td>66</td>
<td>Power cycle (PC off/on) is needed to update the card's firmware (a simple OS reboot is not sufficient!)</td>
</tr>
<tr>
<td>ERR_NETWORKTIMEOUT</td>
<td>43h</td>
<td>67</td>
<td>A network timeout has occurred.</td>
</tr>
<tr>
<td>ERR_BUFFERSIZE</td>
<td>44h</td>
<td>68</td>
<td>The buffer size is not sufficient (too small).</td>
</tr>
<tr>
<td>ERR_RESTRICTEDACCESS</td>
<td>45h</td>
<td>69</td>
<td>The access to the card has been intentionally restricted.</td>
</tr>
<tr>
<td>ERR_INVALIDPARAM</td>
<td>46h</td>
<td>70</td>
<td>An invalid parameter has been used for a certain function.</td>
</tr>
<tr>
<td>ERR_TEMPERATURE</td>
<td>47h</td>
<td>71</td>
<td>The temperature of at least one of the card's sensors measures a temperature, that is too high for the hardware.</td>
</tr>
<tr>
<td>ERR_REG</td>
<td>100h</td>
<td>256</td>
<td>The register is not valid for this type of board.</td>
</tr>
<tr>
<td>ERR_VALUE</td>
<td>101h</td>
<td>257</td>
<td>The value for this register is not in a valid range. The allowed values and ranges are listed in the board specific documenta- tion.</td>
</tr>
<tr>
<td>ERR_FEATURE</td>
<td>102h</td>
<td>258</td>
<td>Feature (option) is not installed on this board. It's not possible to access this feature if it's not installed.</td>
</tr>
<tr>
<td>ERR_SEQUENCE</td>
<td>103h</td>
<td>259</td>
<td>Command sequence is not allowed. Please check the manual carefully to see which command sequences are possible.</td>
</tr>
<tr>
<td>ERR_READABORT</td>
<td>104h</td>
<td>260</td>
<td>Data read is not allowed after aborting the data acquisition.</td>
</tr>
<tr>
<td>ERR_NOACCESS</td>
<td>105h</td>
<td>261</td>
<td>Access to this register is denied. This register is not accessible for users.</td>
</tr>
<tr>
<td>ERR_TIMEOUT</td>
<td>107h</td>
<td>263</td>
<td>A timeout occurred while waiting for an interrupt. This error does not lock the driver.</td>
</tr>
<tr>
<td>ERR_CALTYPE</td>
<td>108h</td>
<td>264</td>
<td>The access to the register is only allowed with one 64 bit access but not with the multiplexed 32 bit [high and low dou- ble word] version.</td>
</tr>
<tr>
<td>ERR_EXCEEDSINT32</td>
<td>109h</td>
<td>265</td>
<td>The return value is int32 but the software register exceeds the 32 bit integer range. Use double int32 or int8 accesses instead, to get correct return values.</td>
</tr>
<tr>
<td>ERR_NOWRITEALLOWED</td>
<td>10Ah</td>
<td>266</td>
<td>The register that should be written is a read-only register. No write accesses are allowed.</td>
</tr>
<tr>
<td>ERR_SETUP</td>
<td>10Bh</td>
<td>267</td>
<td>The programmed setup for the card is not valid. The error register will show which setting generates the error message. This error is returned if the card is started or the setup is written.</td>
</tr>
<tr>
<td>ERR_CLOCKNOTLOCKED</td>
<td>10Ch</td>
<td>268</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_MEMINIT</td>
<td>10Dh</td>
<td>269</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_POWERSUPPLY</td>
<td>10 Eh</td>
<td>270</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_ADCCOMMUNICATION</td>
<td>10Fh</td>
<td>271</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_CHANNEL</td>
<td>110h</td>
<td>272</td>
<td>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 hardware limitations (e.g. Only channel 0 is accessible in interface mode)</td>
</tr>
<tr>
<td>ERR_NOTIFYFSIZE</td>
<td>111h</td>
<td>273</td>
<td>The notify size of the last spcm_dewDefTransfer 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.</td>
</tr>
<tr>
<td>ERR_RUNNING</td>
<td>120h</td>
<td>288</td>
<td>The board is still running, this function is not available now or this register is not accessible now.</td>
</tr>
<tr>
<td>ERR_ADJUST</td>
<td>130h</td>
<td>304</td>
<td>Automatic card calibration has reported an error. Please check the card inputs.</td>
</tr>
<tr>
<td>ERR_PRETRIGGERLEN</td>
<td>140h</td>
<td>320</td>
<td>The calculated prtgapper size (resulting from the user defined pretrigger values) exceeds the allowed limit.</td>
</tr>
<tr>
<td>ERR_DIMMSMATCH</td>
<td>141h</td>
<td>321</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_POSTERCDSIZE</td>
<td>142h</td>
<td>322</td>
<td>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!</td>
</tr>
<tr>
<td>ERR_SEGMENTMAXMEM</td>
<td>143h</td>
<td>323</td>
<td>Memsize is not a multiple of segment size when using Multiple Recording/Repeat or ABA mode. The programmed segment size must match the programmed memory size.</td>
</tr>
<tr>
<td>ERR_MULTIPLEPW</td>
<td>144h</td>
<td>324</td>
<td>Multiple pulsewidth counters used but card only supports one at the time.</td>
</tr>
</tbody>
</table>
### Error Codes

<table>
<thead>
<tr>
<th>error name</th>
<th>value (hex)</th>
<th>value (dec.)</th>
<th>error description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERR_NOCHANNELPWOR</td>
<td>145h</td>
<td>325</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_ANDORMASKOVRLAP</td>
<td>146h</td>
<td>326</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_ANDMASKEDGE</td>
<td>147h</td>
<td>327</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_ORMASKLEVEL</td>
<td>148h</td>
<td>328</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_EDGEPERMULT</td>
<td>149h</td>
<td>329</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_DOLEVELMINDIFF</td>
<td>14Ah</td>
<td>330</td>
<td>The minimum difference between low output level and high output level is not reached.</td>
</tr>
<tr>
<td>ERR_STARHUBENABLE</td>
<td>14Bh</td>
<td>331</td>
<td>The card holding the star-hub must be enabled when doing synchronization.</td>
</tr>
<tr>
<td>ERR_PATPWPSMALLEDGE</td>
<td>14Ch</td>
<td>332</td>
<td>Combination of pattern with pulsewidth smaller and edge is not allowed.</td>
</tr>
<tr>
<td>ERR_XMODESETUP</td>
<td>14Dh</td>
<td>333</td>
<td>The chosen setup for (SPCM_X0_MODE .. SPCM_X19_MODE) is not valid. See hardware manual for details.</td>
</tr>
<tr>
<td>ERR_MEMALLOC</td>
<td>203h</td>
<td>515</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_EEPROMLOAD</td>
<td>205h</td>
<td>517</td>
<td>The card holding the star-hub must be enabled when doing synchronization.</td>
</tr>
<tr>
<td>ERR_CONFIGACCESS</td>
<td>206h</td>
<td>518</td>
<td>Internal memory allocation failed. Please restart the system and be sure that there is enough free memory.</td>
</tr>
<tr>
<td>ERR_FIFOHWOVERRUN</td>
<td>301h</td>
<td>769</td>
<td>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.</td>
</tr>
<tr>
<td>ERR_FIFOFINISHED</td>
<td>302h</td>
<td>770</td>
<td>FIFO transfer has been finished, programmed data length has been transferred completely.</td>
</tr>
<tr>
<td>ERR_TIMESTAMP_SYNC</td>
<td>310h</td>
<td>784</td>
<td>Synchronization to timestamp reference clock failed. Please check the connection and the signal levels of the reference clock input.</td>
</tr>
<tr>
<td>ERR_STARHUB</td>
<td>320h</td>
<td>800</td>
<td>The auto-routing function of the Star-Hub initialization has failed. Please check whether all cables are mounted correctly.</td>
</tr>
<tr>
<td>ERR_INTERNAL_ERROR</td>
<td>FFFFh</td>
<td>65535</td>
<td>Internal hardware error detected. Please check for driver and firmware update of the card.</td>
</tr>
</tbody>
</table>

## Spectrum Knowledge Base

You will also find additional help and information in our knowledge base available on our website:

Pin assignment of the multipin connector

The 40 lead multipin connector is the main connector for all of Spectrum’s digital boards and is additionally used for different options, like e.g. the additional digital inputs (on analog acquisition boards only) or additional digital outputs (on analog generation boards only).

The connectors for all the optional digital functions are mounted on an extra bracket, while the main connectors for the digital boards are mounted directly on the board’s bracket. Only in case that a digital board uses more than two connectors (more than 32 in and/or output bits) an additional bracket will be used for mounting the connectors as well.

The pin assignment depends on what type of board you have and on which of the below mentioned options are installed.

Digital inputs/outputs

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D0</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
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</tr>
<tr>
<td>Clk out</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
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<td>GND</td>
<td>GND</td>
</tr>
<tr>
<td>Clk in</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
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<td>GND</td>
<td>GND</td>
<td>GND</td>
</tr>
<tr>
<td>X0</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
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<td>GND</td>
<td>GND</td>
<td>GND</td>
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</tr>
<tr>
<td>X1</td>
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<td>GND</td>
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<td>GND</td>
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<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
</tr>
</tbody>
</table>

Pin assignment of the multipin cable

The cable ends are assembled with two standard 20 pole IDC socket connector so you can easily make connections to your type of equipment or DUT (device under test).

The required two 20 pin flat ribbon cables each provide the signals of either the A or the B labeled pins as described above.
IDC footprints
The 20 pole IDC connectors have the following footprints. For easy usage in your PCB the cable footprint as well as the PCB top footprint are shown here. Please note that the PCB footprint is given as top view. Pin 1 is marked on each IDC as shown:

The following table shows the relation between the card connector pin and the IDC pin and the signal

### Connector 0

<table>
<thead>
<tr>
<th>Signal</th>
<th>IDC pin</th>
<th>Card pin</th>
<th>Card pin</th>
<th>IDC pin</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0</td>
<td>1</td>
<td>A1</td>
<td>A2</td>
<td>2</td>
<td>GND</td>
</tr>
<tr>
<td>D1</td>
<td>3</td>
<td>A3</td>
<td>A4</td>
<td>4</td>
<td>GND</td>
</tr>
<tr>
<td>D2</td>
<td>5</td>
<td>A5</td>
<td>A6</td>
<td>6</td>
<td>GND</td>
</tr>
<tr>
<td>D3</td>
<td>7</td>
<td>A7</td>
<td>A8</td>
<td>8</td>
<td>GND</td>
</tr>
<tr>
<td>D4</td>
<td>9</td>
<td>A9</td>
<td>A10</td>
<td>10</td>
<td>GND</td>
</tr>
<tr>
<td>D5</td>
<td>11</td>
<td>A11</td>
<td>A12</td>
<td>12</td>
<td>GND</td>
</tr>
<tr>
<td>D6</td>
<td>13</td>
<td>A13</td>
<td>A14</td>
<td>14</td>
<td>GND</td>
</tr>
<tr>
<td>D7</td>
<td>15</td>
<td>A15</td>
<td>A16</td>
<td>16</td>
<td>GND</td>
</tr>
<tr>
<td>X0</td>
<td>17</td>
<td>A17</td>
<td>A18</td>
<td>18</td>
<td>GND</td>
</tr>
<tr>
<td>Clk out</td>
<td>19</td>
<td>A19</td>
<td>A20</td>
<td>20</td>
<td>GND</td>
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</tbody>
</table>

### Connector 1

<table>
<thead>
<tr>
<th>Signal</th>
<th>IDC pin</th>
<th>Card pin</th>
<th>Card pin</th>
<th>IDC pin</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>D16</td>
<td>1</td>
<td>A21</td>
<td>A22</td>
<td>2</td>
<td>GND</td>
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<tr>
<td>D17</td>
<td>3</td>
<td>A23</td>
<td>A24</td>
<td>4</td>
<td>GND</td>
</tr>
<tr>
<td>D18</td>
<td>5</td>
<td>A25</td>
<td>A26</td>
<td>6</td>
<td>GND</td>
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<tr>
<td>D19</td>
<td>7</td>
<td>A27</td>
<td>A28</td>
<td>8</td>
<td>GND</td>
</tr>
<tr>
<td>D20</td>
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<td>A29</td>
<td>A30</td>
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<td>GND</td>
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<tr>
<td>D21</td>
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<tr>
<td>RFU*</td>
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<td>A40</td>
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</tbody>
</table>

### Cable/IDC A

<table>
<thead>
<tr>
<th>Signal</th>
<th>IDC pin</th>
<th>Card pin</th>
<th>Card pin</th>
<th>IDC pin</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>D8</td>
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<td>B2</td>
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</tr>
<tr>
<td>D9</td>
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<td>B3</td>
<td>B4</td>
<td>4</td>
<td>GND</td>
</tr>
<tr>
<td>D10</td>
<td>5</td>
<td>B5</td>
<td>B6</td>
<td>6</td>
<td>GND</td>
</tr>
<tr>
<td>D11</td>
<td>7</td>
<td>B7</td>
<td>B8</td>
<td>8</td>
<td>GND</td>
</tr>
<tr>
<td>D12</td>
<td>9</td>
<td>B9</td>
<td>B10</td>
<td>10</td>
<td>GND</td>
</tr>
<tr>
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<td>B11</td>
<td>B12</td>
<td>12</td>
<td>GND</td>
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<td>D14</td>
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<td>B17</td>
<td>B18</td>
<td>18</td>
<td>GND</td>
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<tr>
<td>Clk in</td>
<td>19</td>
<td>B19</td>
<td>B20</td>
<td>20</td>
<td>GND</td>
</tr>
</tbody>
</table>

### Cable/IDC B

<table>
<thead>
<tr>
<th>Signal</th>
<th>IDC pin</th>
<th>Card pin</th>
<th>Card pin</th>
<th>IDC pin</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>D8</td>
<td>1</td>
<td>B1</td>
<td>B2</td>
<td>2</td>
<td>GND</td>
</tr>
<tr>
<td>D9</td>
<td>3</td>
<td>B3</td>
<td>B4</td>
<td>4</td>
<td>GND</td>
</tr>
<tr>
<td>D10</td>
<td>5</td>
<td>B5</td>
<td>B6</td>
<td>6</td>
<td>GND</td>
</tr>
<tr>
<td>D11</td>
<td>7</td>
<td>B7</td>
<td>B8</td>
<td>8</td>
<td>GND</td>
</tr>
<tr>
<td>D12</td>
<td>9</td>
<td>B9</td>
<td>B10</td>
<td>10</td>
<td>GND</td>
</tr>
<tr>
<td>D13</td>
<td>11</td>
<td>B11</td>
<td>B12</td>
<td>12</td>
<td>GND</td>
</tr>
<tr>
<td>D14</td>
<td>13</td>
<td>B13</td>
<td>B14</td>
<td>14</td>
<td>GND</td>
</tr>
<tr>
<td>D15</td>
<td>15</td>
<td>B15</td>
<td>B16</td>
<td>16</td>
<td>GND</td>
</tr>
<tr>
<td>X1</td>
<td>17</td>
<td>B17</td>
<td>B18</td>
<td>18</td>
<td>GND</td>
</tr>
<tr>
<td>Clk in</td>
<td>19</td>
<td>B19</td>
<td>B20</td>
<td>20</td>
<td>GND</td>
</tr>
</tbody>
</table>

*RFU: reserved for future use. Do not connect these lines, can be left floating.
Temperature sensors

The M2p card series has integrated temperature sensors that allow to read out different internal temperatures. These functions are also available for the M2p cards mounted inside of the digitizerNETBOX, generatorNETBOX or hybridNETBOX series. In here the temperature can be read out for every internal card separately.

The Spectrum driver (starting with version 5.09) checks for over temperature at every opening of the driver and also uses a background temperature watchdog to ensure that the card’s operating temperature stays within the recommended operating range and an ERR_TEMPERATURE error will be issued if exceeded.

In case of a detected temperature error, please carefully check the cooling requirements of the card as explained in the „Cooling Precautions“ chapter earlier in the manual.

Temperature read-out registers

Up to three different temperature sensors can be read-out for each M2p card. The temperature can be read in different temperature scales at any time:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_MON_TK_BASE_CTRL</td>
<td>500022</td>
<td>read</td>
<td>Base card temperature in Kelvin</td>
</tr>
<tr>
<td>SPC_MON_TK_MODA_0</td>
<td>500023</td>
<td>read</td>
<td>Temperature in Kelvin of front-end module A.</td>
</tr>
<tr>
<td>SPC_MON_TK_MODB_0</td>
<td>500024</td>
<td>read</td>
<td>Temperature in Kelvin of front-end module B.</td>
</tr>
<tr>
<td>SPC_MON_TC_BASE_CTRL</td>
<td>500025</td>
<td>read</td>
<td>Base card temperature in degrees Celsius</td>
</tr>
<tr>
<td>SPC_MON_TC_MODA_0</td>
<td>500026</td>
<td>read</td>
<td>Temperature in degrees Celsius of front-end module A.</td>
</tr>
<tr>
<td>SPC_MON_TC_MODB_0</td>
<td>500027</td>
<td>read</td>
<td>Temperature in degrees Celsius of front-end module B.</td>
</tr>
<tr>
<td>SPC_MON_TF_BASE_CTRL</td>
<td>500028</td>
<td>read</td>
<td>Base card temperature in degrees Fahrenheit</td>
</tr>
<tr>
<td>SPC_MON_TF_MODA_0</td>
<td>500029</td>
<td>read</td>
<td>Temperature in degrees Fahrenheit of front-end module A.</td>
</tr>
<tr>
<td>SPC_MON_TF_MODB_0</td>
<td>500030</td>
<td>read</td>
<td>Temperature in degrees Fahrenheit of front-end module B.</td>
</tr>
</tbody>
</table>

Temperature hints

- Manual monitoring of the temperature figures might be used for application specific limits or for logging purposes.
- The temperature sensors can be used to optimize the system cooling.

75xx temperatures and limits

The following description shows the meaning of each temperature figure on the M2p.75xx series and also gives maximum ratings that should not be exceeded. All figures given in degrees Celsius:

<table>
<thead>
<tr>
<th>Sensor Name</th>
<th>Sensor Location</th>
<th>Typical figure at 25°C environment temperature</th>
<th>Maximum temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE_CTRL</td>
<td>Inside FPGA</td>
<td>50 °C ±5°C</td>
<td>80°C</td>
</tr>
<tr>
<td>MODULE_0</td>
<td>FrontEnd</td>
<td>30 °C ±5°C</td>
<td>80°C</td>
</tr>
<tr>
<td>MODULE_1</td>
<td>not used</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>
Details on M2p cards status LED

Every M2p card has a two-color status LED mounted at the very bottom location of the PCIe bracket.

Different color codes of the status LED

This chapter explains the different color codes and offers some possible solutions in case of an error condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>LED color</th>
<th>Status</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.K. (Booting)</td>
<td>temporarily static: red</td>
<td>PCI Express enumeration has not finished, PCIe Reset is still active</td>
<td>Red LED should turn off latest as soon as all BIOS messages have disappeared and the PC's operating system boot screen shows up.</td>
</tr>
<tr>
<td>Error</td>
<td>Static: red</td>
<td>Power supply error</td>
<td>Restart the PC. In case that the error persists, please contact Spectrum support for further assistance.</td>
</tr>
<tr>
<td></td>
<td>Fast blinking (approx. 8 Hz):</td>
<td>PCI Express link training has not yet finished</td>
<td>1) Power down the PC, un-plug and re-plug the card to verify that there is a proper contact between the card and the slot.</td>
</tr>
<tr>
<td></td>
<td>green - off - green - off ...</td>
<td></td>
<td>2) Try another PCI Express slot, maybe the currently used one is not properly working.</td>
</tr>
<tr>
<td></td>
<td>Strobed fast blinking (approx. 8 Hz</td>
<td>Internal PCIe error</td>
<td>3) In case that this error is occurring after a firmware update or of the above steps did not help, please contact Spectrum support for assistance on how to boot the card's golden recovery image.</td>
</tr>
<tr>
<td></td>
<td>strobes every half second):</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>green/off - off - green/off - off ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O.K.</td>
<td>Static: green</td>
<td>Card is ready for operation</td>
<td>A full width PCIe link has been established (PCIe x4, Gen 1) and the card is ready for operation.</td>
</tr>
<tr>
<td></td>
<td>(at full PCIe speed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Static: off</td>
<td>Card is ready for operation</td>
<td>A reduced speed PCIe link has been established with less than all of the possible 4 lanes. The card is ready for operation, but the data transfer throughput over the PCI Express bus is reduced.</td>
</tr>
<tr>
<td></td>
<td>(at reduced PCIe speed)</td>
<td></td>
<td>For getting the highest PCIe performance please consult your PC or motherboard manual for details on the PCI Express slots of your system.</td>
</tr>
<tr>
<td></td>
<td>Slow blinking (approx. 1 Hz):</td>
<td>Indicator mode on</td>
<td>To ease the identification of a specific card in a multi-card system without un-installing the card it is possible to activate the card identification status by software. This mode changes the static „Ready for Operation“ indication (see above) into a slowly green blinking state.</td>
</tr>
<tr>
<td></td>
<td>green - off - green - off ...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Turning on card identification LED

To enable/disable the cards LED indicator mode or to read out the current setting, please use the following register:

<table>
<thead>
<tr>
<th>Register</th>
<th>Value</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC_CARDIDENTIFICATION</td>
<td>201500</td>
<td>read/write</td>
<td>Writing a '1' turns on the LED card indicator mode, writing a '0' turns off the LED indicator mode.</td>
</tr>
</tbody>
</table>

The default for the card identification register is the OFF state.
Continuous memory for increased data transfer rate

⚠️ The continuous memory buffer has been added to the driver version 1.36. The continuous buffer is not available in older driver versions. Please update to the latest driver if you wish to use this function.

Background

All modern operating systems use a very complex memory management strategy that strictly separates between physical memory, kernel memory, and user memory. The memory management is based on memory pages (normally 4 kByte = 4096 Bytes). All software only sees virtual memory that is translated into physical memory addresses by a memory management unit based on the mentioned pages.

This will lead to the circumstance that although a user program allocated a larger memory block (as an example 1 MByte) and it sees the whole 1 MByte as a virtually continuous memory area this memory is physically located as spread 4 kByte pages all over the physical memory. No problem for the user program as the memory management unit will simply translate the virtual continuous addresses to the physically spread pages totally transparent for the user program.

When using this virtual memory for a DMA transfer things become more complicated. The DMA engine of any hardware can only access physical addresses. As a result the DMA engine has to access each 4 kByte page separately. This is done through the Scatter-Gather list. This list is simply a linked list of the physical page addresses which represent the user buffer. All translation and set-up of the Scatter-Gather list is done inside the driver without being seen by the user. Although the Scatter-Gather DMA transfer is an advanced and powerful technology it has one disadvantage: For each transferred memory page of data it is necessary to also load one Scatter-Gather entry (which is 16 bytes on 32 bit systems and 32 bytes on 64 bit systems). The little overhead to transfer (16/32 bytes in relation to 4096 bytes, being less than one percent) isn’t critical but the fact that the continuous data transfer on the bus is broken up every 4096 bytes and some different addresses have to be accessed slow things down.

The solution is very simple: everything works faster if the user buffer is not only virtually continuous but also physically continuous. Unfortunately it is not possible to get a physically continuous buffer for a user program. Therefore the kernel driver has to do the job and the user program simply has to read out the address and the length of this continuous buffer. This is done with the function spcm_dwGetContBuf as already mentioned in the general driver description. The desired length of the continuous buffer has to be programmed to the kernel driver for load time and is done different on the different operating systems. Please see the following chapters for more details.

Next we’ll see some measuring results of the data transfer rate with/without continuous buffer. You will find more results on different motherboards and systems in the application note number 6 „Bus Transfer Speed Details”. Also with newer M4i/M4x/M2p cards the gain in speed is not as impressive, as it is for older cards, but can be useful in certain applications and settings. As this is also system dependent, your improvements may vary.
Continuous memory for increased data transfer rate

### Bus Transfer Speed Details (M2i/M3i cards in an example system)

<table>
<thead>
<tr>
<th>Mode</th>
<th>PCI 33 MHz slot read</th>
<th>PCI 33 MHz slot write</th>
<th>PCI-X 66 MHz slot read</th>
<th>PCI-X 66 MHz slot write</th>
<th>PCI Express x1 slot read</th>
<th>PCI Express x1 slot write</th>
</tr>
</thead>
<tbody>
<tr>
<td>User buffer</td>
<td>109 MB/s</td>
<td>107 MB/s</td>
<td>195 MB/s</td>
<td>190 MB/s</td>
<td>130 MB/s</td>
<td>138 MB/s</td>
</tr>
<tr>
<td>Continuous kernel buffer</td>
<td>125 MB/s</td>
<td>122 MB/s</td>
<td>248 MB/s</td>
<td>238 MB/s</td>
<td>160 MB/s</td>
<td>170 MB/s</td>
</tr>
<tr>
<td>Speed advantage</td>
<td>13%</td>
<td>14%</td>
<td>27%</td>
<td>25%</td>
<td>24%</td>
<td>23%</td>
</tr>
</tbody>
</table>

### Bus Transfer Standard Read/Write Transfer Speed Details (M4i.44xx card in an example system)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Notifysize 16 kByte read</th>
<th>Notifysize 16 kByte write</th>
<th>Notifysize 64 kByte read</th>
<th>Notifysize 64 kByte write</th>
<th>Notifysize 512 kByte read</th>
<th>Notifysize 512 kByte write</th>
<th>Notifysize 2048 kByte read</th>
<th>Notifysize 2048 kByte write</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous kernel buffer</td>
<td>229 MB/s</td>
<td>133 MB/s</td>
<td>788 MB/s</td>
<td>457 MB/s</td>
<td>2270 MB/s</td>
<td>1470 MB/s</td>
<td>2055 MB/s</td>
<td>2121 MB/s</td>
</tr>
<tr>
<td>Speed advantage</td>
<td>-1.6%</td>
<td>+0.7%</td>
<td>-0.6%</td>
<td>-1.5%</td>
<td>-1.5%</td>
<td>-3.7%</td>
<td>-27.3%</td>
<td>+11.6%</td>
</tr>
</tbody>
</table>

### Bus Transfer FIFO Read Transfer Speed Details (M4i.44xx card in an example system)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Notifysize 4 kByte FIFO read</th>
<th>Notifysize 8 kByte FIFO read</th>
<th>Notifysize 16 kByte FIFO read</th>
<th>Notifysize 32 kByte FIFO read</th>
<th>Notifysize 64 kByte FIFO read</th>
<th>Notifysize 256 kByte FIFO read</th>
<th>Notifysize 1024 kByte FIFO read</th>
<th>Notifysize 4096 kByte FIFO read</th>
</tr>
</thead>
<tbody>
<tr>
<td>User buffer</td>
<td>455 MB/s</td>
<td>185 MB/s</td>
<td>1794 MB/s</td>
<td>7005 MB/s</td>
<td>3335 MB/s</td>
<td>3386 MB/s</td>
<td>3386 MB/s</td>
<td>3335 MB/s</td>
</tr>
<tr>
<td>Continuous kernel buffer</td>
<td>540 MB/s</td>
<td>833 MB/s</td>
<td>1767 MB/s</td>
<td>1945 MB/s</td>
<td>3316 MB/s</td>
<td>3386 MB/s</td>
<td>3386 MB/s</td>
<td>3335 MB/s</td>
</tr>
<tr>
<td>Speed advantage</td>
<td>+18.6%</td>
<td>-2.9%</td>
<td>-1.5%</td>
<td>-2.0%</td>
<td>-3.5%</td>
<td>0%</td>
<td>+0.6%</td>
<td>+1.7%</td>
</tr>
</tbody>
</table>

### Bus Transfer FIFO Read Transfer Speed Details (M2p.5942 card in an example system)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Notifysize 4 kByte FIFO read</th>
<th>Notifysize 8 kByte FIFO read</th>
<th>Notifysize 16 kByte FIFO read</th>
<th>Notifysize 32 kByte FIFO read</th>
<th>Notifysize 64 kByte FIFO read</th>
<th>Notifysize 256 kByte FIFO read</th>
<th>Notifysize 1024 kByte FIFO read</th>
<th>Notifysize 4096 kByte FIFO read</th>
</tr>
</thead>
<tbody>
<tr>
<td>User buffer</td>
<td>282 MB/s</td>
<td>462 MB/s</td>
<td>597 MB/s</td>
<td>800 MB/s</td>
<td>800 MB/s</td>
<td>799 MB/s</td>
<td>799 MB/s</td>
<td>799 MB/s</td>
</tr>
<tr>
<td>Continuous kernel buffer</td>
<td>279 MB/s</td>
<td>590 MB/s</td>
<td>577 MB/s</td>
<td>800 MB/s</td>
<td>800 MB/s</td>
<td>800 MB/s</td>
<td>800 MB/s</td>
<td>800 MB/s</td>
</tr>
<tr>
<td>Speed advantage</td>
<td>-1.1%</td>
<td>+27.7%</td>
<td>-3.4%</td>
<td>+0.0%</td>
<td>+0.0%</td>
<td>0%</td>
<td>+0.1%</td>
<td>+0.3%</td>
</tr>
</tbody>
</table>

### Setup on Linux systems

On Linux systems the continuous buffer setting is done via the command line argument `contmem_mb` when loading the kernel driver module:

```
insmod spcm.ko contmem_mb=4
```

As memory allocation is organized completely different compared to Windows the amount of data that is available for a continuous DMA buffer is unfortunately limited to a maximum of 8 MByte. On most systems it will even be only 4 MBytes.

### Setup on Windows systems

The continuous buffer settings is done with the Spectrum Control Center using a setup located on the „Support“ page. Please fill in the desired continuous buffer settings as MByte. After setting up the value the system needs to be restarted as the allocation of the buffer is done during system boot time.

If the system cannot allocate the amount of memory it will divide the desired memory by two and try again. This will continue until the system can allocate a continuous buffer. Please note that this try and error routine will need several seconds for each failed allocation try during boot up procedure. During these tries the system will look like being crashed. It is then recommended to change the buffer settings to a smaller value to avoid the long waiting time during boot up.

Continuous buffer settings should not exceed 1/4 of system memory. During tests the maximum amount that could be allocated was 384 MByte of continuous buffer on a system with 4 GByte memory installed.
Usage of the buffer

The usage of the continuous memory is very simple. It is just necessary to read the start address of the continuous memory from the driver and use this address instead of a self allocated user buffer for data transfer.

Function spcm_dwGetContBuf

This function reads out the internal continuous memory buffer (in bytes) if one has been allocated. If no buffer has been allocated the function returns a size of zero and a NULL pointer.

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

Please note that it is not possible to free the continuous memory for the user application.

Example

The following example shows a simple standard single mode data acquisition setup (for a card with 12/14/16 bit per resolution one sample equals 2 bytes) with the read out of data afterwards. To keep this example simple there is no error checking implemented.

```c
int32 lMemsize = 16384;                                                // recording length is set to 16 kSamples
spcm_dwSetParam_i64 (hDrv, SPC_CHENABLE, CHANNEL0);                    // only one channel activated
spcm_dwSetParam_i32 (hDrv, SPC_CARDMODE, SPC_REC_STD_SINGLE);          // set the standard single recording mode
spcm_dwSetParam_i64 (hDrv, SPC_MEMSIZE, lMemsize);                     // recording length in samples
spcm_dwSetParam_i64 (hDrv, SPC_POSTTRIGGER, 8192);                     // samples to acquire after trigger = 8k

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

// we now try to use a continuous buffer for data transfer or allocate our own buffer in case there’s none
spcm_dwGetContBuf_i64 (hDrv, SPCM_BUF_DATA, pvData, &qwContBufLen);
if (qwContBufLen < (2 * lMemsize))
    pvData = pvAllocMemPageAligned (lMemsize * 2); // assuming 2 bytes per sample

// read out the data
spcm_dwDefTransfer_i64 (hDrv, SPCM_BUF_DATA, SPCM_DIR_CARDTOPC , 0, pvData, 0, 2 * lMemsize);
spcm_dwSetParam_i32 (hDrv, SPC_M2CMD, M2CMD_DATA_STARTDMA | M2CMD_DATA_WAITDMA);

// ... Use the data here for analysis/calculation/storage

// delete our own buffer in case we have created one
if (qwContBufLen < (2 * lMemsize))
    vFreeMemPageAligned (pvData, lMemsize * 2);
```