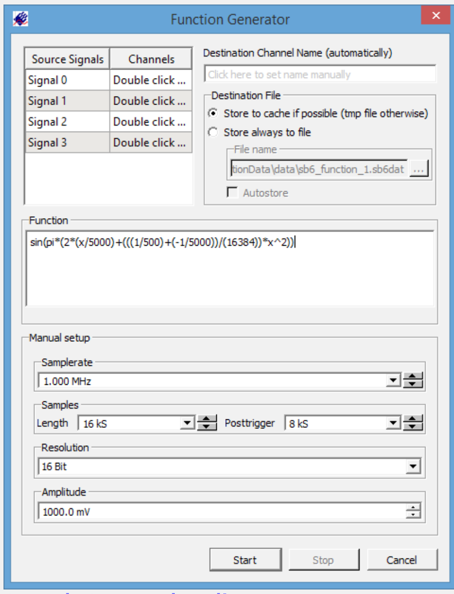
Application Note

Creating AWG Waveforms in SBench 6 using Equations



SBench 6 Formula Editor

Arbitrary waveform generators (AWG's) are among the most powerful signal sources available for testing. They offer an extensive range of waveshapes which can be created and selected to rapidly provide a broad range of test events.

Spectrum Instrumentation offers two families of arbitrary waveform generators. The first is theM2i.60 series which offers sample rates to 125 Megasamples/second (MS/s) and signal bandwidths of up to 60 MHz at 14 bits amplitude resolution. The second is the newly released M4i.66xx series Arbitrary Waveform Generators that set new standards in bandwidth, time and amplitude resolution. The new models of the M4i.66xx series offer one, two and four channels with each channel capable of outputting electronic signals at rates of up to 625 MS/s with 16 bit vertical resolution. These two families of AWG's are ideal for generating either low or high frequency signals up to 200 MHz with the best possible accuracy and fidelity.

Supporting all its modular digitizer and AWG products Spectrum offers a sophisticated software application known as SBench6. On the AWG side SBench6 provides an editor for creating waveforms using equations as shown in Figure 1.

Waveform Equation Components

This application note provides an overview of the rules for waveform creation along with a series of detailed examples. Let's start with an overview of the waveform creation elements available in SBnech6

Constants

Two constants are pre-defined:

e = Euler's number = 2.7182...
pi = PI = 3.14159 ...

Users can define their own constants using the function 'const' function :
const SpeedOfLight=299792458;

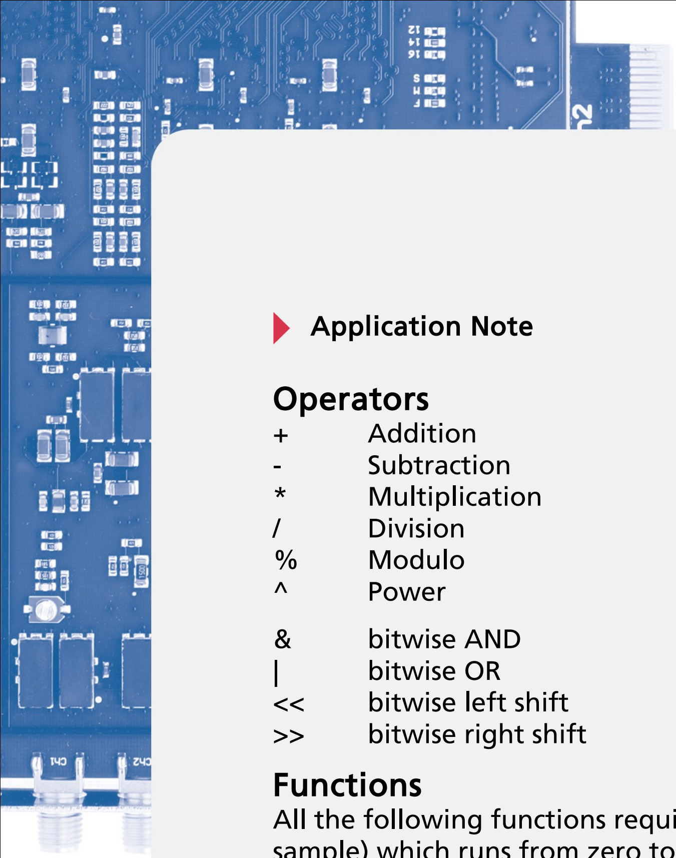
Comments

Comments can be inserted into the formula by using /* and */ mark (C language style comments).

Spaces, blank lines or line feeds may be added to the equation structure to improve understandability

Source Signals

sig0(x) value of source signal 0
sig1(x) value of source signal 1
sig2(x) value of source signal 2
sig3(x) value of source signal 3



Operators

+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Modulo
^	Power
&	bitwise AND
|	bitwise OR
<<	bitwise left shift
>>	bitwise right shift

Functions

All the following functions require an argument. The standard argument is the x (current sample) which runs from zero to [length-1]. The argument can also be modified using another expression. This allows manipulation of the time base of the resultant signal.

The bitwise functions AND, OR, SHIFT can only be used on signals or on other bitwise functions but it is not possible to use them on functions.

Function List

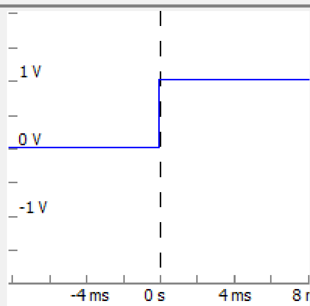
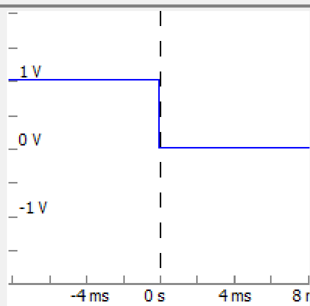
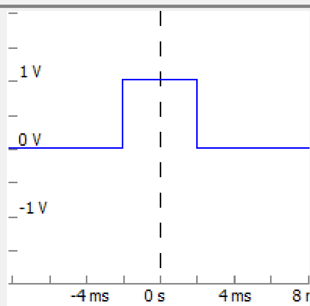
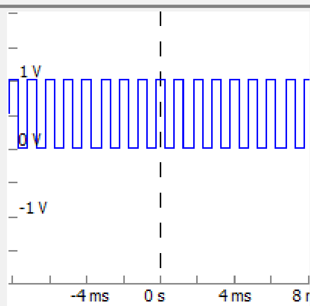
sin(x)	Sine
cos(x)	Cosine
tan(x)	Tangent
asin(x)	Arc Sine
acos(x)	Arc Cosine
atan(x)	Arc Tangent
sinh(x)	Hyperbolic Sine
cosh(x)	Hyperbolic Cosine
tanh(x)	Hyperbolic Tangent
ln(x)	Natural Logarithm
abs(x)	Absolute Value

Conditional Functions

if (x, min, max)	if x >=min and x<=max the result is 1.0, otherwise zero
sign (x)	is -1.0 if argument is negative, +1.0 if argument is positive
tri (x,d)	Triangle with d% of one period rising, the other 100- d% falling
rect (x,d)	Rectangle with d% of one period high, the other 100-d% low

Examples of Creating Waveforms in SBench 6 Using Equations

The following table contains many examples of waveforms based on equations using the elements discussed previously. Note all equations are based upon the current sample value represented by the symbol x. This results in equation arguments expressed in terms of the signal period which is always an integer number of samples. The time axis can be determined by multiplying the sample value by the sampling period. Adjusting the sample rate of the AWG allows any frequency or time interval to be produced within the waveform memory length and sampling rate resolution limits.

Waveform	General Equation	Example
Unit Step	If (x, X_D, X_{MAX}) X_D- Location of step in samples X_{MAX} – Duration of the waveform in samples **Example:** if (x,8192,16384)	
Time Reversed Step	1 - If (x, X_0, X_{MAX}) X_0- Location of step in samples X_{MAX} – Duration of the waveform in samples **Example**: 1-if (x,8192,16384)	
Unit Pulse	If (x, X_S, X_E) X_S – Location of leading edge in samples X_E – Location of trailing edge in samples **Example**: if (x,6192, 10192)	
Rectangular Unit Pulse Train	0.5+0.5 *sign (sin (2*pi*x/X_P)) X_P - Period in samples **Example**: 0.5+0.5*sign(sin (2*pi*x/1000))	

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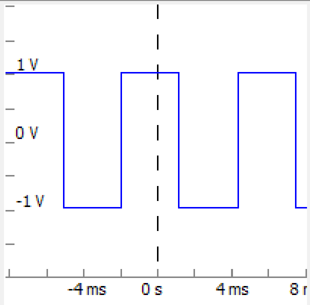
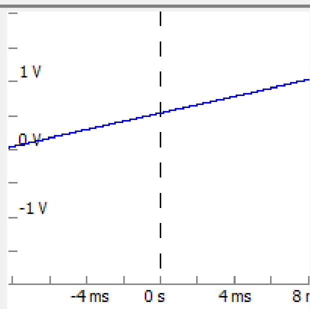
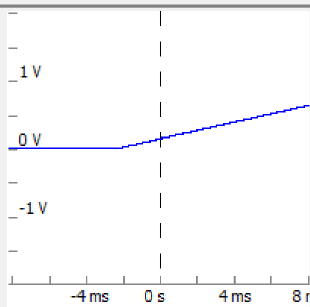
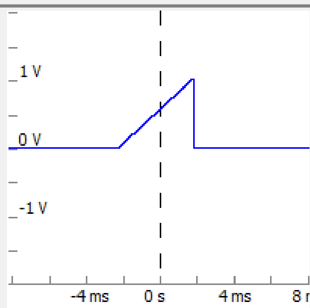
Waveform	General Equation	Example
Bipolar Pulse Train	rect (x/X_P, d) X_P - Period in samples d- Duty cycle in percent (%) **Example**: rect(x/1000,50)	
Ramp	x*(DV/DX) DV/DX – Slope of the ramp in volts/samples **Example**: x*(1/16384)	
Delayed Ramp	(x-X_D)* (DV/DX)* if(x, X_D, X_{MAX}) X_D – Delay in samples DV/DX – Slope of the ramp in volts/samples X_{MAX} – Duration of the waveform in samples **Example**: (x-6192)*(1/16384)*if(x,6192,16384)	
Truncated Ramp (Delayed)	(x-X_D)* (DV/DX)* if(x, X_D, X_E) X_D – Delay in samples DV/DX – Slope of the ramp in volts/samples X_E – Location of trailing edge in samples **Example**: (x-6000)*(1/4000)*if(x,6000,10000)	

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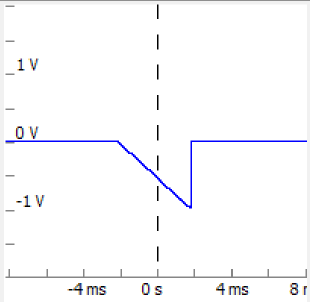
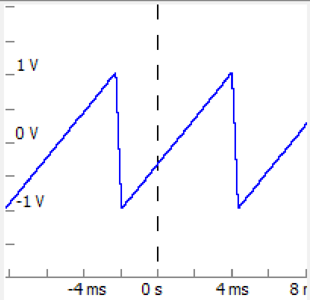
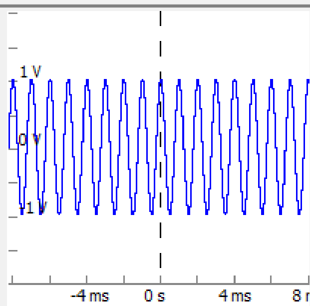
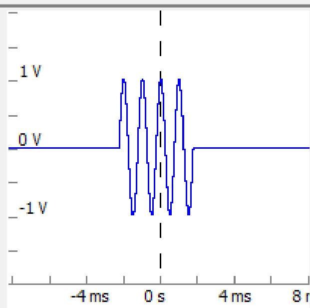
Waveform	General Equation	Example
Negative Ramp (Truncated)	(x-X_D)* (-1*DV/DX)* if(x, $X_{D,}$ X_E) X_D – Delay in samples DV/DX – Slope of the ramp in volts/samples X_E – Location of trailing edge in samples **Example**: (x-6000)*(-1/4000)*if(x,6000,10000)	
Periodic Triangle Wave	Tri (x/ X_P, d) X_P - Period in samples d- Duty cycle in percent (%) **Example**: tri(x/1000,95)	
Sinewave	sin(2*pi*x/X_P) X_P - Period in samples **Example**: sin(2*pi*x/1000)	
Gated Sine	sin(2*pi*x/ X_P) * if(x, X_S,X_E) X_P - Period in samples X_S – Location of leading edge in samples X_E – Location of trailing edge in samples **Example**: sin(2*pi*x/1000)*if(x,6000,10000)	

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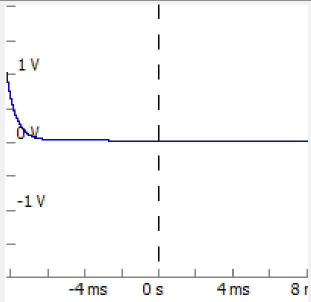
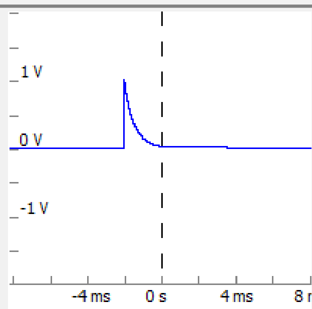
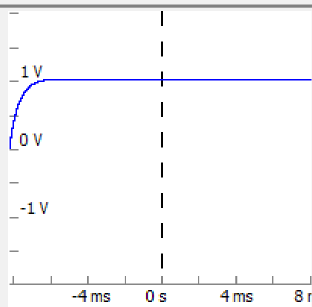
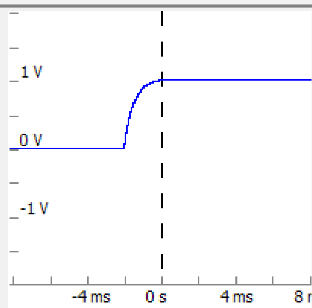
Waveform	General Equation	Example
Decaying Exponential	e ^ (-1*(x/X_t)) X_T – Exponential time constant in samples **Example**: e^(-1*(x/500))	
Delayed Decaying Exponential	(e ^ (-1*(x- X_D)/ X_t))* if(x,X_D,X_{MAX}) X_D – Delay in samples X_T – Exponential time constant in samples X_{MAX} – Duration of the waveform in samples **Example**: (e^(-1*((x-6192)/500))) * if (x,6192,16834)	
Rising Exponential	1-(e^(-1*(x/X_T))) X_T – Exponential time constant in samples **Example**: 1-(e^(-1*((x)/500)))	
Delayed Rising Exponential	(1-(e^(-1*(x-X_D/X_T))))* if(x,X_D,X_{MAX}) X_D – Delay in samples X_T – Exponential time constant in samples X_{MAX} – Duration of the waveform in samples **Example**: 1-(e^(-1*((x-6192)/500)))) * if(x,6192,16384)	

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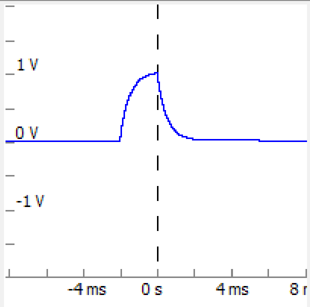
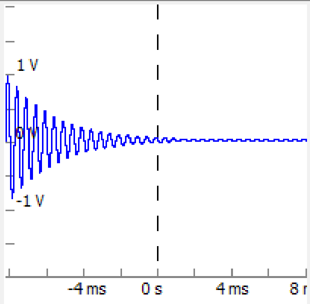
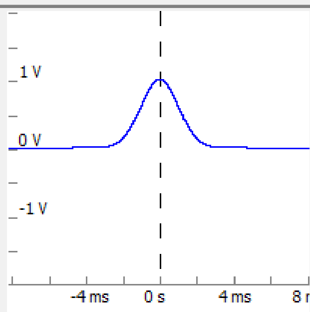
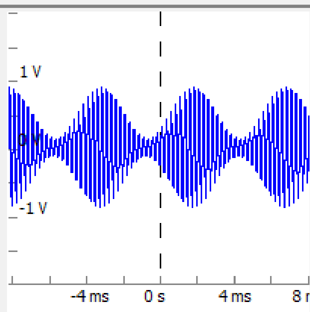
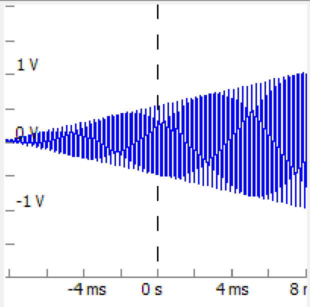
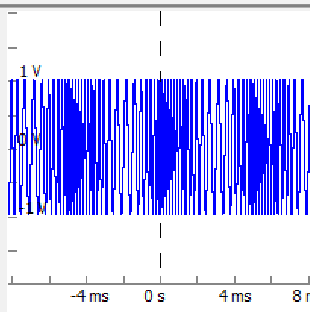
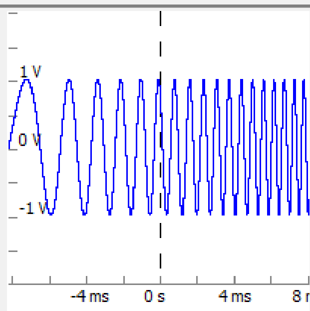
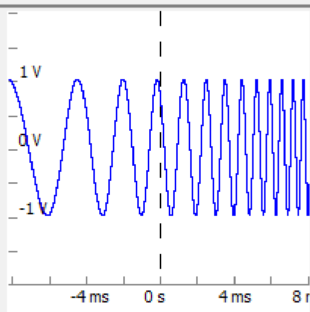
Waveform	General Equation	Example
Exponential Pulse	(1-(e^(-1*(x-X_S/X_T))))* if(x,X_S,X_P) + (e ^ (-1*(x- X_P)/ X_t))* if(x,X_P,X_{MAX}) X_T – Exponential time constant in samples X_{MAX} – Duration of the waveform in samples X_S – Location of start of rise in samples X_P – Location of peak in samples **Example**: (1-(e^(-1*((x-6192)/500)))) * if(x,6192,8192)+ (e^(-1*((x-8192)/500))* if(x,8192,16384))	
Exponentially Damped Sine	(e ^ (-1*(x/X_t)) * sin(2*pi*x/ X_P) X_T – Exponential time constant in samples X_P - Period in samples **Example**: e^(-1*(x/2500)) *sin(2*pi*x/500)	
Gaussian Pulse	e^((-1/2)*((x-X_D)^2)/(Xs^2)) X_D – Delay (mean) in samples Xs - Pulse Width (sigma) **Example**: e^((-1/2)*((x-8192)^2)/(1000^2))	
Amplitude Modulation	**0.5*sin(2*pi*x/X_C)*(1+ K_M *f(x))** X_C _ Carrier period in samples K_M – Modulation index 0 to 1 F(x) – modulation waveform **Example**: 0.5*sin(2*pi*x/250)*(1+(0.75*cos(2*pi*x/5000)))	

Waveform	General Equation	Example
Sine Amplitude Sweep	x*(DV/DX) * sin(2*pi*x/X_C) DV/DX – Slope of the ramp in volts/samples X_C _ Carrier period in samples **Example**: x*(1/16384)*sin(2*pi*x/250)	
Frequency Modulation	Sin(2*pi*x/X_C+(X_M/X_{Dev})*cos(2*pi*x/X_M) X_C _ Carrier period in samples X_M – Modulation Period in samples X_{Dev} – Period deviation in samples **Example**: sin(2*pi*x/250+(5000/500)*cos(2*pi*x/5000))	
Linear Frequency Sweep	Sin(pi*(2*(x/X_s)+(((1/X_E)-(1/X_S))/X_{MAX})*x^2)) X_S – Start Period in samples X_E – End Period in samples X_{MAX} – Duration of the waveform in samples **Example**: sin(pi*(2*(x/5000)+(((1/500)+ (-/5000))/16384)*x^2))	
Logarithmic Frequency Sweep	Sin*2*pi(X_{MAX}/ln(X_S/X_E)/X_S)*e^((ln(X_S/X_E)/X_S)*x)-1) X_S – Start Period in samples X_E – End Period in samples X_{MAX} – Duration of the waveform in samples **Example**: sin(2*pi*(16384/ln(5000/500)/5000) * e^((ln(5000/500)/16384)*x)-1)	

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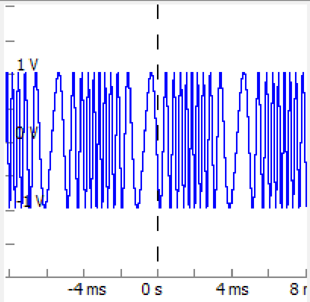
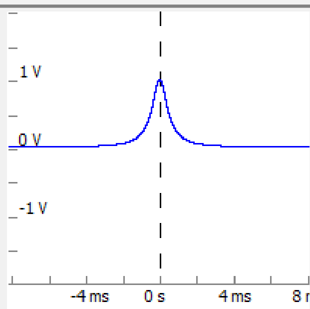
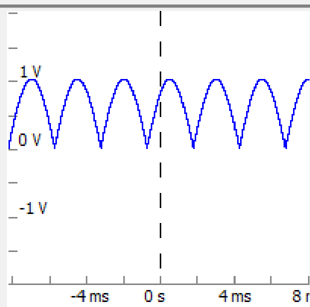
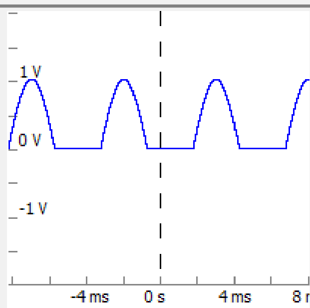
Waveform	General Equation	Example
Phase Modulation	Sin((2*pi*(x/X_C)+ K*Sin(2*pi*(x/X_M))) X_C _ Carrier period in samples X_M – Modulation Period in samples K– Peak phase excursion in radians **Example**: sin(2*pi*(x/500)+7* sin(2*pi*(x/5000)))	
Lorentzian Pulse	1/(1+((x-X_D)/(X_W))^2) X_D- Time delay in samples T_W - Half width point of the pulse in samples **Example**: 1/(1+((x-8192)/500)^2)	
Full Wave Rectified Sine	Abs(Sin(2*pi*x/ X_P)) X_P – Sine wave period in samples **Example**: Abs(Sin(2*pi*x/5000))	
Half Wave Rectified Sine	0.5*(sin(2*pi*x/X_P)+Abs(Sin(2*pi*x/ X_P))) X_P – Sine wave period in samples **Example**: 0.5*(sin(2*pi*x/5000)+Abs(Sin(2*pi*x/5000)))	

Waveform	General Equation	Example
Sinc	**$\sin((x-X_D)/X_P)/((x-X_D)/X_P)$** X_D- Time delay in samples X_P – Sinc period in samples **Example**: sin((x-8192)/500)/((x-8192)/500)