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Hands-On Experimentation using Digilent Analog Discovery 2

Complete analog & digital circuits in or out of the lab

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Analog Discovery 2

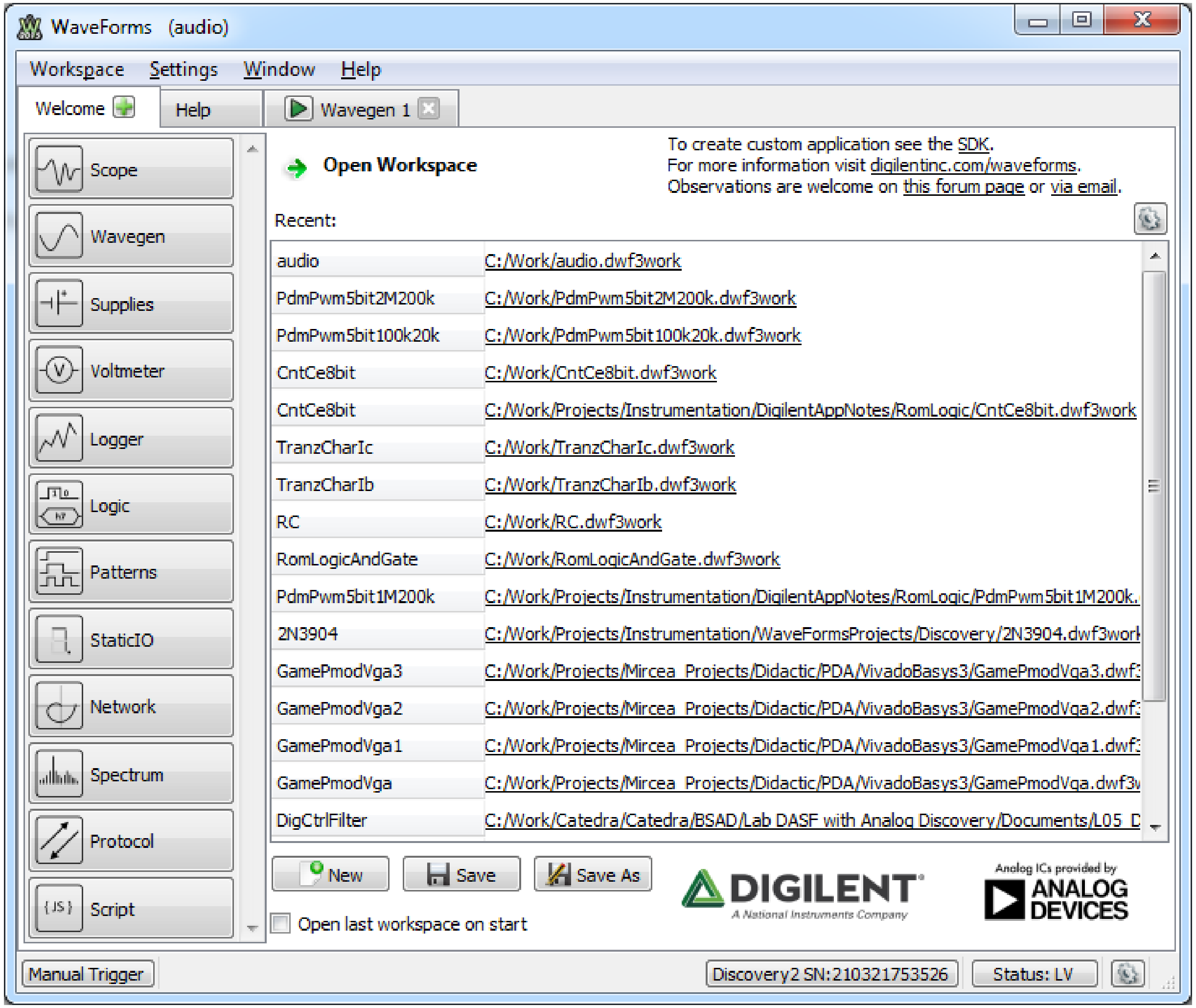
Primary HW resources:

- Two-channel scope (1MΩ, ±25V, differential, 14-bit, 100MS/s, 30MHz+ with the BNC Adapter)
- Two-channel AWG (±5V, 14-bit, 100MS/s, 12MHz+ with the BNC Adapter)
- Stereo audio amplifier to drive external headphones with AWG signals
- 16-ch digital logic analyzer/pattern generator/static IO (3.3V CMOS, 100MS/s)
- Two input/output digital triggers for linking multiple instruments (3.3V CMOS)
- Two programmable power supplies (0…+5V , 0…-5V):
  - 250mW max for each supply or 500mW total when powered through USB
  - 2.1W max for each supply when powered by an auxiliary supply
  - 700mA maximum current for each supply

HW resources re-usage (by WaveForms):

- Single channel voltmeter (AC, DC, ±25V)
- Network analyzer – Bode, Nyquist, Nichols diagrams of a circuit; 1Hz to 10MHz
- Spectrum Analyzer –spectrum and measurements (noise, SFDR, SNR, THD, etc.)
- Digital Bus Analyzers (SPI, I^2C, UART, Parallel)

Waveforms 2015



Cross platform

- Windows
- Linux
- OS

Supports Digilent instrumentation HW

- Electronics Explorer
- Analog Discovery
- Analog Discovery 2
- Digital Discovery

Programmer support

- SDK
- LabVIEW support

Optimal use of HW resources

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Waveforms 2015

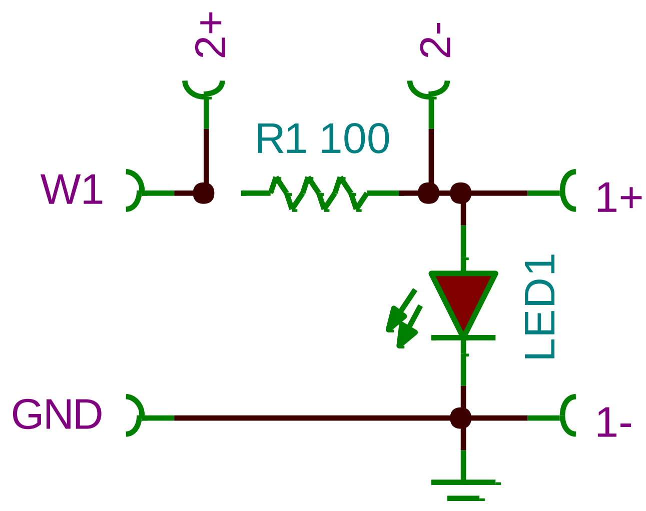
	AWG	Scope	Network Analyzer	Spectrum Analyzer	Pattern Generator	Logic Analyzer	Static I/O
LED I/V characteristics	simple	Time					
		Math					
		XY					
		Trigger					
Transistor characteristics	custom	Units					
	sync	offset =div					
RC Low Pass Filter		Measure	Bode				
		Export	Nyquist				
			Nichols				
Audio	Modulation						
	Sweep						
	Play						
3-bit And Gate					ROM logic - comb	Bus	SW
					Counter	Signal	LED
					Clock		
8-bit counter with CE					ROM logic - FSM		
PDM/PWM modulator				Spectrum	Custom		
				Measure			

LED I/V characteristics

Scope, Channel 2
- Offset: 0V
- Range: 1V/div
- Invisible

AWG, channel 1
- Mode: Simple
- Shape: Triangle
- Frequency: 1kHz
- Amplitude: 5V
- Offset: 0V
- Symmetry 50%

Scope, Math 1
- Mode: Custom
- C2/100
- Units: A
- Offset: 0A
- Range: 5mA/div

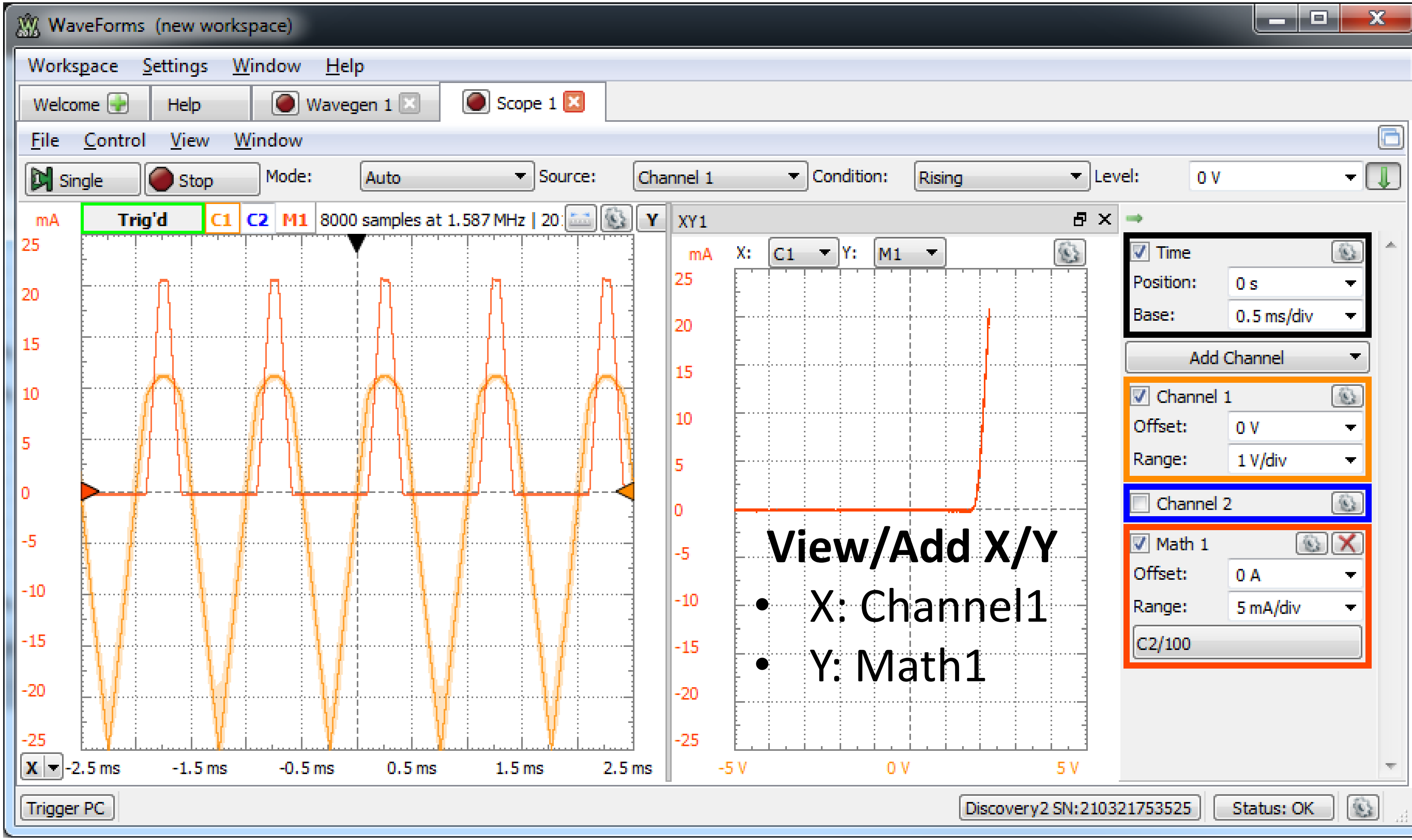


Scope, Trigger
- Mode: Auto
- Source: Channel 1
- Cond: Rising
- Level: 0V

Scope, Time Base
- Position: 0s
- Base: 0.5ms/div

Scope, Channel 1
- Offset: 0V
- Range: 1V/div

LED I/V characteristics



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LED I/V characteristics

More easy experiments…

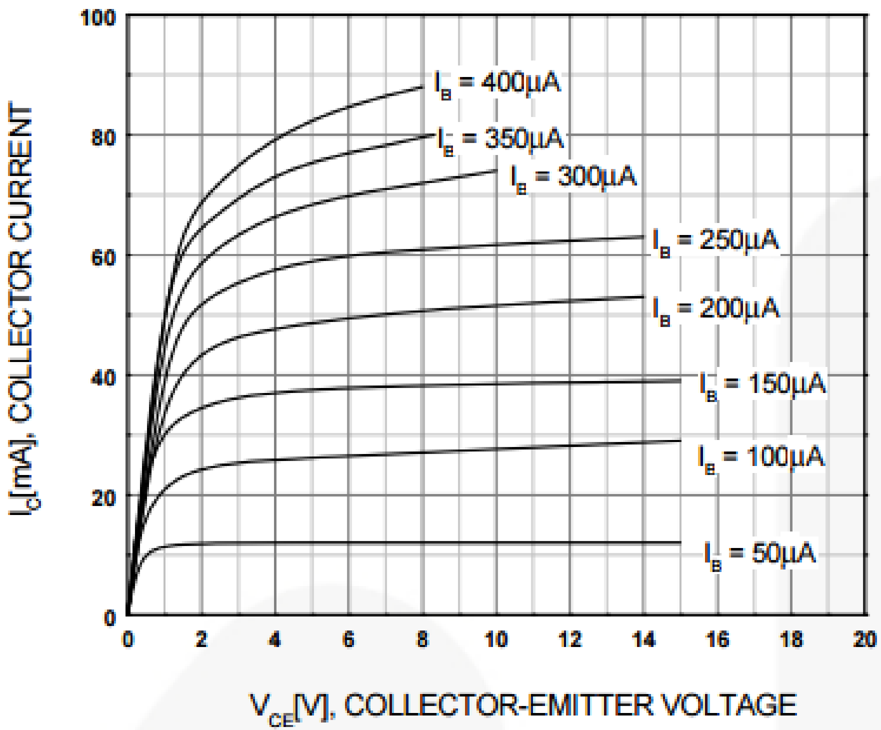
- Change stimulus shape to sinus
  - Does the X/Y view change? Why?
- Change stimulus shape to rectangle
- Play with frequency
  - you might first want to set the Min/Max limits for Frequency to 100mHz/1kHz.
  - Understand the human eye limitation in stimulus pulse frequency
  - Understand the basics of multiplexed LEDs display
- Play with symmetry (0 to 100%).
  - Understand PWM modulation of LEDs equivalent luminous intensity.

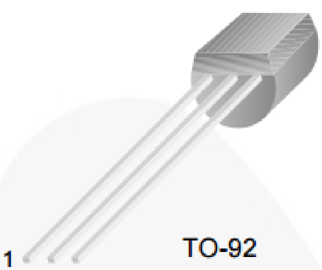
Transistor characteristics

FAIRCHILD

November 2014

BC546 / BC547 / BC548 / BC549 / BC550
NPN Epitaxial Silicon Transistor





TO-92

1. Collector 2. Base 3. Emitter

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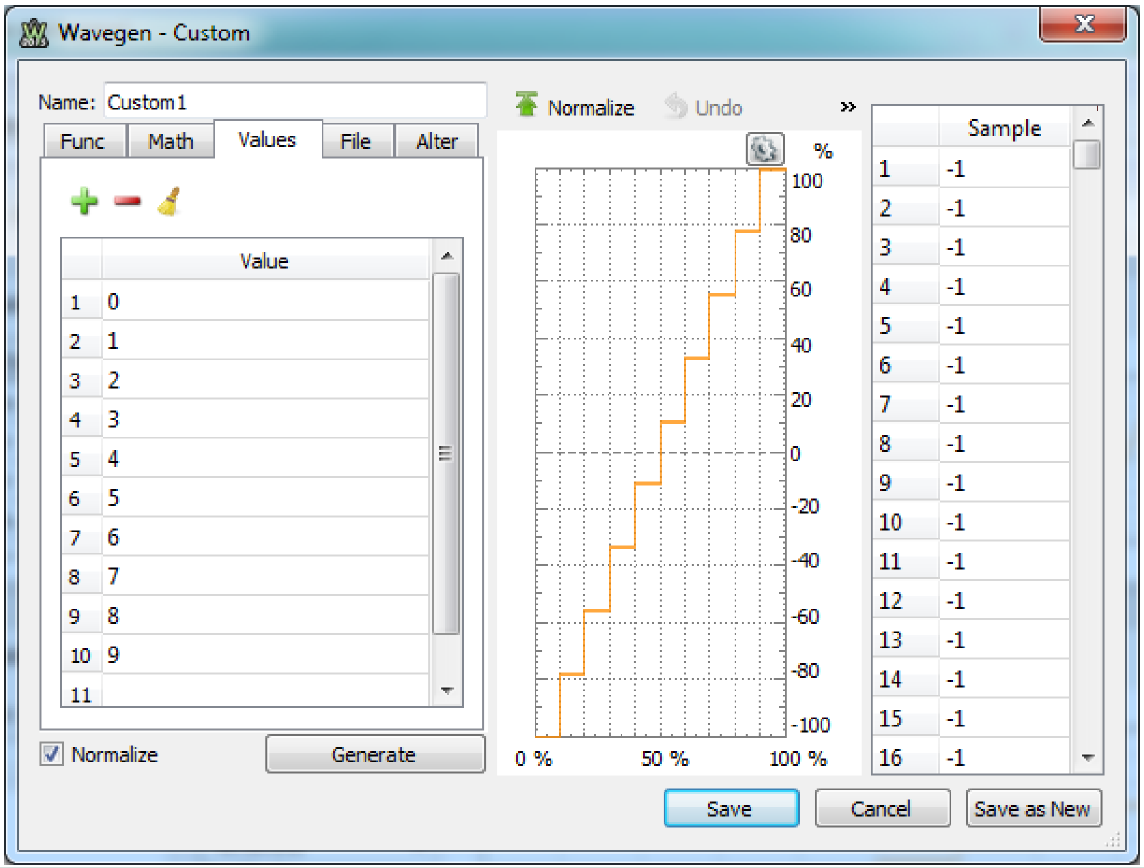
Transistor characteristics

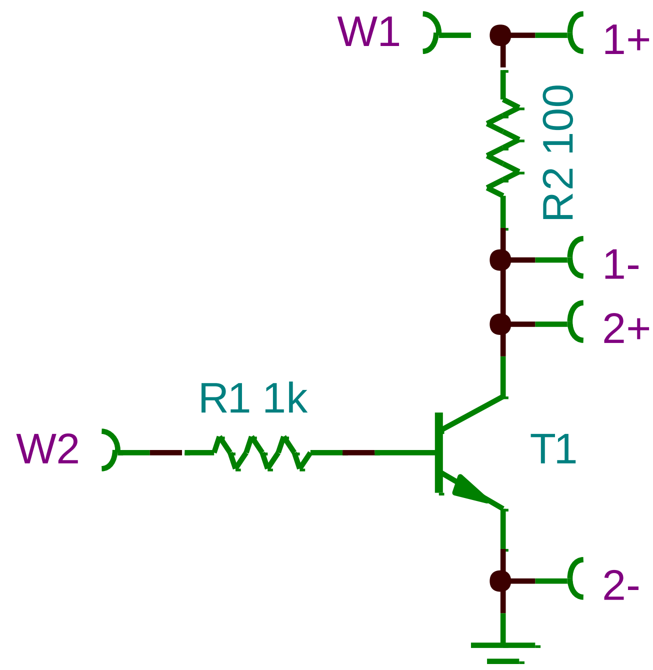
AWG, channel 2

- Mode: Custom
- Edit/Values:0,1,2,…9
- Normalize



AWG, channel 1

- Mode: Simple
- Shape: Triangle
- Frequency: 50Hz
- Amplitude: 2.5V
- Offset: 2.5V
- Phase: 270º



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Transistor characteristics

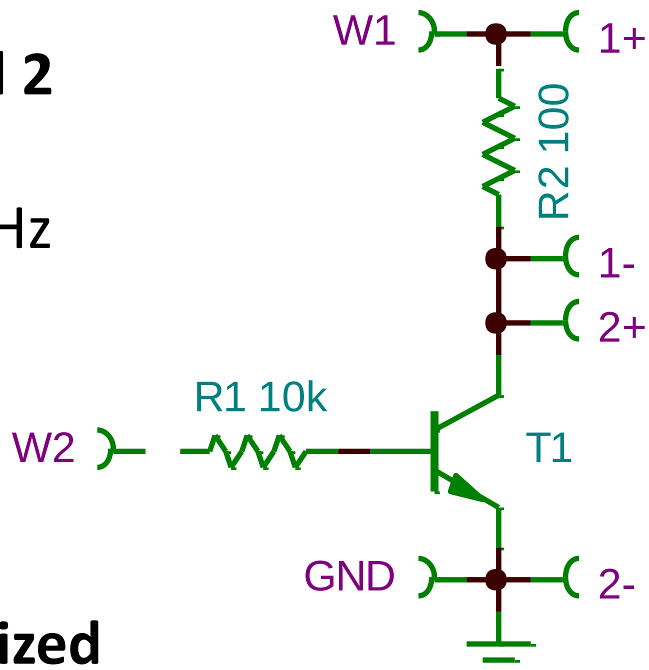
AWG, channel 1
- Mode: Simple
- Shape: Triangle
- Frequency: 50Hz
- Amplitude: 2.5V
- Offset: 2.5V
- Phase: 270º

AWG, channel 2
- Mode: Custom
- Frequency: 10Hz
- Amplitude: 1V
- Offset: 1.6V
- Phase: 0º

AWG, Synchronized

Scope, Channel 1
- Offset: -2.5V
- Range: 500mV/div

Scope, Channel 2
- Offset: -2.5V
- Range: 500mV/div

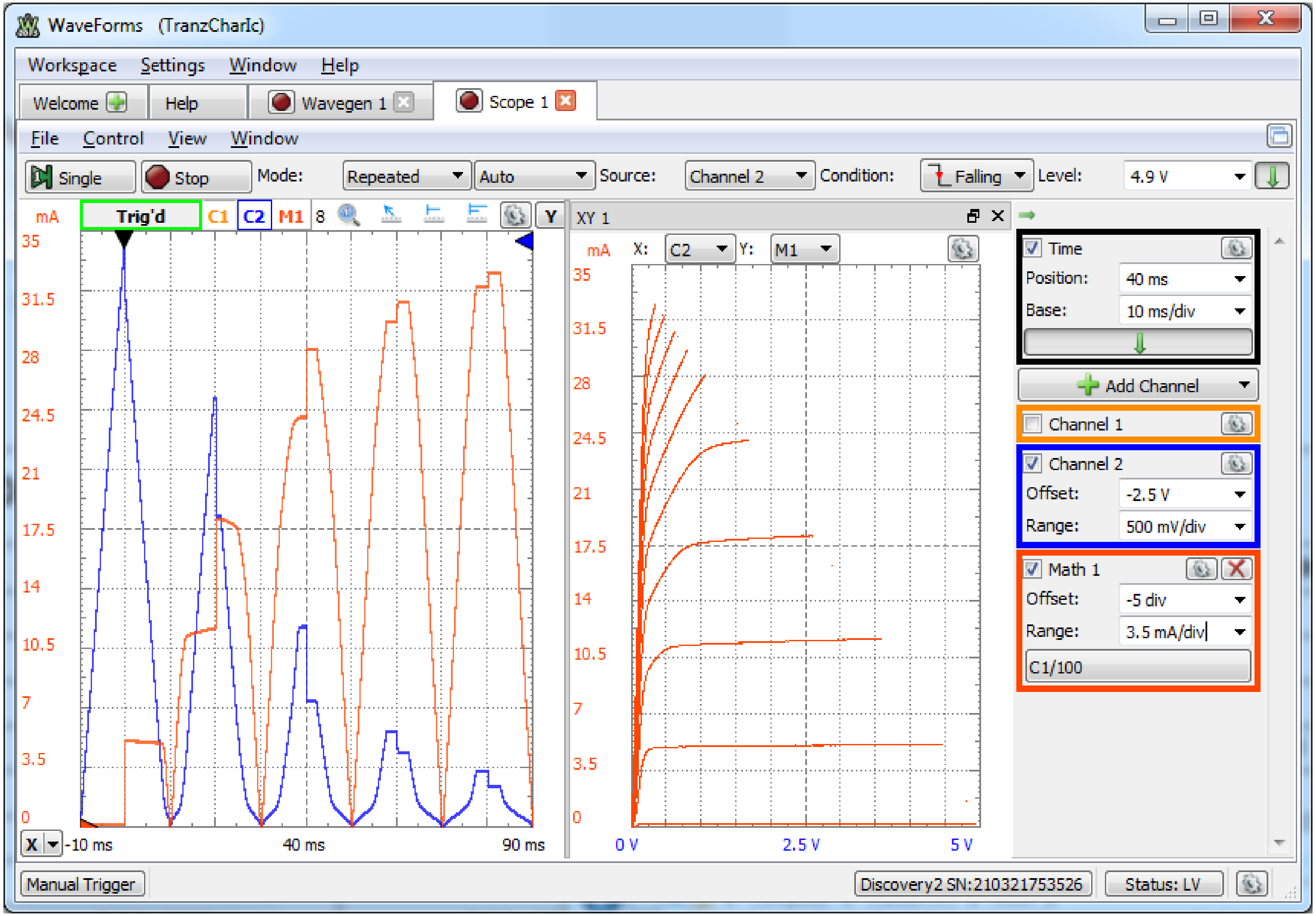


Scope, Trigger
- Mode: Auto
- Source: Channel 2
- Cond: Falling
- Level: 4.9V

Scope, Time Base
- Position: 40ms
- Base: 10ms/div

Scope, Math 1
- Add Ch/Simple
- C1/100
- Settings: Offset as divisions
- Settings: Units = A
- Offset: -5div
- Range: 3mA/div

Transistor characteristics $I_C(V_{CE})$; I_B parameter



Scope

- View
- Add X/Y
- X: C2
- Y:M1

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Transistor characteristics; I_B values

Scope, Channel1

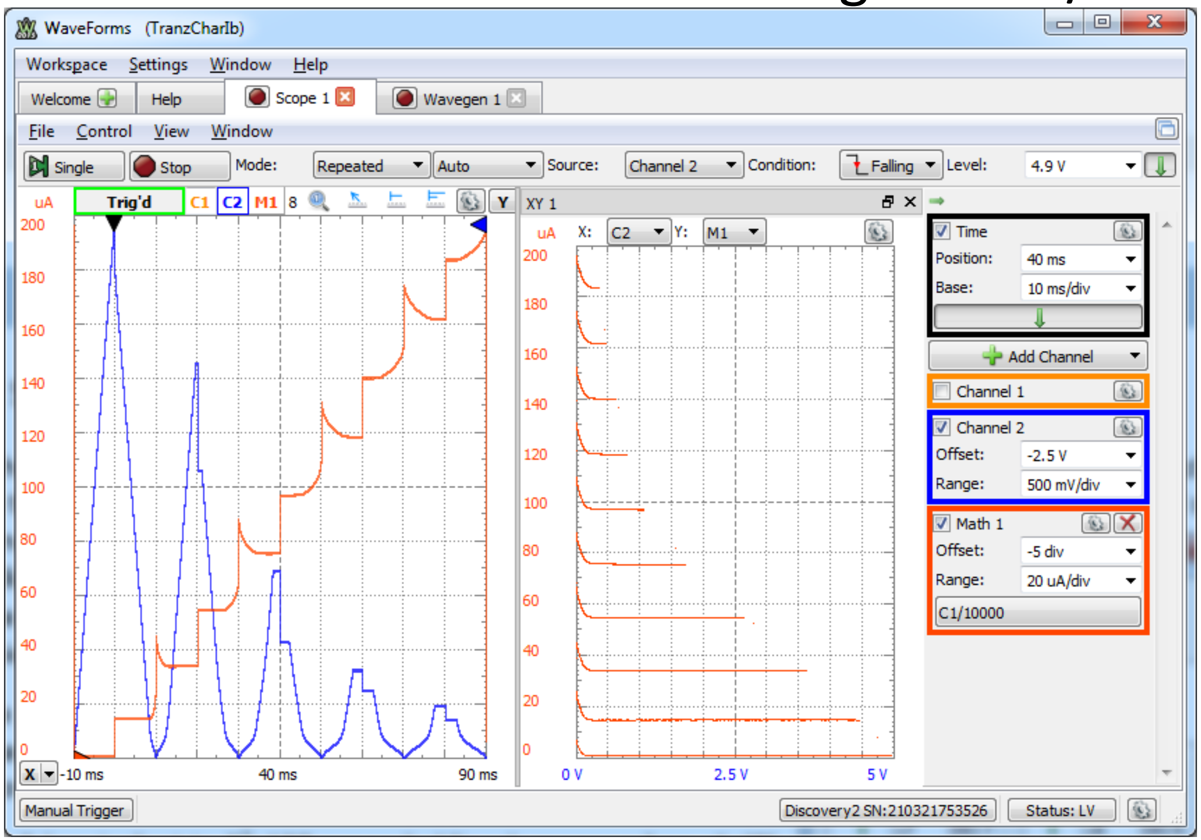
- Offset: -5div
- Range: 200mV/div

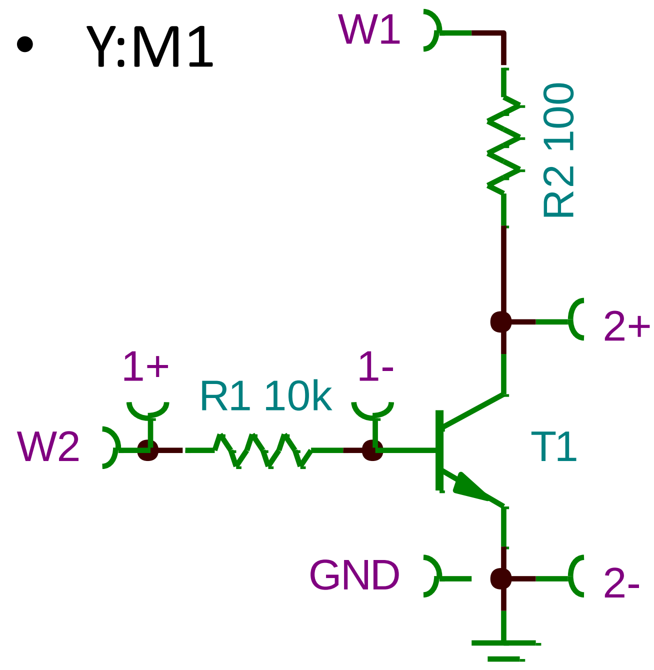
Scope, Math 1

- Add Ch/Custom
- C1/10000
- Range: 20uA/div

Scope

- View
- Add X/Y
- X: C2
- Y:M1





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RC Low Pass Filter
Time domain - step response

AWG, channel 1

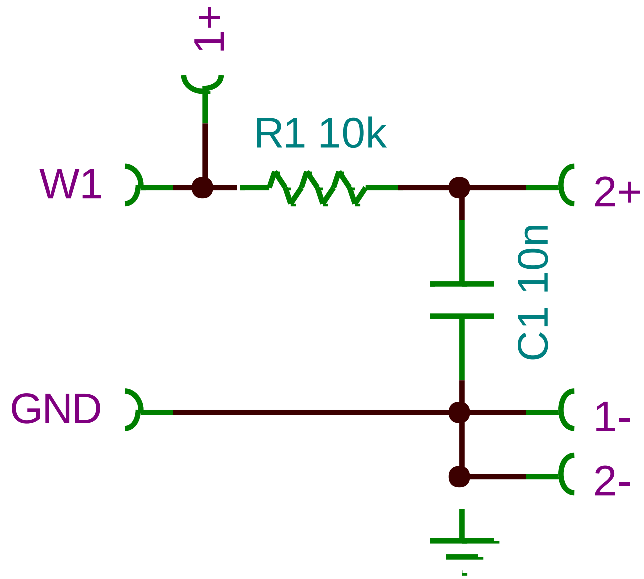
- Mode: Simple
- Shape: Square
- Frequency: 50Hz
- Amplitude: 2.5V
- Offset: 2.5V

Scope, Channel 1

- Offset: -2V
- Range: 1V/div

Scope, Channel 2

- Offset: -2V
- Range: 1V/div



Scope, Trigger

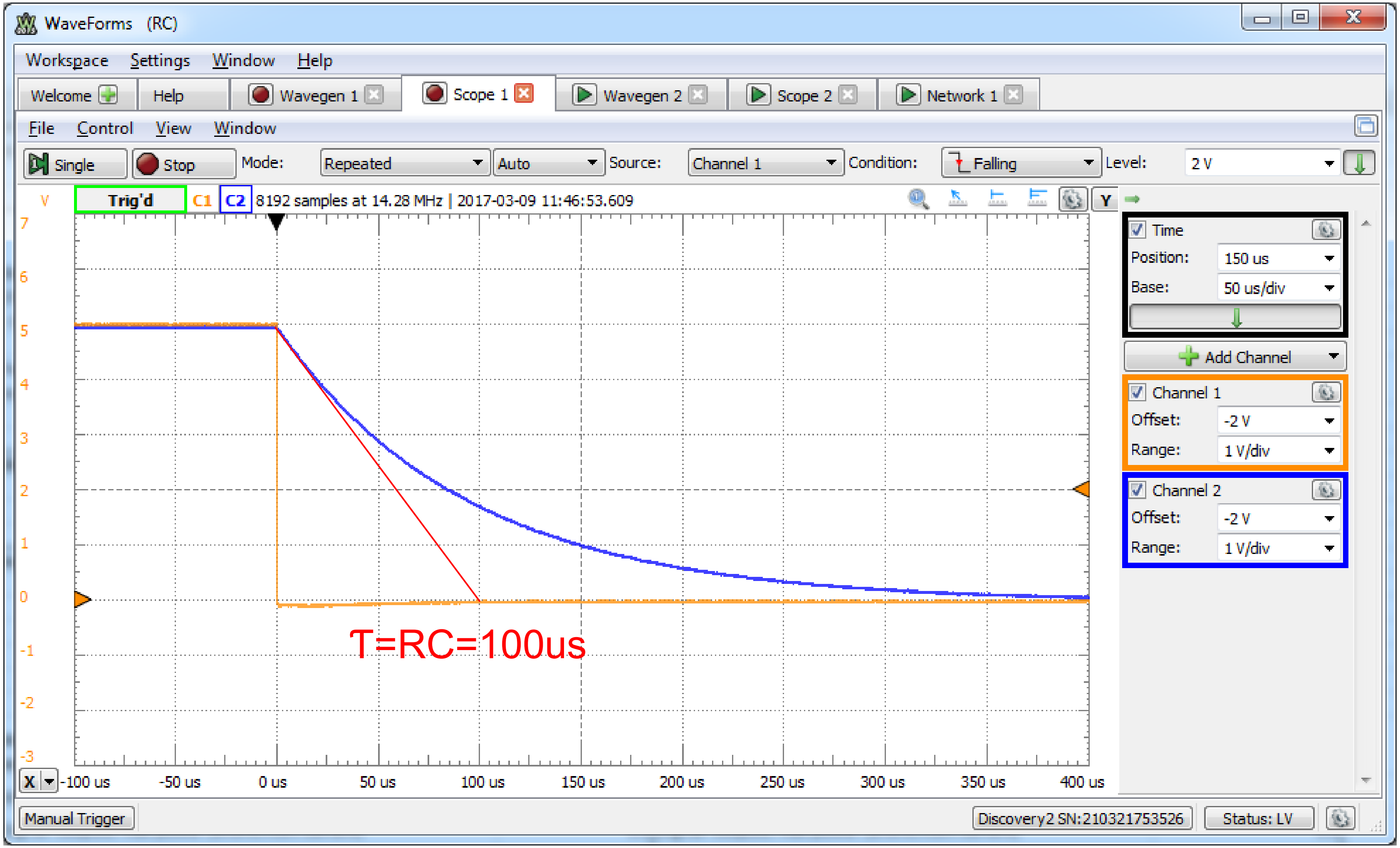
- Mode: Auto
- Source: Channel 1
- Cond: Falling
- Level: 2V

Scope, Time Base

- Position: 2ms
- Base: 500us/div

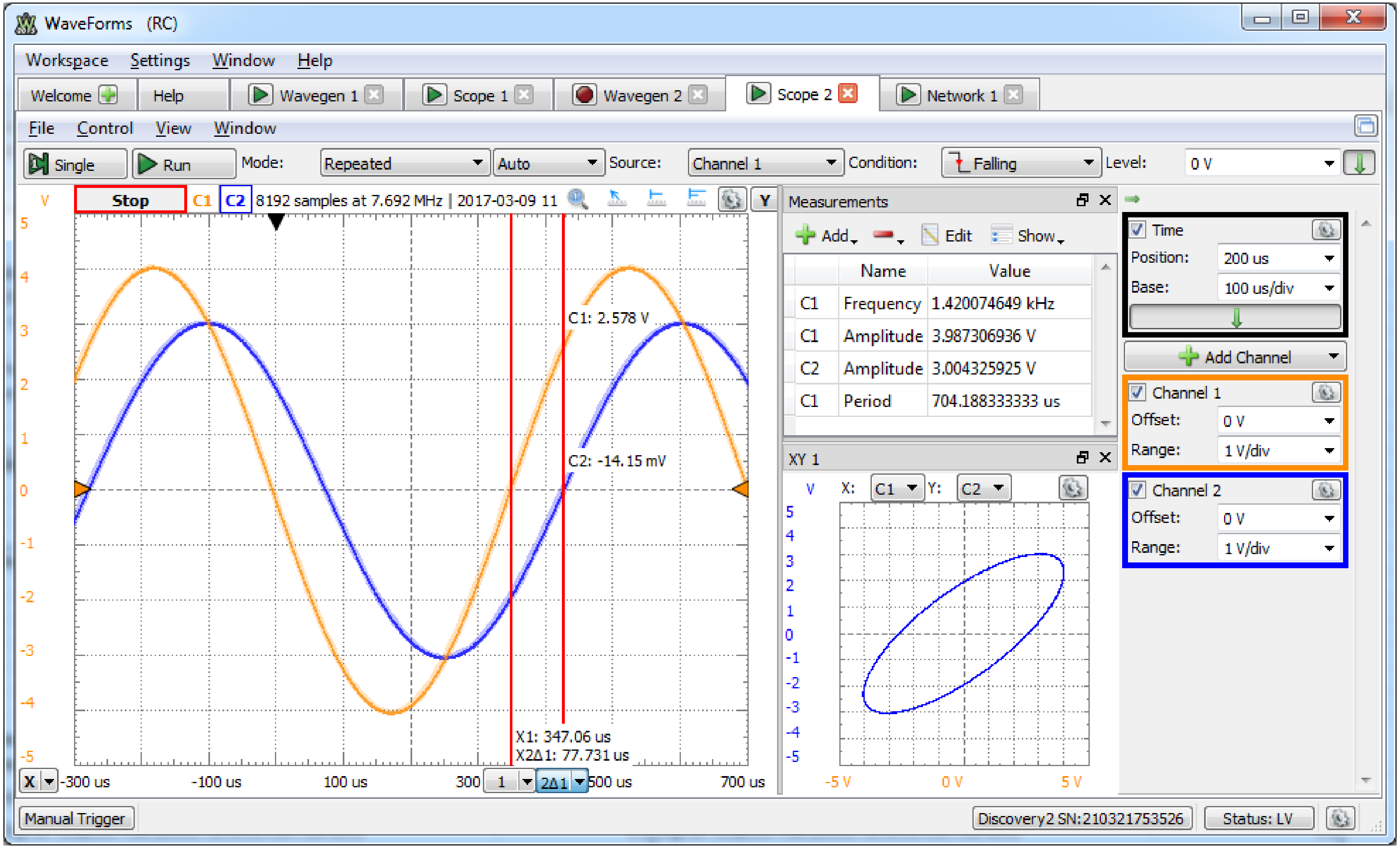
RC Low Pass Filter

Time domain - step response



RC Low Pass Filter

Time domain - sinus response



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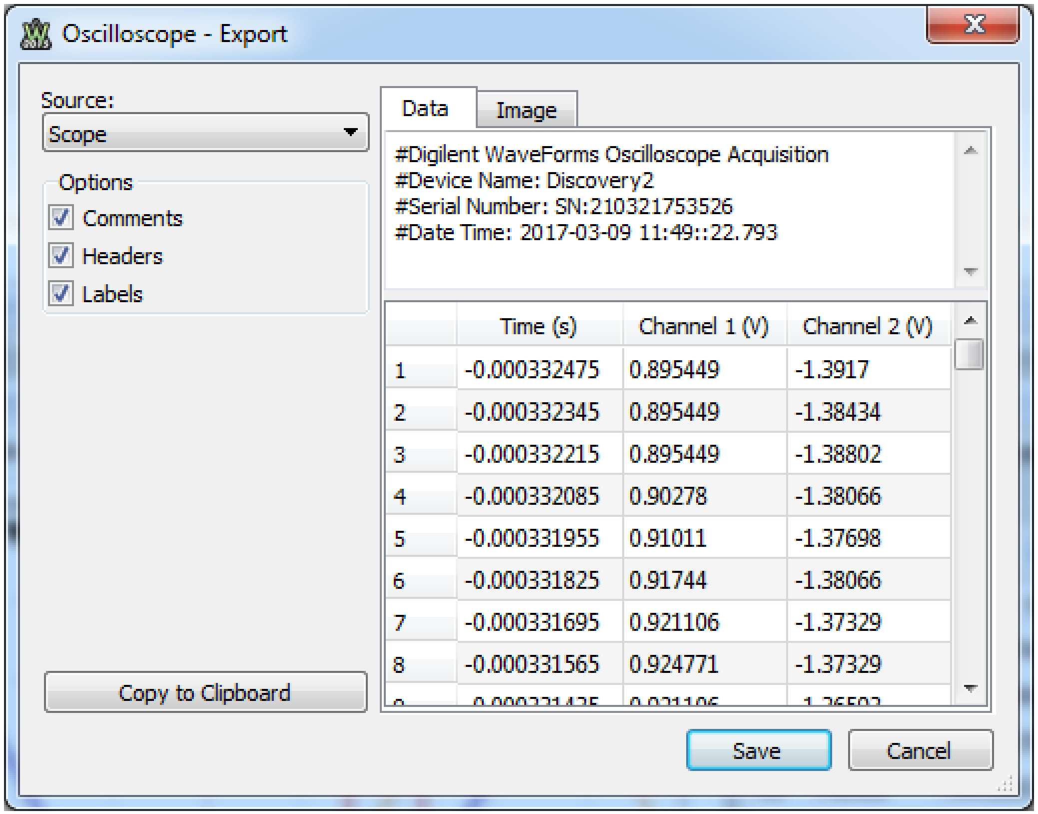
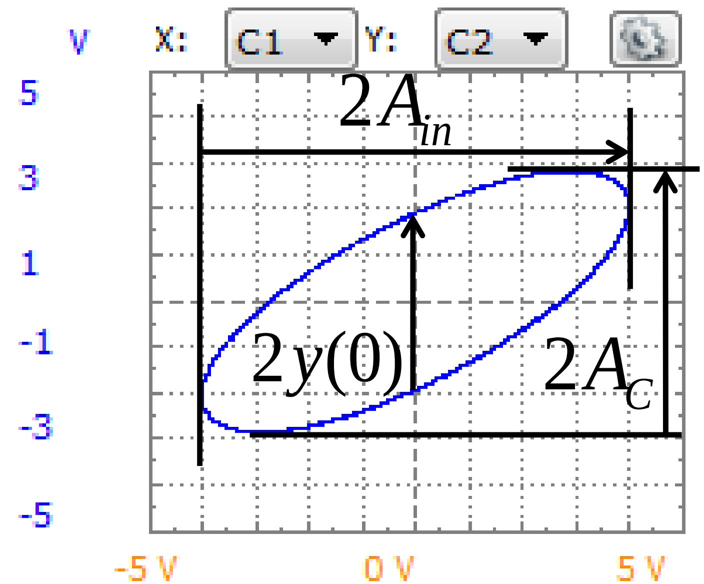
RC Low Pass Filter

Time domain - sinus response

Export – Data – Scope



Export – Image – XY1



$$x(t) = V_{in}(t) = A_{in}\sin(2\pi f t)$$

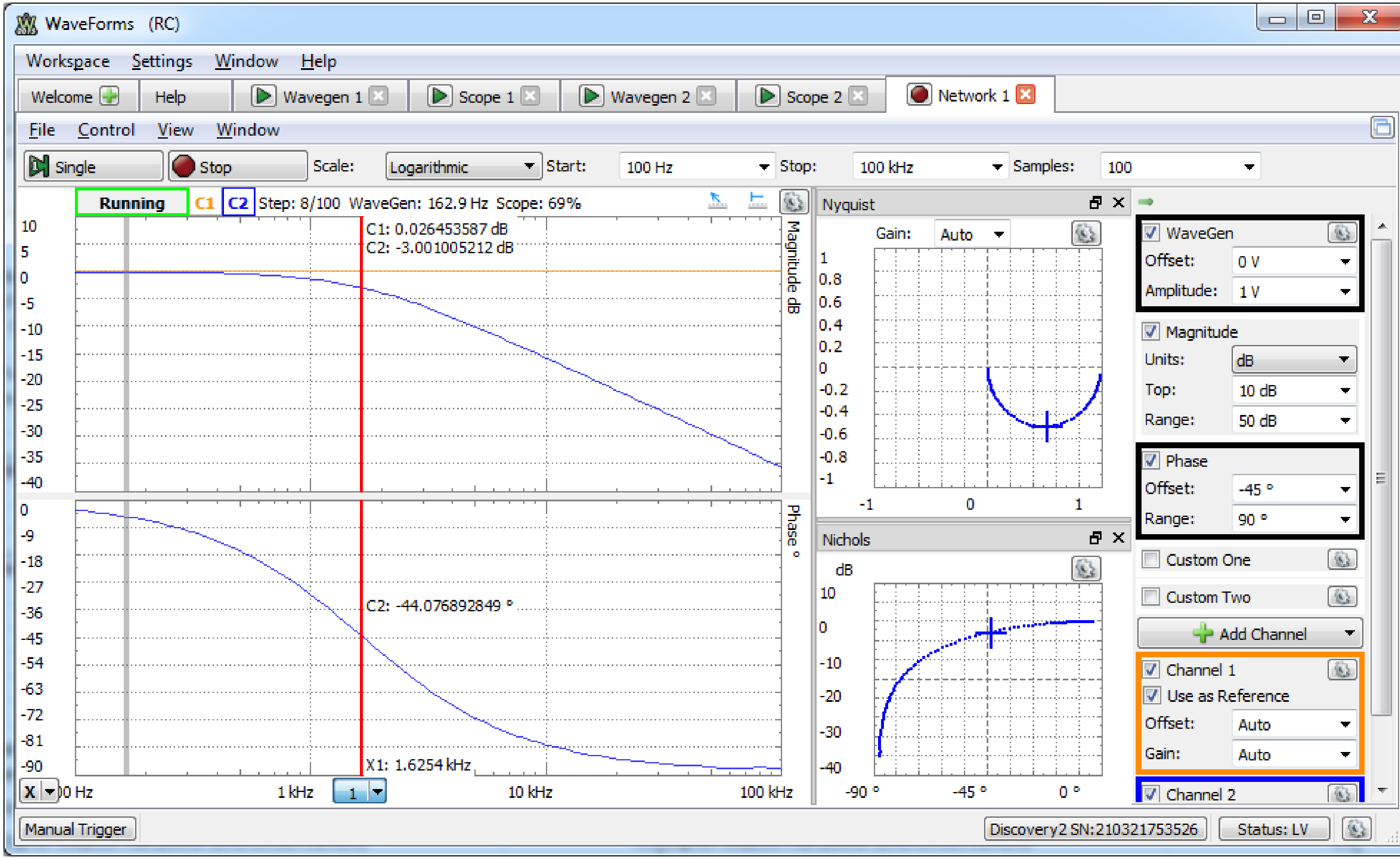
$$y(t) = V_C(t) = A_C\sin(2\pi f t + \varphi)$$

$$y(0) = V_C(0) = A_C\sin(\varphi)$$

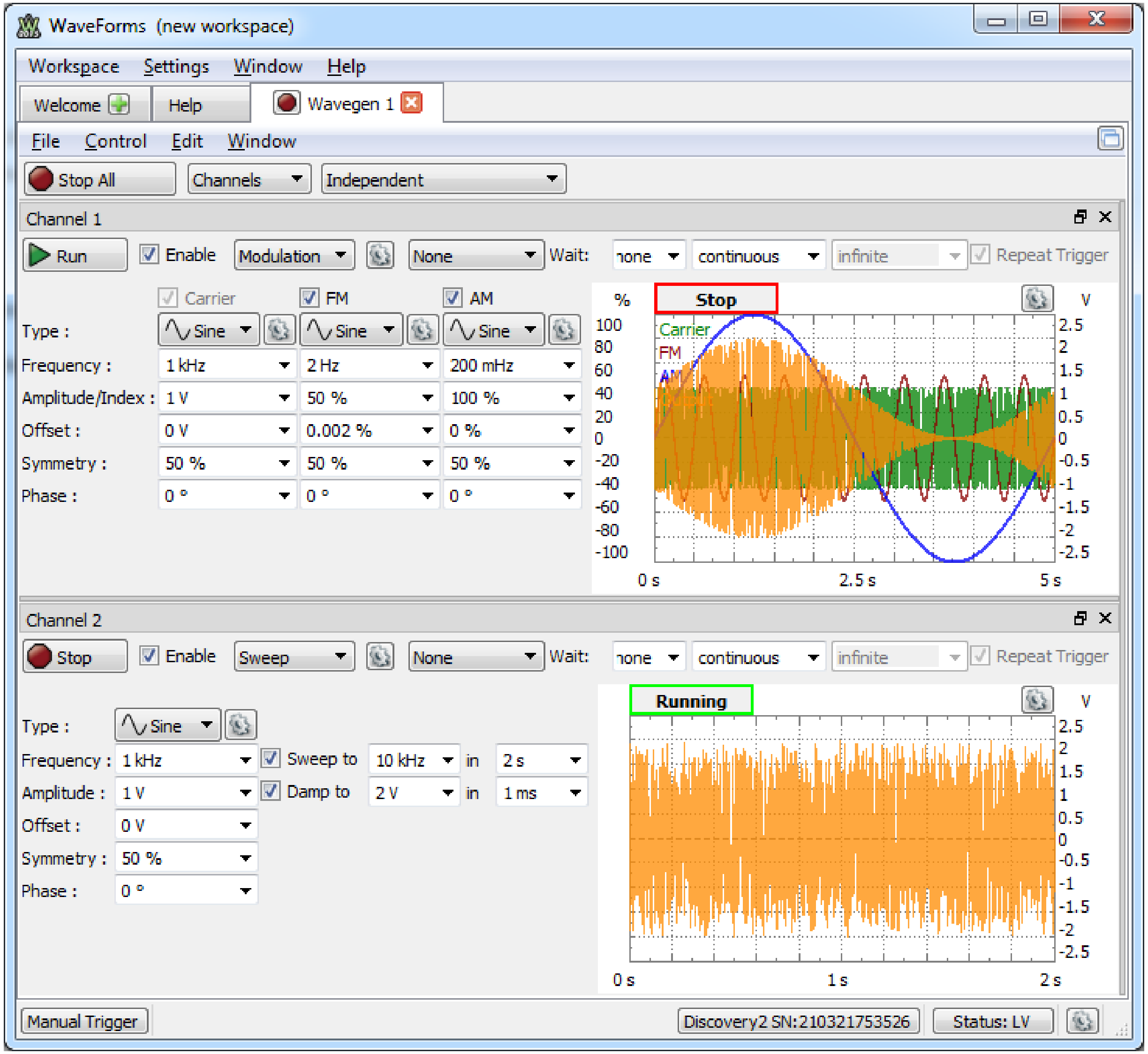
$$\varphi = \arcsin\left(\frac{y(0)}{A_C}\right) = \arcsin\left(\frac{2y(0)}{2A_C}\right)$$

RC Low Pass Filter

Frequency domain – Bode, Nyquist, Nichols diagrams



Audio - Wavegen - modulation, sweep



- Attach an audio headset to the Analog Discovery 2.
- AWG channel 1 in the right speaker, channel 2 in the left speaker.
- Control the amplitude for convenient audio volume.

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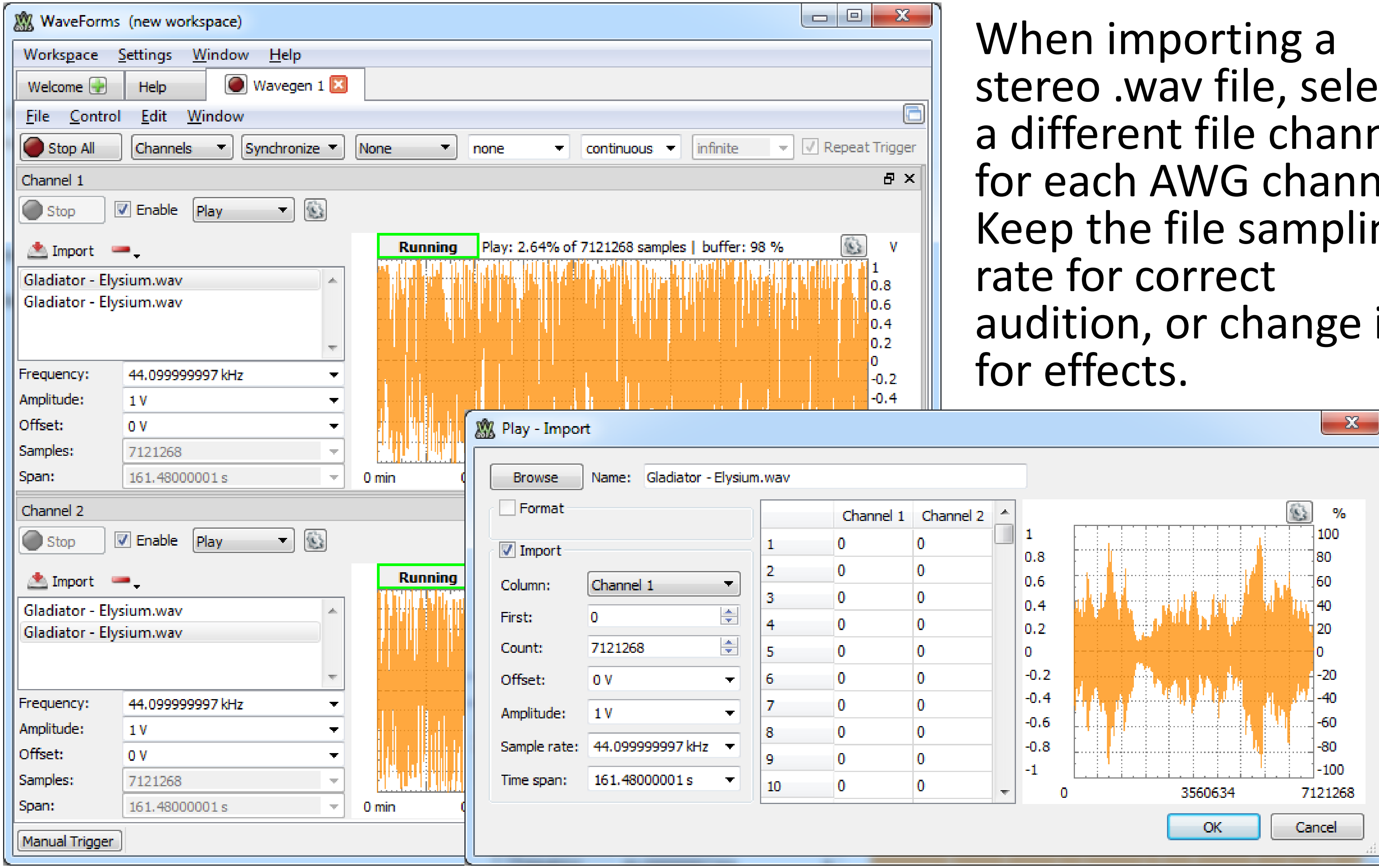
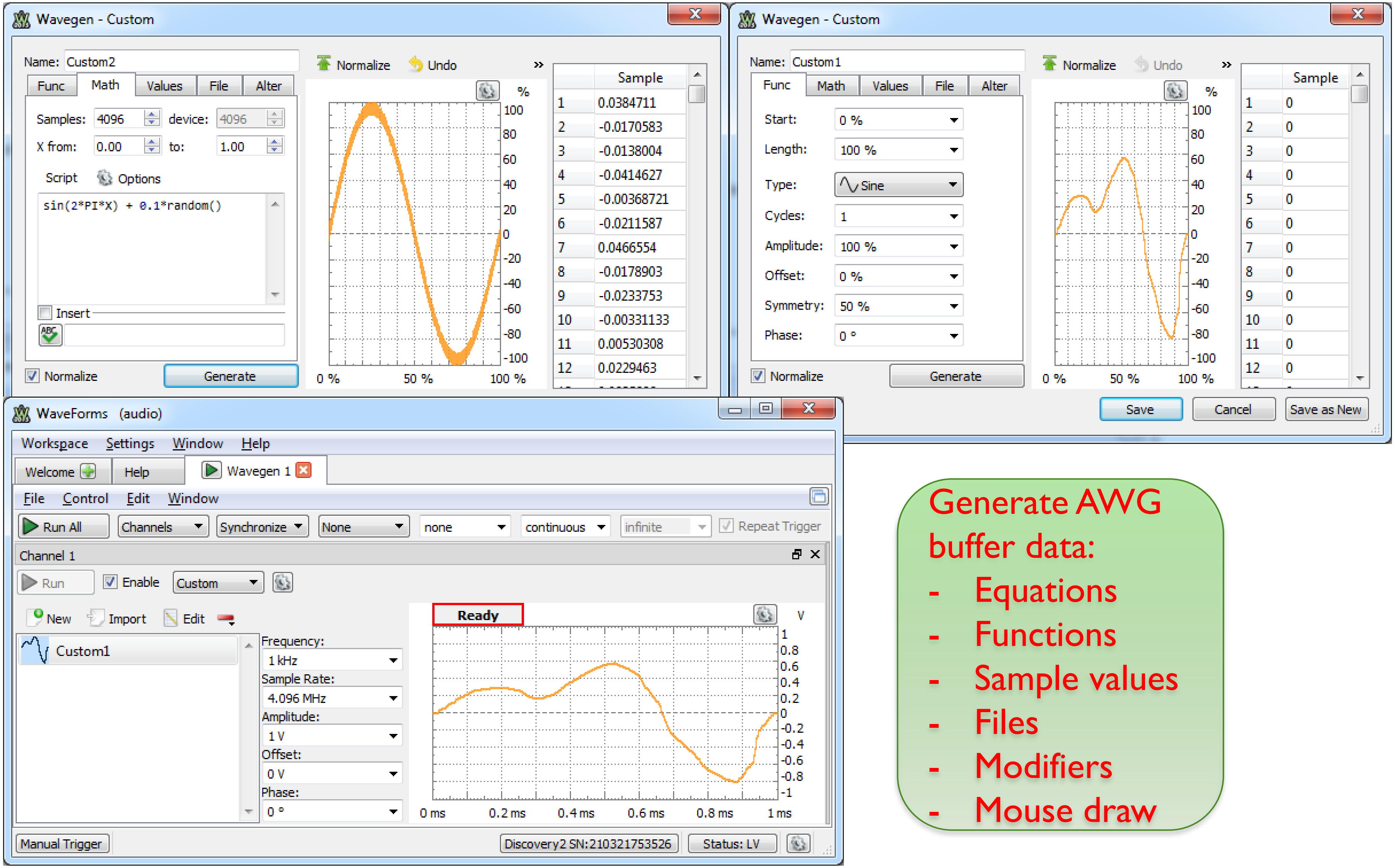
Audio - Wavegen - play



When importing a stereo .wav file, select a different file channel for each AWG channel. Keep the file sampling rate for correct audition, or change it for effects.

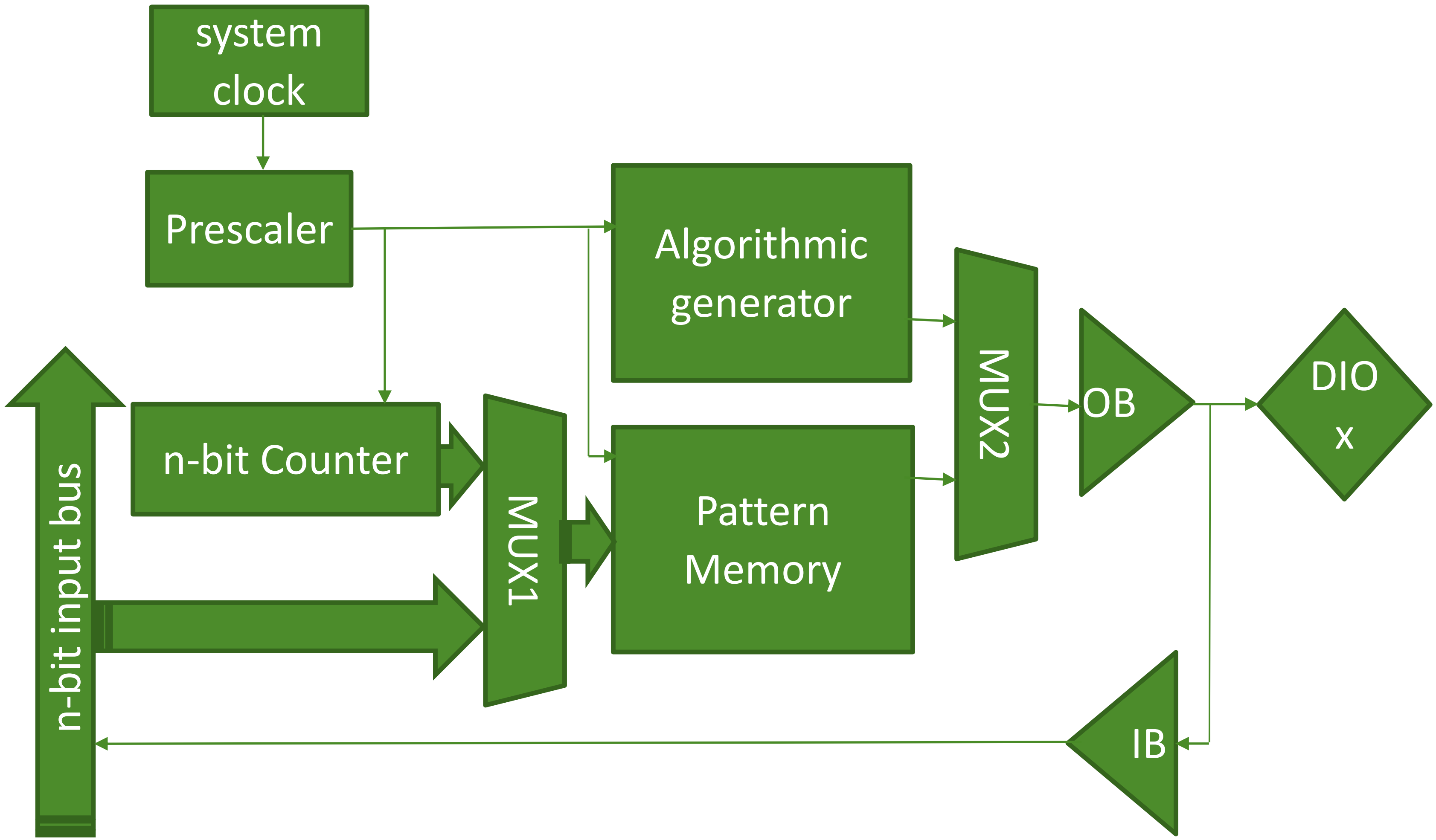
Audio - Wavegen - Custom



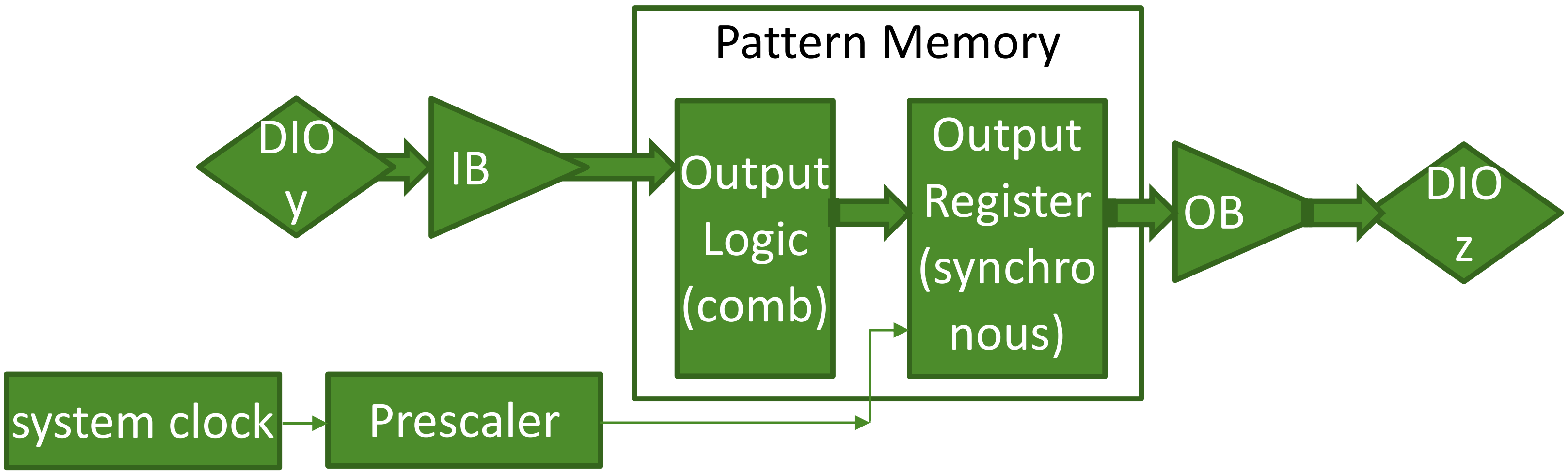
Generate AWG buffer data:

- Equations
- Functions
- Sample values
- Files
- Modifiers
- Mouse draw

ROM Logic
DIO pin block diagram

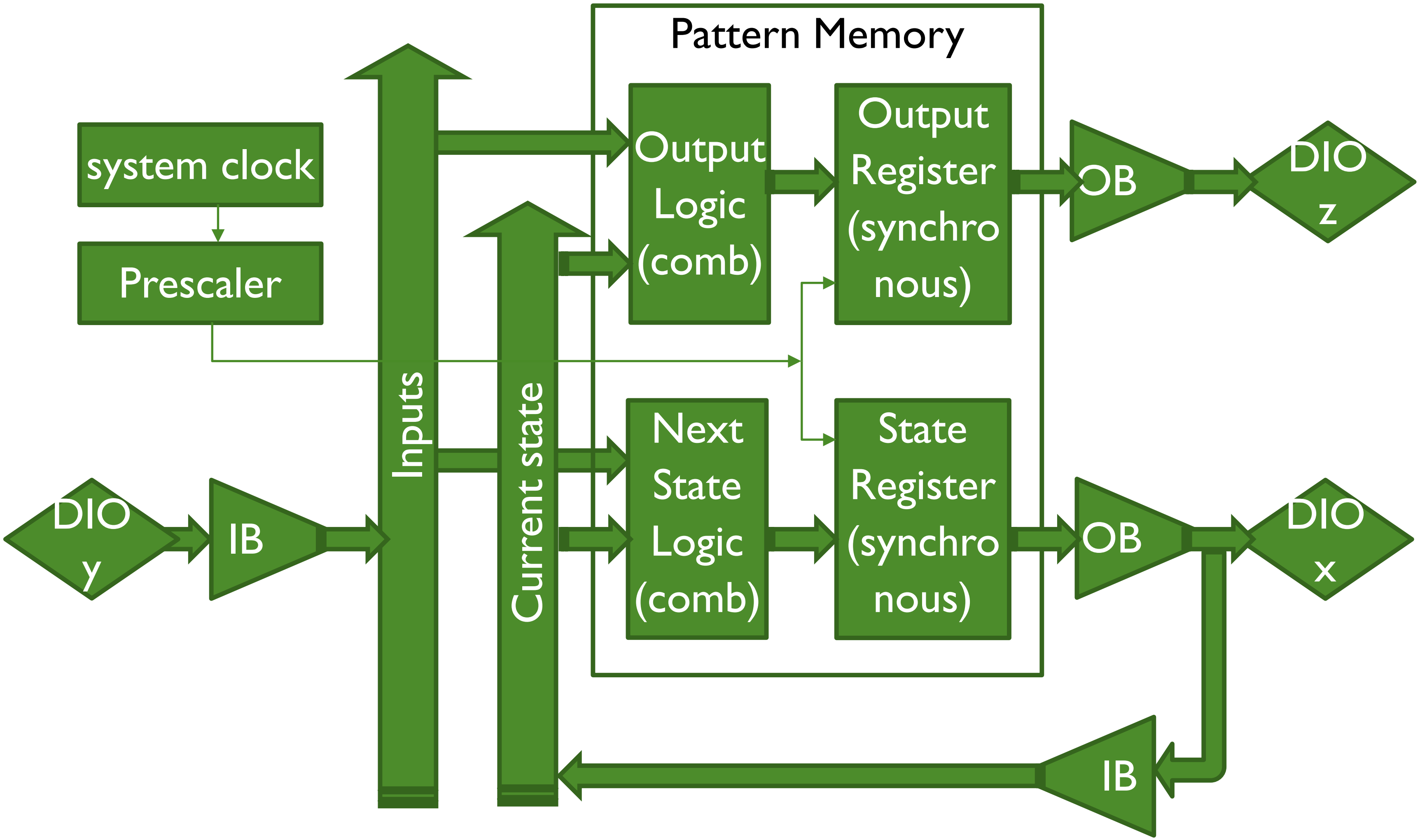


ROM Logic
Synchronized combinatorial circuit



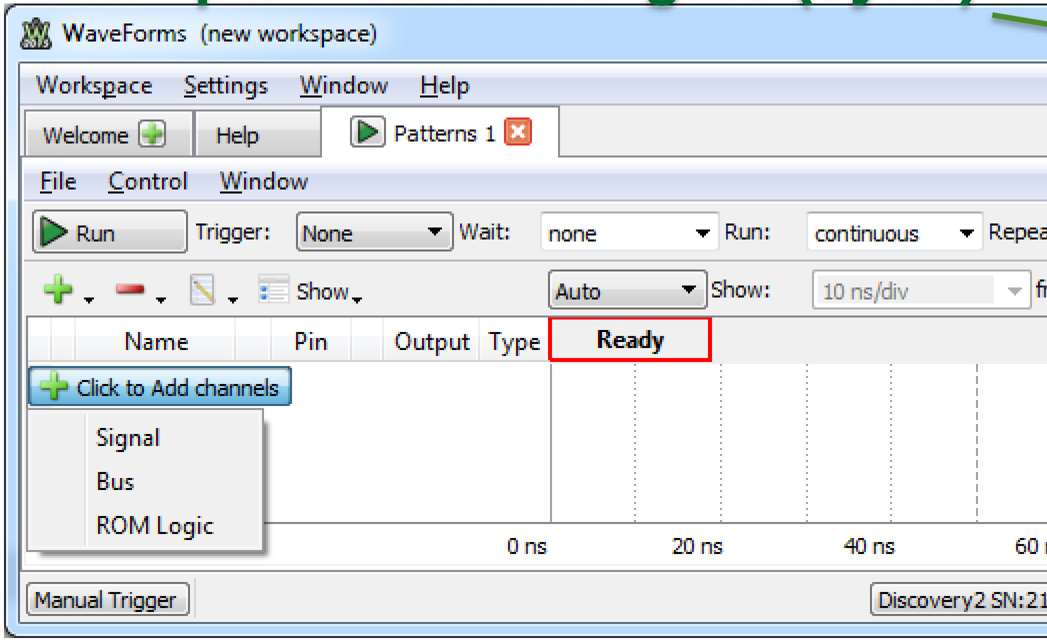
ROM Logic

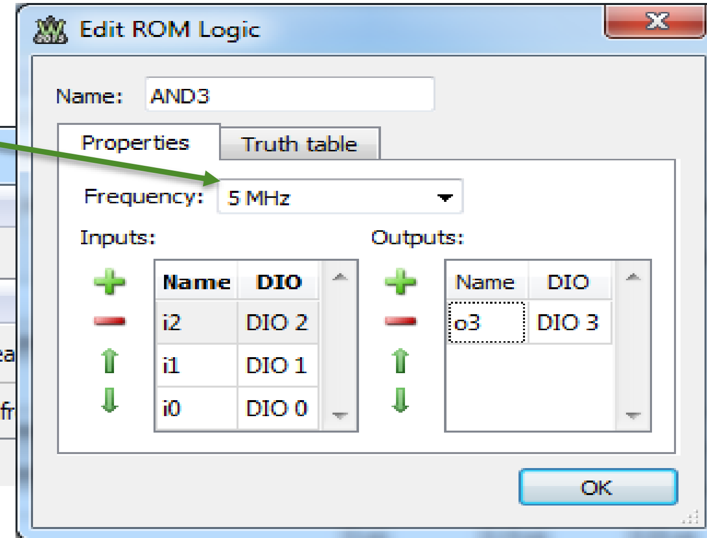
Mealy State Machine

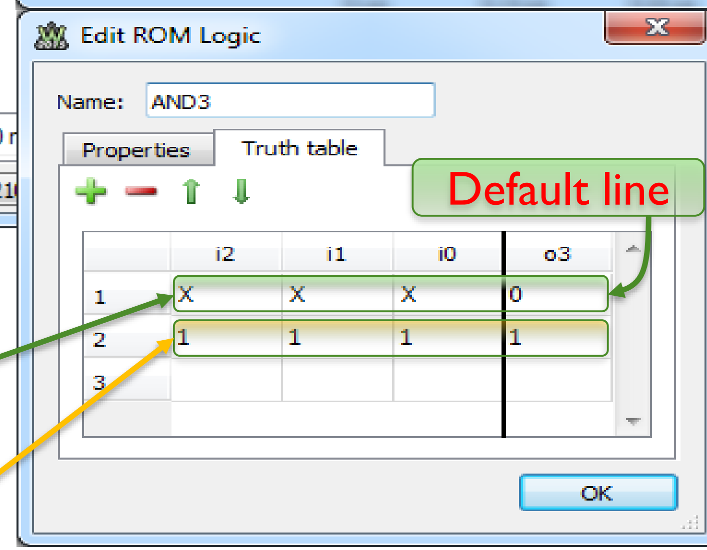


ROM Logic

Example – 3bit AND gate (sync)

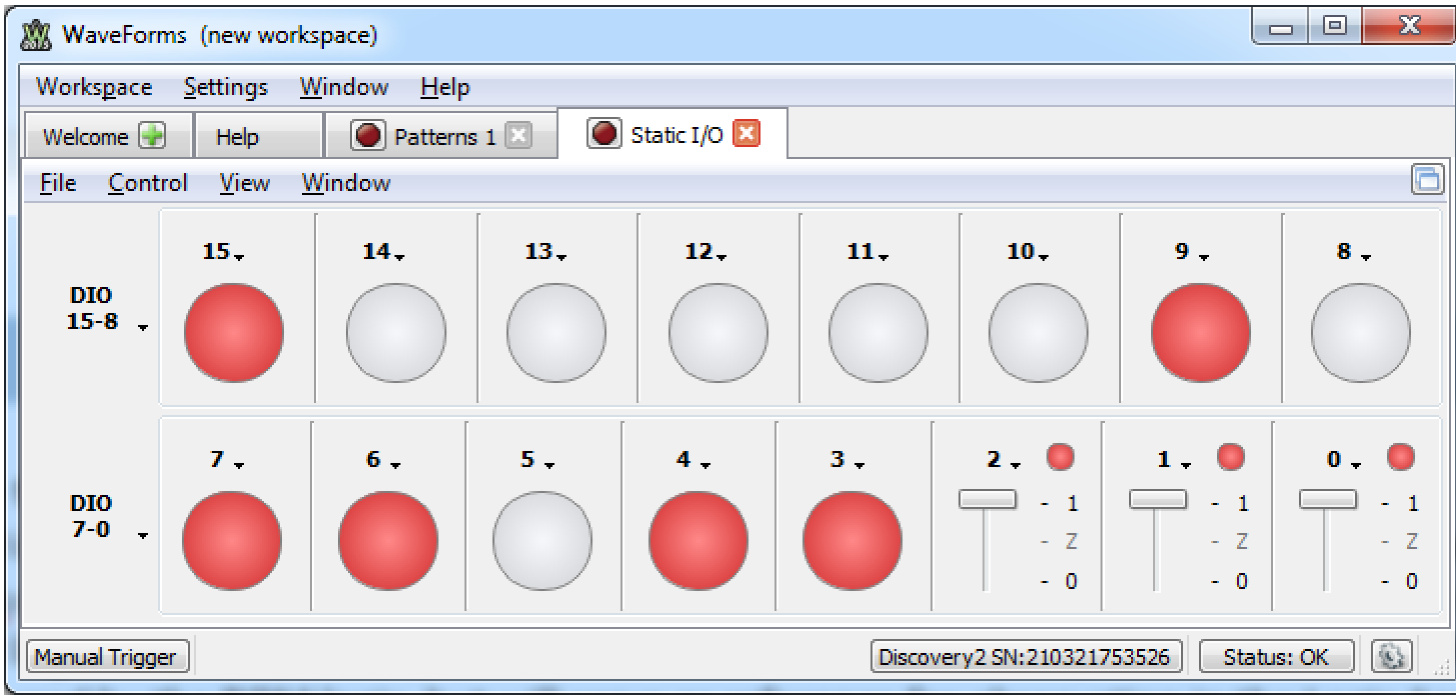






a. Rename signals in the Properties tab, (optional).
b. Use 0, 1 or X (don't care) in the input pane.
c. An n-bit expanded Truth Table has 2^n lines. A line with k X values is the collapsed version of 2^k expanded lines.
d. All possible input cases need to be covered.
e. The table lines are "sequential", i.e. a line can override lines above it in the table.

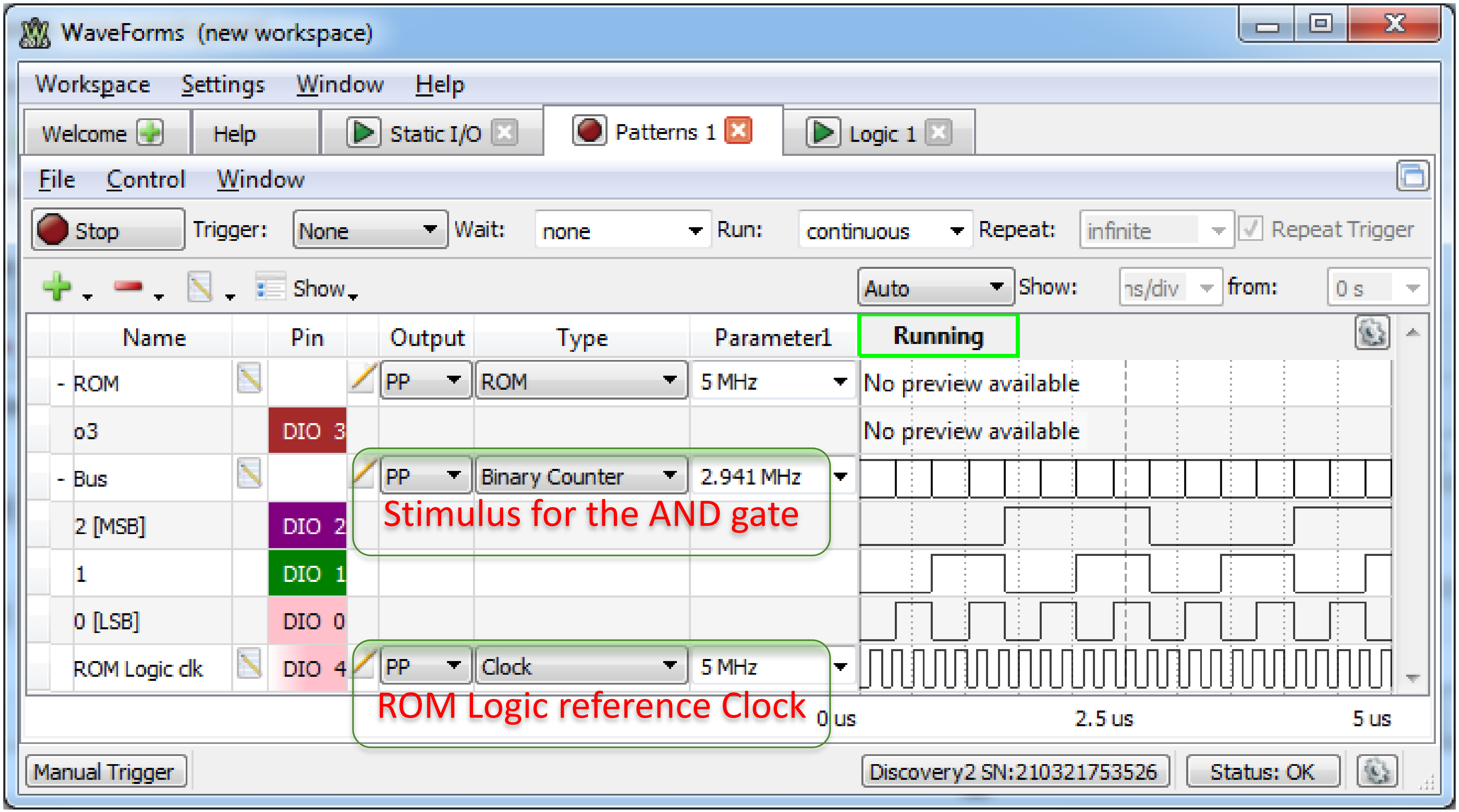
ROM Logic
Example – 3bit AND gate (sync); static verification



ROM Logic

Example – 3bit AND gate (sync); dynamic verification

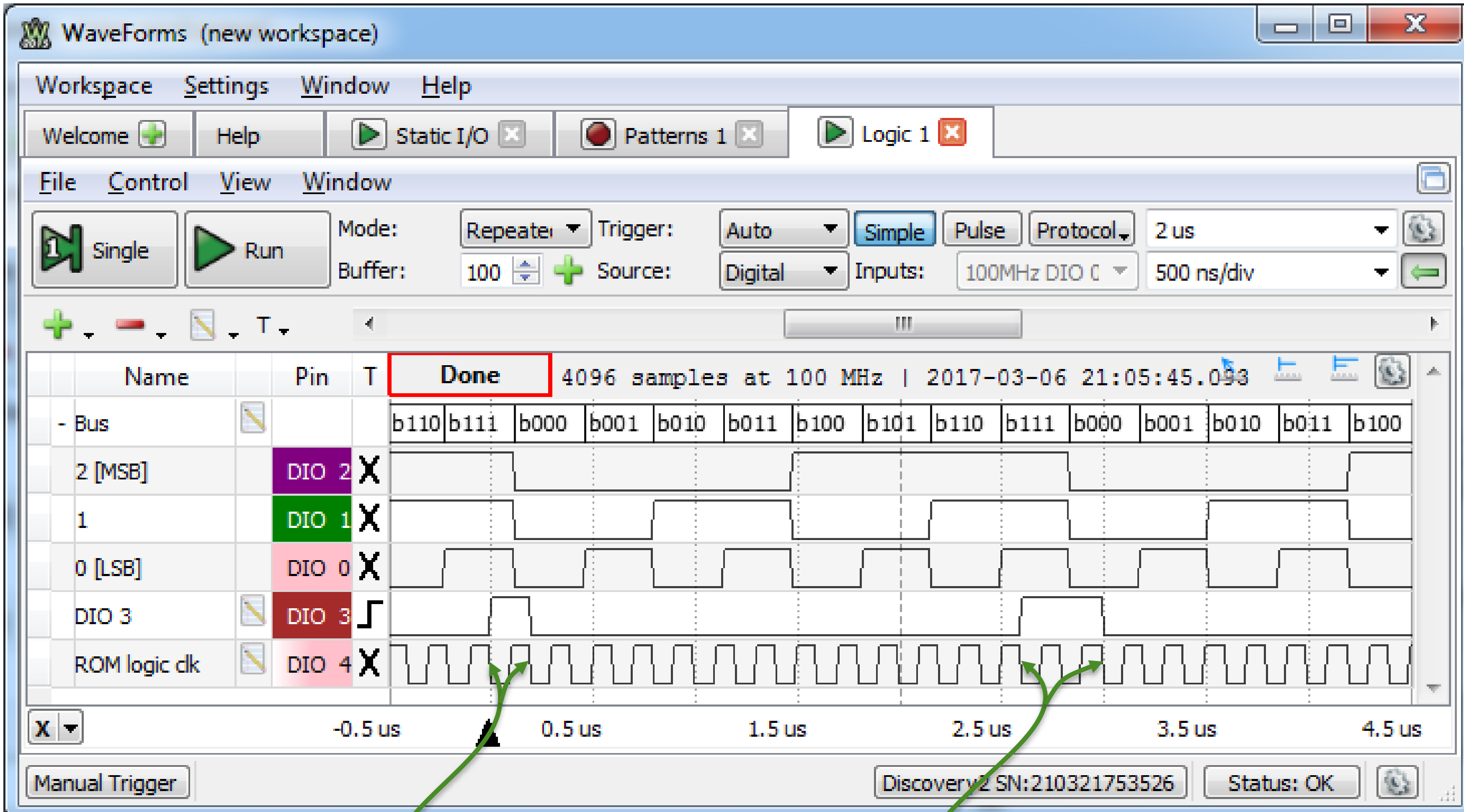
Adding stimuli and clock reference in the Pattern Generator



ROM Logic

Example – 3bit AND gate (sync); dynamic verification

Observing output (DIO3) on the Logic Analyzer



DIO3 output synchronized on the 5MHz ROM logic clk (falling edge)

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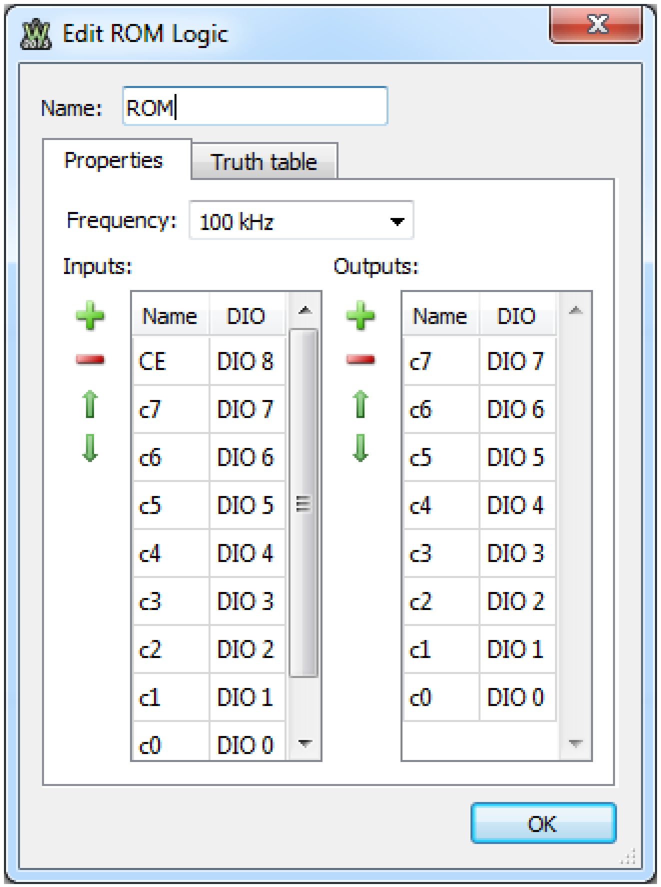
ROM Logic

Example – 8bit binary counter with CE



f. If a signal is used in both input and output panes, it is a State Variable; the input pane shows its value in the Current State and the output pane indicates its value in the Next State.

g. The same functional block might be split in multiple ROM logic objects, to optimize the Truth Table(s).

ROM Logic

Example – 8bit binary counter with CE

Edit ROM Logic

Name: ROM

Properties | Truth table

	CE	c7	c6	c5	c4	c3	c2	c1	c0	c7	c6	c5	c4	c3	c2	c1	c0
1	X	X	X	X	X	X	X	X	0	c7	c6	c5	c4	c3	c2	c1	CE
2	X	X	X	X	X	X	X	0	1	c7	c6	c5	c4	c3	c2	CE	/CE
3	X	X	X	X	X	X	0	1	1	c7	c6	c5	c4	c3	CE	/CE	/CE
4	X	X	X	X	X	0	1	1	1	c7	c6	c5	c4	CE	/CE	/CE	/CE
5	X	X	X	X	0	1	1	1	1	c7	c6	c5	CE	/CE	/CE	/CE	/CE
6	X	X	X	0	1	1	1	1	1	c7	c6	CE	/CE	/CE	/CE	/CE	/CE
7	X	X	0	1	1	1	1	1	1	c7	CE	/CE	/CE	/CE	/CE	/CE	/CE
8	X	0	1	1	1	1	1	1	1	CE	/CE	/CE	/CE	/CE	/CE	/CE	/CE
9	X	1	1	1	1	1	1	1	1	/CE	/CE	/CE	/CE	/CE	/CE	/CE	/CE
10																	

OK

g. 1, 0, “SignalName” or “/SignalName” in the output pane (“/” for logical NOT).

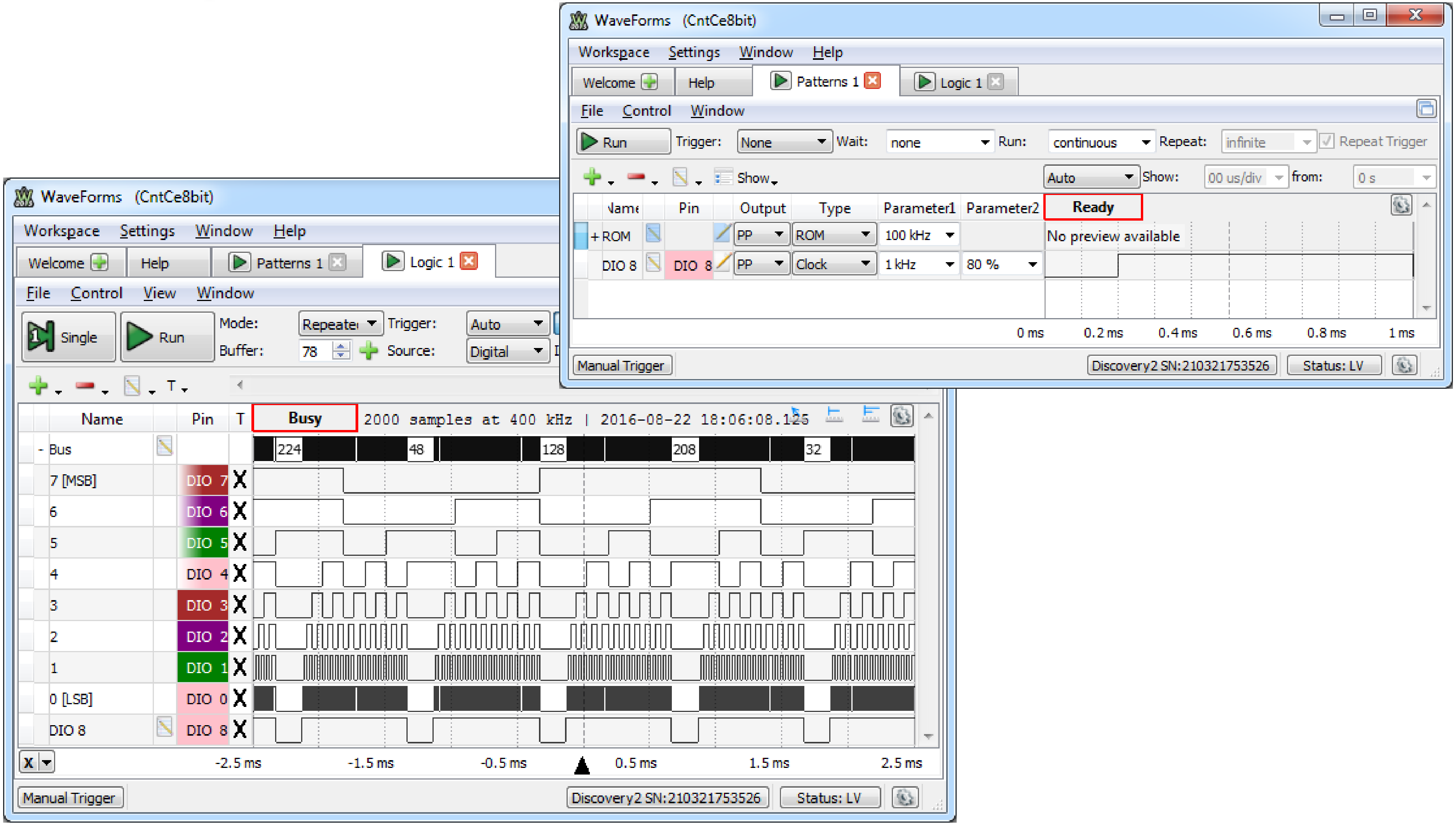
h. A yellow background of a cell indicates a syntax error.

Remember:

c. An n-bit expanded Truth Table has 2^n lines. A line with k X values is the collapsed version of 2^k expanded lines.

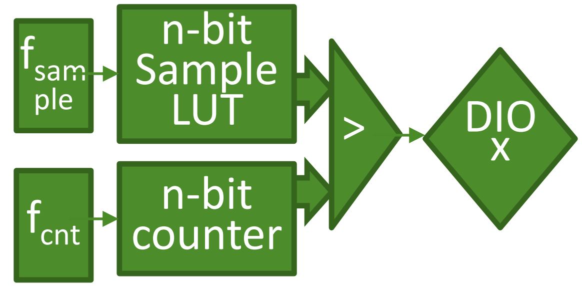
ROM Logic

Example – 8bit binary counter with CE; verification

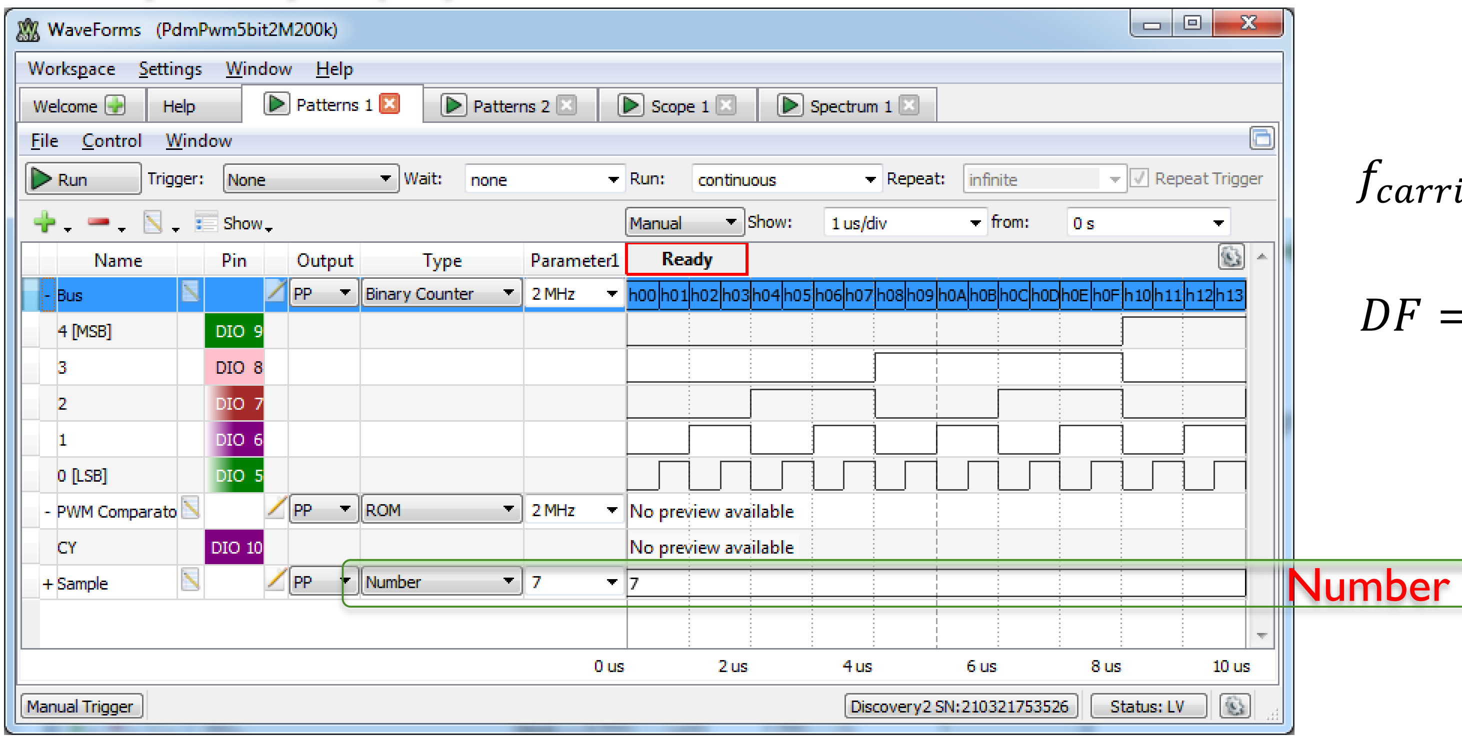


ROM Logic

Example – PWM modulator – constant sample



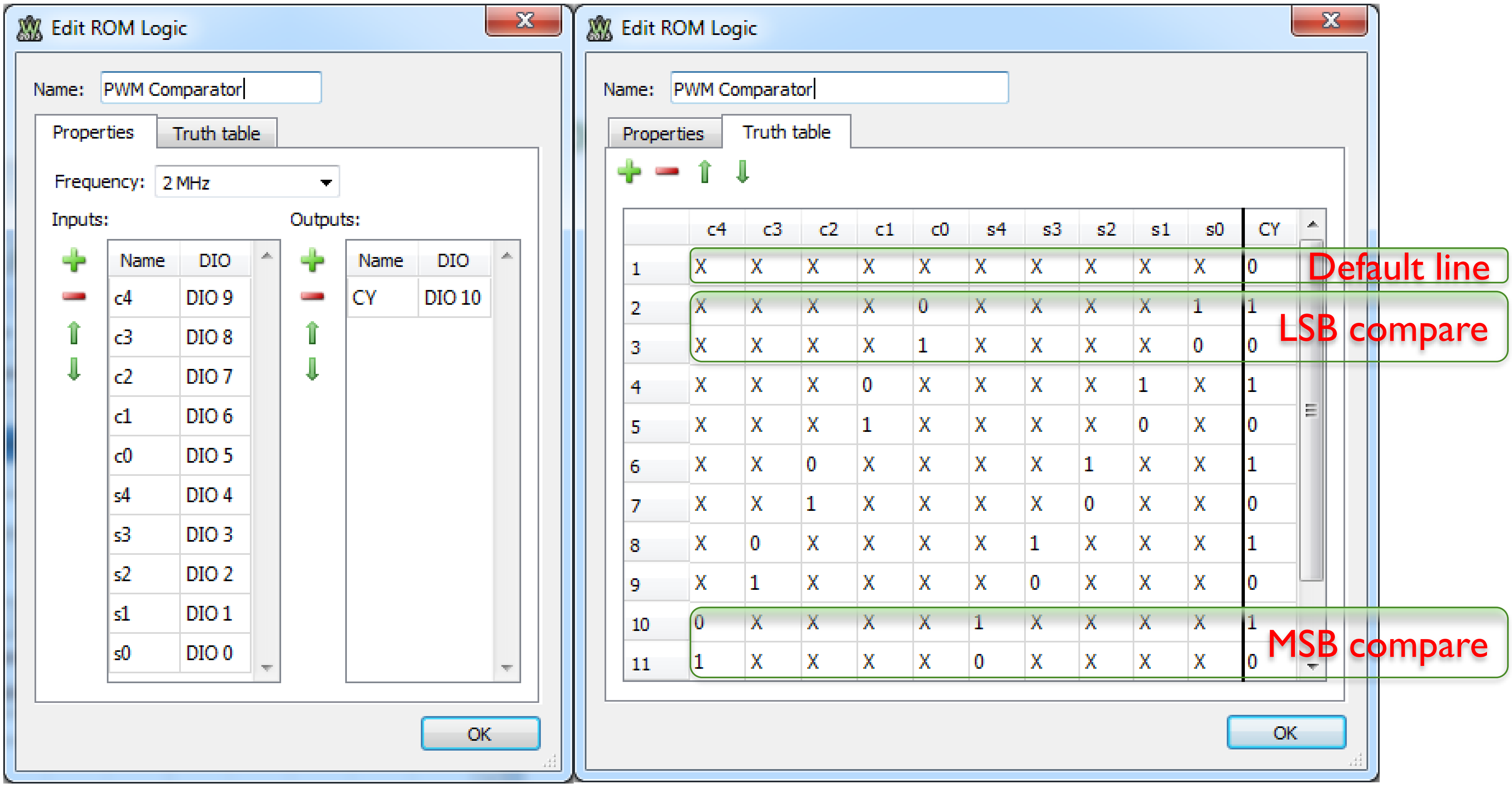
Workspace/Open/(No)/PdmPwm5bit2M200k.dwf3work



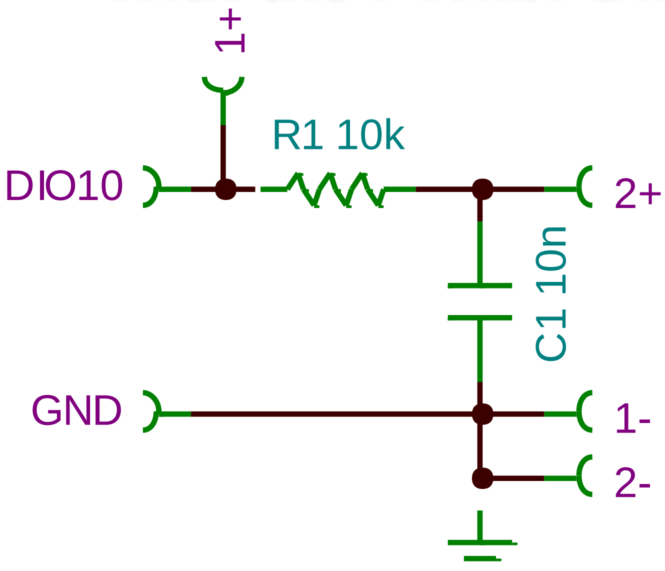
$$f_{carrier} = \frac{f_{cnt}}{2^n}$$

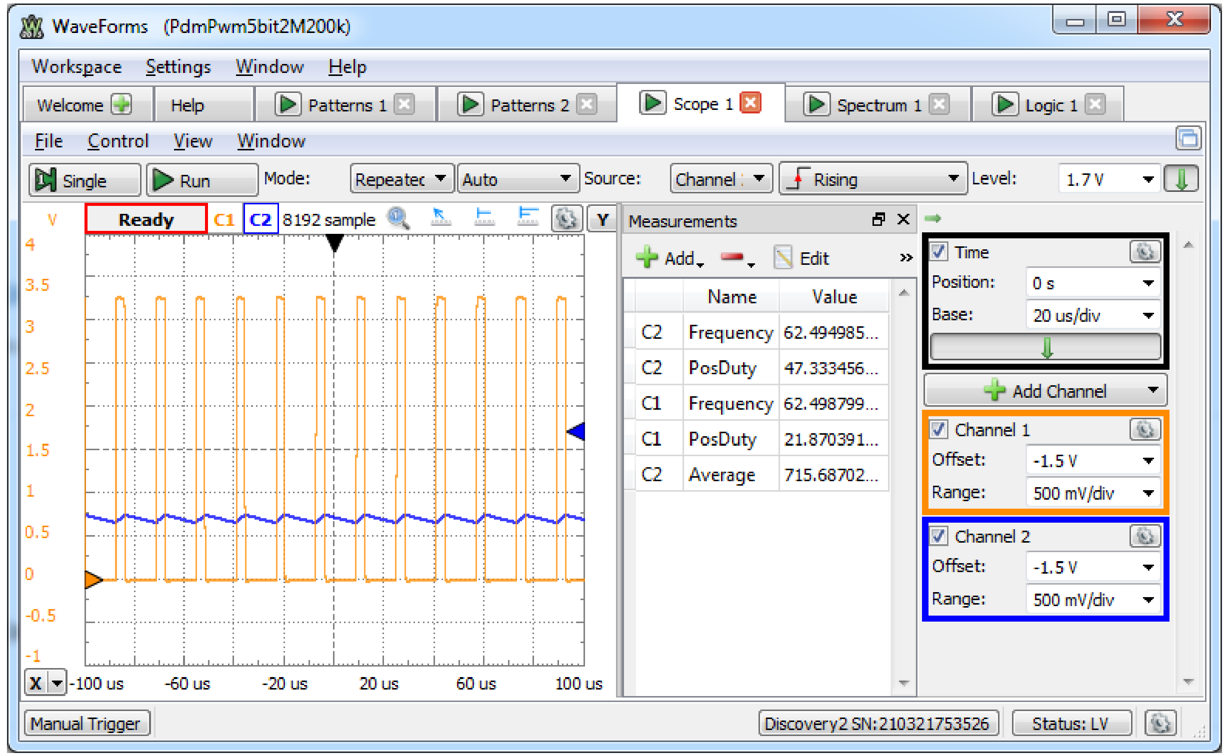
$$DF = \frac{sample}{2^n}$$

ROM Logic
Example – PWM modulator



RC Low Pass Filter
With the PWM/PDM Modulator





Scope, Trigger
- Mode: Auto
- Source: Channel 2
- Cond: Rising
- Level: 1.7V

Scope, Time Base
- Position: 0
- Base: 100us/div

Scope, Ch 1 and Ch 2
- Offset: -1.5V
- Range: 500mV/div

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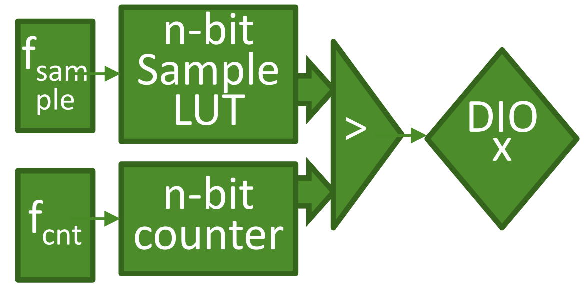
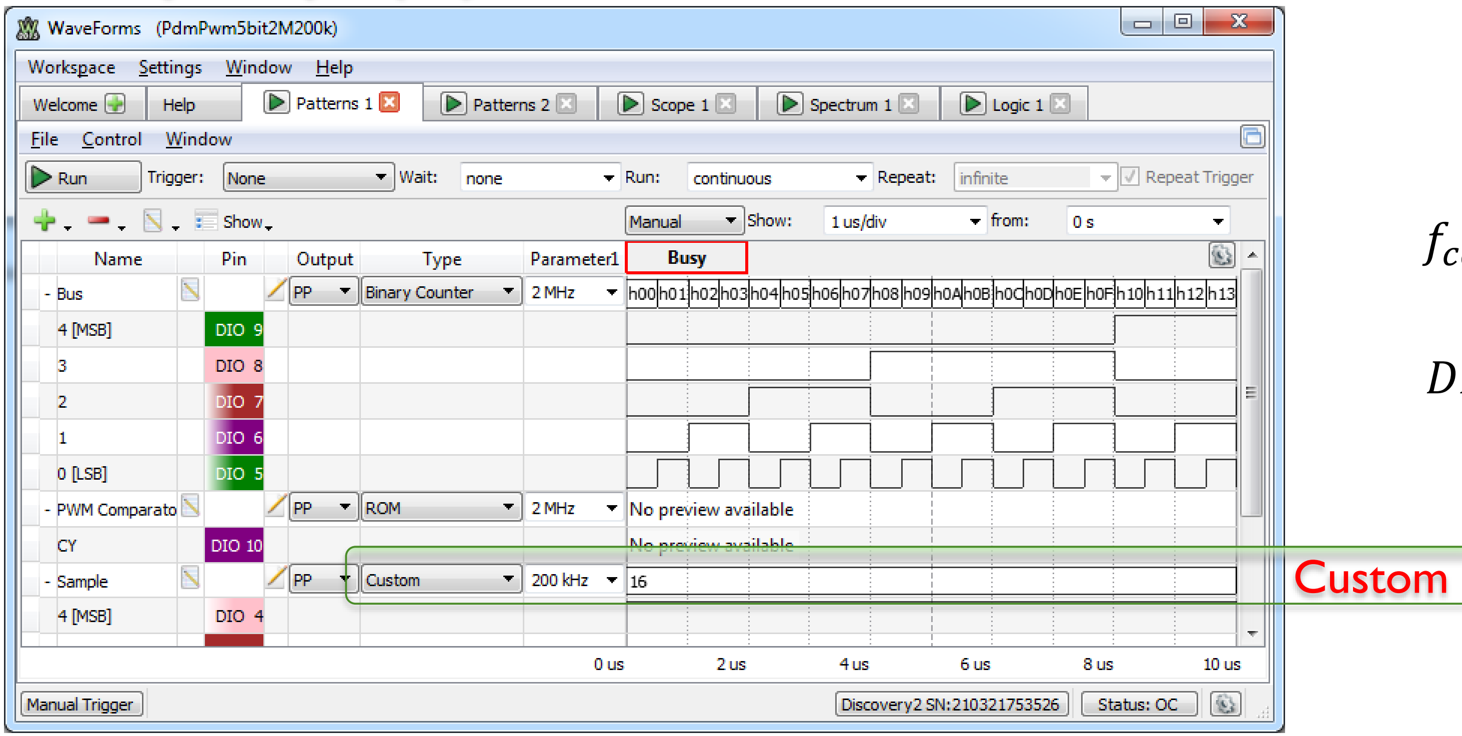
ROM Logic

Example – PWM modulator – variable sample



Workspace/Open/(No)/PdmPwm5bit2M200k.dwf3work



$$f_{carrier} = \frac{f_{cnt}}{2^n}$$

$$DF = \frac{sample}{2^n}$$

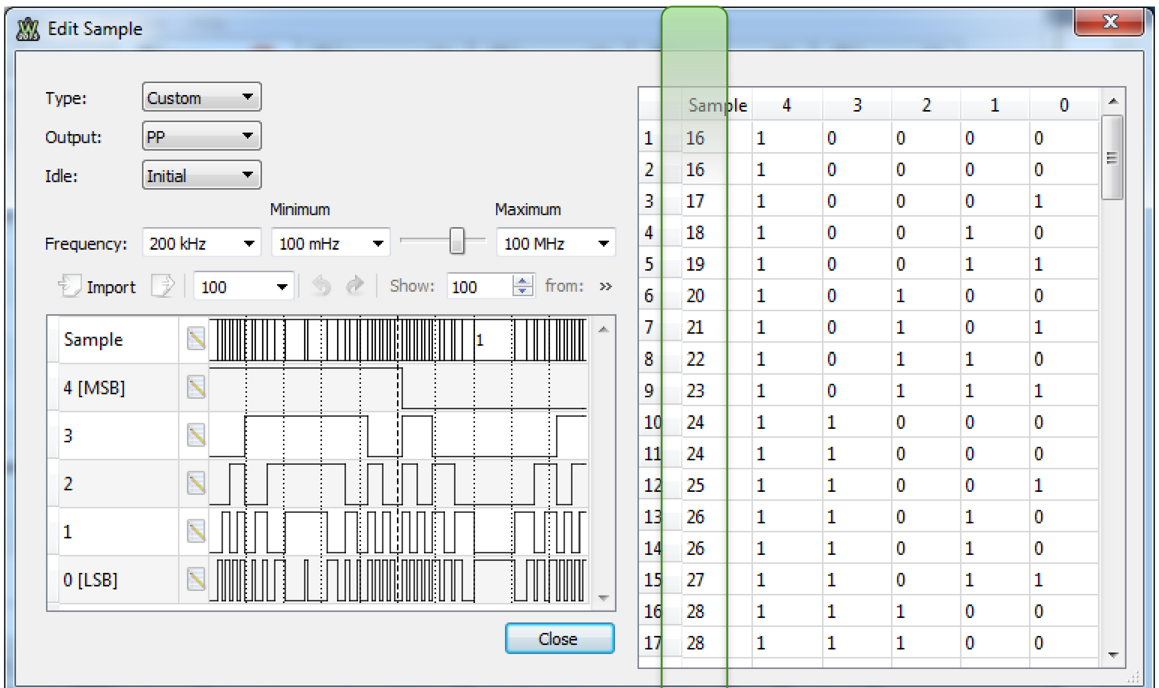
ROM Logic

Example – PWM modulator – variable sample (sinus)

Building a sinus sample string

$$sample_i = 16 + int\left(15 * sin\left(\frac{2 \cdot \pi \cdot i}{100}\right)\right) \in [1 \ldots 31]$$

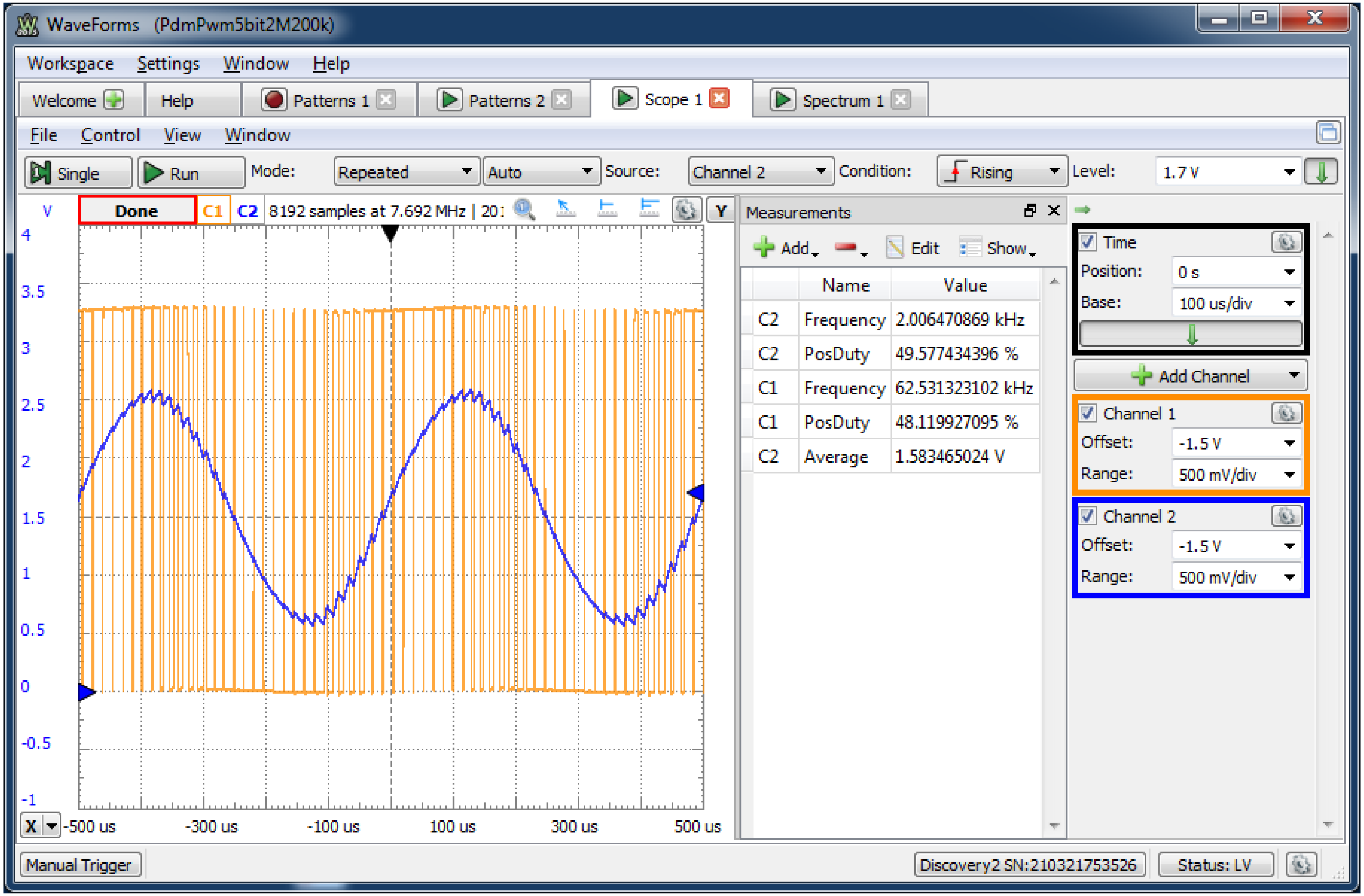
$$f_{modulator} = \frac{f_{sample}}{100} = \frac{200KHz}{100} = 2kHz$$



Copy 100 cells of “samples” into Sample column

ROM Logic

Example – PWM modulator – variable sample (sinus)



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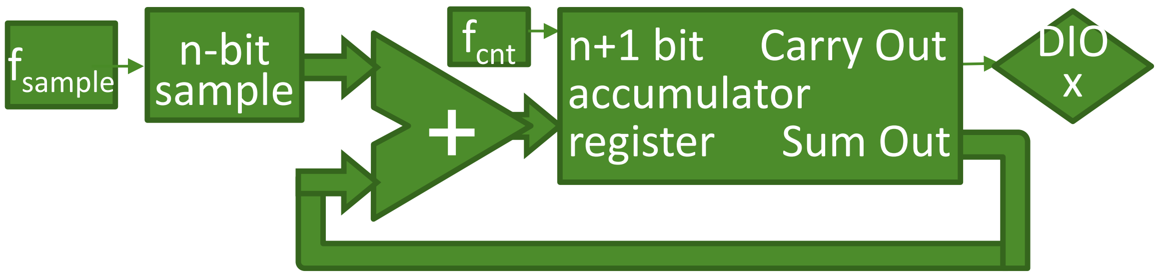
ROM Logic
PDM modulator – constant sample



$$sample \in [0 \ldots 2^n - 1)$$

$$\mathrm{DF_{avg}} = \frac{int\left(\frac{\mathrm{M} \cdot sample}{2^{\mathrm{n}}}\right)}{M}$$

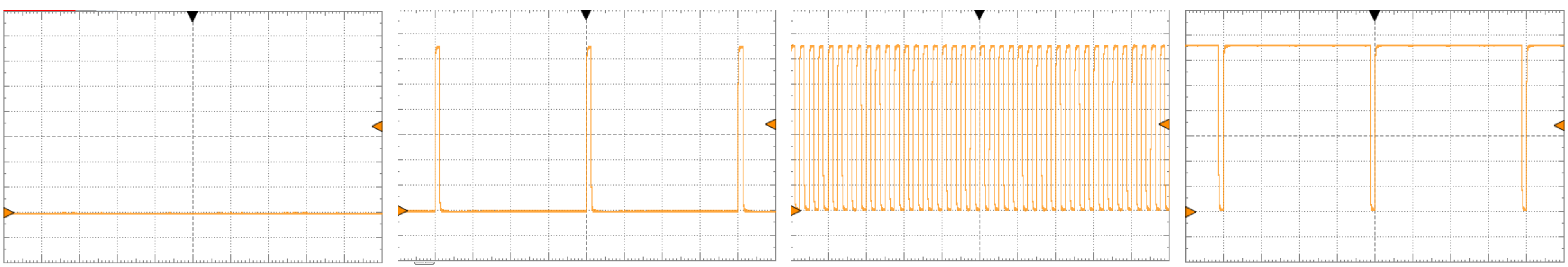
$$f_{carrier} \in \left(0, \frac{f_{cnt}}{2^n} \ldots \frac{f_{cnt}}{2}\right)$$

$$\begin{cases} sample = 0 \\ \mathrm{DF_{avg}} = 0 \\ f_{carrier} = 0 \end{cases}$$

$$\begin{cases} sample = 1 \\ \mathrm{DF_{avg}} = \frac{1}{2^n} \\ f_{carrier} = \frac{f_{cnt}}{2^n} \end{cases}$$

$$\begin{cases} sample = \frac{2^n}{2} \\ \mathrm{DF_{avg}} = \frac{1}{2} \\ f_{carrier} = \frac{f_{cnt}}{2} \end{cases}$$

$$\begin{cases} sample = 2^n\text{-}1 \\ \mathrm{DF_{avg}} = \frac{2^n - 1}{2^n} \\ f_{carrier} = \frac{f_{cnt}}{2^n} \end{cases}$$



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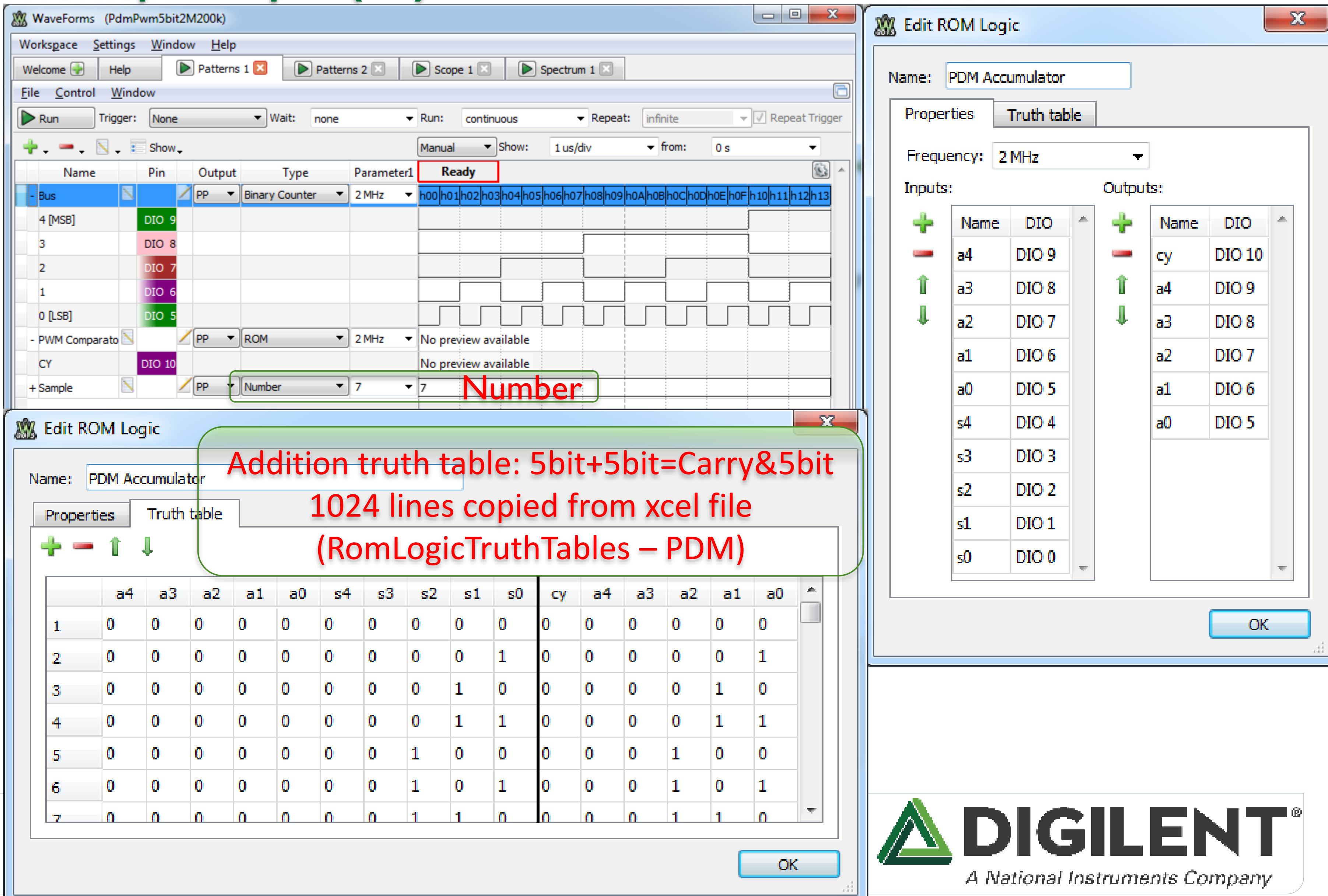
ROM Logic - PDM modulator

Workspace/Open/(No)/PdmPwm5bit2M200k.dwf3work



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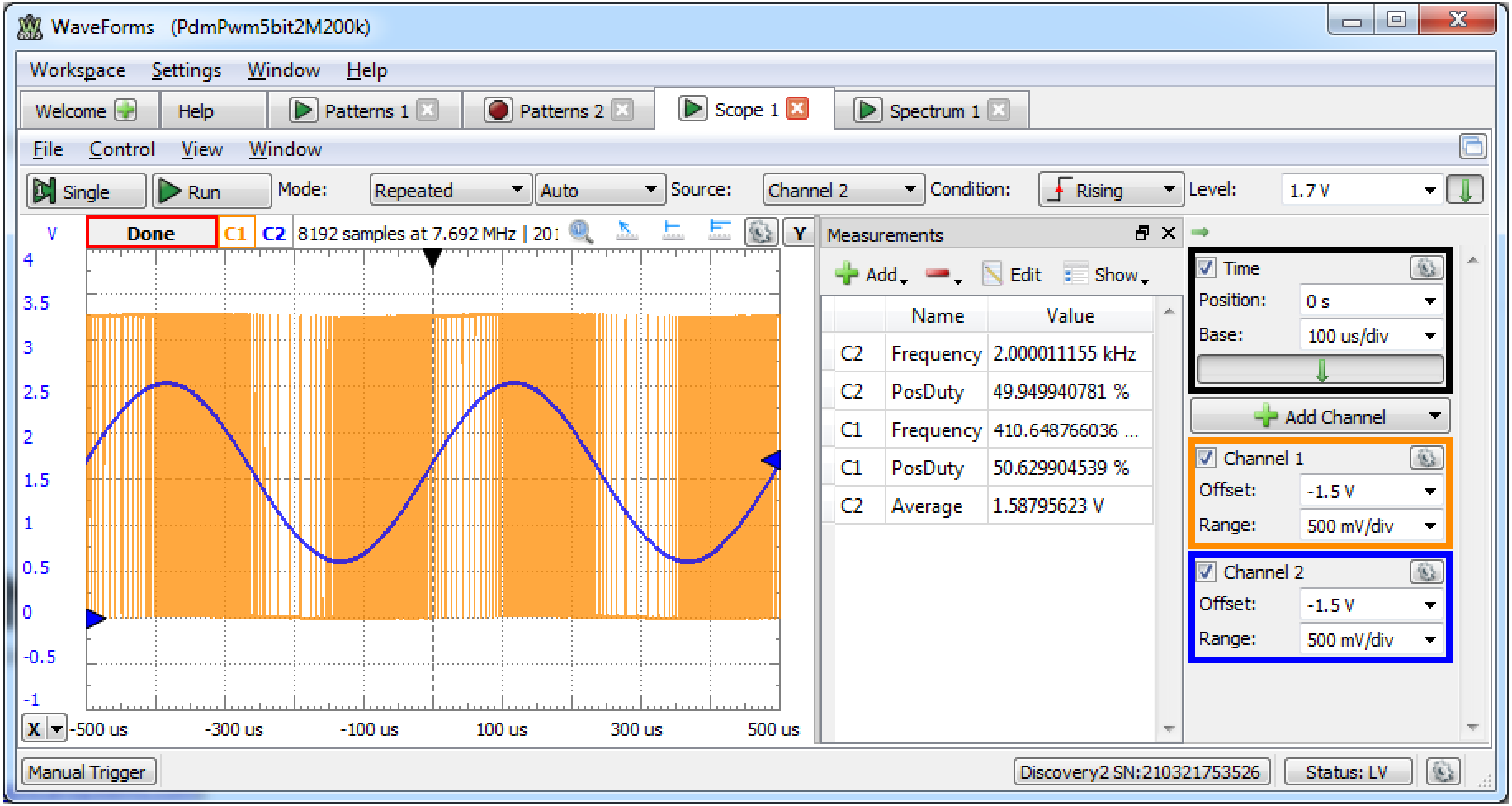
ROM Logic

Example – PDM modulator – variable sample (sinus)



ROM Logic

Example – PDM modulator – variable sample (sinus)