AWG Quick Reference Guide

version 2: 30-Nov-2021

Change log:

- Reflects new UI with adjuster widget
- Switch off the display update when generator is running to reduce noise

Remark: some pictures may show the UI version 1, however functionality is described correctly.

1. User Interface Overview

The Arbitrary Wave form Generator's (AWG) User Interface (UI) consists of three sections, the Input section, the Output section and the Display.

1.1 The input section: three push buttons and the rotary encoder

The *Previous* and *Next* push buttons are used to move the focus to the desired AWG control. The focus is shown by a white border around the control. (In the display picture section 1.3 the *setup* button has the focus.)
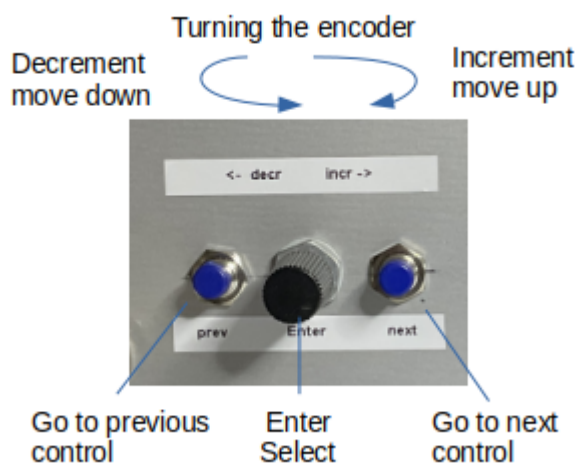
Pushing the Next button moves to focus forward to the next control

Pushing the Previous button moves the focus backwards to the previous control

Pushing the Encoder button enters a control to change the value, exits a control or executes a control such as *setup* or *stop.*

Pushing the encoder for more than 1 second, enters precision mode when entering the frequency.

Turning the encoder **clockwise increments** a value or **moves up** in a drop down menu
Turning the encoder **counterclockwise decrements** a value or **moves dow**n in a drop down menu
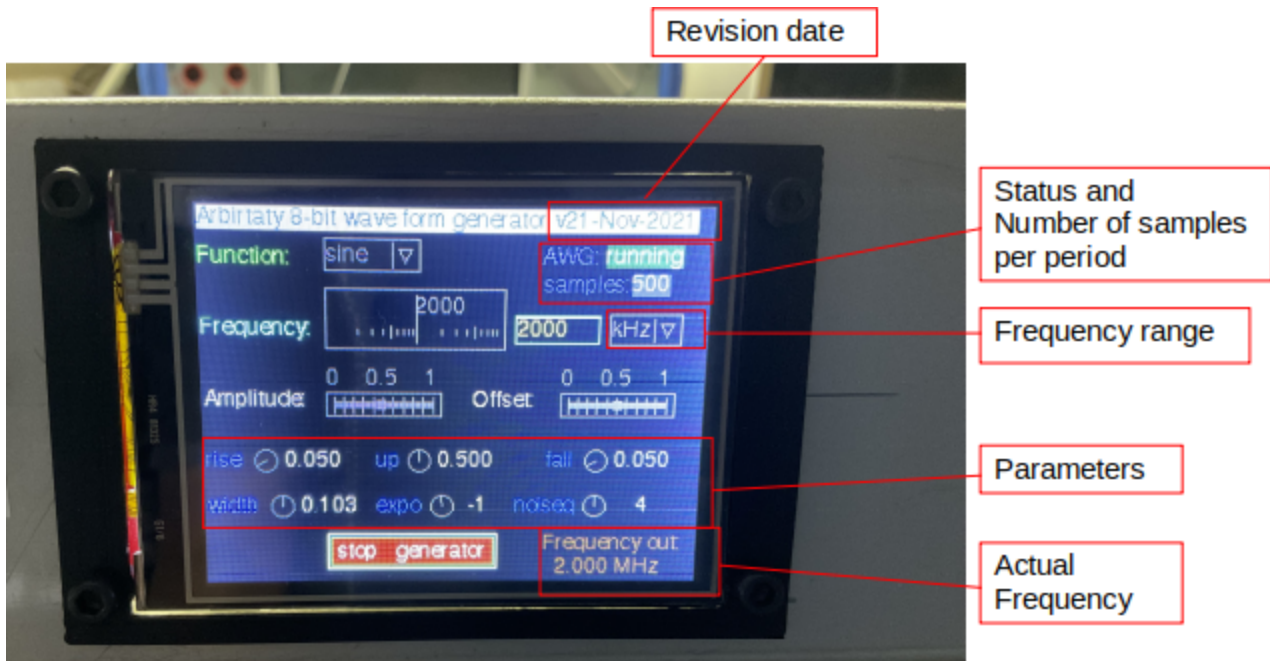
1.2 The output section
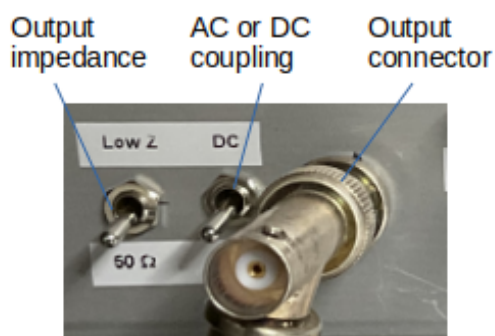
Output Impedance can be switched between Low Z (approx. 5 Ohm) or 50 Ohm.

Output coupling can be switched between AC and DC. DC coupling is recommended for low frequencies.

Connect to the AWG signal using the output connector.

1.3 The Display: Information areas, Input areas and the *setup* and *stop* buttons

Information areas:

The top right corner shows the revision date of the AWG software.

Just below the revision date the AWG status and the number of samples used for the calculated wave are shown.

The bottom right corner shows to actual AWG output frequency.

Remark: due to the digital nature of the AWG, the output frequency may not be exactly the same as the frequency value input in the *frequency* control.

Input areas: (from top to bottom)

Remark: Input areas are only active when the generator is stopped. When the generator is started (by pushing the setup generator button) the controls and display update are switched of, which significantly reduces digital noise on the output signal. Input widgets are "greyed_out".

Function is a drop down menu to select the wave form. When the drop down has focus, press *Enter*, then turn the encoder counterclockwise to move down the list, press *Enter* to select the wave form. When you select a wave form the following controls are set to default values: *Amplitude, Offset* and the *Parameters* relevant for the wave form.

Frequency consists of two controls. The first is a scale to select the frequency. Move the focus to the scale, press *Enter* and turn the encoder to dial in the frequency. Pressing *Enter*, *Next* or *Previous* stores the value. As the AWG supports a wide range (2...20000) the scale is logarithmic. The small window to the right displays the frequency value. The second control is a drop down menu to select the frequency range, either Hz or kHz.

Two frequency ranges are available: 2Hz … 20.000Hz (20kHz) and 2kHz … 20.000kHz (20MHz).

Remark: Not all wave forms work nicely up to the maximum frequency of 20MHz.

Amplitude is a scale from 0 to 1 (0% to 100%). This is deliberately a relative scale as the output voltage depends on the impedance of the buffer stage and the load connected to the AWG output.

Offset is a scale from 0 to1 (0%...100%). Example: If you want to generate a pulse with full output swing, set the offset to 0 and the amplitude to 1.

 Amplitude and *Offset* influence each other, in wave calculation they are added. An example: a sine wave swings positive and negative around a base line. Set the base line by setting the offset to 0.5. With the amplitude set to 0.5, the resulting sine wave's output swing is from 0 to 1.

Parameters are additional variables, which are used to calculate the wave. Based on the wave selected, parameters are activated or deactivated. Parameters are set to default values when selecting a wave. Active parameters can receive focus and can be changed. In-active parameters are grey-ed out.

Table: parameters per wave and typical value ranges.

	Range	AWG Functions						comment
		sine	pulse	gaussian	sinc	exponential	noise	
frequency	2e0...20e6	X	X	X	X	X	X	2Hz...20kHZ and 20kHz … 20Mhz
amplitude	[0...1]	0...0.5	0...0.8	0...0.5	X	0...0.6	X	0...1 is equivalent to 0V...3.2V
Offset / base line	[0...1]	0.5	0	0	0.5	X	X	0...1 is equivalent to 0V...3.2V
replication	[-1,0,1]					[1,-1]		
phase	not used							visible when combining waves
parameters	# of pars	none	3	1	1	1	1	
Rise time	[0...1]		[0...1]					Sum of rise time, up time and fall time should result in <=1
Up time	[1...0]		[1...0]					
Fall time	[0...1]		[0...1]					
width	multiple			[0.01...0.15]	[0.003...0.02]	[0.02...0.20]		float values
expo	[-1, 1]					[-1, 1]		define rising or falling exponential
pdf							[1...8]	integer Value

Parameter ranges for AWG functions show typical ranges
Wave combination: summing, multiplying, phase modulation, not yet implemented
"grey cells" do not apply for the function

The *setup generator* button is used to trigger calculation of the wave and start the output of the generator. Use *Previous* or *Next* buttons to move the focus to the *setup generator* button and press *Enter*. AWG status will change to *calc-wave* and eventually changes to *running* once the generator's output is on. The controls are disabled ("greyed_out") and display update is switched off , while the generator is running, to reduce digital noise.

While the generator is in status *running* only the *stop generator* button is active. Pressing the stop generator button stops the generator's output and enables the controls and display update.

2. Wave examples
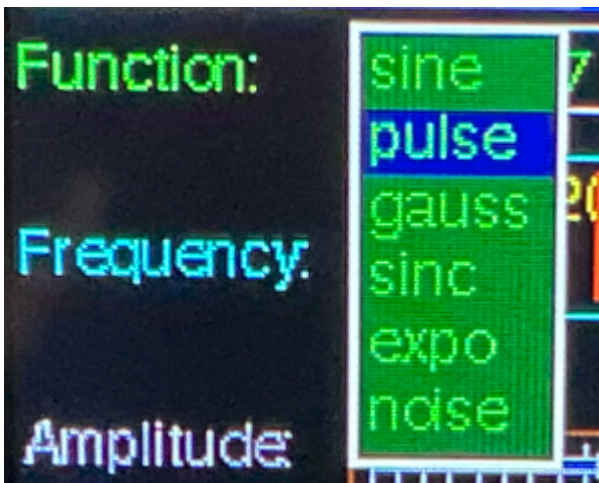
The current AWG version supports six basic wave forms (see picture).

Remark: When you select a wave form, default values for the parameters of the wave are set up. However the AWG does not put boundaries to the controls. This means you can enter any value in the full range of a control. Values outside the ranges as shown in the table above may not lead to the desired result. (see 2.1 sine wave second example)

2.1 The Sine wave

The sine wave has three controls only. Frequency, Amplitude and Offset. No parameters. When *sine* is selected *amplitude* and *offset* are set to 0.5 as default values. Here *frequency* is set to 5MHz.
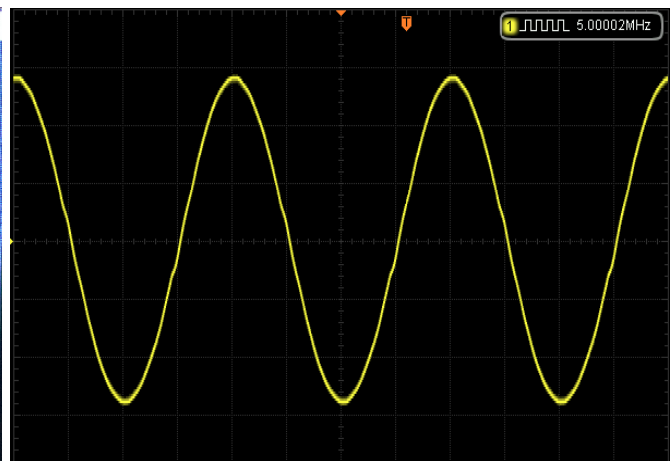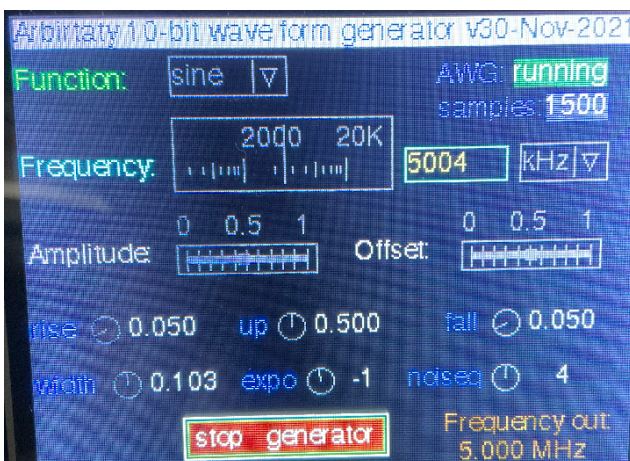

Sine wave with frequency 651kHz, amplitude set to 0.7 and offset set to 1. (picture of rev. 1 UI) Wave is clipped on the positive side.


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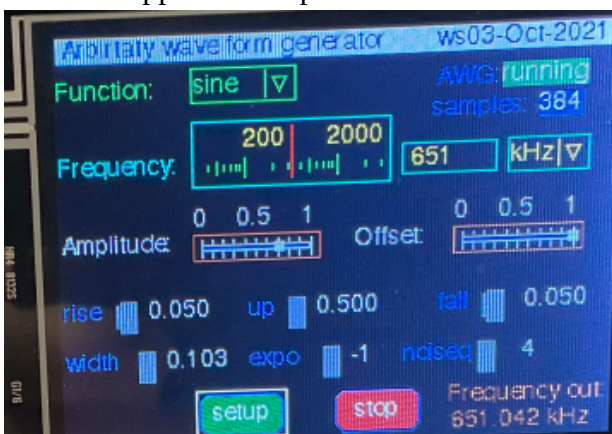
2.2 The wave form Pulse (pictures of rev. 1 UI)

Pulse is a very versatile wave form. Additional to Frequency, Amplitude and Offset, three parameters can be selected: rise time, up time and fall time of the pulse. Default values for *Amplitude* is set to 0.89, this limits overshooting and *Offset* is set to 0.

For this example *rise* is set to 0.25, *up* is set to 0.5 and *fall* is set to 0.05. Please see picture of the wave to see impact of the parameters. The low time of the wave is automatically calculated to: low = 1- (rise + up + fall)
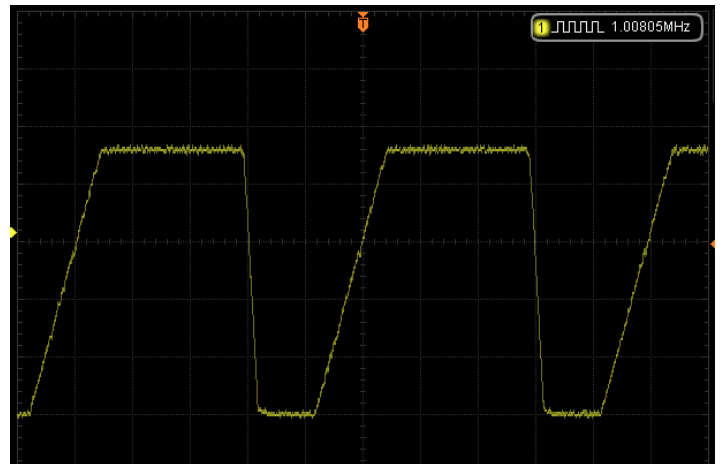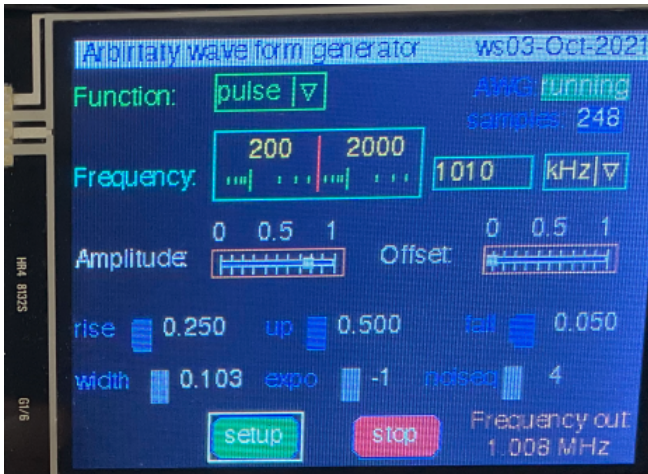
Important note: The sum of *rise, up* and *fall* should be <= 1, otherwise the pulse is just truncated as can be seen in next example, where rise+up+fall = 1,25. The trailing edge of the signal falls fast and even undershoots the zero line, the fall time of 0.25 is neglected.
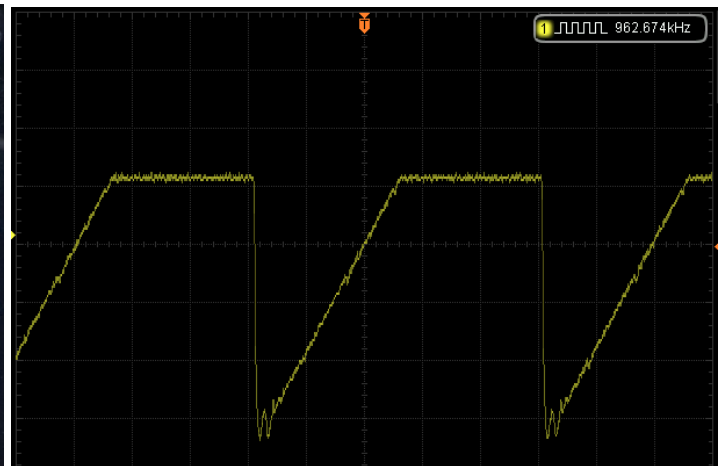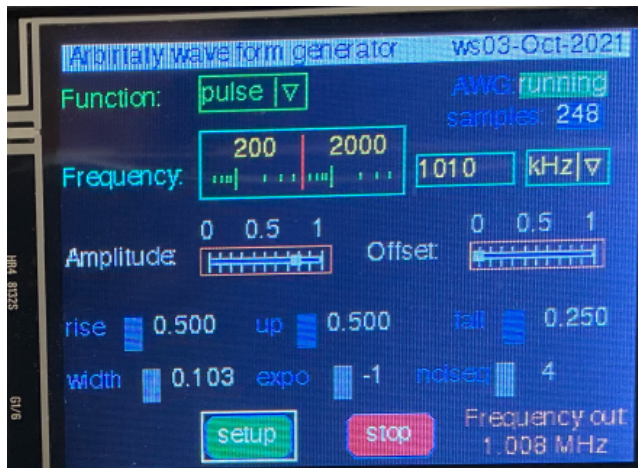
Hints:
 A saw tooth wave can easily be generated by setting *rise* to 1 and *up* and *fall* to 0 or *fall* to 1 and *rise* and *up* time to 0.

A triangular wave can be generated by setting *rise* and *fall* to 0.5 and *up* to 0.

Remark: To reduce over or undershoot of the output signal it is recommended to set a small rise time and fall time such as 0.05. Depending on cable and load more or less time might be needed.

2.3 Gaussian, Sinc, Expo and Noise

The other wave forms work very similar to the two examples above

For Gaussian you can adjust the width parameter, values up to 0.175 work well. For higher frequencies number of samples get low and you can see the shape of the curve deviating from gaussian.

Sinc works well up to approx 2MHz. Above this frequency number of samples gets too low and wave form starts to deviate. Sinc also has the width parameter.

Expo has one parameter, which can have the value of -1 or +1. This identifies if the is wave rising or falling exponentially. Same frequency limitations, if number of samples becomes low, the wave "goes out of shape".

For noise frequency should be low, a few hundred kHz at max, if higher you can see some repeating pattern in the noise. I did not further investigate. Noise has one parameter of value 1,2,3...8

3. Remarks and Limitations

The AWG was designed to be versatile, easy to reproduce and low cost. Six basic waves are implemented.

If the Pico board is connected to a PC, basically any wave form can be produced by adding the wave to module wave_gen.py.

One of the major limitations is the "low" base frequency of 250MHz. This results in a low number of samples for higher output frequencies and wave forms start to deviate from its intended shape.

The output stage of the AWG is a "simple" design. It is short circuit prove and provides a 6V pp swing. There is no impedance matching over frequency range.

If the output signal is clipped or distorted, adjusting the amplitude, offset or parameters might help to reduce the clipping or distortion. Tweak the parameters to optimize the output.

As the parameter values can be adjusted over the full range, the user must be aware of what the impact to the wave form is, when adjusting the parameters (see impact of offset in sine wave example 2.1).

The Pico board produces the output signal and runs the user interface and display as well. This leads to all kind of digital noise on the generator's output signal, such as e.g. noise resulting from the SPI interface. The noise can be reduced by taking some caution when building on a prototype board or making a layout.

"Have fun building and using this nice little tool"