

Syscomp Electronic Design Limited

WGM-201 Waveform Generator Manual

<http://www.syscompdesign.com>
Version 1.00



Revision History

Version	Date	Notes
100	October 2009	First revision

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1 Overview

The Syscomp WGM-201 Waveform Generator is a general-purpose waveform generator, 8 bit digital word generator and general purpose counter. With many advanced features, it is useful for the teaching, development and debugging of electronic circuits.

The WGM-201 is one of a series of instruments from Syscomp Electronic Design. All instruments use a computer host for the graphical user interface (GUI) control panel, and connect with the hardware via a USB virtual COM port. The software is Open Source and runs under Windows, Linux and Mac operating systems. The generator hardware receives power from the host PC via the USB connection so that no other power source is required.

The generator hardware is capable of producing a variety of waveforms. Sine, square, triangle and ramp (sawtooth) waveforms are installed in the firmware. In addition, an arbitrary waveform can be created and downloaded into the generator. The generator can produce these waveforms at frequencies between 0.1Hz and 10MHz with variable amplitude and variable DC offset.

The waveform frequency is derived from a crystal oscillator, so it is precise and stable. The waveform amplitude is determined by digital-analog conversion of digital values. The amplitude stability is determined by internal voltage reference source and 1% resistor values.

A PC host displays a graphical user interface for the function generator with frequency readouts, sliders, clickable buttons and various other controls. The PC connects to the function generator hardware via a USB cable so that no other power source is required.

A Graphical User Interface (the *GUI*) program for operating the waveform generator is provided on the accompanying CDROM. The program is written in the Tcl/Tk language. It is completely Open Source, so it may be modified and distributed freely.

The USB interface emulates a serial port so that it may be accessed as a serial port device from a host computer. Any language that can talk to a serial port can send commands to and receive data from the hardware unit.

1.1 Specification

The core waveform generator is uses Direct Digital Synthesis to create standard and arbitrary waveforms with accuracy based on a crystal oscillator. Amplitude and offset are controlled by DAC hardware independent of the core waveform generator, so that the waveform vertical resolution remains at 256 points regardless of amplitude or offset.

The waveform can be adjusted in frequency in steps of 0.03Hz (more precisely, 0.031247735Hz) over a total range of 0.1Hz to 10MHz (sine) or 3MHz (all other waveforms).

The default upper limit is shown as 3MHz. This may be changed by the operator. Recommended maximum for a sine wave is 10MHz. Recommended maximum for other waveforms (square, ramp, triangle) is 3MHz. An arbitrary waveform may contain spectral content up to a maximum of 10MHz. Maximum and minimum frequency can be set to any points within that range. For example, the range can be set as 20Hz to 20kHz for audio work. The characteristic curve of the control may be set to logarithmic or linear.

The frequency may be set to sweep manually or automatically between the two limit frequencies, with adjustable sweep rate and frequency increment.

Core Waveform Generator

Architecture	Direct Digital Synthesis (DDS)
Clock rate	134MHz
Waveform	
Vertical resolution	8 bits, independent of amplitude or offset
Amplitude	$\pm 10V_{p-p}$ max, adjustable with 8 bit resolution
Offset	$\pm 10V$ max, adjustable with 8 bit resolution
Maximum output	$\pm 10V$, signal plus offset
Output impedance	150 ohms
Sine wave signal-Noise	>48db S/N, independent of output amplitude or offset
Square wave rise and fall time	24nSec
Waveform timebase	256 points
Types	Sine, square, triangle, ramp, noise, arbitrary
Arbitrary waveform	8 bit vertical by 256 time points
Noise waveform	Digital, 32 bit sequence generator, clock 134.208MHz
Frequency	
Range, sine	0.031Hz to 10MHz, resolution 0.1Hz
Range, others:	0.031Hz to 10MHz, resolution 0.1Hz
Resolution	0.031Hz
Control	Manual or automatic sweep
Control curve	Linear or Logarithmic characteristic
Frequency limits	Minimum and maximum frequencies are settable
Frequency sweep	
Mode	Linear or logarithmic characteristic
Direction	Initial direction up/down, start top/bottom frequency
Sweep time step	250mSec to 5000mSec per step
Sweep step magnitude	User entered linear increment or log multiple
Others	
Output	Enable/disable
Computer control	All controls are remotely operated from the host PC

Waveform Generator Trigger

Mode	Free-Running, Triggered
Output	Continuous, Tone Burst
Source	External, Manual, Counter input, Counter Threshold
Cycles	On, off, repeat

1.2 Basic Operation

In this section, we assume that the software has been installed successfully. The hardware is plugged into a USB port and the GUI indicates `Connected`.

On the hardware, the left (green) LED indicates `POWER`. The right is a dual LED, which flashes with each command. When connected to the GUI, this LED lights more-or-less continuously.

1.3 Graphical User Interface

The full GUI is shown in figure 1. The main panel (the *core generator*) is on the left. There are four *subsidiary panels* to the right, each with an X closer in the upper right corner. When the subsidiary panels are not being used,

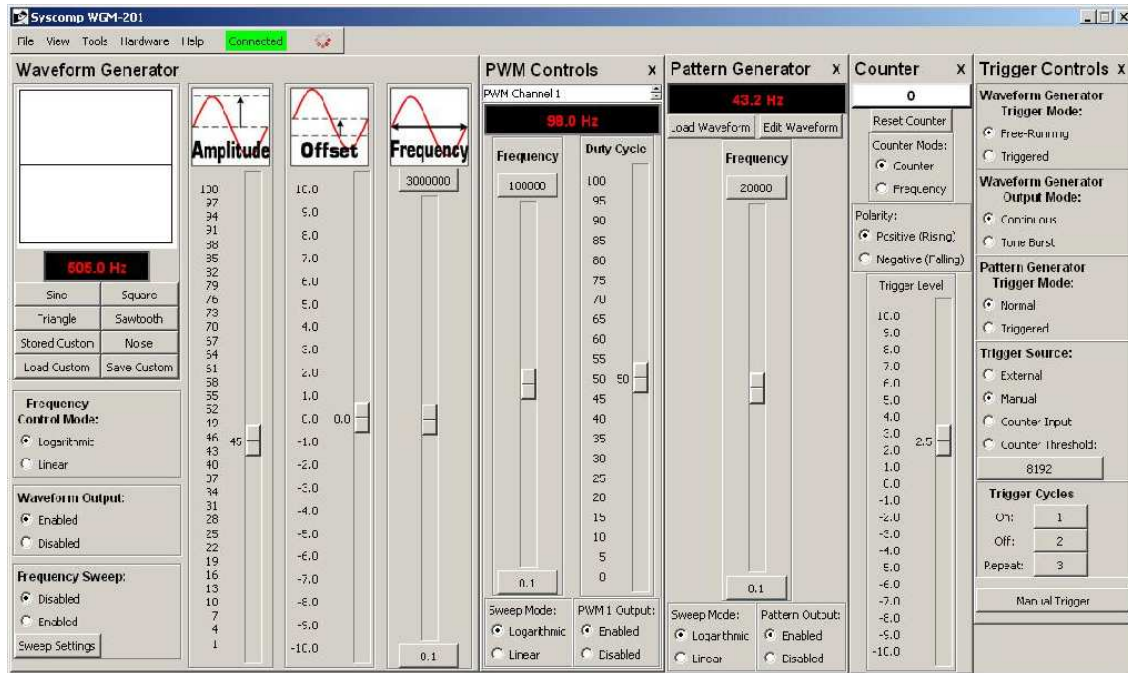


Figure 1: WGM-201 Graphical User Interface

they may be hidden to minimize screen space. Click on the X closer in the upper right corner to hide a panel. It is replaced by a button on the main panel. Figure 2 shows all the subsidiary panels hidden. Notice the buttons in the upper-right corner - they restore the subsidiary panels.

1.4 Manual Frequency Setting

There are three methods of setting the output frequency.

1. Set the output frequency by moving the Frequency slider. The output frequency is shown in the frequency readout display, to the nearest 0.1Hz. The total frequency range of the frequency slider is established by the maximum and minimum frequencies shown at the top and bottom of the slider. Left-click on one of these to enter a new value.
2. Move the frequency slider incrementally up or down with a left-click in the track area (the non-button area) of the frequency slider.
3. Left-click on the frequency readout display. A data entry widget pops up. Type in the desired frequency. Left-click on OK.

2 Frequency Sweep

Frequency may be swept manually or automatically.

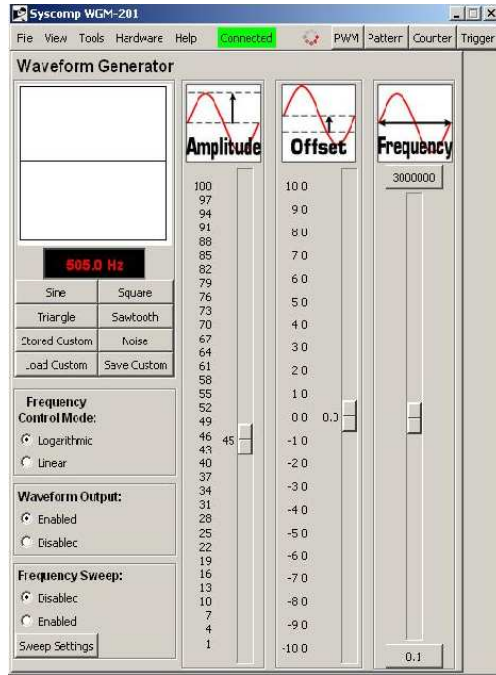


Figure 2: Minimum User Interface

2.0.1 Manual sweep

- Click on the upper frequency limit (at the top of the frequency slider) and enter the maximum frequency of the sweep in Hertz, eg 20000.
- Click on the lower frequency limit (at the bottom of the frequency slider) and enter the minimum frequency of the sweep in Hertz, eg 20.
- Now drag the frequency slider between the bottom and the top limits. The frequency will sweep between 20Hz and 20kHz as the slider is moved.

The characteristic (Frequency Control Mode) of the frequency slider can be switched to Logarithmic or Linear.

In linear mode, the frequencies between maximum and minimum are spread evenly over the range of the slider. In the default state, this means that 3MHz is at the top of the slider, 1.5MHz at the mid point, and 300kHz at 10% from the bottom. The bottom end of the scale is very compressed.

In logarithmic mode, the frequencies are distributed like the keys on a piano. This is a more natural arrangement for human hearing and means for example that each decade (frequency f to frequency $10f$) occupies the same linear space on the slider¹. Consequently, it's much easier to use to set a given frequency.

Logarithmic sweep mode has another advantage. Many response curves have linear segments when the amplitude is measured in decibels (another logarithmic scale) and the frequency is a logarithmic scale. This simplifies

¹Signal generators of the past have used an approximation of the logarithmic control. There was a Range switch, which selected the frequency in multiples of 10, and a Tune knob, which varied the frequency in a linear fashion over each range. The sweep was generally limited to a range of 10:1. A few special-purpose instruments could sweep the audio band 20Hz to 20kHz, a range of 1000:1. The WGM-201 has a maximum sweep range of $10^7 : 1$ and can also sweep over a very narrow range.

interpreting the result of a frequency sweep.

2.0.2 Automatic (Repetitive) sweep

The WGM-201 can automatically sweep the output frequency over its entire frequency range or some part thereof.

1. Click on the upper frequency limit (at the top of the frequency slider) and enter the maximum frequency of the sweep in Hertz, eg 20000.
2. Click on the lower frequency limit (at the bottom of the frequency slider) and enter the minimum frequency of the sweep in Hertz, eg 20.
3. Click on the Sweep Settings button to open up the Frequency Sweep Settings control panel, figure 3.
4. In the Frequency Sweep Settings control panel:

- (a) Select Linear or Logarithmic sweep. Logarithmic is most useful.
- (b) Select the Frequency Time Step using the slider. The generator produces a series of frequencies, stepping from one to the next. This control sets the time interval between frequency steps, ranging from 250mSec to 5 seconds. A slower sweep is required for example when sweeping a device with a high-Q resonance.
- (c) Choose the Frequency Step Setting.
For a linear sweep, click on the Linear Step button and enter the frequency increment between each output frequency. For example, if this is set to 10, then the frequency will increment by 10Hz with each new output.
For a logarithmic sweep, click on the Logarithmic Step button and enter the frequency increment between each output frequency. For example, if this is set to 1.2, then each new frequency is 1.2 times the previous frequency. This produces output frequencies that are equally spaced on a logarithmic frequency scale.
- (d) Select the Initial Sweep Direction: Up or down.

The generator will now sweep between the two limits. The position of the Frequency slider moves to indicate progress of the sweep.

3 Tone Burst

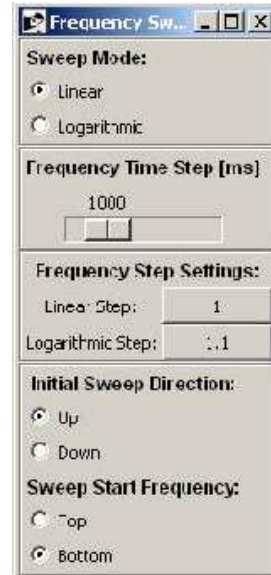


Figure 3: Sweep Mode Control Panel

These controls are in the Trigger Controls panel, figure 4.

- For normal continuous waveform output operation of the generator, set Trigger Mode to Free-Running and Output Mode to Continuous. (This is the power-on default setting.)
- For continuous generation of tone bursts, set Trigger Mode to Free-Running and Output to Tone Burst. The tone burst pattern is specified by the Trigger Cycles On, Off settings. Trigger Cycles On sets the number of complete cycles in the burst. Trigger Cycles Off sets the number of cycles between bursts. Trigger Cycles Repeat has no effect.
- For manually triggered generation of a tone burst, set Trigger Mode to Triggered and Output Mode to Tone Burst. Set Trigger Source to Manual.

The tone burst pattern is specified by the Trigger Cycles On, Off settings. Trigger Cycles On sets the number of complete cycles in the burst. Trigger Cycles Off sets the number of cycles between bursts.

Trigger Cycles Repeat effectively sets the number of tone bursts. The total number cycles is constrained, according to the following:

$$(N_{on} + N_{off}) \times N_{repeats} < 2^{16}$$

where

- N_{on} is the number of ON cycles in each burst
- N_{off} is the number of OFF cycles in each burst
- $N_{repeats}$ is the number of tone burst repeats.

A tone burst is best observed with a digital storage oscilloscope set to Single Shot. On the generator, set up the tone burst configuration as above. Set the scope to single-shot triggering. Reset the scope sweep. Actuate Manual Trigger on the generator. The scope should capture the desired tone burst.

Figure 5 shows these tone bursts captured by a Syscomp CGR-101 CircuitGear oscilloscope in single-shot mode.

4 Pulse Generator

The instrument has two independent pulse generators. For each generator, the duty cycle and frequency can be set independently. That is, changing the duty cycle has no effect on the frequency and vice versa.

The duty cycle is defined as the ratio of ON time to the period of the waveform. During the ON time, the waveform is at +5V. During the remainder of the period (the OFF time) the waveform is at zero volts.

- Adjusting duty cycle independent of frequency is useful when testing certain types of switch mode power supplies and power control circuits.
- An adjustable duty-cycle waveform may be used as the basis for digital to analog conversion. If the waveform is low-pass filtered, the resultant average is proportional to the duty cycle.
- Spectrum analysis of a variable duty cycle signal is illustrative of the principles of Fourier Analysis.

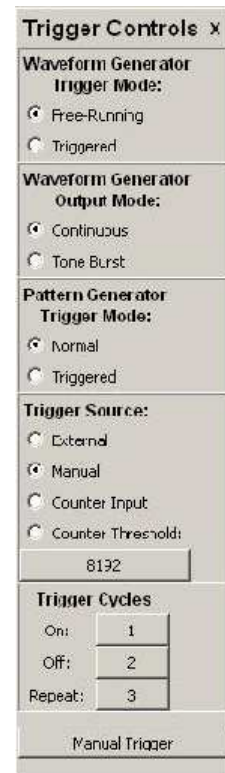


Figure 4: Trigger Controls Panel

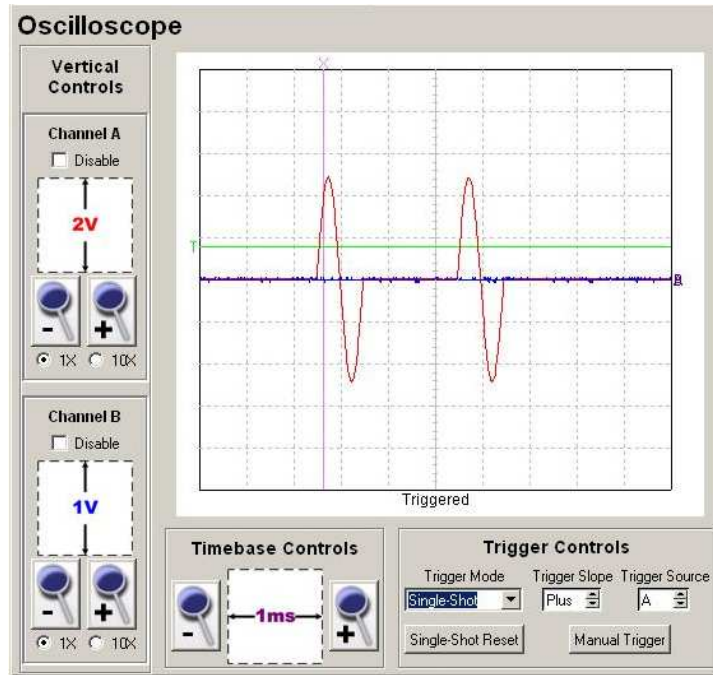


Figure 5: Tone Burst Oscilloscope Display

Each pulse generator output has its own control panel, figure 6. One of these control panels is visible at a time, selected by a switch at the top of the panel, which shows Channel 1 or Channel 2.

Pulse generator output signals swing from 0V to +5V. The two signals and ground connections are available on the rear-panel connector of the instrument (section 8).

The pulse generator controls are identical for Channel 1 and Channel 2.

The output is enabled or disabled by radio-buttons under PWM1 (or-PWM2) Output: When an output is disabled, the frequency and duty cycle sliders are frozen.

As in the case of the core waveform generator, the frequency may be set by direct entry. Left-click on the frequency display in the pulse generator panel. This causes an entry widget to appear. Enter the desired frequency and then left-click on OK.

The frequency slider operates in the same manner as the core waveform generator. The control may be dragged between the maximum and minimum values. Clicking on the slider area outside the button causes the frequency to increment or decrement. The maximum and minimum frequencies are set by clicking on their respective displays and typing in suitable values. The Sweep Mode (control characteristic) may be selected as logarithmic or linear.

A second slider sets the duty cycle of the output waveform.

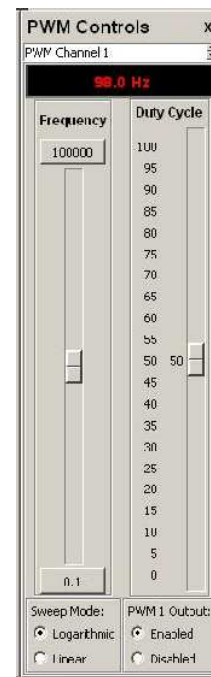


Figure 6: Pulse Generator Control Panel

In general, the pulse generator outputs are unsynchronized with each other and the main generator output. However, if the two pulse generator frequencies are set to the same value, they will remain in a fixed (although arbitrary) phase relationship. This is also true if one pulse generator output frequency is an integer multiple of the second output. The two frequencies can also be made to *walk* with respect to each other. For example, if one frequency is set to 400.0 Hz and the other to 400.1 Hz, then the two frequencies will appear to drift past each other, one complete cycle every 10 seconds.

Similarly, the two pulse generator outputs will synchronize with the main output if they are set to exactly the same frequency.

5 Pattern Generator

The pattern generator produces a series of 8 bit data words at the rear panel connector (section 8 on page 14). The sequence length may be any binary value from 4 to 1024 words.

The pattern generator is controlled from the Pattern Generator Control Panel, figure 7. The frequency slider sets the frequency of the repetition rate of the sequence. For example, if the sequence length is set to 32 words and frequency slider set to 1000Hz, then the 32-word sequence will repeat 1000 times per second. The maximum bit toggle rate is 10MHz. As in the core waveform generator and pulse generator controls, the frequency may be set by direct entry (click on the frequency display), by dragging the slider, or by clicking in the slider area outside the button.



5.1 Creating a Digital Pattern

We'll use an example to illustrate this process. We assume that our digital logic needs 7 shift pulses on one pin, followed by a load pulse on another pin.

Figure 7: Pattern Generator Control Panel

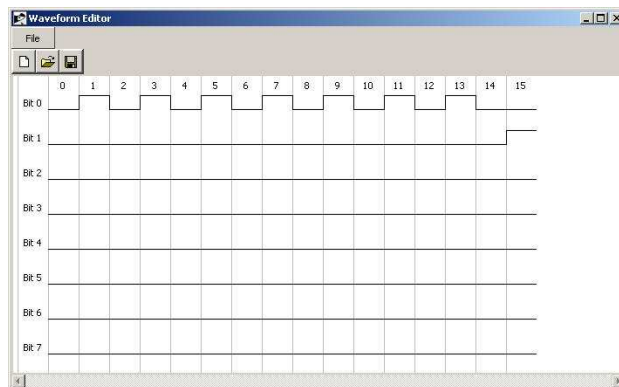


Figure 8: Pattern Editor

1. Click on the Pattern Generator panel Edit Waveform button.

2. The pattern editor panel displays.
3. Click on the pattern editor 'blank sheet' icon.
4. The New Waveform Select Sequence Length panel appears. Select the desired sequence length. in this case we select a sequence length of 16.
5. The pattern editor panel displays 8 traces with timing marks from 0 to 15.
6. Click on a bit cell to change its state from zero to one or vice versa.
7. On the Bit 0 line, create 7 logic ones in a sequence, each separated by a logic zero.
8. On the Bit 1 line, create a single logic 1 in the #15 time slot. The pattern editor should appear as in figure 8.
9. Click on the floppy disk icon and save the file.
10. Return to the Pattern Generator panel and click on 'Load Waveform'. In the load dialog, select the previously saved file.
11. The pattern should now appear at the rear panel connector.

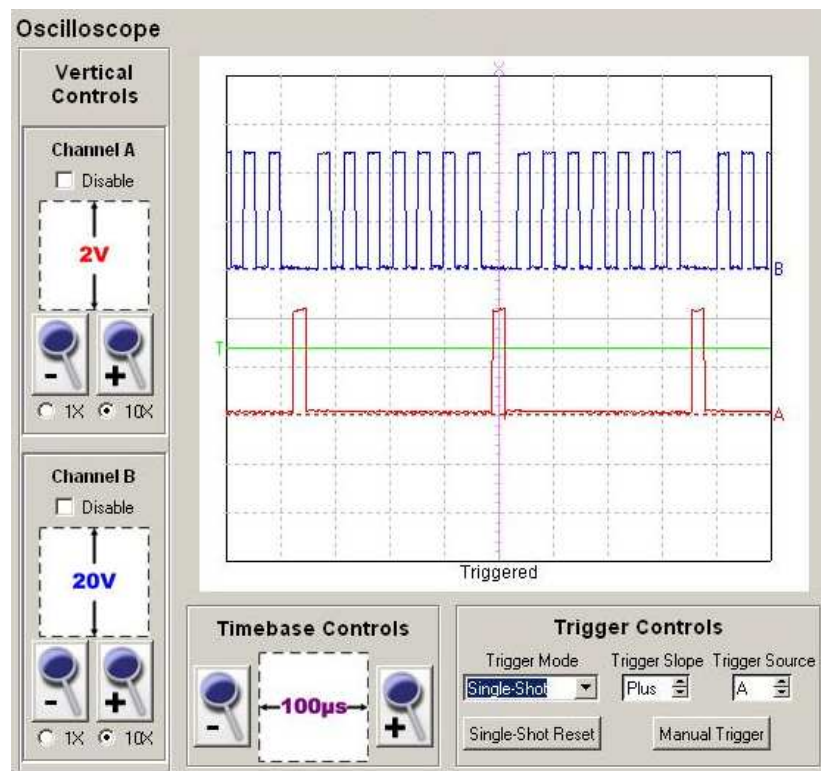


Figure 9: Pattern Demonstration

The resultant computer display, captured by a Syscomp CGR-101 oscilloscope, is shown in figure 9. The upper trace shows 7 shift pulses in sequence. The lower trace shows the single load pulse.

5.2 Pattern File Format

The pattern file is a text file, so it can be edited in any text editor (such as Notepad on a Windows machine). The first entry is the number of time slots (16 in our example). This is followed the one byte value for each time slot entry. In our example, the last entry is '2' because there is a single binary 1 on the Bit 1 line, which has a binary weight of 2.

6 Counter

The Counter is a general purpose event and frequency counter. In the Events mode, the counter increments with each trigger pulse, up to a maximum of $2^{31} - 1$ (approximately 2×10^9) counts. A manual reset restarts the counter from zero.

The counter input connector is the right-hand BNC connector on the front panel.

In the Frequency mode, the counter measures the input frequency to an accuracy of ± 50 ppm ($\pm 0.005\%$).

Counter trigger controls allow one to select the slope of the trigger (rising or falling edge) and the voltage ($\pm 5V$, approx.)

The counter input signal, processed by the trigger slope and level, can be used to trigger a tone burst. Select Trigger Source: Counter Input.

This same trigger signal can be conditioned to delay a number of selected cycles. For example, one could set up the generator to produce a tone burst when 1000 events have occurred. Select Trigger Source: Counter Threshold. Click on the numbered button below Counter Threshold. An entry widget pops up. Enter the number of cycles in that entry.

Counter threshold triggers only once and then must be manually reset.

7 Commands

In this section we document commands that may be issued directly to the hardware. The terminal emulator or programming language that sends these commands appears to do so using a serial port connection to the hardware. It is not necessary to deal with USB in any form. Consequently, any language that can send and receive commands via a serial port can communicate with the WGM-201 hardware.

7.1 Setting up the Terminal

We recommend first testing the connection using a terminal emulator. A terminal emulator (such as Hyperterminal in Windows or Seyon or Minicom in Linux) can be used to send commands to the hardware, and this verifies that the serial connection is working properly.

When the WGM-201 software is running correctly (ie, Connected), actuate Hardware -> Connect -> Port Settings and determine the COM port (serial port) being used by the GUI (graphical user interface).

Shut down the GUI so that it's not trying to use the serial port. The serial port needs to be available to the terminal emulator program.

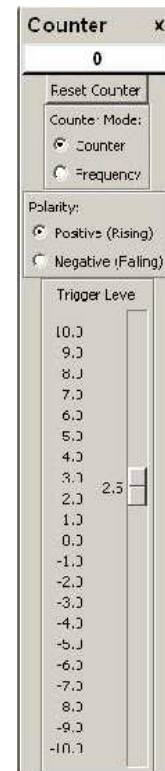


Figure 10: Counter Panel

Start the terminal emulator and connect to that COM port. (On a Linux machine it's probably a `ttUSBx` port, where `x` is the number of the port.) Set the terminal emulator parameters to 8 bits, no parity, one stop bit. Since the serial port is a VCP (virtual COM port) that is actually USB, the baud rate is unimportant.

With the WGM-201 hardware connected, you should now be able to send commands to the hardware. The first command to try is the `Identify` command. Send `i` followed by a carriage return. The right-hand LED on the hardware should flash, since the hardware received a character and has sent a string. The identification string (see table, below) should appear on the terminal screen.

7.2 Command Listing

The commands that are used to control the WGM-201 hardware are shown in the following tables.

All commands are terminated by a carriage return character. A terminating line-feed character is ignored.

General	
i	Identification string request. Returns: *Syscomp Advanced Waveform Generator VX.XX where X.XX is the firmware revision.
Function Generator	
A	Amplitude, sets peak voltage of waveform. Usage: A nnn where nnn is an 8bit ascii number ranging from 0 to 255, representing the amplitude. Output amplitude = (nnn/255)*10V Example: A 127 sets the amplitude to 5 volts.
F	Frequency Command. Usage: F aaa bbb ccc ddd where aaa through ddd are 8bit ascii numbers that make up a 32bit number (YYYY) to set the output frequency. Output frequency = YYYY*0.031247735 [Hz] (See below for an example).
O	Offset command. Usage: O nnn where nnn is an 8bit ascii number representing the offset. Output offset = ((nnn127)/127)*10V
W n	Select waveform, where n is one of the following. 0 Sine 1 Triangle 2 Square 3 Sawtooth 4 User
S a d	Write volatile [1] waveform sample into device. a eight bit address d eight bit data
J a d	Write semi-permanent [1] waveform sample into device. a eight bit address d eight bit data
E	Enable waveform output [2]
D	Disable waveform output
N	Enable noise output [2]
n	Disable noise output
M n	Select trigger mode, where n is one of the following. 0 Waveform Generator FreeRunning Mode 1 Waveform Generator Triggered Mode 2 Pattern Generator FreeRunning Mode 3 Pattern Generator Triggered Mode
X n	Select trigger source, where n is one of the following. 0 External Trigger 1 Manual Trigger 2 Counter Trigger

Notes: [1] A *volatile* sample is one sample of the arbitrary waveform. It is volatile because it is held in RAM, so it disappears when the power is disabled. A total of 256 8-bit samples constitute a waveform and will show as the current output waveform.

A *semi-permanent* sample is written into the hardware EEPROM. It does not appear immediately in the output waveform. It is transferred into the waveform RAM and appears in the output with the `Select waveform - User` command W 4.

[2] Enable Waveform output enables and disables *all* waveforms, including noise. Enable Noise enables and disables only the noise source. When noise is enabled, other waveforms (such as Sine) are disabled and vice versa.

Converting Frequency

Here we show the example of converting output frequency of 2MHz into a command.

1. Convert the desired output frequency into the correct count, using the conversion factor.

$$\begin{aligned} 2\text{MHz} &= \frac{2 \times 10^6 \text{ Hz}}{0.031247735 \text{ Hz/Count}} \\ &= 64004639 \text{ Counts} \end{aligned}$$

2. Convert this value to a hexadecimal number. (Some scientific calculators have this function, or use the web site <http://www.statman.info/conversions/hexadecimal.html>)

$$64004639 \text{ base 10} = 3\text{d}0\text{a}21\text{f} \text{ hexadecimal (base 16)}$$

3. Group the hex number by pairs starting at the right end. Convert each pair to the corresponding decimal number, which will range from 0 to 255. Again, use a calculator for each pair, or the website mentioned previously.

$$\begin{aligned} 3\text{d}0\text{a}21\text{f} &= 3 \text{ d}0 \text{ a}2 \text{ 1f} \\ &= 3 \text{ 208 } 162 \text{ 31} \end{aligned}$$

You can verify that this is correct. Use `View -Debug Console` to enable the console, which shows messages being sent to the hardware. Click on the frequency readout, enter the frequency value 2000000 into the New Frequency widget. You will see the message `F 3 208 162 31` sent to the hardware.

Trigger	
M n	Select trigger mode, where n is one of the following. 0 Waveform Generator FreeRunning Mode 1 Waveform Generator Triggered Mode 2 Pattern Generator FreeRunning Mode 3 Pattern Generator Triggered Mode
X n	Select trigger source. 0 External Trigger 1 Manual Trigger 2 Counter Trigger
Y a b	Set trigger count command. Parameters a and b make up a 16bit number which dictates how many waveform or pattern generator cycles are executed in triggered mode.
T	Manual trigger

Pulse Generator	
P c n	pulse generator duty cycle command. Parameter c is the channel number. Valid values are 1 and 2. Parameter n is an eightbit duty cycle value. 0 is off, 255 is fully on.
G c a b c d	pulse generator frequency. Parameter c is the channel number. Valid values are 1 and 2. Parameters a b c d make up frequency integer (see frequency command)
1	Enable pulse generator 1 Output
!	Disable pulse generator 1 Output
2	Enable pulse generator 2 Output
@	Disable pulse generator 2 Output
Pattern Generator	
3	Enable pattern generator output.
#	Disable pattern generator output.
H a b c d	Pattern generator frequency. (See frequency command)
B h l d	Pattern generator sample command. Parameters h and l are the high and low bytes of a 10bit address value. Parameter d is an 8bit sample value.
Counter	
C	Counter threshold. Usage: C nnn where nnn is an 8bit ascii number representing the counter threshold voltage. Threshold voltage = (nnn127)/127*10V.
R	Read counter Command returns 4 bytes corresponding to a 32bit counter value, high byte first.
r	Reset counter to zero.

8 Rear Panel Connector

The rear panel connector provides access to the following signals:

- Digital Pattern outputs 0 through 7
- Trigger signals for the waveform generator, pattern generator and counter.
 - **Waveform Trigger Out** A logic level signal that goes high at the beginning of each waveform. It goes low at approximately the mid-point of the waveform.
 - **Pattern Generator Trigger Out** A logic level signal that goes high at the beginning of each pattern sequence. It goes low at approximately the mid-point of the pattern.
 - **Counter Trigger Out** A logic level signal that corresponds to the counter trigger signal.
- Pulse Generator outputs (2)
- External trigger input
- Ground

The pinout is shown in figure 11 and on the case label of the instrument.

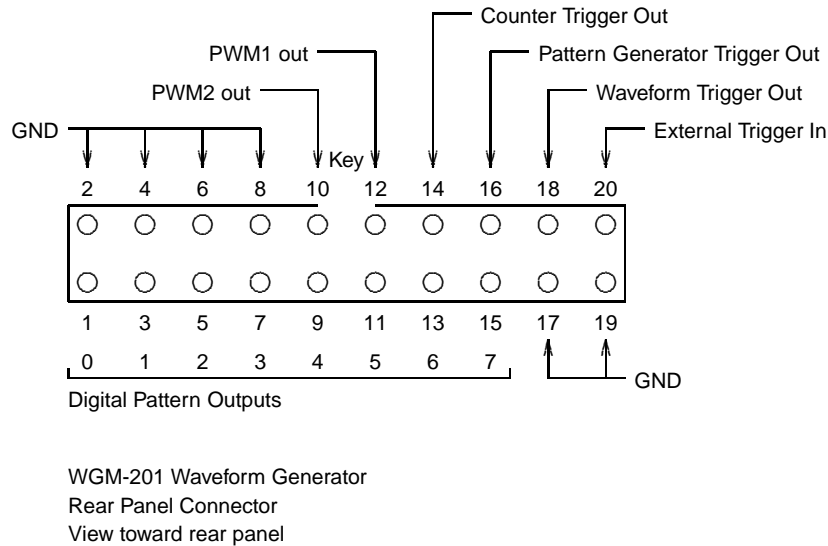


Figure 11: WGM-201 Rear Panel Connector Pinout

8.1 Rear Panel Connector Mating Plug

One suitable rear panel connector mating plug is as follows:

MODE part # 35-0202-0
20 position, 2 row, 0.1" (2.54mm) contact spacing.
Mates with 20 way 0.050" spacing flat cable.
Polarizing key (Centre bump)
Strain Relief

Available from MODE Electronics, <http://www.mode-elec.com>
Distributed by Active-Tech Electronics in Canada, <http://www.active123.com>

Another suitable connector is this one:

3M part # D89120-0131HK
Digikey part # MKC20E-ND
20 position, 2 row, 0.1" (2.54mm) contact spacing.
Mates with 20 way 0.050" spacing flat cable.
Polarizing key (Centre bump)
Contacts 10u gold plate

Mating strain relief for this connector:

3M part # D3448-89120
Digikey part # MESR20-ND

Available from Digikey, <http://www.digikey.com>

Any flat cable with 0.050" conductor spacing that will mate with IDC (Insulation displacement connector) should be suitable for use with these plugs. For example:

3M 3302 Series

Digikey part # MCM-20M-5-ND (5 foot length)

10 colour repeat, clear carrier