Syscomp Computer Controlled Instruments
CircuitGear CGR-201 Manual

Syscomp Electronic Design Limited
`http:\\www.syscompdesign.com`
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Revision History

Version	Date	Notes
1.00	May 2015	First revision

Contents

List of Figures

Caution: Never connect this instrument to the AC line. Doing so may result in personal injury and extreme damage to the operator, the instrument and to an attached computer. See section 11 on page 26.

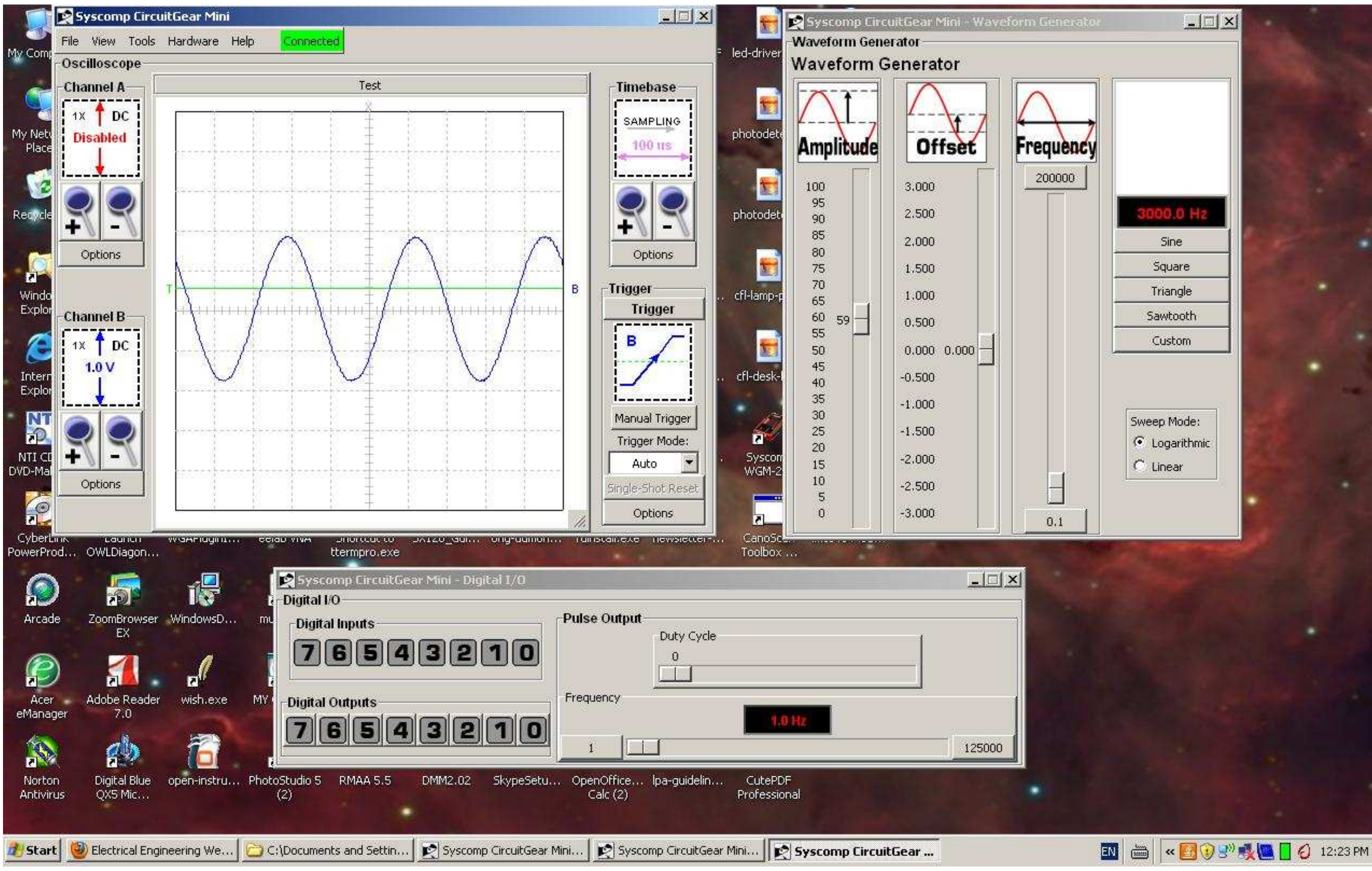


Figure 1: The CGR-201 Graphical User Interface

1 Overview

The Syscomp CircuitGear MkII (CGR-201) is a combination of three electronic instruments: a two-channel digital storage oscilloscope, a waveform generator, and a digital input-output port. Host software can operate the instrument as a spectrum analyser and as a vector-network analyser (Bode plotter).

CircuitGear includes a small hardware module and display software that runs on a host PC. Figure 1 shows the user interface.

The CGM-101 is a development based on the successful CircuitGear products CGR-101 and CGM-101 with many enhancements and additional features.

The initial release of the CGR-201 includes enhanced features of the CGR-101 CircuitGear and CGM-101 CircuitGear Mini. The hardware supports additional features and these will be added with subsequent firmware and software releases.

1.1 Oscilloscope

The oscilloscope is a dual-channel, 40MSample/sec oscilloscope with 10 bit A/D conversion, digital storage and display.

Channels A and B are sampled simultaneously and stored in the oscilloscope memory before being sent for display to the host computer. Consequently, the signals are always time aligned and associated with the same trigger signal. Triggering is accomplished by digital circuitry so it is precise and consistent. Trigger controls include *Mode: Auto, Normal, Single-shot, Manual*, *Source: A or B*, and *Slope: Positive or Negative*.

The time at which the trigger occurs is continuously adjustable by adjustment of an on-screen cursor so that the operator can display the signal before and/or after the trigger event.

The oscilloscope timebase frequency is derived from a crystal oscillator, so it can be expected to be precise and stable. The displayed amplitude is determined by 1% resistors and analog-digital conversion. The vertical preamplifier is gain-switched to optimize the signal-noise ratio and will accept x10 and x100 scope probes.

1.2 Waveform Generator

The waveform generator is a direct-digital synthesis (DDS) based device with frequency range between 0.05Hz and 10MHz (sine wave) with a frequency resolution of 0.05Hz. The frequency can be adjusted, without range switching, over that entire range or some part of that range.

The usual sine, square, triangle and sawtooth waveforms are supplied with the instrument. The generator can also load and produce an arbitrary waveform. Waveforms are nominally 8 bits (1:256) vertical resolution at all amplitude settings, and 2048 points in length.

For acoustical measurements and other tone-burst applications, the waveform generator is triggerable from an external signal and can be configured to generate a series of one or more cycles `ON` time followed by adjustable number of cycles `OFF` time.

1.3 Digital Input-Output

The digital I/O section includes an 8 bit output port and 8 bit input port. Outputs are controlled by 8 GUI buttons. Inputs are displayed on 8 GUI indicators.

In addition, there is a pulse generator output which is continuously variable over the same range as the waveform generator, with continously adjustable duty cycle.

In combination, these controls form the basis for digital controls and displays for basic digital exercises or more advanced control systems.

1.4 Vector Network Analyser (Bode Plotter)

For automatic sweep, a *Vector Network Analyser* (VNA) (aka Bode Plotter) program is available. The VNA software operates the oscilloscope and generator sections in concert to sweep a network over a specified range and plot the amplitude and phase of the response.

1.5 Spectrum Analyser

A frequency spectrum of the input signal can be shown at the same time as the time-domain waveform display on the oscilloscope screen. The spectrum display is generated by the Fast Fourier Transform algorithm, so that it responds instantaneously to changes in the input waveform. This is ideal for demonstrating the relationship of signals in the time and frequency domains.

1.6 General

The hardware is in a pocket-sized package that can easily be carried in a student backpack or with a laptop computer. Power and control signals are provided to the hardware via a single serial-emulated USB connection with the host PC. An external power module (wall-wart) is not required.

The PC host displays a graphical user interface for the oscilloscope with frequency readouts, sliders, clickable buttons and various other controls. Each instrument appears in its own window: unused instruments can be minimized. The screen of the oscilloscope is resizeable.

The hardware is entirely controlled by software: there are no electro-mechanical switches or adjustments. This makes the hardware very reliable and supports development of custom control software in OEM applications.

The GUI software is written in the Tcl/Tk language. The software is open source and entirely in Tcl/Tk. The GUI software will operate under Linux, Mac or Windows operating systems. Tcl/Tk is an open-source, interpreted language, so reading and modifying the source code is straightforward.

The applications programming interface (API) is documented, so the hardware can be accessed by other computer programs and languages. The only requirement is that the language be able to communicate with a serial port.

1.7 Software Updates and Help

The CircuitGear manual in .pdf format is available from the `Help` menu. Clicking on that menu item automatically invokes Acrobat Reader.

The software checks the Syscomp website and advises if there is a later version of the software. You can do that manually by selecting `Check for Update` in the `Help` menu. Alternatively, you can configure the software to do that automatically every time it starts. Select the `Check for Updates on Startup` menu item.

The `Change Log` (record of changes with each version) is available as a `Help` menu item.

2 Applications

In addition to the usual operation of oscilloscope and signal generator, here are some possible applications of the CircuitGear unit.

- **Logic Net** The digital controls supply the functionality of a digital *Exerciser Unit*, which can apply a stimulus to a digital circuit and measure the output.

  For example the 8 bit digital lines can be used as inputs and indicators for a logic net. Students set up various combinations of input signals to the net and record the outputs to generate logic equations or a truth table for the logic net.

- **State Machine Exerciser** A single manual output line and the PWM output can be used as a pulser for counter and state machine circuits. The manual output exercises the circuit at low speeds, where the behaviour can be observed on the GUI indicators. The PWM output is then used to operate the circuit at higher frequencies, and the oscilloscope can be used to observe faster events.

- **Mixed Analog and Digital Circuits** The digital outputs control a MDAC (multiplying D-A converter) which sets the centre frequency of a bandpass filter. The generator and oscilloscope function as a Vector Network Analyser, showing how the frequency response changes as the digital value is adjusted.

- **Switching Power Supply** The PWM output controls a power MOSFET and LC network which functions as a simple switching power supply. Similarily, PWM output can modulate the power to a DC motor as a simple method of speed control.

- **PWM DAC** It is common for the PWM output of a microprocessor to be used as the basis for a low-cost digital-analog converter. The PWM signal is filtered to produce a variable analog control signal. In this exercise students design the PWM filter and then measure the ripple using the CircuitGear oscilloscope. They can also operate the PWM signal at various frequencies to illustrate the effect of frequency on ripple.

3 Features and Specifications

The features and performance specifications are as follows:

Oscilloscope

Channels	2 independent channels sampled simultaneously
Sampling Frequencies	40 MSamples/second maximum
Vertical Resolution	10 bits per channel (1:1024)
Vertical Bandwidth	Greater than 5MHz
Vertical Input Range	±100mV to ±25V full scale
Vertical Gain Settings	7 settings, 20mV/div to 5V/div, in 1:2:5 sequence
Vertical Coupling	AC or DC coupling
Vertical Offset	Full screen, ±20V max
Vertical Scale	10 major divisions
Horizontal Time Settings, Timebase Mode	21 settings in 1:2:5 sequence 100mSec/div to 50nSec/div
Horizontal Time Settings, Strip Chart Mode	7 settings in 1:2:5 sequence 200 mSec/div to 20 seconds/Div
Horizontal Scale	10 major divisions
Input Impedance	1M Ohm parallel 27pF
Triggering	Digital comparison with input signal
Trigger View	Pre and Post trigger simultaneously viewable
Trigger Controls	Source (A, B, Manual), level and slope select
External Trigger Out	Rear panel, source channel A, logic level
External Trigger In	Rear panel, logic level signal
Memory Depth	4K Samples each channel
Software	Cursor Readouts Spectrum Analysis (FFT) X-Y Plot Waveform math (Add, subtract, multiply) Data record to CSV file (oscilloscope and VNA plot Save/Load Settings Cursor Readouts Auto Measurements Vertical Calibration Offset Calibration

Waveform Generator

Frequency Range	0.1Hz to 10MHz (sine wave)
Output Waveform Amplitude	+/-3.0V
Amplitude Control	Hardware
Output Offset Control	+/-2.5V
Offset Control	Hardware
Vertical Resolution	8 bits at all amplitude and offset settings
Output Impedance	50 ohms
Waveforms	Sine, Square, Triangle, Ramp, Arbitrary
Arbitrary Waveform	8 bit resolution vertical, 1024 time points

Digital I/O

Output	8 bits, GUI (Graphical User Interface) controlled, 5 volt, HCMOS
Input	8 bits, GUI indicators, 5 or 3 volt, HCMOS
Pulse waveform	Variable frequency, 1Hz to 1MHz in steps of 1Hz Variable duty cycle, 0 to 100% in steps of 1%

Other	
Indicators	Power LED (Green)
	Activity LED (Red)
Interface	USB 2.0: Emulated serial port
Physical Dimensions	8cm W x 2.4cm H x 12.5cm D
	3.1in W x 1in H x 5in D
GUI Source Code	Tcl/Tk language
	Open source, OSI Compliant
	Windows, Linux, Mac operating systems
Current Consumption	400mA (approx)

4 Installation and Operation

Once the software is installed and operational, starting the CGM-101 is a matter of plugging in the hardware to a USB port, and clicking on the software icon (or executing a command line instruction). This applies to all operating systems: Windows, Mac OS-X, Linux.

The installation procedure is briefly described in section 16, page 34 and in more detail in section 17 on page 35.

5 Oscilloscope

The oscilloscope *Graphical User Interface* (*GUI*) is shown in figure 2.

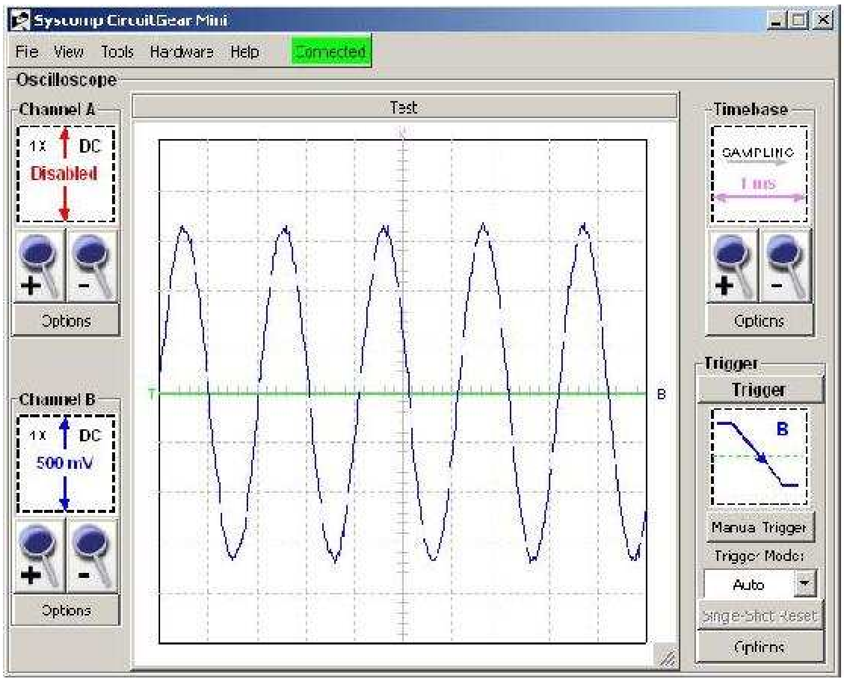


Figure 2: Oscilloscope GUI

Many of the scope controls are similar in function to those of the classic analog oscilloscope. Other controls are unique to the CGM-101. They provide functions - such as cursor readouts - that are only possible in a digital oscilloscope.

The scope controls divide into various groups: *amplitude*, *timebase*, *display* and *triggering*.

5.1 Amplitude

There are two input channels, A and B, each with identical controls.

- **Scale** Sets the vertical scale factor of the display between 20mV per division and 5 volts per division in the traditional oscilloscope 1:2:5 sequence. The amplitude may be read off the display by measuring the number of divisions and multiplying by the scale factor. Alternatively, the *display amplitude cursors* may be used (see *display* below.)

  Changes to the *scale* control adjust the sensitivity of the front-end of the oscilloscope, adjust the preamp gain and change the software scale factor.

- **Option** This button opens a sub-menu, with the following controls:

  - **Coupling, DC and AC** This switch controls the *input coupling* of the oscilloscope. In the `DC` position, the signal is coupled directly into the oscilloscope preamplifier, so that all components of the signal are displayed.

    In the AC coupling position, the signal is passed through a capacitor, so that the DC component of the signal is removed. This is particularly useful when you are trying to observe a small AC signal sitting on a larger DC component. If the input is DC coupled, Increasing the vertical sensitivity increases size of the AC component, but also sends the AC component off the screen. When AC coupling is selected, the AC component can be magnified and viewed without shifting.

    Warning Our recommended maximum input voltage on the AC coupling setting is 40 volts DC. Exceeding this may cause damage to the electronic switch that selects between AC and DC coupling. You cannot use the AC setting to block DC voltages larger than this value. (For example, in audio tube amplifiers, DC voltages of 350 volts or higher are not uncommon.) If you need AC coupling where the DC component of the signal is larger than 40 volts, you should put the coupling in the DC position and connect an external capacitor of the appropriate voltage rating in series with the input.

    The AC coupling position rolls off frequency response below a cutoff frequency, which is given by:

    $$f_c = \frac{1}{2\pi RC}$$

    The resistance is 1MΩ. The internal capacitor is 100nF, giving a low-frequency cutoff of 1.5Hz.

  - **Hide** This selection allows one to hide a trace that is not in use, in order to reduce screen clutter.

  - **Invert** This selection inverts the display. This is most useful in conjuction with the 'Add waveform' display. Inverting one channel and adding the two inputs creates a display of the *difference* between the two signals.

  - **Probe ×1, ×10, ×100** These settings adjust the vertical scale factor to match the scale factor of the probe. For example, if you are using a ×10 setting on the oscilloscope probe and select ×10 in this control, the displays and screen scale factors will change appropriately.

5.2 Oscilloscope Mode: Timebase

The timebase has two modes of operation: *oscilloscope mode* and *stripchart mode*. Oscilloscope mode is most suitable for displaying rapidly changing events. For example, it is possible to capture and display the transient voltage from the closing of an electromechanical switch. Stripchart mode is suitable for recording slowly changing events. It mimics the behaviour of old-fashioned pen recorders that were used for recording such phenomena as earthquake waves or changing temperature.

The timebase changes automatically from oscilloscope mode to stripchart mode at the timebase settings 100 to 200mSec per division. During oscilloscope mode, the timebase interval shows `Sampling`, to indicate that a sampling oscilloscope is in operation. During stripchart mode, the timebase interval shows `Scan`.

In oscilloscope mode, the trigger functions (section 5.4) are operational. On the occurrence of a trigger signal, the oscilloscope hardware captures samples into a buffer, and then ships them to the host computer for display. The complete capture-display sequence happens, as in a conventional analog oscilloscope, several times per second.

The *Main Time Base* (*MTB*) can be varied between 100mSec/division 500 nSec/division and 100mSec/-division in the traditional oscilloscope 1:2:5 sequence.

5.3 Oscilloscope Mode: Display

Refer to figure 2 on page 6.

- **Vertical Position** A waveform may be moved in vertical position. At startup, the **A** and **B** cursors - which are the zero reference for the channel – are placed at centre screen. Using the mouse, drag the letter **A** or **B** at the right edge of the display area up or down to change the vertical position of the corresponding waveform.

  Shifting the zero position of the trace is done by DC offset of the input signal. This ensures that the full screen height is available for display at all settings of the shift control.

- **Time Cursors** It is possible to enable and disable various time and amplitude cursors.

  Right click in the display area. A menu appears:

Toggle Time Cursors	Left Click to enable and disable vertical cursor lines that mark the time between two locations on screen.
Toggle Channel A (or B) Cursors	Left Click to enable and disable horizontal cursor lines that mark the amplitude between two locations on screen.
Grid	Left Click to select the appearance of the graticule grid in the display area: enable and disable the display of the grid, or change colours of the grid lines.

  Notice that the cursor readout text can be dragged to different positions on the screen. This is useful when setting up a screen display for capture in a document.

- **Resizing**

  Drag the bottom right corner of the oscilloscope display area to change the size of the display. This is particularly useful for teaching and lab demonstrations, where the CGM-101 display is projected on an overhead screen, as shown in figure 3.

5.4 Oscilloscope Mode: Triggering

In order to present a stable waveform display, each display update must start at the same point on a waveform. The trigger functions determine how that *trigger point* on the waveform is selected.

The trigger controls must meet certain requirements in order to generate trigger signals for waveform capture. If these controls are not set properly, it is possible that the scope will not capture waveforms and the display will appear to be frozen. Alternatively, the display may appear to jump between captures, without a stable waveform display.

- **Trigger Level**

  The *trigger level* is marked by a horizontal green cursor with a **T** symbol at the leftmost edge of the screen (figure 4 on page 10). The trigger level may be dragged vertically to set the amplitude on a waveform that establishes the trigger point. In order to cause triggering, the triggering waveform must cross through the trigger cursor level.

  As the trigger level cursor is dragged, an accompanying readout displays the trigger level in volts.

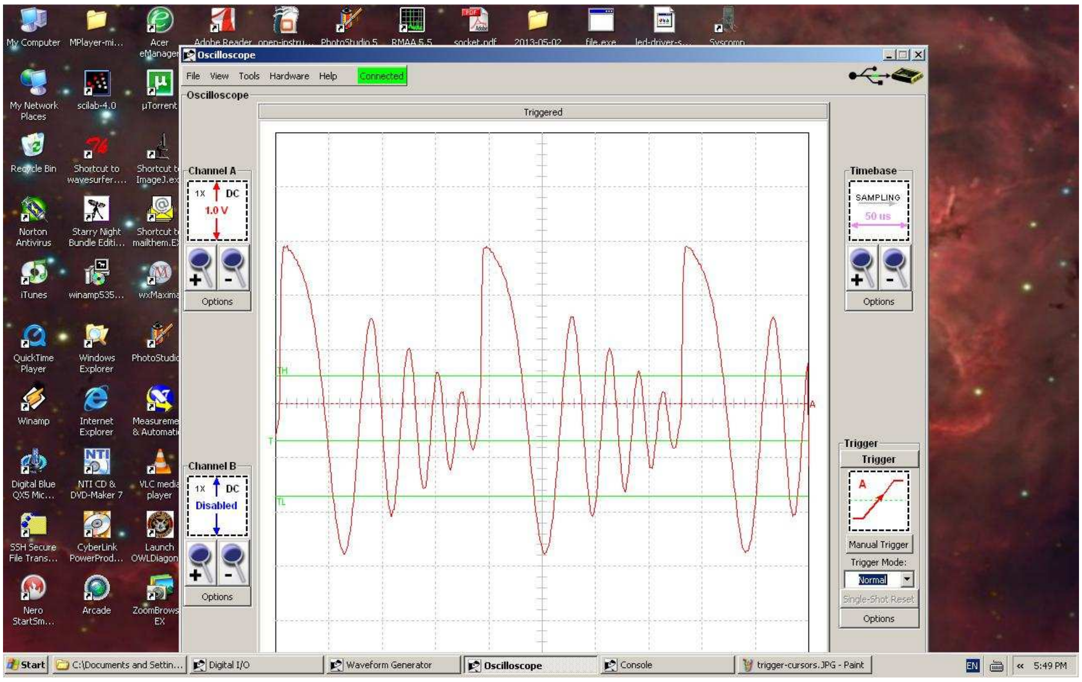


Figure 3: Enlarged Screen

- **Trigger Mode: Auto/Normal/Single**
  - In the **Normal** position, the scope hardware *must* get a proper trigger signal in order to display a new waveform. Without a trigger signal, the display simply waits. (The **Manual Trigger** button can be used to force a trigger event, that is, display one capture.)
  - In the **Auto** position, if there is a trigger signal, the scope uses the trigger signal to synchronize waveform capture. If there is no trigger signal the scope hardware waits for a period of time and then generates a trigger signal internally. That way, there are periodic updates to the waveform display, even if triggering is not occurring from an input waveform.

    In general, the most convenient position is **Auto**. However, there are two situations where **Normal** triggering is necessary:
    - For very low frequency waveforms, the trigger signals occur infrequently. If **Auto** triggering is enabled, the scope will decide that trigger signals are not present and generate them internally. This is not what is wanted: the scope should wait for a waveform trigger signal.
    - If the scope is being used to capture a single-shot event, then it should not trigger itself: it should wait for a waveform trigger signal, regardless of how long it takes for that trigger signal to occur.
  - In the **Single** position, the scope waits for a trigger signal. (This is known as the **Armed** state.) When a trigger signal occurs, the software captures and displays that waveform and disables further triggers. The **Single-Shot Reset** button clears the display and returns the scope to the **Armed** state.
- **Manual Trigger** Actuating this button generates a trigger signal. This is sometimes useful to cause the scope to capture one waveform.
- **Trigger Options**

  The `Options` trigger menu leads to the following controls:

– **Trigger Source**
  The trigger signal may be derived from the Channel A waveform or the Channel B waveform. Generally, it is easier to obtain a stable trigger signal from the simpler of the two waveforms.
– **Trigger Slope**
  The *trigger slope* control selects a positive-going or negative-going slope at the trigger point. This allows one to trigger off the leading or trailing edge of a positive pulse waveform, for example. An slope symbol on the GUI in the Trigger area shows the currently selected slope.

- **Trigger Hysterysis Display**

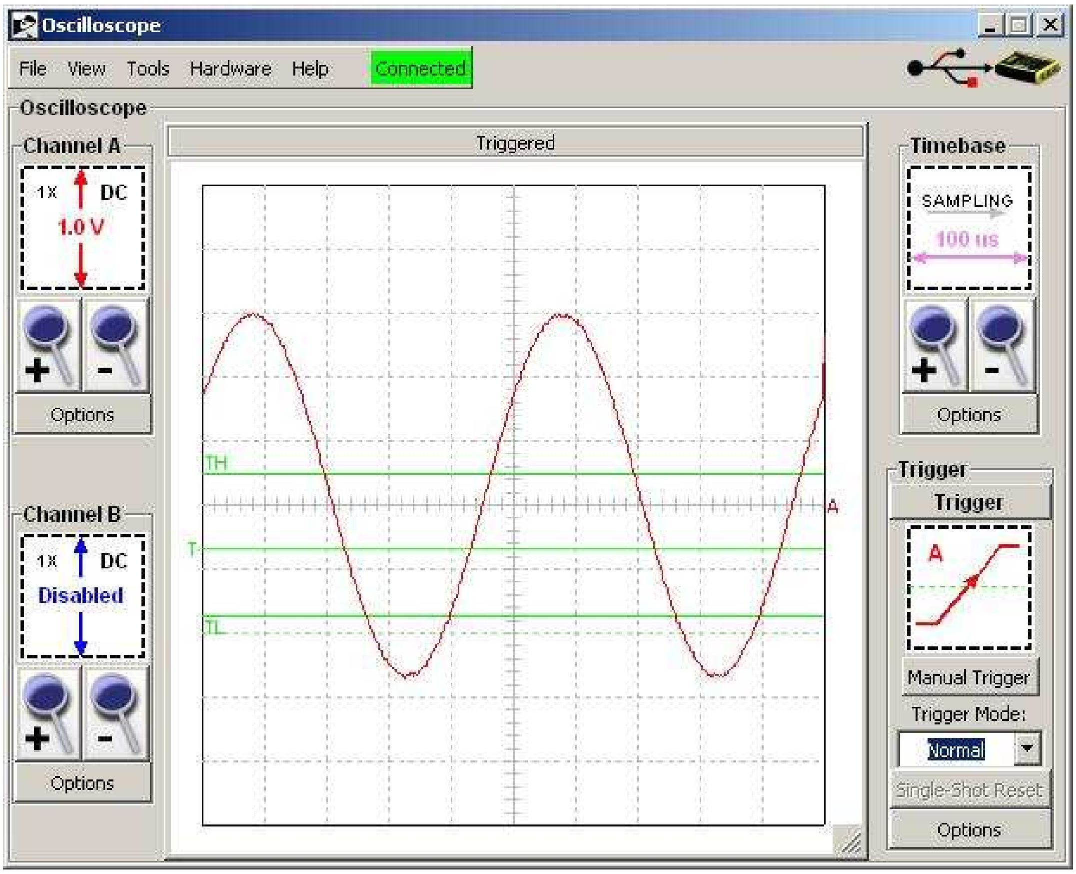


Figure 4: Trigger Cursors

Noise on the triggering signal can cause mis-triggering and jitter. To prevent this, there is a *hysterysis band* associated with the trigger level **T**. Referring to figure 4, the hysterysis band is defined by an upper trigger hysterysis level **TH** and a lower trigger hysterysis level **TL**. All three trigger cursors can be dragged vertically.(**TH** must always be above the trigger level cursor, and **TL** must be below the trigger level cursor.)

A positive-going trigger signal must cross through both the upper trigger hysterysis level and then through the lower trigger hysterysis level.

Normally, there is no need to adjust the hysterysis band, and you can leave it at its default settings. However, for a noisy signal it may help to increase the hysterysis band.

5.5 Measurements Screen

The Measurements Screen shows cursor and automatic measurements of the most common features of a waveform: amplitude and time.

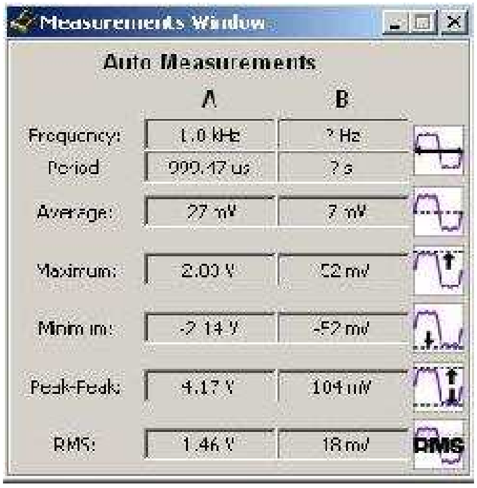


Figure 5: `Measurements` Screen

As shown in figure 5, the Measurements Screen is in a separate window. This window defaults to being displayed, that is, it is displayed when the program is first started.

The Measurements Screen may be hidden by clicking on the X in the upper right corner of the measurements window. It may be displayed by clicking on the menu item `View -> Auto Measurements`.

The Measurements Screen shows the `Auto Measurements`, in which the software automatically measures waveform parameters. The `Frequency` and `Period` readouts are based on the zero-crossings of the waveform. Consequently the waveform must be periodic and the main display must show at least one complete cycle of the waveform for the frequency and period values to be meaningful. As well, the frequency and period measurement can be fooled if the waveform includes noise that causes multiple spurious zero crossings.

The RMS measurement requires that the time cursors be visible and set to the beginning and end of one cycle. This is required to define the limits of integration in the RMS calculation.

For multiple measurements on a reasonably clean waveform, the Auto Measurements can be a real time saver. However, it is best to verify that the measurement is reliable before relying on it extensively.

5.6 XY Mode

The usual oscilloscope display shows a plot of the two signal amplitudes, voltage on Channel A and Channel B, vs time. It is also possible to plot the two voltages against each other: Channel A as the X axis and channel B as the Y axis.

Select `View -> XY Mode` to enable the XY display.

The CGR-101 can simultaneously display both the XY display and the conventional voltage-time waveforms, which is useful in teaching situations and for debugging purposes. If you wish to hide the conventional waveforms, and just show the XY display, disable the individual channels using the Enable/Disable button.

Lissajous Figures

When the two signals are sine waves of the same frequency, with a phase shift between them, the display is as shown in figure 6. This type of looping display is known as a *lissajous figure*.

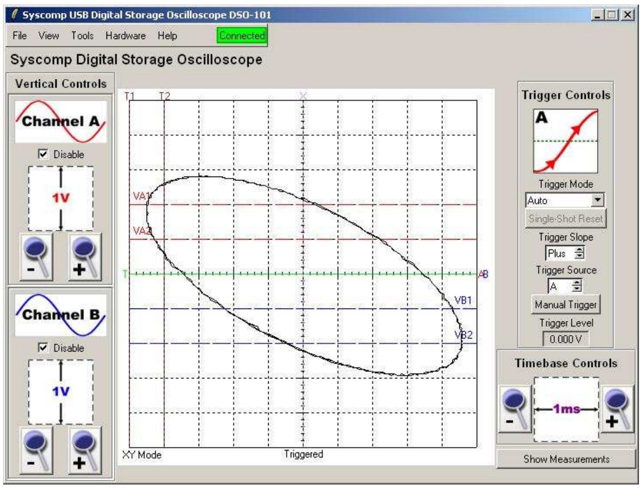


Figure 6: XY Display Mode

If the two frequencies different but integer multiples of each other, then the lissajous figure will have multiple nodes. In the early days of oscilloscopes, lissajous figures were used in this manner for frequency measurement. The vertical amplifiers of the day could not work at high frequencies, so the signals were applied directly to the deflection plates of the cathode ray tube. The lissajous figure gave an indication of frequency ratio and relative phase.

To form a complete lissajous loop, the timebase setting must be such that both waveforms show at least one complete cycle.

Magnitude Measurement

If the two signals are exactly in phase, the XY plot is a straight line. If the two signals are of exactly the same magnitude, the angle of the straight line is 45°. If the magnitudes are different, then the line is at some other angle. This is a sensitive method of comparing the amplitude of two waveforms, which need not be sine waves. Any waveshape should function in this measurement.

General Purpose Plotting

The XY Mode display may be used for a variety of applications where a plot of some kind is required.

Figure 7 shows an example. The CGR-101 has been configured to plot the voltage-current curve of a silicon diode. Notice that the diode threshold is around 0.6 volts. The vertical scale is voltage measured across a current sensing resistance, equivalent to 10mA per division.

5.7 Screen Capture

It is extremely useful to be able to capture oscilloscope screen shots. One or more screen shots may be used to document a particular measurement situation as a record of the measurement or to capture the result for a larger document.

Because the instrument screens of the CGR-Mini are separate windows, it is possible to capture the screen image of the oscilloscope, the generator or the digital-IO section to a screen image. Usually, one is interested in capturing the oscilloscope, showing the waveforms. This type of screen capture is useful because it also captures the control settings, which is important for complete documentation.

The various computer operating systems use different methods to capture to capture a window or full screen.

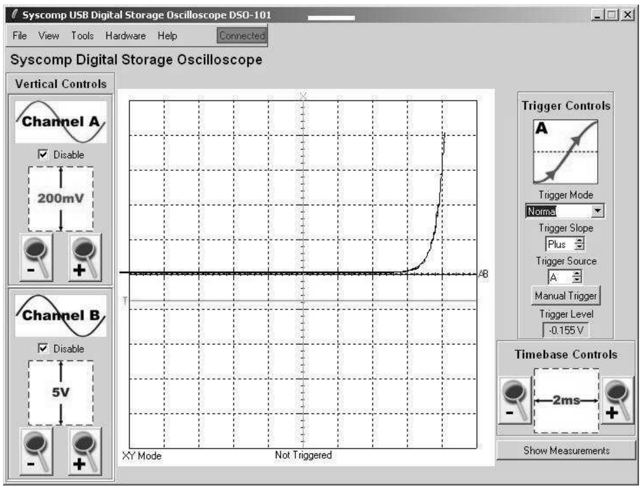


Figure 7: Diode Voltage-Current Characteristic

Windows XP To capture the entire desktop (multiple windows), press the `Print Screen` keyboard key. To capture a single window (such as the oscilloscope), position the mouse cursor somewhere inside that window and press the `Alt` and `Print Screen` keys simultaneously.

Both these actions copy the screen image to a cut/copy/paste buffer.

To view the screenshot and save it to a file, open
`Programs -> Accessories -> Paint.`
Inside paint, choose the menu item `Edit -> Paste` and the image will appear in the Paint workspace. Now you can save it to the directory of your choice, in the file format of your choice, using the
`File -> Save As`
menu item. The precise instructions for other Windows operating systems are similar to XP.

Mac Sue Chastain describes several methods of screen capture on the Mac.
`http://graphicssoft.about.com/od/screencapturemac/ht/macscreenshot.htm`
Here's her method of capturing a specific window (such as the oscilloscope window).

> *To capture a specific application window, press Command-Shift-4, then press the Spacebar. The cursor will change to a camera, and you can move it around the screen. As you move the cursor over an application window, the window will be highlighted. The entire window does not need to be visible for you to capture it. When you have the cursor over a window you want to capture, just click the mouse button and the screen shot will be saved as a PNG file on your desktop. (The file is saved as PDF in Mac OS 10.3 and earlier.)*

Linux Under linux, screen capture is handled by the window manager. Under Suse Linux:

Similar to Windows, pressing the keyboard `Printscreen` key captures the entire desktop. `Alt-Printscreen` captures the window where the mouse currently resides.

A popup dialog box prompts you for the file name and location to save the image. The image is saved in .png format. Use the 'convert' command to change it to some other format, eg: `convert foo.png foo.jpg`

As one would expect from Linux, there are many other ways to capture a screenshot. Google will help you find them.

5.8 Aliasing

The oscilloscope is a *sampled-data-system*. It works by taking a series of samples of the input waveform and displaying them. However, when the signal contains high frequency components compared to the sampling rate, the display may be incorrect. In theory, at least two samples per cycle of the highest frequency present in the waveform are required to reconstruct the waveform correctly.

Some sampled-data-systems have a constant sampling rate. For example, audio is typically sampled at 44.1k samples per second. In that situation, usual practice is to incorporate a low-pass filter such that frequencies above 22 kHz are prevented from entering the system[1]

Most – if not all – digital oscilloscopes do not incorporate an anti-aliasing filter. The sample rate of a digital scope varies over a wide range of frequencies, and so the cutoff frequency of the anti-aliasing filter would have to do so as well. Combined with the bandwidth requirement, that is a difficult technical challenge. Instead, the oscilloscope relies on the operator to recognize when aliasing is occurring and increase the sample rate until the effect disappears.

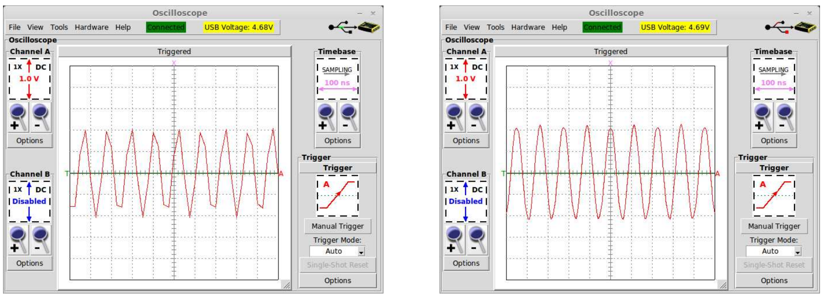
A useful strategy in measuring an unknown waveform is to approach it from a high sampling rate (aka timebase setting) and reduce the setting until a readable display appears. It is also required of the operator to know (approximately) the frequency of the waveform that is being observed. That is often the case.

A useful rule of thumb is this: the display must contain about 10 samples per cycle of the waveform to reconstruct it. For this oscilloscope the maximum sampling rate is 40MSamples/second, so it can usefully observe frequencies up to about 4MHz. The oscilloscope preamplifier analog frequency response has been designed to be 5MHz±0.2db to meet this requirement.

5.9 Interpolation

At high sweep rates, the number of sample points becomes visible and the waveform consists of line segments between those points. Interpolation smooths the waveform and helps with the interpretation of the waveform (figure 8).

Interpolation is accomplished by adding additional zero-value sample points between each real sample, and then passing the resultant sequence of points through a low-pass filter. Interpolation must be used with care: on a waveform with abrupt transitions, such as a square wave, interpolation adds a spurious overshoot to the waveform.



(a) Interpolation Off (b) Interpolation On

Figure 8: Interpolation

[1]In practice, the lowpass cutoff frequency is set to somewhat less than half the sampling frequency to allow for the finite rolloff rate of the filter.

6 Waveform Generator

The waveform generator controls are shown in figure 9.

The *Amplitude* control is calibrated from 0 to 100%.

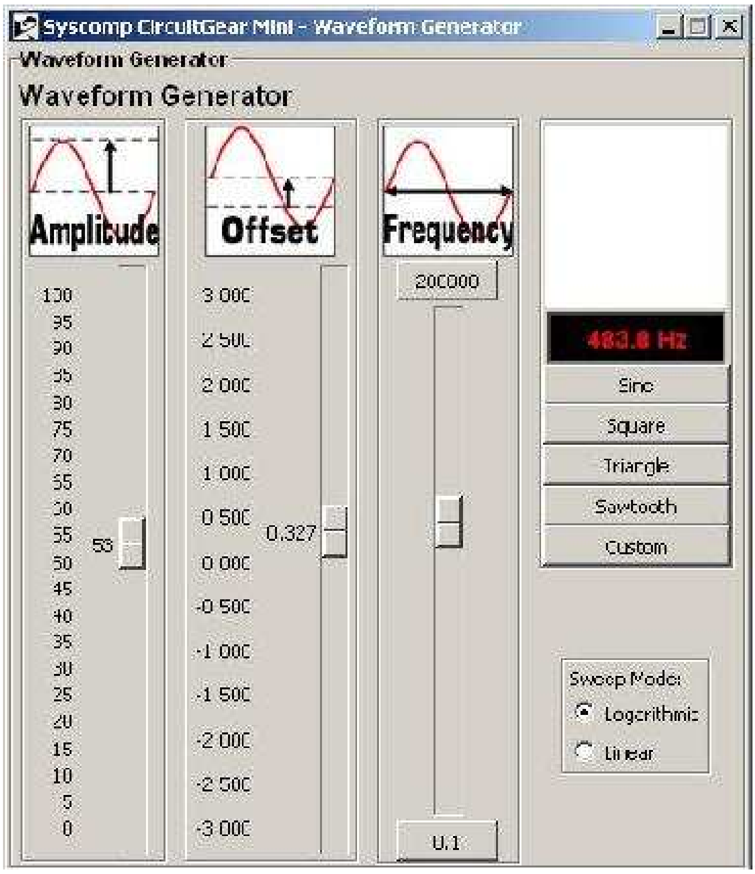


Figure 9: Generator Controls

6.1 Setting Frequency

The frequency control adjusts frequency between the limits shown in the two buttons at the top and bottom of the frequency slider. In the default, these limits are 0.1Hz to 10MHz. The frequency resolution is 0.1Hz. The accuracy is based on a crystal clock. A readout shows the current frequency to a resolution and accuracy of 0.1Hz.

You can set the frequency by moving (left mouse button down and drag) the slider. Alternatively, left-click on the frequency display and enter a frequency value in the pop-up dialog. You can also click in the trough of the frequency slider to increment or decrement the current setting.

6.2 Setting Sweep Limits

To change one of these slider limits, left-click on it. An entry widget appears, prompting for a new maximum or minimum frequency. Enter a new value and left-click on OK or hit <carriage-return>. The new value appears above or below the frequency slider.

For example, if you are sweeping an audio device, you can set the maximum and minimum frequencies to 20,000 and 20Hz. Then the full scale movement of the slider applies to that range.

As another example if you are investigating the frequency response of a 3kHz narrow-band active filter, you could set the frequency range to 3050Hz maximum and 2950Hz minimum. Then the adjustment range of the generator is 100Hz, giving effective fine-grain control of frequency.

6.3 Sweep Mode

The control characteristic of the frequency slider can be set to *Logarithmic* or *Linear*. The Logarithmic control increases the frequency in an exponential fashion as it is increased, which is the most convenient characteristic is most situations. In Logarithmic Mode, the physical mid-point of the scale corresponds to about 700Hz.

In Linear Mode, the control characteristic is linear and the mid-point of the control is 1.5MHz. In effect, this assigns most of the physical movement to high frequencies.

6.4 Manual and Automatic Sweep

The CircuitGear GUI provides frequency control of the generator with a manual frequency control. Automatic sweep is provided with a separate feature: the VNA (Vector Network Analyser), aka Bode Plotter software, which operates the generator to make a sweep and the oscilloscope to plot the response of some device or network. See section 9 on page 22.

6.5 Waveform Amplitude

The waveform can be adjusted between 0 and 2.5 volts peak. Combinations of amplitude and offset that exceed +/-2.5 volts will cause the waveform to clip. You can also left click in the trough of the slider to make small adjustments to the amplitude.

6.6 Waveform Offset

The CGM-101 includes a waveform offset capability of +/-2.5 volts. Combinations of amplitude and offset that exceed +/-2.5 volts will cause the waveform to clip. For example, it is possible to create an unclipped waveform of +/-1 volt with +1.5 volts of offset, but not 2 volts of offset. Adjust the waveform offset by dragging the offset slider. You can also left click in the trough of the slider to make small adjustments to the offset.

6.7 Waveform Selection

There are four built-in waveforms: sine, square, triangle and sawtooth. Select the desired waveform by left-clicking on the corresponding waveform selection button.

Selection of a waveform causes that waveform data to be downloaded from the host PC into the CircuitGear hardware. Each waveform data file consists of 2048 data points. Each data point has a value between 0 and 255. The waveforms for *Sine*, *Square*, *Triangle Sawtooth* and *Noise* are programmed into the firmware of the device.

You can load a custom waveform. Selecting the `Load Custom` waveform pops up a file selection box so you can select any waveform. (See section 6.8 below on creating a custom waveform.) Figure 3 on page 9 shows the oscilloscope trace of a custom waveform produced by the generator.

There is a 1 to 2 second download delay after selecting a waveform before the generator begins producing the waveform. During that time, other waveform selection buttons are locked out to prevent *button mashing*.

Having loaded a custom waveform, you can save it to the CGM-101 hardware memory, by clicking on the `Save Custom` button. Thereafter, clicking on `Stored Custom` will select that waveform. (Using `Stored Custom` avoids having to use the file selector widget to select a custom waveform, so it's a shortcut to select a commonly-used custom waveform.)

6.8 Waveform Format

Waveform data files are stored in the same directory with the source code. On a Windows machine, the path to this directory would be something like:
`C:\Program Files\Syscomp\CGM101-1.19\Source`.
By convention, waveform files end in a `.dat` suffix, for example, `sawtooth.dat`. Other suffixes are permitted. These are plain vanilla text files, so they can be loaded into a text editor such as `Notepad`.

Each file consists of 2048 entries (X values). Each of these 2048 entries is the value of the waveform at that point (Y value), ranging from 0 (most positive) to 255 (most negative). Each entry value is terminated by a carriage-return, line-feed pair.

A waveform data file can be constructed manually, using a programming language (eg, Visual Basic) or from a spreadsheet (eg, Open Office `calc`).

Amplitude can be set by the CircuitGear generator hardware, so it is best to scale the amplitude between 0 and 255. The CGM-101 includes offset hardware, so waveform offset need not be included in the waveform description.

If the waveform can be described by an equation, you can use a spreadsheet to generate the corresponding waveform values. Save the column of waveform file values as a `.csv` (comma-separated values) file. Then examine the file using a text editor (such as Notepad) to ensure that there are no extraneous characters and the file is formatted correctly. Then on the graphical user interface for the CGM-101, load the file into the generator by selecting the `Load Custom` waveform.

7 Digital Input-Output Section

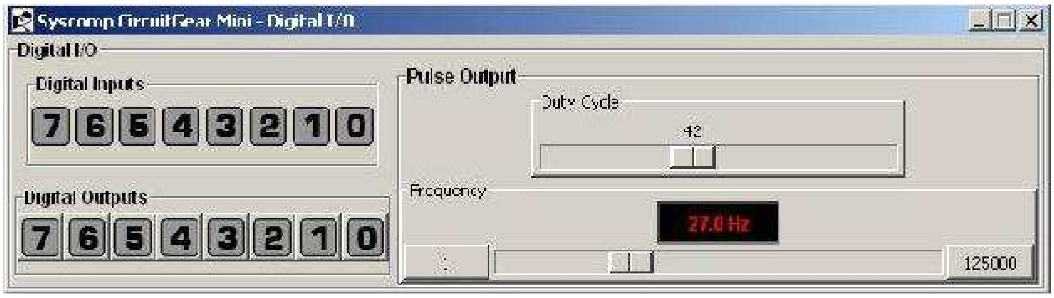


Figure 10: Digital Controls

The CircuitGear digital controls are shown in figure 10. These input and output lines can be operated from the GUI controls in figure 10 or they may be controlled by software that communicates with the CircuitGear API (applications program interface, section 13 on page 30).

On a netbook computer, the digital controls run off the bottom of the screen. The digital I/O controls are in their own window, and can be moved somewhere convenient or minimized.

7.1 8 Bit Digital Output

Clicking on an individual `Digital Output` button bit causes the corresponding bit to illuminate on the GUI and the corresponding output line to go into the high `HIGH` state. Clicking again causes the bit to extinguish and the corresponding output line to go `LOW`.

The available current to a USB device is 500mA maximum, and this current must operate the oscilloscope and signal generator as well as the digital circuitry. Consequently the digital drive current is very limited: a few milliamps per output. Load devices such as high-current LEDs or DC motors will require their own power supply.

7.2 8 Bit Digital Input

The GUI digital input indicators illuminate when the corresponding input level is a logic `HIGH`. The logic levels may correspond to 3V HC logic or 5V HC logic. Great care should be taken not to exceed 5 volts on any input. Inputs are buffered but all devices are surface-mount soldered, so they are not trivial to replace.

7.3 PWM: Pulse Width Modulated Waveform

The PWM output (available on the rear panel connector) is a 5 volt pulse. The duty cycle is continuously adjustable with the `Duty Cycle` slider, over a range of 0% to 100%. The output frequency is set by the `Frequency` slider, over a range of 1Hz to 1MHz.

The output drive current should be limited to a few milliamperes of current.

7.4 External Trigger

When the `Trigger Mode` control on the GUI is set to `External`, a positive-going transition on this pin rear panel pin causes the scope to trigger. To test external trigger:

1. Set the trigger mode to 'auto'.
2. Connect the output of the generator to channel A of the scope and adjust the generator amplitude so the scope shows a sine wave.

3. On the rear panel, use a jumper cable to connect the `Ext Trig pin to the Digital output 0 pin.`

4. `Under Trigger Mode select External.`

5. `From the GUI, use the mouse to click on Digital Output 0.`

6. `On the 0V to 5V transition on digital output 0, the scope should briefly display 'triggered' and a new sample of the waveform should display. On the 5V to 0V transition, triggering will not occur.`

Edge polarity is not selectable on external triggering, the trigger edge is always positive going.

The trigger input is protected against overvoltages but we do not recommend relying on that. We recommend keeping the trigger signal between 0 and +5volts.

8 Spectrum Analyser

A complex waveform may be treated as being composed of a number of sinusoid waveforms. These sinusoids are of various phases, frequencies and amplitudes. The description of the magnitude, phase and frequency of these various waves is known as the *spectrum* of the signal, by analogy with the spectrum of light.

Spectrum Analysis or *Fourier Analysis* is the process of analysing some time-domain waveform to find its spectrum. We also say that the time domain waveform is converted into a frequency spectrum by means of the *Fourier transform.*

Clicking on `Tools -> Spectrum Analysis` brings up the spectrum analysis display of figure 11. The displayed spectrum in this image is a 10kHz square wave.

The theory of Fourier Analysis shows that a square wave is composed of a fundamental of magnitude E volts at frequency f (10kHz in this case) with the following harmonics: $E/3$ magnitude at frequency $3f$, $E/5$ magnitude at frequency $5f$, $E/7$ magnitude at frequency $7f$, and so on. The spectrum display shows this pattern.

Each vertical line represents one of these frequency components. The height of the line is proportional to the magnitude of that particular component. The horizontal axis is a linear scale of frequency, with zero frequency (DC) at the left edge.

The vertical cursor can be dragged horizontally to determine the frequency and magnitude of a component of the spectrum.

The spectrum display and main waveform display are active at the same time, allowing one to simultaneously observe a waveform in the time domain and frequency domain.

8.1 Interpreting the Spectrum Analyser Display

Because of fundamental limitations in a sampled-data system, it is possible for the display to be misleading. Here are some important points to keep in mind when using spectrum analysis based on digital methods:

- Adjust the oscilloscope timebase control to show many cycles of the waveform. Then switch to the Spectrum display. This will result in a wide range of frequencies on the x axis.

- The `Effective Sampling Rate` is shown in a readout at the bottom right corner of the spectrum display. This is important: the sampling rate must be at least twice the frequencies being analysed to avoid aliasing. Put another way, there must not be frequency components above the Nyquist rate, which is half the sampling rate. In the example shown in figure 11, the sample rate is 20kHz. The frequency components range from 1kHz to 9kHz, below the Nyquist rate of 10kHz[2].

[2]Harmonics of the square wave extend to much higher frequencies but we assume their amplitude is small enough to be ignored.

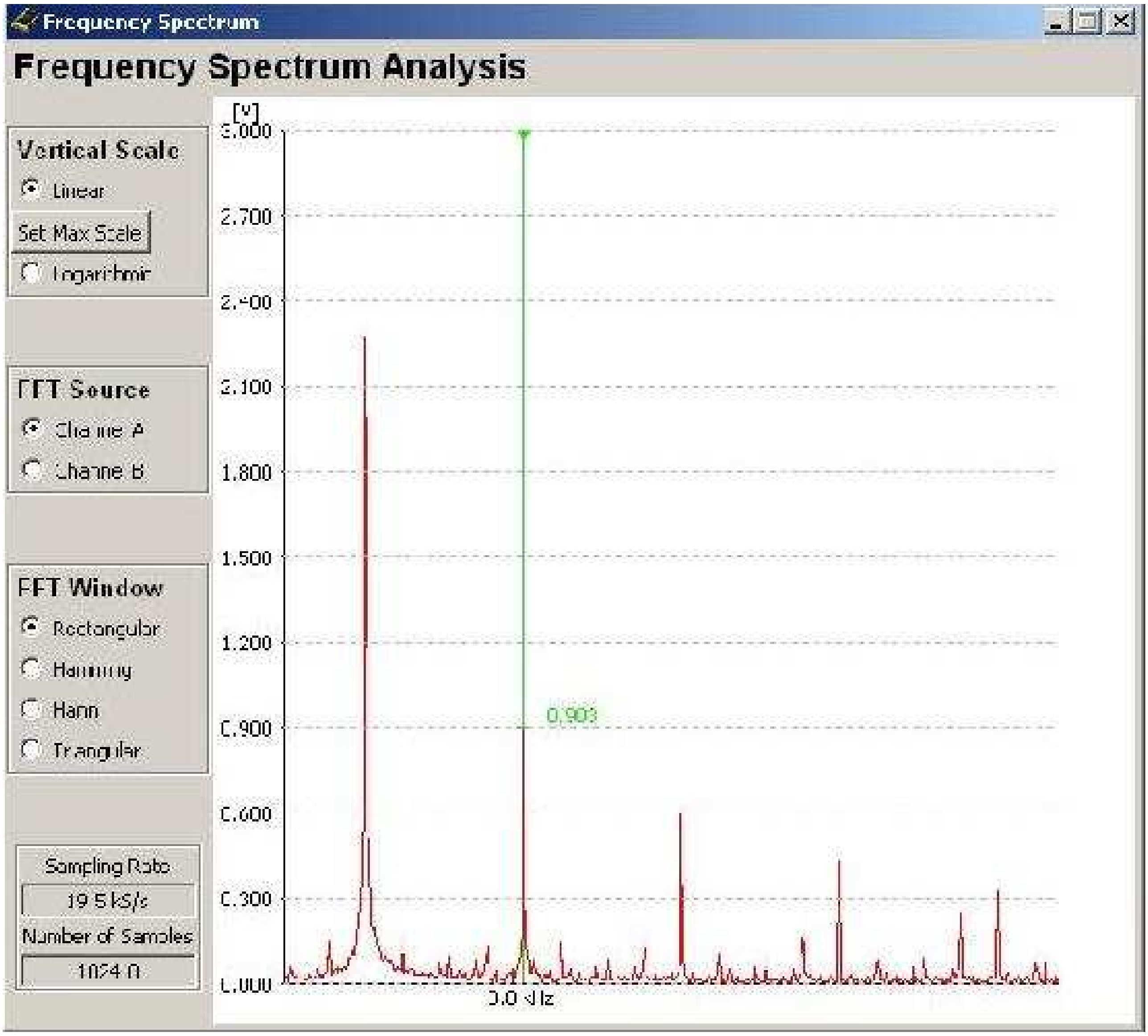


Figure 11: Square Wave Spectrum

- A *sweeping type* analog spectrum analyser moves a bandpass filter across a range of frequencies to determine the spectrum. A digital spectrum analyser such as this one divides up the frequency range into a number of *bins* and then measures the energy in those bins.

  The main oscilloscope display of the CGR-101 is 500 points. This is padded to 512 points[3] by appending zeros to the waveform record. As a result, there are 256 frequency bins when using the main oscilloscope display.

  The centre frequency of each of these bins may not coincide exactly with the frequency components present. If that is the case, then the displayed amplitude will be incorrect and should only be regarded as an approximation of the true situation.

- As the readout cursor is dragged higher in frequency it jumps from bin to bin, reading out the centre frequency of each bin. A given frequency component may not be centred in its bin, so the

[3] The FFT routine requires that the number of points be a power of 2.

frequency readout will be only approximate. For example, in figure 11, the square wave frequency (generated by a Syscomp WGM-101 waveform generator) is at a frequency 1kHz to within a fraction of a Hz. The 9th harmonic is at 9kHz. The spectrum display readout puts the 9th harmonic at 9.0234 Hz, which is approximately correct.

8.2 Frequency Scale, Bin Spacing

It is sometimes useful to be able to determine the resolution of the frequency axis. Each frequency bin has a width $\Delta f = 1/T$ Hz where T is the length of the data record in seconds. If there are N points in the data record, then $N/2$ points are displayed as positive frequency. (The other $N/2$ points are redundant.)

Example

Determine the frequency resolution (bin spacing) for the case of the display of figure 11.

Solution

The sample rate is 200kS/sec. The sample interval ΔT is the reciprocal of this:

$$\begin{aligned} \Delta T &= \frac{1}{200 \times 10^3} \\ &= 5\ \mu\text{Sec} \end{aligned}$$

The number of points N in the data record is 512 points, so the total length of the data record is:

$$\begin{aligned} T &= N\Delta T \\ &= 2.56\ \text{mSec} \end{aligned}$$

The resolution Δf is the reciprocal of the record length:

$$\begin{aligned} \Delta F &= \frac{1}{T} \\ &= 390.625\ \text{Hz} \end{aligned}$$

For example, the 7th harmonic should appear at $f_7 = 70$kHz. The spectrum display actually puts it at 70313 Hz, which is bin 180.

$$\begin{aligned} F_7 &= 180 \times 390.625 \\ &= 70313\ \text{Hz} \end{aligned}$$

The maximum frequency f_{max} on the display occurs at bin 256:

$$\begin{aligned} f_{max} &= 256 \times 390.625 \\ &= 100\ \text{kHz} \end{aligned}$$

8.3 Spectrum Display Cursor Control

For fine control over the spectrum frequency readout. the left and right cursor buttons on the keyboard move the spectrum display cursor one pixel to the left or right.

8.4 Spectrum Weighting Functions

Weighting or *window* functions are often applied to the time-sequence data prior to transformation into the frequency domain. All window functions taper the data down to zero at its ends. Then the discontinuity caused by a finite record length does not affect the shape of the transform.

The choice of window function depends on the application, and all window functions are a compromise of some sort. For example, some window functions provide very accurate amplitude readings, others are best for separating closely spaced frequencies. A collection of window functions is shown at `http://en.wikipedia.org/wiki/Window_function`.

The current spectrum analyser includes the *rectangular window*. This window does not shape the time function, all points on the time record are weighted equally. The Hamming, Hann and Triangular weighting functions are also available.

8.5 Applications

Spectrum analysis has a number of applications in electronics and mechanical engineering:

- A pure tone has no harmonics and will show up on a spectrum display as one single vertical line. Distortion of a sine wave will create additional harmonics. Consequently, a measure of the magnitude of the harmonics is a measure of the magnitude of the *harmonic distortion*.
- In a distortion-free (linear) system, two separate input tones (single frequencies) will emerge as the same two tones at the output. If the system is distorting (non-linear), then the system will generate other tones at the sum and difference frequencies of the input signals. A measure of these extra signals is a measure of the *intermodulation distortion*.
- The existence of certain frequencies in a signal may give some clues as to its source. For example, if a signal contains the power line frequency (eg, 60Hz in North America, 50Hz for the UK), then it is probably picking up interference from the AC power line.
- Power systems frequently manipulate waveforms by chopping them or combining them with other signals. Spectrum analysis allows one to measure the harmonic content of a signal, which may be specified as a requirement.
- The analysis of a mechanical system for resonances can be done by driving the system with a wide-band excitation signal, an impulse hammer blow or random noise from a shaker. Microphones or accelerometers convert the mechanical vibration of the system to an electrical signal. The spectrum analysis of this signal indicates the mechanical resonances in the structure.
- The extraction of signals from noise may require some knowledge of the spectrum of the signal and the noise.
- It is useful to see the spectrum diagram for modulation and other signal manipulations.

Further information on spectrum analysis is in the paper *Introduction to Digital Spectrum Analysis*, which is on the Syscomp web site.

9 Vector Network Analyser

An electrical network, such as a lowpass filter, is characterized by its amplitude and phase response. The amplitude response is a plot against frequency of the *gain* of the network: the ratio of output signal amplitude to input signal amplitude. The phase response is a plot of the *phase* of the network: the difference between the output phase and input phase. The test signal is a sine wave that is swept over a range of frequencies, taking care not to overload the network.

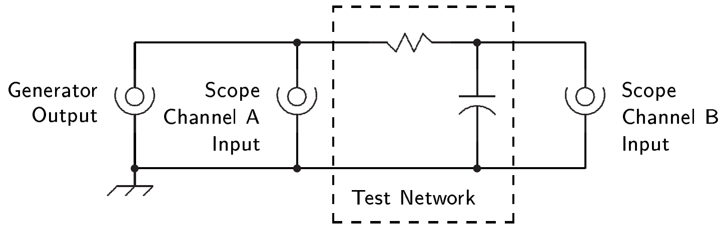


Figure 12: Network Analyser Wiring

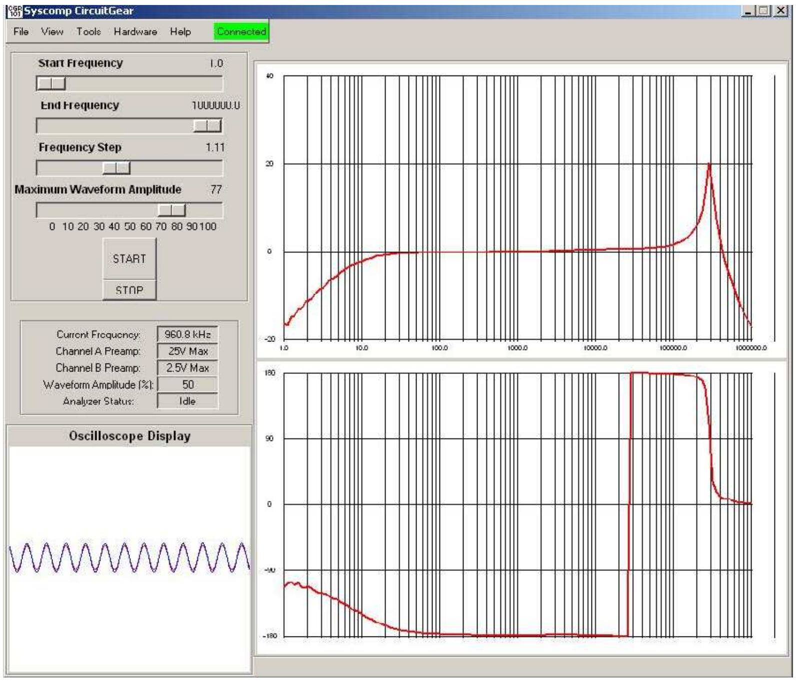


Figure 13: Vector Network Analyser

As part of their AC Circuits lab, electrical engineering students are required to plot these response curves by hand. This is a very tedious process. Each point in the plot requires setting the generator frequency, reading the input signal amplitude, reading the output signal amplitude, reading the output signal phase, and plotting the result. The CGR-101 vector network analyser does this automatically over a range of 1Hz to 1MHz, or some part thereof. This makes it practical to explore the effect of changing component values. For example, if the resistor or capacitor value in an RC lowpass filter is changed, one can immediately determine the effect on frequency and phase response.

The CGR-101 has two principal modes: as an oscilloscope and signal generator (with digital input-output), and as a network analyser. To change between them, select:
`Hardware -> Network Analyser Mode`, or
`Hardware -> Circuit Gear Mode`.

Figure 13 shows a screen shot of a VNA plot of a small transformer. Notice how the frequency response rolls off at low frequencies and shows a resonant peak at high frequencies.

Figure 12 shows how an RC low-pass filter circuit would be connected. Notice that there is no internal connection between the generator output and the channel A input. The instrument grounds are connected internally, so only one ground wire is required to the external circuit.

To measure the impedance of some other two terminal device such as an inductor or loudspeaker, connect it in place of the capacitor in figure 12. Choose the resistor to be larger than the maximum impedance of that component. Then, in effect, the device is driven by a constant current and the voltage across the device is proportional to its impedance.

The display of figure 13 is the amplitude and phase response of a small 1:1 audio transformer. The primary was driven by the generator and connected to Channel A. The secondary was connected to Channel B.

Notice that the amplitude response rolls off below 20Hz and exhibits very substantial peaking around 300kHz. (This shows up as ringing in the square wave time-domain response.) The transformer midband phase response because the transformer primary and secondary are deliberately wired out of phase. The jump in the phase response from $-180°$ to $+180°$ is correct: plus or minus 180 degrees is the same physical result.

- Two slide controls set the start and finish frequency
- A third slider sets the *frequency step*. The frequency step is the amount by which a frequency is to increase to create each new measurement frequency. Or, put another way, it's the ratio between two adjacent measurement frequencies. The frequency step multiplies by a factor (rather than adding a constant factor) because the frequency scale is logarithmic.

  The network analyser frequency labels can be viewed in fixed-point or scientific notation. This is selectable under the `View` menu.
- A fourth slider sets the signal amplitude.
- The *Oscilloscope Display* window shows the input and output waveforms, which should be sine waves. If the signals show clipping, reduce the signal amplitude.
- The *Start* button initiates a frequency sweep. Sweeping is slow at low frequencies and speeds up as the frequency increases.
- The display autoscales, that is, tries to select a scale that just fills the display.
- The amplitude dynamic range of the VNA is in excess of 50db. The VNA automatically adjusts the input signal attenuators of the oscilloscope section to obtain the best possible signal-noise ratio without clipping. It also uses the full 10 bit range of the oscilloscope A/D converters. In the frequency response plot of figure 13, the amplitude and phase plots become erratic at high frequencies. This occurs because the output signal from the low pass filter is extremely small in that region.
- The amplitude and phase information may be saved to a `.csv` format data file (which can be loaded into Matlab or a spreadsheet). With the VNA operational, select `Tools -> Export Waveform (CSV)`.

9.1 Phase Display

When the phase is close to the top or the bottom of the display, small phase changes can cause it to *jitter* in an annoying fashion from one limit to the other. For a signal that changes over a wide range of phase, this cannot be entirely prevented. However, it can be reduced by adjusting the vertical scale of the phase display.

By default, the phase display ranges from $+180°$ to $-180°$, with $0°$ in the centre. To change this, place the cursor in the phase plotting area and right click. A menu appears allowing the selection of a different phase display arrangement: $+360°$ to $0°$, for example.

9.2 Linear and Narrow Band Sweep

It is possible to set the analysis to a narrow range of frequencies to characterize narrow-band filters and piezoelectric crystals.

- Click on the numeric readout for `Start Frequency`. An entry window appears. Enter the starting frequency, in Hz.
- Click on the numeric readout for `End Frequency`. An entry window appears. Enter the ending frequency, in Hz.
- Click on the numeric readout for `Frequency Step`. An entry window appears. Enter the amount by which the frequency increases for each measurement. (This value must be greater than the minimum frequency step for the waveform generator, which is 0.1Hz.)
- Both Logarithmic and Linear sweep will work, but the Linear Sweep setting allows more precise control of the display range. Select `Linear Sweep` to precisely set the display frequency span to the previously entered Start and End frequencies.
- Select the maximum amplitude range.
- Press `Start` and the analysis will proceed.

If the sweep range is substantially outside the passband of the filter, the VNA may complain about insufficient signal. In that case, change the sweep range to start and end on the skirts of the filter.

9.3 VNA Theory

More information on the theory of the vector network analyser is in the Syscomp Application Note *A Software-Based Network Analyser* at `http://www.syscompdesign.com/na-theory.pdf`.

10 Rear Panel Connector

The rear panel connector provides access to the following signals:

- Digital outputs 0 through 7
- Digital inputs 0 through 7
- External trigger output
- PWM (Pulse Width Modulated) output
- External trigger input
- Ground

The pinout is shown on the case label of the instrument and in figure 14 below. These functions are described in section 7 above.

10.1 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
Active-Tech price: \$0.38
```

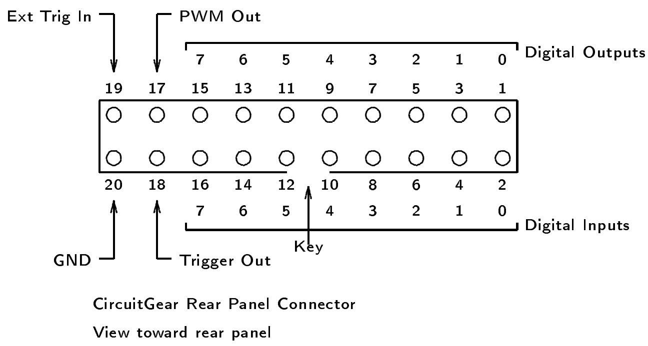


Figure 14: CGM Mini Rear Panel Connector Pinout

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
Digikey price: \$0.69
```

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
Digikey price: $7.50
```

The installation of an IDC connector onto flat cable is described here:
`http://hubbard.engr.scu.edu/embedded/guide/ribbon/`

Socket-Pin or Socket-Socket Lead

Another connection device that is very handy is the socket-pin lead. This consists of short length of wire with a socket at one end and a pin at the other. The socket fits exactly onto one of the pins of the Mini rear panel connector. The pin plugs nicely into a protoboard.

A similar lead has sockets at both ends of the wire: one end can connect to a Mini rear panel connector pin, and the other to a header pin on a PC board.

Both types of leads are available from Creatron in Toronto: `http://www.creatroninc.com/`.

11 Safe Measurement Technique

These notes are included for the benefit of those who are new to using an oscilloscope. The information is not unique to this oscilloscope, but applies to most oscilloscope measurement instruments.

Rather than simply state rules and prohibitions, we explain why certain procedures are dangerous and why some techniques should be avoided. This information is provided for guidance in using the oscilloscope and is not intended to replace proper training in working around high voltage circuits.

In general, this oscilloscope may be used safely to observe signals in low-voltage circuits where the power supply is *floating* from the AC line.

11.1 Floating Power Supply

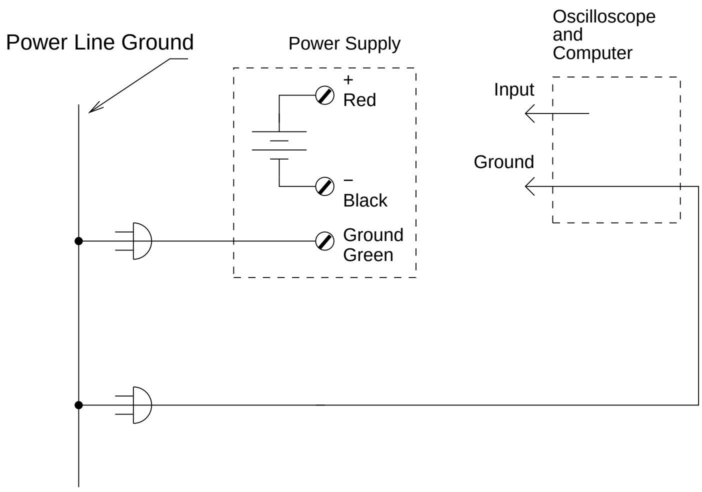


Figure 15: Floating Power Supply

In this context, *floating* power supply is one in which neither terminal is connected to the power line ground.

Consider the circuit shown in figure 15. Like many lab power supplies, the power supply has three terminals: positive, negative and ground. The ground terminal is connected to the third prong on the line cord, which connects to the power line ground wire.

The oscilloscope has two connections: the *input* terminal and *ground* terminal. On the front panel BNC connector, the inner contact is the input, the outer ring is ground. The ground connector finds its way to the AC ground line via the third prong on its line cord.

As shown in figure 15, *either* lead on the oscilloscope can be safely connected to the positive or negative terminal of the power supply. With proper care to avoid short-circuits of the power supply, this is a safe measurement situation.

11.2 Grounded Power Supply

Now consider that the negative terminal of the power supply is connected to its `Ground` terminal, as shown in figure 16.

If the ground terminal of the oscilloscope is connected to the ground terminal of the power supply, then the circuit is in no danger and will work properly. However, **if the ground terminal of the oscilloscope is inadvertently connected to the positive terminal of the power supply, then the power supply will be connected to a short circuit. The power supply short circuit will drive current around the ground connections of the power supply and oscilloscope.** Since lab power supplies are usually current limited to less than an ampere of current, the equipment will likely

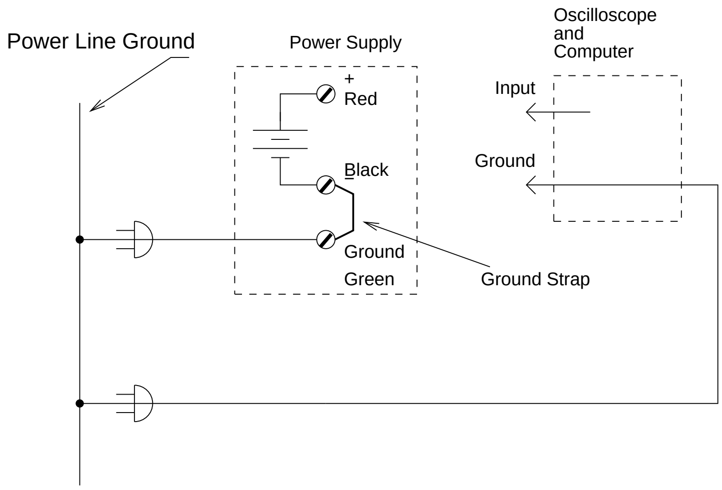


Figure 16: Floating Power Supply

survive. However, the circuit will not function properly because the power supply is in a short-circuited condition.

To avoid this situation, **do not connect the positive or negative terminal of the lab power supply to the ground terminal. Leave the supply floating.**

11.3 Battery and AC Adaptor Power Supplies

If batteries are used to power the circuit under test, the problematic situation of section 11.2 is not likely to occur, because batteries do not normally have a ground connection to the AC line[4].

An *AC Adaptor* is essentially a small transformer coupled DC power supply. These are usually supplied with a two-prong line cord, so there is no ground connection to the AC power line ground. The supply is floating so the problem of section 11.2 cannot occur.

11.4 Russian Roulette and AC Line Voltage

The unsafe situation of an oscilloscope being used to measure AC line voltage, is shown in figure 17. The AC line consists of three connections: the *hot* line, the *neutral* line, and the *ground* wire. For safety reasons, the neutral and ground are connected together and to an earth ground at the system AC distribution panel. The hot and neutral line carry load current in the system – normally the ground wire does not carry any current. Because the neutral is carrying current and because the neutral wire has resistance, at any given point in the system there likely will be a small voltage difference between the neutral and ground wires.

If the ground wire of the oscilloscope is inadvertently connected to the *hot* wire of the AC line, an extremely large short circuit current will flow through the ground connection. Eventually, a circuit breaker will open, a fuse will blow, or the short-circuit current will destroy a conductor. However, until that occurs, the short circuit current can be in the order of hundreds of amperes. This current will destroy the oscilloscope and computer, and the resultant flaming debris may cause injury to nearby living organisms, including humans. It may also start a fire.

Furthermore, connecting the ground lead of the oscilloscope to the AC neutral line causes another problem - it effectively connects the neutral and ground AC lines at that point. Now the neutral current has another path, and some of it will flow through the oscilloscope and computer ground leads. If this current is sufficient, it may damage the oscilloscope and computer.

[4]The disadvantages of batteries are (a) they run down and (b) they are not current limited. A short circuited battery can do significant damage.

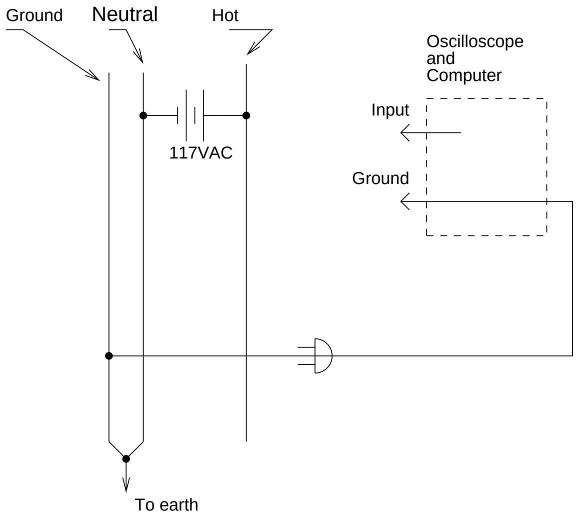


Figure 17: AC Line Voltage

Notice that *this same situation can occur with equipment that is not transformer isolated from the AC line.* For example, some electronic equipment has a direct connection to the AC line, so that the chassis is connected directly to the neutral line of the AC system. To safely observe the signals in this device with an oscilloscope *the equipment must be isolated from the AC line by a transformer.* The transformer must function as an *isolation transformer*, the secondary winding must not have an electrical connection to either of the primary leads, and the transformer must consist of a separate primary and secondary winding.

An *autotransformer* (common trade name *Variac*) is an adjustable transformer that is often used for adjusting line voltage. An auto transformer does *not* have an independent secondary winding and cannot be used to isolate electronic equipment from the AC line.

11.5 Removing the Ground

The potential for a short circuit is reduced if the ground connection is removed from the computer. However, this is extremely dangerous because metallic connections on the computer (such as the shell around a connector) are connected to the ground line. A connection to the AC line puts those metallic points at line potential, presenting a serious shock hazard to the user and possible short circuit if attached equipment is grounded.

The AC ground connection (the 'third prong' on a plug) is there specifically to prevent the chassis of the equipment from assuming a potential that is above ground, and therefore dangerous to a human operator. Removing that ground connection removes any grounding protection. This is a serious violation of health and safety regulations.

Similarily, a battery-powered laptop computer, when disconnected from its line-operated charger, is not connected to the ground line of the AC power system, so it is less likely to cause the kind of short circuit described in the previous section. However, it is extremely dangerous to rely on this. The laptop may itself become live at the AC line potential, which makes it hazardous to the operator and any attached equipment (such as a line-operated video monitor).

11.6 Observation of AC Line Voltages

If you must observe line voltage, here are the rules:

- The oscilloscope must be able to cope with the peak value of the input AC voltage. The Syscomp DS-101 is certified to reliably accept up to 50 volts on its input terminal.

  A *times-ten* oscilloscope probe increases this by a factor of ten. It is absolutely essential to use a probe that can withstand this voltage, and it essential to ensure that the probe cannot inadvertently be switched to a *times-one* setting.

  Notice that the peak value of a sinusoidal voltage is 1.41 times the RMS value. So a 117VAC line voltage will peak at around 170 volts.

- There must be no direct connection to the AC line. If the equipment is line operated, then it must be powered by an isolation transformer (see above).

- It is possible to obtain electronic probes that provide an *isolation barrier* between the line circuit and the oscilloscope. For example, the measurement signal is transferred from the AC line side to the oscilloscope side by means of an optically coupled circuit. There is no electrical connection between the oscilloscope and the AC line. The signal is transferred over a beam of light. This method removes all possibility of short-circuiting the line voltage to ground. See for example `http://www.powertekuk.com/`.

12 Adjustments

The oscilloscope has been adjusted before shipping, so it should not need adjustment before use. These instructions are provide for reference purposes.

12.1 Input Compensation Capacitors

The schematic of the input circuitry of the oscilloscope vertical preamplifier is shown in figure 18.

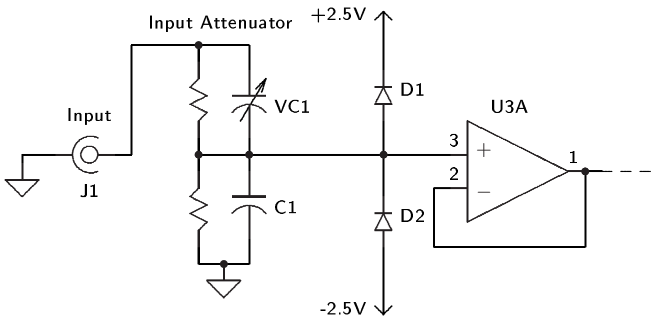


Figure 18: Scope Input Compensation Network

The two channels are identical.

Stray capacitance at the output of the voltage divider has the potential for limiting the bandwidth. To make the divider frequency independent, the resistive divider R1, R2 is accompanied by a capacitive voltage divider VC1, C1. The capacitive divider must be adjusted to have the same division ratio as the resistors. This is accomplished by adjusting VC1.

To do so, remove the circuit-board from its plastic case. Connect it to the computer via its USB cable and start the host software. Apply a square wave input signal to one of the scope channels. Adjust the magnitude of the square wave such that it makes a suitable display. Adjust the oscilloscope timebase such that the leading edge of the square wave is visible.

The two variable capacitors are relatively large, square components that rise above the other components on the board. (The current versions have orange casings.) On the current design they are designated C61 for Channel A and C81 for Channel B. Locate the variable capacitor on the circuit that corresponds to the input channel with the signal. With a tiny screwdriver, adjust that variable capacitor until the square wave shows the fastest possible rise time without overshoot. It is best to use a screw-driver with an insulated shaft because a non-insulated screwdriver will connect human body capacitance into the circuit which affects its operation. If the screwdriver is not insulated, make an adjustment and then remove the screwdriver to see the effect.

Repeat the same procedure with the second oscilloscope channel.

Reassemble the unit back in its case.

If you are using a x10 oscilloscope probe, the input capacitance of the scope channels will have changed slightly. You will need to adjust a x10 probe for best square wave response.

If the probe is a x1 x10 switchable unit, ensure that the probe is switched to the x10 position. Attach it to one of the channels. Connect the probe to a square wave source, such as the CGM-101 generator output. Find the compensation adjustment screw on the scope probe. In the economy probes we sell, the screw adjust is red and located in the base of the probe cable, near the BNC connector. In the professional probe we sell, the screw adjust is yellow and located in the probe, near the handle. Adjust this screw for best square wave response.

13 Instrument Commands

These commands are low-level instructions to the scope hardware. The commands (and where relevant, messages back from the hardware) are ASCII strings so that they can be generated easily by software or a human operator.

There are two situations where the interface commands may be useful.

- The scope hardware may be operated directly from a terminal emulator program such as `Hyperterminal` under Windows, `Minicom` or `Seyon` under Linux.
- Knowing the commands allows one to create a scope control program with different functionality. For example, a program could be created to read the oscilloscope and plot the results on a strip-chart type of display.

  Should undertake such a project, the Tcl source code for the Oscilloscope GUI, which is included in the install files, will be a useful source of ideas in controlling the scope.

  There is no requirement that the controlling program be written in the Tcl language. Any program that can issue ASCII strings to a serial port will be capable of controlling the scople hardware (eg `Matlab`, `Visual Basic`).

13.1 Using the Debug Console

When you send a command to the scope, it does not echo any confirmation back to the host terminal. This is because you are doing with the terminal exactly what is done with a control program, and responses from the scope would slow down the overall operation of the system.

Each command consists of an ascii string of characters, such as T55`<cr>` to set the trigger level to 55, where `<cr>` is a carriage return character.

If you are running under a Windows operating system, in addition to the material in the user manual, you can see commands being sent to the oscilloscope by selecting

```
View -> Debug Console.
```

This brings up a terminal screen which lists commands as they are being sent to the scope hardware, and some other debug information.

If the operator starts the program from a terminal window, executing a command like `wish main.tcl`, then the terminal window becomes the console.

This information scrolls past rather quickly when the scope is in auto trigger mode, because it is repeatedly obtaining data from the hardware. To slow this down, put the scope in 'Manual Trigger' mode. Now each time you hit the 'manual trigger' button, the debug screen will show the commands that were sent to the scope hardware.

Now you can change control settings on the scope GUI and see the corresponding commands as they are sent to the scope hardware. For example, move the trigger level cursor on the scope screen and you will see a series of trigger level commands being sent to the hardware. Similarily, changing the vertical preamplifier gain settings to show the corresponding hardware commands.

Regarding the oscilloscope operation: For normal triggering, the host PC issues a request for an update. When a trigger occurs, the hardware acquires the waveform and sends it to the host. The host receives it on an asynchronous basis, using the `fileevent` command. That command then processes the data.

Debug Level

If you'd like to see more detail of the commands being sent to the hardware, you can turn on a debugging flag in the software. Here's the way to do that on a Windows system:

- Open the source file directory, which is something like

  `C:\Program Files\Syscomp\CGR101-1.17\source`

- Load the file `main.tcl` into notepad
- find the line (near the beginning of the file) that says `set debugLevel 0`
  Change this to `set debugLevel 1`
  Save the file
- Run the Syscomp software. Select the menu item `View -> Debug Console`.
- A new window will appear, which shows the commands being sent to the scope. The scope is on `Auto` triggering by default. Change this to `normal` triggering to stop the scrolling.

  The window shows only commands being sent to the scope, not the data being returned. If you need that, modify the source code with print statements for the quantities of interest.

14 Manual Operation

The oscilloscope may be operated by sending it commands from a terminal emulator. If you are creating new software to control the hardware this can be useful for debugging.

14.1 Windows

The `Hyperterminal` program that is supplied as part of Windows operating systems (previous to Win 7) is suitable for this.

1. To simplify matters, it is probably best to unplug any USB devices that are connected.
2. Plug the scope hardware into a USB port on the computer.
3. Using the steps described in section 18.2.1, determine the COM port that the scope is currently connected to.
4. Start Hyperterminal:
   Start -> Programs -> Accessories -> Communications -> Hyperterminal
5. Hyperterminal starts with a 'Connection Description' popup window. Cancel the popup.
6. Select File -> Properties
7. Operate the `Connect Using` menu to select the COM port that you found previously.

8. Select `Configure` which pops up a `Port Settings` window. Most of the port settings can be left at their default values, but the baud rate (`Bits per Second)` must be changed to the correct value. At this time, the correct value is 230400. The correct port settings are:

Bits per Second:	230400 Baud
Data bits:	8
Parity:	None
Stop Bit:	1
Flow Control	,Hardware (RTS/CTS) Handshaking

   If you have a version of the scope Tcl program that works correctly with the scope hardware, you can verify the baud rate. Load that code into a text editor and look for the baud setting. Search for a variable `baud` or a procedure `openSerialPort`.

   Hit `OK` and back out to the hyperterminal screen.

9. Issue some command from the list in section 13. Type it in followed by the 'Enter' key. A good choice is `i`, which should result in a message from the scope indicating its version number.

14.2 TeraTerm: An Alternative to Hyperterminal

The `Hyperterminal` terminal emulator is not available with the Win 7 operating system. TeraTerm is an open-source alternative, and it's somewhat less confusing to use than Hyperterminal. To use TeraTerm:

1. Download and install the TeraTerm software from Sourceforge:
   `http://en.sourceforge.jp/projects/ttssh2/releases/`
   This should create a TeraTerm icon on your desktop.

2. Plug in the CGM-101 hardware to an unused USB port.

3. Start TeraTerm. The 'New Connection' window appears. 'TCP/IP' is selected by default. Change the selection to 'Serial'.

4. On that same window, select 'Port'. In this case, it shows `COM3` and `COM5: USB Serial Port`. For example, if we know the CGM-101 is connected to COM5, select COM5. Click on OK. Window closes.

5. Select the menu item `Setup -> Serial Port`
   The port has been selected, no need to change that.
   Set the Baud Rate to `230400`.
   Set Data Bits to `8`.
   Set Stop Bits to `1`
   Set Parity to `None`
   Set Flow Control to `Hardware`.
   Click on OK. Window closes.

6. Select the menu item `Setup -> Terminal`
   Change the New-line Receive to `CR+LF`
   Change the New-line Transmit to `CR+LF`
   Click on OK. Window closes.

7. In the main terminal window, type the letter `i` followed by the `Return` key. You should see a message something like `*Syscomp Advanced Waveform Generator V1.0/1.0`.
   If so, you are now connected and can issue commands to the generator. Notice that all commands are terminated by the Return key.

14.3 Linux

For manual operation under the Linux operating system, you will need to communicate with the hardware using a *terminal emulator* program. There are two terminal emulators in common use under Linux: `seyon` and `minicom`. These may not be installed as part of your linux distribution. To check whether the program is installed, use the `which` command:

```
phiscock@panther:~> which seyon
/usr/X11R6/bin/seyon
```

Seyon must be properly configured to be used. This is described in the document *Seyon: Quick Start Guide*, available for download here: `http://www.ee.ryerson.ca/~phiscock/papers/using-seyon.pdf`.

Information on using `minicom` may be found at the following location:

Using Minicom and Seyon
Chapter 11 of *Learning Debian GNU/Linux*
Bill McCarty
O'Reilly Books, 1999
`http://www.oreilly.com/catalog/debian/chapter/book/ch11_07.html`

1. Plug the scope hardware into a USB port on the computer.
2. Run the command `dmesg` to identify the serial port that the is allocted to this USB device. It may be a few seconds before the operating system finishes its allocation, so run dmesg repeatedly until you see the serial port number, which will be something like `\ttyUSB1`.
3. Start the terminal communications program (Seyon or Minicom):
4. Set the port settings to:

Bits per Second:	230400
Data bits:	8
Parity:	None
Stop Bit:	1
Flow Control	Hardware

   If you have a version of the oscilloscope Tcl program that works correctly with the scope hardware, you can verify the baud rate. Load that code into a text editor and look for the baud setting. Search for a variable `baud` or a procedure `openSerialPort`.

5. Issue some command from the list in section 13. Type it in followed by the 'Enter' key. A good choice is `i`, which should result in a message from the oscilloscope indicating its version number.

   Now you can type in other commands.

15 Modifying and Running the Source Code

15.1 Preparation for Modifying the Software

The software for the Syscomp instruments is written in the Tcl/Tk language. The source code is *interpreted*, which means that there is a *Tcl language interpreter* program present that executes the Tcl source code. Consequently, you can modify the operation of the program by modifying the source code, which we provide.

We provide as the install an executable which is machine specific (ie, there are Windows, Linux and Mac versions) which contains the Tcl interpreter and libraries necessary to run the source code. The easiest development process is to use that executable to run the source code.

If you want to change the operation of the code, then make a safety copy of the relevant Tcl source code file and edit the source code Tcl file with any text editor.

You can also run the source code without that executable, by executing the command 'wish main.tcl' (or it's equivalent on your machine) in the source code directory. If that causes errors, the first thing to do is to download the latest version of Tcl from the Activestate website: `http://www.activestate.com/`. Then try again.

If there are further error messages concerning the BWidget or Img package, you'll need to download those as well, using these commands:

teacup install –with-recommends BWidget

teacup install –with-recommends Img

At that point, it should be possible to run 'wish main.tcl' and make the graphical user interface appear.

15.2 Modifying the Software

The host software for the scope (and other Syscomp instruments in this series) is released in plain text format under the GPL (Gnu Public Lincense). Consequently, it is legal to modify the program in whatever way you may find useful. We also encourage you to share your work with others.

The program itself is in text form. The code does not need to be compliled or linked, it is executed directly from the text form by the `wish` interpreter.

Although the scope program is fairly complicated, it is possible to create a powerful Tcl/Tk program, with a sophisticated user interface, with only a few lines of Tcl/Tk code.

To set up for development, ensure that the `wish` interpreter is installed on your computer. Under Linux, it is probably already there. Under Windows, you need to download and install a file from the ActiveState website:
`http://www.activestate.com/Products/languages.plex?tn=1`
Download the appropriate .exe file for your operating system. Run the program to install Tcl/Tk.

Make a copy of the original code, of course, and put it in a safe place. Then, using a text editor, read and modify the existing code. When you want to test the code, run the `wish` interpreter. Execute the `source` command with the name of your file, and the program will execute. Repeat this cycle until you have the desired result.

We'd like to hear about your work. Check out our web page for the latest contact information.

16 Installation Overview

The installation should work correctly under modern versions of Windows, Linux and Macintosh operating systems. Installation only needs to be done once: thereafter, the program can be started by double-clicking on an icon.

16.1 Windows

Download the Windows setup executable from our website, `www.syscompdesign.com/downloads`. Run it. Everything (including driver install) is automatic.

16.2 Linux

Download the Linux zip archive from our website, unzip it into a folder of your choice (where you have permissions). Run either the `Install-Linux-32-bit.sh` or `Install-Linux-64-bit.sh`.

You may need to change the permissions on those files to get them to execute. As superuser, run:

chmod 777 <file name>

16.3 Macintosh

Download the DMG image from our website, `www.syscompdesign.com/downloads`. Open it. First, drag the CGR-MINI icon into the Applications shortcut in the DMG. Then run the driver installer in the DMG.

As of August 2012, Apple has added a `GateKeeper` function to OSX Mountain Lion and subsequent operating systems. Gatekeeper prevents installing the Syscomp software and generates a `Defective Software` message. You'll need to disable Gatekeeper while doing the download and install. A Google search for 'OSX disable gatekeeper' will show the necessary instructions.

Gatekeeper should be re-enabled once the installation is completed and it is verified that the software is operational.

16.4 First Time Operation

These instructions apply to all operating systems: Windows, Linux and Mac.

1. Using the supplied USB cable (or similar one of your own choosing), plug the oscilloscope into a computer USB port. If you have more than one USB port, you can chose any port.

2. The green LED on the hardware unit should illuminate. (Under Windows the computer will make its USB boing noise.)

3. On Windows and Mac machines there should be a Syscomp icon on the desktop. The exact name will vary, but it should be something like `Syscomp CircuitGear`. Start the oscilloscope program by double clicking on this icon. On a Linux machine, run the executable

4. A screen `Unable to Connect to Device. Examine Connection Settings?` appears. Click on `Yes`.

5. The `Port Settings` control panel appears. Click on `Autodetect`.

6. The program scans through the available COM ports, 1 through 99.

7. If it finds an available port, a notification screen will pop up saying something like `CGM-101 found on COM6`.

   If it does not find an available COM port, try clicking on `Autodetect` again. If this also fails, you'll need to set the COM port manually.

8. Assuming that the system finds an available COM port, click on `OK`. A `Port Settings Listing` window shows a list of the unavailable COM ports and the one that was found. Click on `Back`

9. The Port Settings control panel shows which port has been selected. Click on `Save and Exit`. This causes a small text file `scopeport.cfg` to be written to the directory where the scope program was launched. This file contains the connection port number.

10. At this point, the `Connected` indicator at the top of the GUI screen show show a green colour. The unit is operational.

From now on, whenever you double-click the program icon, the program should start and automatically connect.

17 Installation Details

In this section we provide more detail of the installation procedure.

17.1 Windows Installation

The installation procedure unpacks and installs the Syscomp Graphical User Interface (GUI) program that interacts with the hardware. It also install two Future Technology Devices International (FTDI) virtual COM port (VCP) drivers necessary to communicate with the hardware.

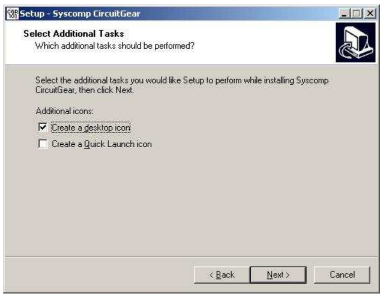
Screen shots of the install procedure are in figure 19 on page 37.

1. Point your browser at the Syscomp web site, `www.syscompdesign.com`.
2. Navigate to the `Downloads` section of the website. Download the software for a Windows operating system installation. When the software download completes, find the downloaded file. Execute that file by double-clicking on it.
3. After a brief pause, the screen of figure 19(a) appears. Click `Next`.
4. The screen of figure 19(b) appears. Click `Next`.
5. The `Select Start Menu Folder` of figure 19(c) appears. Click `Next`.
6. The `Select Additional Tasks` screen of figure 19(d) appears. We recommend enabling `Create a Desktop Icon`. Click on `Create a Desktop Icon` until a check mark appears next to it. Click `Next`.
7. The `Ready to Install` screen of figure 19(e) appears. If you are satisfied with the install directories, click on `Install`. Otherwise, click `Back` and revise the necessary entries.
8. The `Installing` screen and progress bar of figure 19(f) appears. Wait while that completes.
9. The `USB Device Driver` install screen of figure 19(g) appears. Click `Next`.
10. The `Installing drivers` screen of figure 19(h) appears.
11. The `Congratulations! You are finished installing drivers...` screen appears, figure 19(i). Click `Finish`.
12. The `Completing the Syscomp Setup Wizard` screen appears, figure 19(j). Click `Finish`.
13. The software is installed.

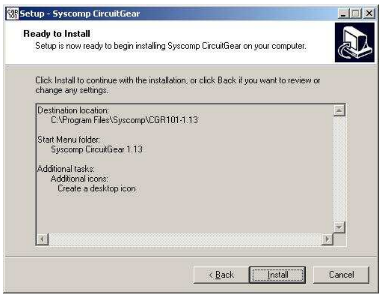
(a) Welcome to Setup Wizard

(b) Select Destination

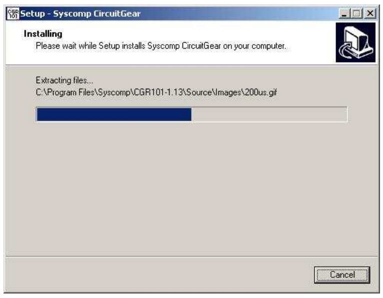
(c) Select Start Menu Folder



(d) Additional Tasks



(e) Ready to Install



(f) Installing

(g) Welcome to Driver Install

(h) Installing Drivers

(i) Finished Drivers

(j) Completing the Install

Figure 19: Windows Installation Screens

17.2 Macintosh Install

This section describes how to install Syscomp instruments on a MacBook running OSX. These instructions describe a 'one button' procedure for software version 1.13 and following.

You may also wish to check section 18.4 on page 54, which describes setup for a Mac-equipped multiple station lab.

17.2.1 Checking the Host Machine

The Syscomp software is interpreted by the Tcl/Tk language interpreter, so it is essential that the machine is capable of running Tcl/Tk.

The ActiveState website (originators of Tcl/Tk) indicate that Tcl/Tk should run correctly on platforms with 'Mac OS X 10.2+'. There is no mention of requirement for Intel or Power PC processors [5].

The first step is to determine that the computer is capable of running this software. To do that:

1. Click on the Apple icon in the top left corner of the screen.
2. Select 'About this Mac'

For example, on the local Mac machine the Mac information is:

- Mac OSX 10.5.6
- 2.4GHz Intel Core 2 Duo
- 2GB 667MHz RAM

The key items are that the operating system is OSX and it's version is later than 10.2. So the software should run on this machine.

17.2.2 Installing Software

As of August 2012, Apple has added a `GateKeeper` function to OSX Mountain Lion and subsequent operating systems. Gatekeeper prevents installing the Syscomp software and generates a `Defective Software` message. You'll need to disable Gatekeeper while doing the download and install. A Google search for 'OSX disable gatekeeper' will show the necessary instructions.

Gatekeeper should be re-enabled once the installation is completed and it is verified that the software is operational.

1. Start the Mac.
2. Plug in the Syscomp CGM-101 hardware. The green LED on the hardware should illuminate.
3. Point your browser at the Syscomp web site, `www.syscompdesign.com`.
4. Navigate to the `Downloads` section of the website. Download the software for a Windows operating system installation. When the software download completes, find the downloaded file. Execute that file by double-clicking on it.
5. The CGM-101 icon appears on the desktop. Open it.
6. Open `setup.htm`.
7. Click on `Click here for the DMG installer`.
8. Open `CircuitGear.dmg`

[5] `http://www.tcl.tk/software/tcltk/platforms.html`

9. A screen appears on the desktop, showing the Applications folder and the Syscomp CircuitGear unit. Drag and drop the Syscomp image onto the Applications folder. A progress bar appears and completes.

10. Go to the Applications folder:
`Finder -> Macintosh HD -> Applications`.

11. Find the entry for the Syscomp CircuitGear. Double click on it. The CGM-101 GUI should appear. It will probably show 'Not Connected' in red. A dialog box will pop up saying 'Examine hardware settings?'. Click on Yes.

12. Examine the hardware settings. Select the entry that says `cu-usbserial-xxxx` where `xxxx` is some serial number. The gui indicator should turn green and show `Connected`.

    If the GUI does not connect, exit from the gui. Unplug the CGM hardware and plug it in again. Restart the GUI and this time the hardware should connect properly.

13. The program should indicate `Connected`, some activity should be visible on the scope trace, the red LED on the scope hardware should flash. The unit is operational.

17.2.3 Installing Driver

In order to connect, the USB-Serial driver must be installed on the Mac. On some machines, this is in place without further intervention. However, if you followed the previous steps and the hardware still will not connect, you may have to download and install the driver.

1. Point your browser at this website:
`http://www.ftdichip.com/Drivers/VCP.htm`
This is the website for the FTDI 'Virtual Com Port (VCP) driver that is needed.

2. Find and click on the driver that corresponds to your operating system (Mac OSX) and processor type (x86 or x64). At the time of writing, the same driver (2.2.17) applies to both types of processors. Click on that driver number. A window will open, allowing you to download the driver.

3. You should now have a `.DMG` version of the driver on your desktop. Double click on that file to run it. This will install the driver.

4. When that completes, restart the Syscomp GUI software as you did before:
Go to the Applications folder:
`Finder -> Macintosh HD -> Applications`.

5. Find the entry for the Syscomp CircuitGear. Double click on it. The CGM-101 GUI should appear. It will probably show 'Not Connected' in red. A dialog box will pop up saying 'Examine hardware settings?'. Click on Yes.

6. Examine the hardware settings. Select the entry that says `cu-usbserial-xxxx` where `xxxx` is some serial number. The gui indicator should turn green and show `Connected`.

    If the GUI does not connect, exit from the GUI. Unplug the CGM hardware and plug it in again. Restart the GUI and this time the hardware should connect properly.

7. The program should indicate `Connected`, some activity should be visible on the scope trace, the red LED on the scope hardware should flash. The unit is operational.

17.3 Linux Installation

1. Point your browser at the Syscomp website, `www.syscompdesign.com`. Navigate to the `Downloads` section. Download the file for the Linux operating system. Unzip that file. Move into the directory created by the unzip operation.

2. Change to the `Source` subdirectory. Copy all files and folders from the /Source directory to a suitable directory on your machine, for example:
`/home/yourname/Syscomp/CGM101`

3. Copy the appropriate binary file from the /Source/bin/ directory into the folder you selected *or* execute the appropriate shell script in the Source directory. For example:

   ```
   sh Install-Linux-32-bit.sh
   ```

   or

   ```
   cp /home/yourname/Syscomp/CGM101/bin/linux/linux_ix86/CGM101-linux-x86
                /home/yourname/Syscomp/CGM101/
   ```

   (The above command should be executed on one line.)

4. Execute the binary executable to start the software. For example, use these two commands:

   ```
   cd /home/yourname/Syscomp/CGM101
   ./CGM101-linux-x86
   ```

17.3.1 Hardware Installation

1. Plug the hardware device into an available USB port.

2. Run the program `dmesg` to show which serial port the instrument has been attached. For example, `/dev/ttyUSB0`.

3. Start the binary executable (the `GUI`, Graphical User Interface) as described above.

4. On the GUI, use the `Hardware-->Port Settings` menu in the instrument software GUI to manually connect to the serial port we found using `dmesg`, eg, `/dev/ttyUSB0`.

5. The GUI should indicate `Connected` and the oscilloscope trace should show activity.

Note that currently, Linux assigns USB serial ports in the order in which the instruments are plugged in. You may have to manually reassign the port settings in the GUI intrumentation software if multiple usb-serial devices (such as Syscomp Instruments) are used simultaneously. Use `dmesg` each time you attach an instrument to the computer to determine its serial port assignment.

17.3.2 Optional: Running the GUI from Source

You can execute the source code directly using the Tcl interpreter `wish`. See section 15 on page 33. For information on the Tcl language, see the application note on the Syscomp website, `Hello Button`.

18 Troubleshooting

18.1 Overview of USB Operation

In general, the operation of the USB connection is seamless and invisible to the user. Operation of the oscilloscope is usually as simple as plugging it in to an USB port and running the oscilloscope GUI software. However, it may be useful to understand some of the details.

The USB interface uses a USB-Serial chip FT245BM from FTDI. This chip, with the appropriate driver software on the host PC, emulates a serial port. Consequently, the Tcl/Tk GUI software can access the hardware just as if it was accessing a device connected to the host serial port. This is orders of magnitude simpler than dealing with USB, which is extremely complicated. We refer to this as a `USB-serial` interface.

The `USB-serial` has major advantages over the traditional serial port. First, the data transfer rate is much faster (especially using the USB2.0 standard). Furthermore, power is transmitted from the host to the hardware over the USB cable so that an AC adaptor is not needed. Third, the USB system handles enumeration automatically so that multiple devices are accessed correctly without manual configuration.

- Under Windows, the FTDI `USB-serial` drivers are automatically loaded by the `Install` program, so the user should not normally be required to intervene.

  Thereafter, the operating system always associates that hardware with that serial port, even if it is plugged into a different USB port.

- Under Linux, the FTDI driver is included in the Linux kernel since 2.4, so it does not need to be installed under Linux. The assignment of the USB-Serial port depends on the order of connection of devices. If you are just using one USB-Serial device, then the same port will be assigned each time. If you are using multiple USB-Serial devices (which, in general, will work correctly), then you will need to plug in each device, one at a time, and run `dmesg` to determine the port assignment.

  In Linux, the default permission of the `/dev/ttyUSBx` ports is set for root access only, so the permissions must be changed as described under 18.3. (The `x` in `/dev/ttyUSBx` represents a number for a ttyUSB port, something like `ttyUSB0` or `ttyUSB1`, and so on.)

- Under Mac `OS-X`, the FTDI driver may or may not be present. If the Syscomp software will not connect to the hardware, the first step should be to download and install the appropriate driver from the FTDI website, at:
  `http://www.ftdichip.com/Drivers/VCP.htm`
  Notice that the same FTDI driver works for all versions of `OS-X`.

  In Mac `OS-X`, the assigned USB-Serial port is a device named `cu-usbserial-xxxx` where `xxxx` is some serial number Otherwise, the USB-Serial port assignment is similar to Linux.

18.2 Microsoft Windows

18.2.1 Manually Assigning a COM Port Number in Windows XP

It may be useful to know how to set the COM port manually.

For example, under certain circumstances, it is possible for the operating system to assign a low value COM port that conflicts with some other non-Syscomp device. COM values COM1, COM2 and COM3 are risky to use. Then, if the device is assigned to COM3, for example, and is not connecting properly, you should try moving it to another COM port number (such as COM9). (We know that certain Bluetooth devices have caused this problem in the past.) All COM port values up to COM99 should work correctly.

1. Plug in the problem instrument to a USB port.
2. Go to: Start -> Settings -> Control Panel -> System -> Hardware -> Device Manager
3. Double-click on `Ports (COM and LPT)`. This opens to show any USB-serial port assignments. Let's say that it shows `USB Serial Port (COM3)`. We decide to move this to COM9.

4. Double-click on the entry `USB Serial Port (COM3)`. This opens a new dialogue box, `USB Serial Port (COM3) Properties`.

5. Select `Port Settings` and click on `Advanced`.

6. This opens a new dialog box, `Advanced Settings for COM3`. In the upper left corner, there is a scrollbox `COM Port Number`. Use the up/down arrows to scroll through the possible COM port assignments.

7. For the new COM port assignment, it's best to choose a COM port number 4 or larger. (Lower numbers may conflict with a USB keyboard or mouse). Suppose we decide to move to COM5. The scrollbox says `COM5 (in use)`. Select it anyway. Click `OK`.

8. If a warning pops up that the COM port is in use and asks if you want to continue, it's safe to click on `Yes`.

9. Back out through the menues until you have closed the Device Manager panel. Re-open it and examine the `Ports (COM&LPT)`. This time it should read `COM5`.

10. Back out to a clean desktop and restart the instrument program. This time, it should connect properly.

11. If you are connecting multiple instruments, you may need to do this for each instrument. However, having once done the assignment for a given instrument, the operating system associates that instrument with the chosen COM port and connection should be automatic.

18.2.2 Checking the Installed Files

This section details how to determine that the files are installed correctly. This information is included here for completeness, but it should not be necessary to use it.

1. Double click on `My Computer` to obtain a screen like figure 20.

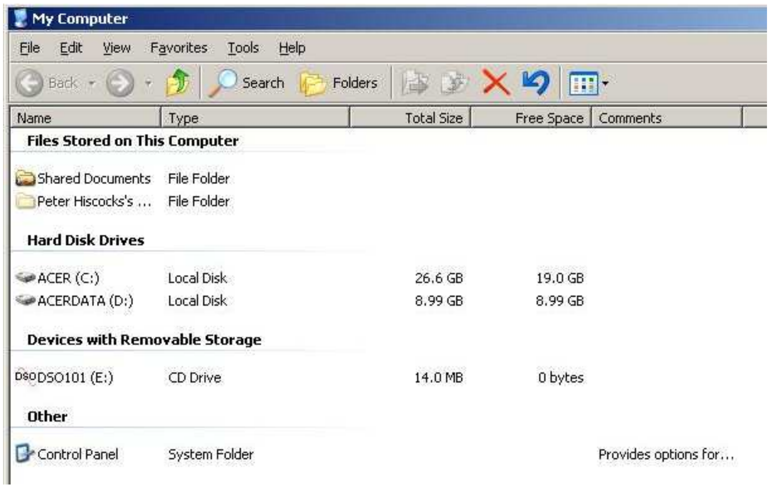


Figure 20: My Computer

2. Double click on `Control Panel`, obtaining a screen like figure 21.

3. Double click on `Add or Remove Programs`, obtaining a screen like figure 22.

   Figure 22 lists the FTDI drivers, so they are installed. Similarily, the Tcl/Tk program for the unit should be shown on the same list under `Syscomp`.

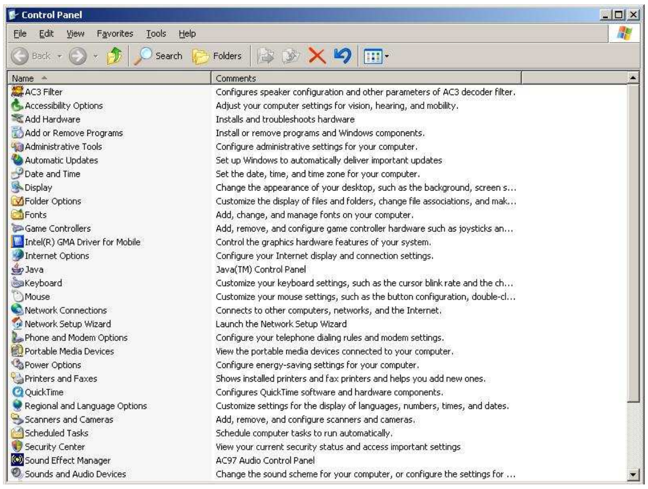


Figure 21: Control Panel

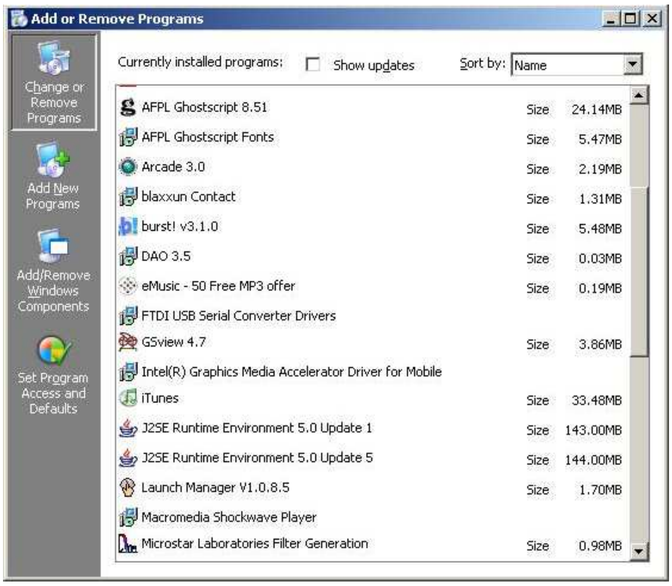


Figure 22: Add or Remove Programs

18.2.3 Obtaining Details of the USB-Serial Port

1. On the `Add or Remove Programs` list of figure 22, find the entry `System`. Double click on it to obtain the `System Properties` screen of figure 23.

2. Double click on the `Hardware` tab to obtain the `Device Manager` screen of figure 24.

3. Ensure that the hardware unit (DSO-101 oscilloscope, WGM-101 waveform generator, CGM-101 CircuitGear, CGM-101, etc) is plugged into a USB port.

   In the System Properties, Hardware panel of figure 24, there should be an entry `Ports (COM & LPT)`. Double click on that and it should open to an entry like `USB Serial Port (COM4)`.

   This specifies the COM port that should be selected in the Tcl/Tk program in order to communicate with the USB hardware unit.

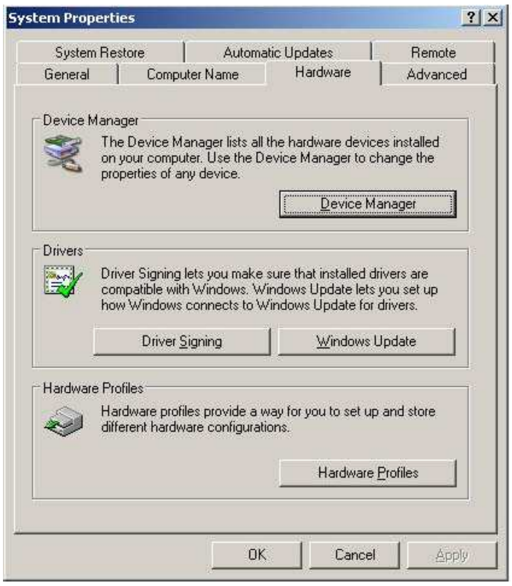


Figure 23: System Properties

18.2.4 Windows 7 Notes

The hardware and software will work correctly under 32 bit and 64 bit versions of Windows 7 operating systems. However, we have found that certain other serial-usb devices can interfere with the operation. These hints may help.

1. Open Device Manager and maximize the entry `Ports: COM and LPT`. Disable the devices that are shown there. We know that some Bluetooth devices and a certain Intel program (ending, appropriately, in the phrase SOL) can be problems. To disable a device, right click on the entry in `Ports: COM and LPT` and navigate to the point where you find a `disable` button.

2. Plug in the Syscomp hardware and verify that it appears as an entry under `Ports: COM and LPT`.

3. Start the GUI program by double-clicking the Syscomp CGM-101 icon on the desktop.

4. If the program announces that it cannot connect, use the port selection dialog to autodetect the port. If the port does not autodetect, then select some port manually. Select a high-ish number, something above 15 for example. The lower numbers tend to get used first. (It's not unusual for autodetect to fail and manual to work. Once the port is selected, you should never have to do that again.)

5. At that point, the device should connect. Now, if you need other devices, you can enable them one by one to find where is the conflict.

If problems continue, please take a screen shot of the expanded `Ports: COM and LPT` and send it to us and we will assist.

18.3 Linux

These troubleshooting notes are specific to Suse Linux 9.2, but should apply in general. They also assume a working knowledge of Linux and its variants.

Figure 24: System Properties, Hardware (Device Manager)

Overview

If the software does not operate correctly, here are some things to check. They are subsequently explained in detail.

- The operating system is too old and does not contain the necessary drivers for the usb-serial ports.
- The operating system for some reason is not recognizing the usb device and assigning it to a usb-serial port. This can occur if the usb device has `root` ownership and permissions. The permissions must be changed to allow a user-mode program to access the usb port.
- The operating system is assigning the hardware to some usb-serial port but the Tcl/Tk program is not automatically selecting that particular port. You'll need to select the usb-serial port manually, using the controls in the Tcl/Tk program.
- The `wish` program, which is the interpreter for all Tcl/Tk programs, is not being found by the operating system. Locate it and change your path so that it is found.
- The device is being recognized and connects properly, but does not respond properly to certain controls. Use the instructions in section 14.3 to send commands to the hardware to determine how it is functioning.

1. **Check the kernel version**.
   The drivers for the FTDI USB-Serial interface are a standard part of the Linux kernel from version 2.4 onward. To check that you have a sufficiently modern kernel, run the `dmesg` command piped to the `more` command.

   ```
   phiscock@panther: dmesg | more
   ```

Examine the first few lines, which should be something like this:

```
Linux version 2.6.8-24-default (geeko@buildhost) (gcc version 3.3.4 (pre
3.3.5 20040809)) #1 Wed Oct 6 09:16:23 UTC 2004
```

In this case, the kernel is 2.6.8-24, so it contains the FTDI drivers.

If your kernel version is older than version 2.4, you may have to upgrade the kernel or install a driver module.

2. **Install the software** per the instructions shown in section 17.3 on page 40.

3. **Determine the serial port used by the USB driver**. In this step, we'll use the `dmesg` command to determine which serial (COM) port is being assigned to the oscilloscope when it is plugged in.

   Execute `dmesg` to get an idea of the most recent kernel messages. Using the USB cable, connect the scope hardware to a USB port. Execute `dmesg` again, and you should see something like this as the last entry in the `dmesg` printout:

```
usb 4-2: new full speed USB device using address 4
usb 4-2: Product: USB <-> Serial Cable
usb 4-2: Manufacturer: FTDI
usb 4-2: SerialNumber: 00000001
ftdi_sio 4-2:1.0: FTDI FT245BM Compatible converter detected
usb 4-2: FTDI FT245BM Compatible converter now attached to ttyUSB0
```

   Unplug the USB cable and run `dmesg` again and see something like this:

```
usb 4-2: USB disconnect, address 4
FTDI FT245BM Compatible ttyUSB0: FTDI FT245BM Compatible converter now
disconnected from ttyUSB0
ftdi_sio 4-2:1.0: device disconnected
```

   Evidently the USB device is being assigned to device `ttyUSB0`.

   This shows that the USB device is being recognized by the operating system and assigned to a usb-serial port.

4. **Set the permissions for the USB-Serial port**
   The default situation is that root is the owner of the USB serial port `ttyUSB0` and operation is restricted to root. For an ordinary user to access the port, the permissions must be changed.

   First, we will show how to do this manually in section 18.3.1. However, Linux is usually set up so that the permissions revert back to root mode every time the USB is plugged and unplugged, and every time the system is rebooted. Therefore, we need to modify the system so that this is done automatically, ie, so that the port permissions are set to user mode by default. This is shown in section 18.3.2 below.

18.3.1 Manually Changing Device Port Permissions

Change to the `/dev` directory.

```
phiscock@linux:~> cd /dev
```

Check the permissions on the `ttyUSB` ports:

```
phiscock@linux:/dev> ls -l ttyUSB*
crw-rw----  1 root uucp 188, 0 2005-11-07 18:25 ttyUSB0
crw-rw----  1 root uucp 188, 1 2004-10-02 01:38 ttyUSB1
<others deleted>
```

In this case, the owner (root) has read-write access. The group that root belongs to, uucp, also has read-write access. Others (that's you) have no access at all. To open up the port to user access, enter root mode using the `su` command:

```
phiscock@linux:/dev> su
```

The system asks for the root password. Enter it. Now you can change the permissions (mode) for the ports. In this case, we'll use the `chmod` command to add read and write permission for 'others'. For example, the first command below says: *change the mode of device ttyUSB0 to add read permission for 'others'*. The second command does the same for write permission.

```
linux:/dev # chmod o+r ttyUSB0
linux:/dev # chmod o+w ttyUSB0
```

Check the permissions again:

```
ls -l ttyUSB*
crw-rw-rw-  1 root uucp 188, 0 2005-11-07 18:25 ttyUSB0
crw-rw-rw-  1 root uucp 188, 1 2004-10-02 01:38 ttyUSB1
```

That's it. You should now be able to access those ports from user mode. Exit from root to user mode.

Incidentally, you may be able to change the permissions by logging in as root and then using the features of the KDE or Gnome desktop to change the permissions.

18.3.2 Setting Default Port Permissions to User Mode: Suse 9.2

This change will ensure that the serial-usb ports are always created with user mode access.
The default permissions for user devices are contained the file: `/etc/udev/permissions.d/50-udev.permissions` .
We have to modify the entry for the `ttyUSBx` ports so that the default is user mode.

1. Change to the directory `/etc/udev/permissions.d` and check that the file `50-udev.permissions` exists.

2. If the file exists, [6] enter root mode, and copy the existing file so you have a copy of the original.

   ```
   cp 50-udev.permissions 50-udev.permissions-orig
   ```

3. Now open the file `50-udev.permissions` with your favourite editor. Find the entry that says:

   ```
   ttyUSB*:root:uucp:660
   ```

   Change that to read:

   ```
   ttyUSB*:root:uucp:666
   ```

   Save the file. Now every time a `ttyUSBx` port is created, you should be able to access that port without problems.

[6] If the file does not exist, please let us know the name of the Linux distribution and we'll look for another solution.

18.3.3 Setting Default Port Permissions to User Mode: Suse 10.3

Suse in their wisdom have changed the method detecting USB devices. Now, USB devices do not exist in /dev until they are plugged in.

Plug in the DSO-101 oscilloscope and execute 'dmesg'. You should see something like the following at the end of the message:

```
usb 1-2: new full speed USB device using uhci_hcd and address 2
usb 1-2: new device found, idVendor=0403, idProduct=6001
usb 1-2: new device strings: Mfr=1, Product=2, SerialNumber=3
usb 1-2: Product: Digital Oscilloscope DSO-101
usb 1-2: Manufacturer: Syscomp
usb 1-2: SerialNumber: DSQ3Q7ZO
usb 1-2: configuration #1 chosen from 1 choice
drivers/usb/serial/usb-serial.c: USB Serial support registered for FTDI USB
Serial Device
ftdi_sio 1-2:1.0: FTDI USB Serial Device converter detected
drivers/usb/serial/ftdi_sio.c: Detected FT245BM
usb 1-2: FTDI USB Serial Device converter now attached to ttyUSB0
usbcore: registered new interface driver ftdi_sio
drivers/usb/serial/ftdi_sio.c: v1.4.3:USB FTDI Serial Converters Driver
```

This indicates that the oscilloscope was detected and it has been assigned to the USB-Serial port ttyUSB0.

You now go to the director /dev and examine the ttyUSB0 entry:

```
phiscock@panther:/dev> ls -l ttyUSB0
crw-rw---- 1 root uucp 188, 0 2008-04-20 12:57 ttyUSB0
```

The uucp group have read-write permission to this device, so the permanent solution is to add uucp as one of your groups. In Suse 10.3 this is done from: `Computer -> Control Center -> Open Administrator Settings` You'll need to enter the root password.

Then go to: `Security and Users -> User Management -> User and Group Administration`.

Select the user (that's you) and click on `Edit`. This brings up the `Existing Local User` page. Click on `Details`. Under `Groups` check off `uucp`. Log out and log back in, or restart the computer. You should now be able to access the USB port without having to change its permissions.

18.3.4 Setting Default Port Permissions to User Mode: Fedora Core 6

This note[7] applies to Fedora Core 6, kernel 2.6.19-1.2911.fc6.

Look in /etc/udev/rules.d/50-udev.rules for the line:
`KERNEL=="tty[A-Z]*", NAME="%k", GROUP="uucp", MODE="0660"`

Change the mode value to 0666.

18.3.5 Running the Program

1. Change to the directory where the program resides. The `wish` interpreter is required to run the tcl program. It is normally included with a Linux distribution, so it is probably present on your system. You can find out by issuing the `which` command.

   ```
   phiscock@linux: which wish
   /usr/bin/wish
   ```

[7] Kindly supplied to us by John Foster.

If this doesn't turn it up, use the 'find' command, starting at the root directory '/'. If it is on the system, then add that location to your path.

```
phiscock@linux: find . -name wish
<much deleted>
/usr/bin/wish
```

2. Start `wish`.

```
phiscock@linux:~/eelab/demos> wish
```

3. A new small window will appear. This is the container for any program that `wish` executes. The cursor remains where the `wish` command was run.

4. Click in that window and run the command:

```
% source main.tcl
```

using the correct name for the oscilloscope program. The oscilloscope GUI should now run correctly.

There are many other ways to start the program. For example, the command `wish scope-101.tcl` (substitute the correct name of the tcl program) can be used. As well, the KDE and Gnome graphical user interfaces be used to set up an icon on the desktop. Then clicking on that icon will start the program.

18.3.6 Ubuntu Linux Install

This sectiondescribes how to install the DSO-101 oscilloscope software on a Ubuntu Linux system. This procedure was tested on an `Edubuntu` system, `Hardy Heron`, April 2008. Similar instructions apply to installation of the WGM-101 Waveform Generator, CGM-101 CircuitGear and CGM-101 CircuitGear Mini(with the corresponding file names).

These instructions assume some familiarity with Linux. Specifically, you must know how to use an editor to modify files. You should know how permissions work, and how to use the `chmod` command to change them. You should have some familiarity with the directory structure and the location of your home directory vs system directories such as `/etc` and `/dev`. You must know how the `ls` command works.

Download and Unpack the Software

The software is available for download from the Syscomp website:
`www.syscompdesign.com/download.htm`

Use the `mkdir` command to reate a directory on your computer. In my case, this directory is:
`/home/peter/eelab`.

Click on the file `Linux (x86bin)` to download it to your computer, check that it is in the `eelab` directory (figure 25).

The file that you downloaded is an *archive*, from which you must extract the files. Right click on the file and select `Extract Here`.

A directory is created with the extracted files in it. Change to that directory and examine the contents (figure 26).

Check that `main.tcl` is present in the file list. This is the file to execute to start the oscilloscope program.

Check that the Tcl Interpreter *wish* is present on your machine:
`which wish`

If *wish* is present, the *which* command will show the directory:
`/usr/bin/wish`

Figure 25: Checking that the File has Downloaded

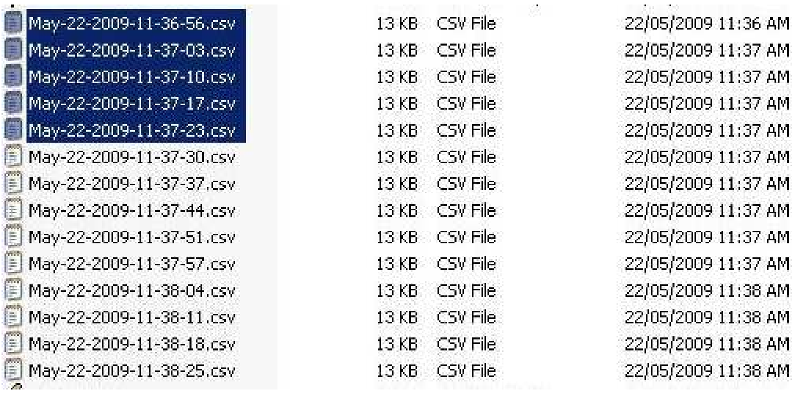


Figure 26: Directory with Files

Since `/usr/bin` is usually on your PATH, wish is present and should execute.

Now you can execute the DSO-101 software with the command:
`wish main.tcl`.

However, the oscilloscope software will not connect properly to a USB port until the permissions are corrected. That's the next step.

Configure Permissions on the USB Ports

Plugging a Syscomp oscilloscope, waveform generator or CircuitGear unit causes the system to create a 'serial USB port' at `/dev/ttyUSB0`. (Notice that this is yew-ess-bee-zero, not yew-ess-bee-oh. If you have another usb-serial device plugged in, the number might be some other digit than zero.)

This port has read-write permissions for root and for the 'dialout' group. It does not have read-write permissions for a lowly user, so the instrument will not connect in this state.

You can change the permissions on `/dev/ttyUSB0`, but the port is transient and disappears when you shut down or disconnect. So you would need to do that every time you start the instrument.

To make this permanent, add your name to the 'dialout' group. I tried to do it using the edubuntu system administration tool, but for some reason the dialout group did not appear.

To do this the old-fashioned command-line way, use the command 'groups' to see which groups you belong to. Probably dialout does not appear. We will edit the groups file to add you. Find the file `/etc/group`. Probably read-write permission is disabled for users on this file as well. Make a note of the permissions, because we'll change it back. For example:.

```
ls -l /etc/group
-rw------- 1 root root 934 2008-05-22 10:17 /etc/group
```

In order to edit it, change the permissions to allow any user to edit that file, using the command:

```
sudo chmod 777 group
<your password here>
ls -l /etc/group
-rwxrwxrwx 1 root root 954 2008-10-24 22:02 /etc/group
```

Now you can edit and save the file. Load that file into a text editor. Find the line with 'dialout' in it. If the line ends in a colon, that means that no one yet belongs to this group. Add your login name. If there already is some other login name, add a comma and then your login name. Here's what it might look like with me (peter) added to the dialout group, after gabe.

```
man:x:12:
proxy:x:13:
kmem:x:15:
dialout:x:20:gabe,peter
fax:x:21:
voice:x:22:
.... and so on
```

Save the file. Reboot the computer. Execute the `groups` command. You should see that you are a member of the `dialout` group.

```
groups
peter dialout
```

Now you should be able to start the instrument code by executing `wish main.tcl` in the directory where `main.tcl` is located. The instrument should find and connect to the USB port.

For security, you may want to return the permissions on `/etc/group` as they were originally, as you noted previously. In my case, giving groups and users read permission as well:

```
sudo chmod 644 /etc/group
<your password here>
ls -l /etc/group
-rw-r--r-- 1 root root 934 2008-05-22 10:17 /etc/group
```

Special thanks to Gabriel Guillen, who loaned me an edubuntu system for this exploration.

18.3.7 64 Bit Linux

One of the packages in the Syscomp distribution is the 'Img' package. The Img package is a Tcl/Tk library that is required for the CGM-101 software. Currently, those libraries are for a 32 bit linux operating system. We are in the process of modifying the distribution to accompodate 64 bit linux, but in the meantime here is a workaround.

Delete the existing Img file. (The best way to do this is to rename it, so that you can back out if this procedure fails.) Once you've deleted it, try running the software. If your Tcl/Tk distribution has the correct Img library it should run fine. If not, download and install the ActiveState Tcl/Tk distribution for 64 bit linux.

18.3.8 Running under 64-bit Sidux (Debian-based Linux)

The following notes were provided by Radio College of Canada student Gabriel:

```
I am currently running the software on a 64 bit Sidux (Debian based linux)
and have noticed that the img library (the .so files in Img13Lin) are 32 bit
only.  This prevents the software from running on any 64bit linux systems.

This can easily be fixed by installing the img package in 64 bit.
the package name is libtk-img  and can be installed by running:

apt-get install libtk-img

on any Debian based OS or by using the default package manager  (this will
work for 32 and 64 bit systems)

Also, the Bwidget package should also be listed as a dependency, the package
name is bwidget  (all lower case)

apt-get install bwidget

will install it on the system
```

18.3.9 Device Properties using `usbview`

In general, it's not necessary to know anything about the USB properties of the hardware in order to use it. However, if you do want to inspect those properties, `usbview` is useful.

It is likely that you will have to install `usbview` from your Linux distribution disks.

Once `usbview` is installed, (figure 27) you can use it to determine whether a USB device is recognized by the operating system USB. As a USB device is plugged and unplugged, an entry appears and disappears in the `usbview` window.

Clicking on an entry opens up a list of USB properties of the device.

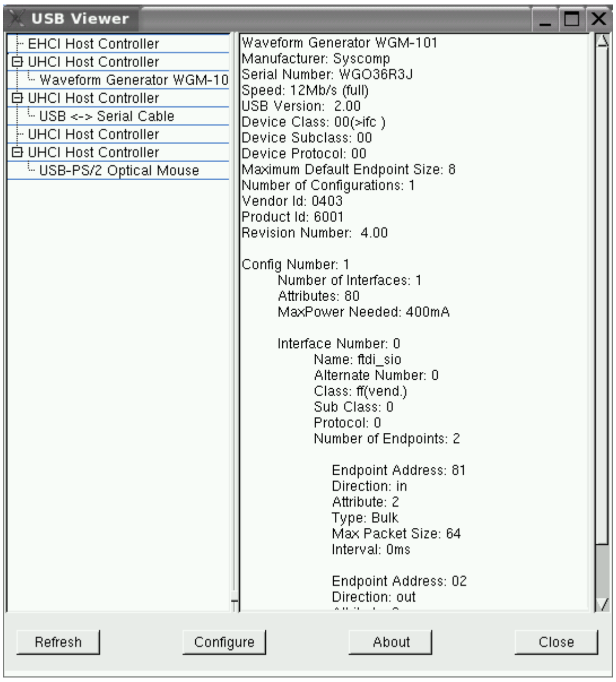


Figure 27: Usbview

Notice that `usbview` does not indicate the serial port (`/dev/ttyUSB2` or whatever) that the operating system has assigned to this device. You must use `dmesg` for that purpose.

18.3.10 Terminal Connection under Linux

It can be useful to connect to the hardware via a terminal emulator to check the operation of the hardware. We used the program `Cutecom` under Ubuntu Linux. It should be possible to install Cutecom under other versions of Linux.

To install `Cutecom` under Ubuntu Linux, enter the following commands into a terminal window:

1. `sudo apt-get update`
2. `sudo apt-get install cutecom lrzsz`

This gets both the `CuteCom` and `lrzsz` packages. The latter is not necessary, but allows the terminal to support zmodem/xmodem/ymodem file transfer. See: `https://help.ubuntu.com/community/Cutecom`.

Now we are ready to test the hardware.

1. Plug in the Syscomp hardware unit.
2. In a terminal window, run the `dmesg` command. Look at the last few lines to confirm the connection port. We'll assume `ttyUSB0`.
3. Run `cutecom`.
4. Set up the cutecom terminal emulator characteristics as follows:
   - Device: /dev/ttyUSB0
   - Baud rate: 230400
   - Data bits: 8
   - Stop bits: 1
   - Parity: none
   - Handshake: Hardware ('Software' not selected)
   - Open for: Reading, writing
   - Apply settings when opening
   - CR,LF line end
   - Char delay: 1 ms
5. In the `Input` window, enter an `i` character, then press the <enter> key.
6. In the upper display window, you should see a message back from the hardware, such as:
   `Syscomp CircuitGear V1.4`
   Then CuteCom is connected to the hardware. You can send various messages to the hardware and get responses back, testing the commands that are documented elsewhere in this manual.

Acknowledgement Jan Portegijs told us about CuteCom and gave us the correct settings to connect.

18.4 Macintosh Lab

The following notes are an edited version of install procedure information kindly provided by Ted Johnson of Greenfield College. This applies to using the software in a lab environment, where everyone using the Mac must be able to start the Syscomp software.

1. Login as an administrator
2. Open Safari and go to web site `www.syscompdesign.com`. Select `Downloads`. Select `Mac OS X` and download.
3. When the download is complete, drag the icon (`Syscomp CircuitGear V1.15` or whatever it's named) into the Applications folder. Open the applications folder, check that it is there and drag an alias to the dock.
4. Open the folder `Drivers`. Select `Mac`. Select `Intel`. Double click on `FTDIUSBSerialDriver`. Double click on the Snow Leopard package. Follow the instructions.
5. Get the scope hardware and plug into an open USB slot.
6. Click on the dock icon `SYSCOMP`. Select `OPEN` from the popup. When the `Unable to Connect, Examine Settings?` popup appears select `YES`. When the `PORT SETTINGS` popup appears, select the button `/dev/cu.usbserial`. Click on `SAVE AND EXIT`.
7. If everything was done correctly a `CONNECTED` rectangle will change from red to green at the top of the open window (the CircuitGear GUI). If not repeat step 4 again.
8. Now we need to set the permissions on the USB port so that all users can access the port. To do this, start the `TERMINAL` program. In the terminal window, type:
   `chmod 777 /Applications/Syscomp\ CircuitGear\ V1.15.app/Contents/MacOS/port.cfg` and hit return.
9. Signout as administrator. Sign in as a student. Put the app in the dock and boot, and make sure it works when the hardware is plugged in.

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19 Sources of Information

19.1 News Groups

`comp.lang.tcl`
Internet News Group

19.2 Websites

`http://www.syscompdesign.com`
Latest information on Syscomp instruments and supporting software.
Many useful application notes and project descriptions.

http://www.tcl.tk/
Home of the Tcl Developer Xchange. Pointers to information and software downloads.

http://www.activestate.com/
ActiveState is a commercial firm that sells various programming tools provides a home for the Tcl/Tk language. Free versions of Tcl/Tk are available for download from their site.

19.3 Paper

Scripting: Higher Level Programming for the 21st Century
John K. Ousterhout
IEEE Computer magazine, March 1998
Currently at: http://home.pacbell.net/ouster/scripting.html
Also at: http://www.tcl.tk/doc/scripting.htm
The definitive paper on Tcl/Tk and scripting languages in general. Ousterhoot shows a Table of Applications which have been coded in Tcl/Tk and in the C language, and the relative effort and time required for each implementation.

19.4 Textbooks

Practical Programming in Tcl and Tk, 4th Edition
Brent B. Welch & Ken Jones with Jeffery Hobbs
Prentice Hall PTR, 2003
The definitive reference for Tcl and Tk. Includes CDROM with Tcl and examples.

Tcl and the Tk Toolkit
John K. Ousterhout
Addison-Wesley, 1994
Now somewhat dated, but a still useful introduction to Tcl/Tk by the inventor of the language.

Graphical Applications with Tcl & Tk, 2nd Edition
Eric Foster-Johnson
M&T Books, 1997
Very accessible introductory textbook.

Tcl/Tk Tools
Mark Harrison
O'Reilly, 1997
Information on a number of extensions to Tcl/Tk.

Effective Tcl/Tk Programming
Mark Harrison, Michael McLennan
Addison Wesley, 1998
Techniques of design for Tcl/Tk programs.

Tcl/Tk for Programmers
Adrian Zimmer
IEEE Computer Society, 1998
An textbook on Tcl/Tk with an academic tone and exercises.

Tcl/Tk for Dummies
Tim Webster
IDG Books, 1997

A useful introduction to Tcl/Tk.

Tcl/Tk for Real Programmers
Clif Flynt
Academic Press, 1999
Medium to high-level material on Tcl/Tk