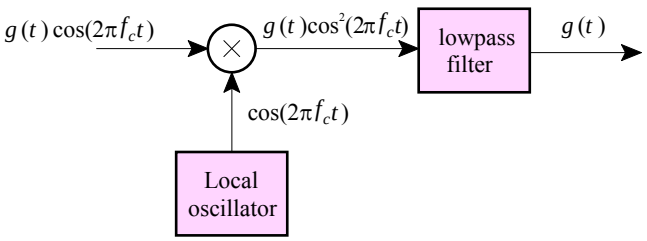
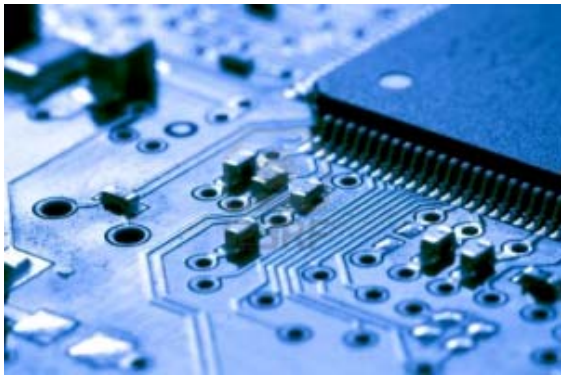
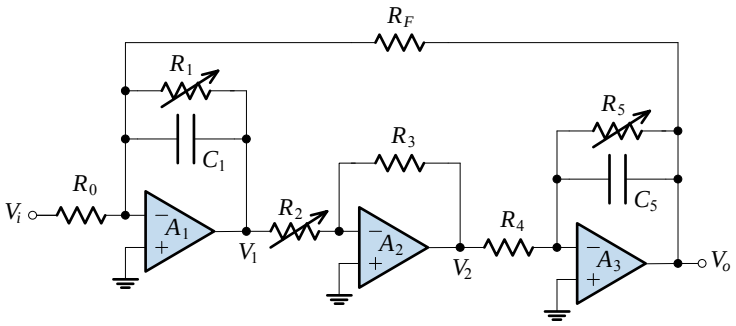
48540
Signals and Systems

Lab Equipment Guide

2015







PMcL

Lab Equipment Guide

Digital storage oscilloscope. Arbitrary waveform generator. TIMS trainer. State variable filter.

Introduction

This guide is a reference for the following equipment:

Equipment

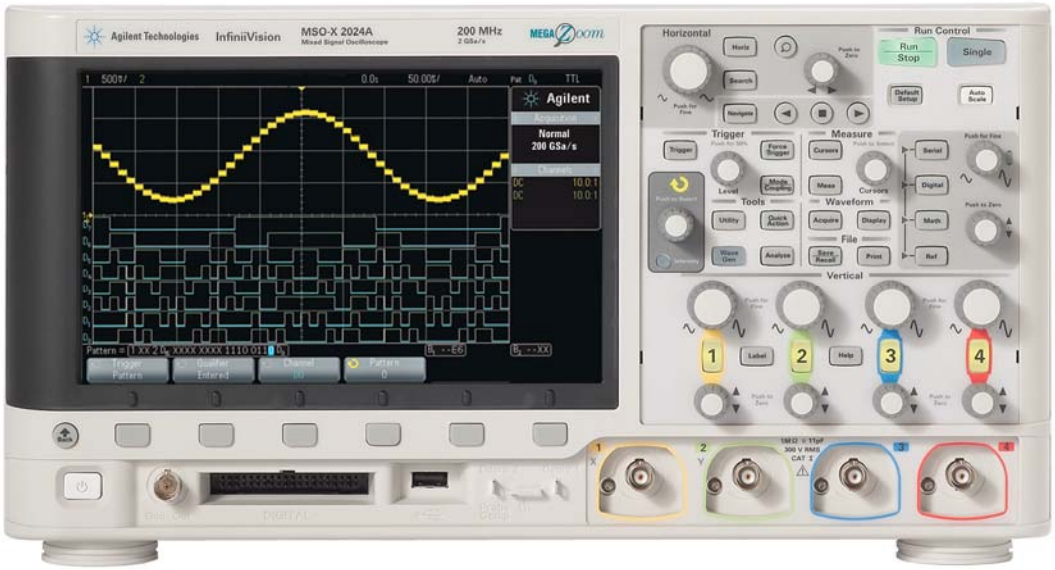
- Digital Storage Oscilloscope (DSO) – Agilent DSO-X 2004A with Wave Gen
- Arbitrary Waveform Generator (AWG) – Agilent 33210A with Option 002
- TIMS trainer - Emona
- State Variable Filter (SVF) - UTS

LEG1.2

Digital Storage Oscilloscope - Agilent DSO-X 2004A with Wave Gen

The digital storage oscilloscope (DSO) front panel has the following layout:

DSO front panel



Front panel keys

The front panel keys are denoted by a box around the name of the key. For example, [Cursors] is the grey front-panel key labelled "Cursors" under the Measure section.

Softkeys

The white [Auto Scale] key is an instant action key. The grey keys bring up a menu on the display. The keys under the display are termed softkeys, because their function is taken from the menu on the display directly above the key. Softkeys are denoted by a different font, e.g. `Line`.

The Back / Up key moves up in the softkey menu hierarchy. At the top of the hierarchy, the Back / Up key turns the menus off, and oscilloscope information is shown instead.

Display

The display contains the acquired waveform, background graticules, trigger information, a status line, menu items for the softkeys, and other information associated with the current function of the DSO.

Entry knob

The Entry knob is used to select items from menus and to change values. Sometimes, you can push the Entry knob to enable or disable a selection.

LEG1.3

Setting up the DSO

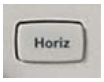
1. Press the white power button located on the lower left corner.
   The DSO will perform a self-test and will be operational in a few seconds.

2. Connect the BNC leads to the appropriate inputs.

3. Press the `Default Setup` button.
   This places the DSO in a known operating condition.

4. Press `1`, `2`, `3` or `4` to bring up the vertical menu. Turn on the channel, set up the coupling, choose whether to invert the trace, and ensure the probe attenuation is correct. Use the larger knob above `1`, `2`, `3` or `4` to set the voltage scale and the smaller knob below to set the vertical position of the trace on the screen.

5. Press `Horiz` to bring up the horizontal menu. Select either `Normal` mode for fast waveforms or `Roll` mode for slow waveforms.



6. Press `Trigger` to bring up the trigger menu. Select the appropriate type, source channel and slope for the trigger source. For analog signals the trigger type is normally set to `Edge`.

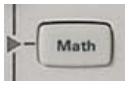
7. Press `Mode/Coupling` to bring up the Trigger Mode and Coupling menu. Select an appropriate trigger mode. For normal use, `Auto` is used. For transient or single-shot acquisitions, select `Normal`.

8. Various options are available to filter the trigger signal. Softkeys for `Noise Rej` and `HF Reject` enable filters which stabilise triggering on noisy signals. The `Coupling` softkey is used to scroll through the trigger coupling options: `DC` (DC coupling), `AC` (AC coupling), `LF Reject` or `TV`. For normal use, `DC` is used.

9. For slow or transient waveforms use `Single` mode in the "Run Control" section.

LEG1.4

Setting up an FFT



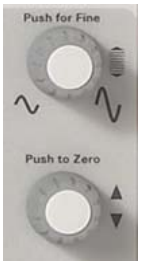
1. Press the Math button. The arrow next to the button is illuminated when the Math function is on.

2. Ensure that f(t) is displayed under Function, as this is the math function that is displayed. The other math function, $g(t)$, is internal.

3. Use the Operator softkey to select FFT.

4. Select the source using the Source 1 softkey.

5. Once the spectrum is displayed, the analog channel may be turned off for better viewing.



6. Use the shared Scale and Position knobs adjacent to the Math key to re-size and re-position the display. Use the upper knob to set the scale to 10dB/. Set the offset to -30dBV using the lower knob. The displayed range at these settings is from -70dBV at the bottom to 10dBV at the top of the display.

7. Turn the Horizontal knob to set the desired sample rate. The sample rate is displayed in the right-hand section of the screen. The oscilloscope will calculate the frequency components between 0Hz and half the sample frequency which are present in the signal.

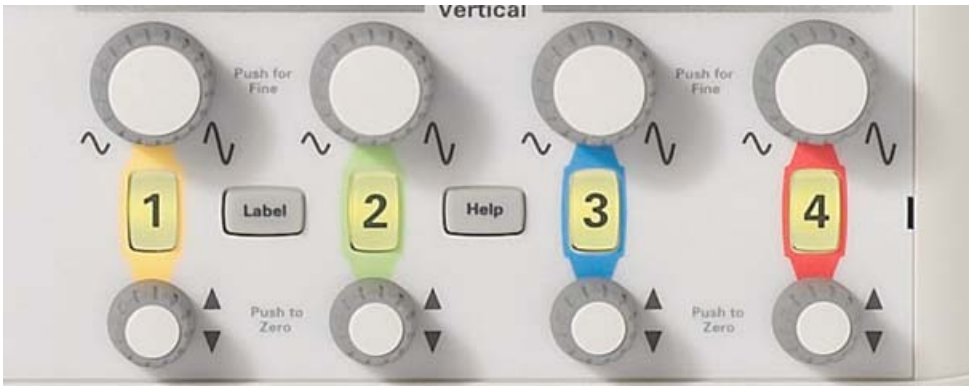
8. Press the Span softkey. Use the ↻ knob to set the frequency span displayed. Span is the difference between the highest and lowest frequency.

9. Press the Center softkey. Use the ↻ knob to set the frequency at the centre of the display. **Note that it is possible to set the centre and span to cover frequencies outside the range calculated by the oscilloscope, but those sections of the display will be blank.**

10. Press the More FFT softkey, then Window to scroll through available options. For normal use Hanning is used.

The following sections describe each of the front panel sections and associated softmenus.

Vertical



Vertical section

The Position knob moves the trace up and down on the display.

Position knob

The Scale knob changes the vertical scale of the display.

Scale knob

Press 1, 2, 3 or 4 to bring up the vertical menu for that channel. The numbered key illuminates when that channel is on. Press the numbered key twice to turn the channel off.

Channel menu

1, 2, 3 or 4

On	displays the trace for that input
Off	hides the trace for that input

Channel display

Coupling

DC	direct couple the signal to the sampler
AC	AC couple the signal to the sampler

Channel coupling

Ground is not available. The ground position is indicated on the display.

BW Lim

Off	the signal is applied directly to the sampler
On	the signal is bandlimited to 20 MHz

Bandwidth limiting

LEG1.6

Vertical vernier scale

`Fine`

Off	the Volts/div knob will be restricted to a 1-2-5 sequence
On	changes the vertical step size to smaller increments

Channel inversion

`Invert`

Off	the signal is displayed normally
On	the signal is inverted

Vertical scale due to probe

`Probe`

Units	**Volts** for a voltage probe, **Amps** for a current probe
Probe	Use the knob to scroll through available settings which range from 0.100:1 to 1000:1. For normal use 1.00:1 is used.
Skew	used to remove cable-delay errors between any two channels
Probe Check	guides you through the process of compensating passive probes

Horizontal

Horizontal section

Horizontal (time/div) scale knob

The horizontal scale knob sets the sample rate and horizontal timescale in a 1-2-5 sequence. Settings range from 5ns/div to 50s/div. The current setting is shown on the top line of the display.

Horizontal delay (position) knob

The horizontal delay knob moves the trigger point horizontally. The zero second reference is normally in the centre of the screen but can be repositioned anywhere on the display and beyond. The time reference at the centre of the screen is shown on the top line of the display.

Press Horiz to bring up the horizontal menu:

Horizontal menu

`Time Mode`

Horizontal modes

Normal	the normal viewing mode
XY	displays the Y input versus the X input
Roll	Causes the waveform to move slowly across the display from right to left, much like a strip chart recorder

`Zoom`

Zoom/split screen

Off	displays the sampled data on the full display at the scale set by the Horizontal knob
On	splits the display to show a magnified portion of the normal display

`Fine`

Horizontal vernier scale

Off	the time/div knob will be restricted to a 1-2-5 sequence
On	changes the horizontal step size to smaller increments

This function can also be accessed by pushing the Horizontal knob.

`Time Ref`

Horizontal reference

Left	the time reference point is displayed one division from the left of the display
Center	the time reference point is in the centre of the display
Right	the time reference point is displayed one division from the right of the display

In roll mode the time reference is on the right of the display.

LEG1.8

Trigger

Trigger section

Trigger level

The Level knob changes the voltage at which the DSO triggers.

Triggering options

Press `Trigger` to bring up the triggering options:

`Trigger`

Trigger type

Edge	the oscilloscope detects a transition across the level set using the Level knob. **For normal operation use Edge**
Pulse Width	the oscilloscope detects a pulse matching the parameters set in the Pulse Width sub-menu
Pattern	the oscilloscope detects a combination of settings
Video	The oscilloscope detects "Sync" pulses embedded in video (TV) signals according to settings in the Video sub-menu

`Source`

Trigger source

1	chooses channel 1 for the trigger source
2	chooses channel 2 for the trigger source
3	chooses channel 3 for the trigger source
4	chooses channel 4 for the trigger source
External	chooses Ext (rear panel) for the trigger source
Line	chooses the line (50 Hz power) voltage as the trigger source
WaveGen	chooses the oscilloscopes internal signal generator for the trigger source

`Slope`

Trigger slope

Rising	detects a transition of the selected source signal from below the set trigger level to above it.
Falling	detects a transition of the selected source signal from above the set trigger level to below it.
↑↓ Alternating	Triggers alternately on rising and falling edges
↕ Either	Triggers on the first edge in either direction

Press `Mode/Coupling` to bring up the trigger mode menu:

Mode

Trigger modes

Normal	the trigger level is set by the Level knob and the DSO only refreshes the display when the trigger conditions have been met. If no trigger condition is present the oscilloscope displays the data stored after the last trigger event.
Auto	operates the same as Normal when a trigger condition is present. If no trigger condition is present the oscilloscope continues to acquire and display data but the display will not be synchronized with the acquired signal. If the input signal is not present (or grounded) the oscilloscope displays a flat line.

Coupling

Trigger coupling

DC	direct couples the selected trigger source signal to the trigger system
AC	AC couples the selected trigger source signal to the trigger system. Signal content below 10Hz is attenuated. Primarily used to eliminate DC from the trigger signal.
LF Reject	filters the trigger signal to reject frequencies below 50kHz
TV	only available when Trigger Type is set to Video

Noise Rej

Trigger filters

Noise Rej	increases the trigger hysteresis band

HF Reject

HF Reject	filters the trigger signal to reject frequencies above 50kHz. This is useful to stabilise the trigger when the trigger signal is small and sampling noise is significant

Holdoff

Holdoff	The Holdoff control keeps the trigger from rearming for an amount of time set by turning the knob. It is useful for viewing complex waveforms where there are multiple trigger conditions.

External

External	accesses a sub-menu to setup the external trigger input scale and coupling

LEG1.10

Run Control

Run Control section

Oscilloscopes are generally used to view waveforms which are continuously repeating at a fast rate. When properly triggered the display is constantly updated with new data which is very similar to previous acquisitions and the display appears stationary. When an event occurs only once or infrequently it is desirable to store this event and display it for viewing.

Run / Stop

For normal operation the Run/Stop button is illuminated in green. Press the Run/Stop button to stop the acquisition of data and freeze the display. The Run/Stop button will be illuminated in red. The data displayed may not be a contiguous block and may be comprised of some new data and some data from the previous frame. Press the button again to resume normal operation.

Single

Single sweep mode waits for a valid trigger condition and then captures and displays one frame of data. Press Single to engage single sweep mode. The Single button will illuminate in orange until a trigger event is detected and one frame of data is captured. Once the data is captured and displayed the Single button is no longer illuminated and the Run/Stop button will be illuminated in red. Press Single again to capture a new frame of data. Data captured in Single mode is contiguous.

Measure

Measure section

Press `Meas` to bring up the measurement menu:

Measurement menu

`Source`

Measurement source

Use the knob to scroll though available options.

Only channels or functions which are turned on are available.

1	chooses channel 1 for the measurement
2	chooses channel 2 for the measurement
3	chooses channel 3 for the measurement
4	chooses channel 4 for the measurement
Math f(t)	chooses the Math function for the measurement
Ref 1	chooses stored waveform Ref1 for the measurement
Ref 2	chooses stored waveform Ref2 for the measurement

`Type`

Use the knob to scroll though available options. Only options applicable to the source selected are available. Press `Add Measurement` to display the selected measurement. Up to 4 measurements can be displayed simultaneously.

Some useful measurements are:

Voltage measurements

Peak - Peak	displays the peak-to-peak voltage
Average N cycles	displays the average value of an integral number of cycles of the selected waveform
DC RMS N cycles	displays the rms value of the AC and DC components of the selected waveform
Maximum	displays the highest value
Minimum	displays the lowest value
Top	displays the highest steady-state value
Base	displays the lowest steady-state value

Time measurements

Frequency	displays the frequency in Hz
Duty Cycle	displays the duty cycle in %
Phase	displays the phase difference between two channels in degrees

Settings

Some measurements require additional settings.

Additional measurement settings

Phase	requires two signals. Source 2 is the reference and the phase of Source 1 is measured relative to Source 2.
Rise Time	requires a lower Threshold and upper Threshold

Press the  button to return to the Measurement Menu.

Clear Meas

Clearing measurements

	provides options to clear individual measurements or all the measurements from the display

---

Cursors measurement menu

Press Cursors to bring up the cursors measurement menu:

Mode

Cursors measurement mode

Manual	X and Y cursors are positioned by the user using the Cursors knob
Track Waveform	The X cursors are positioned manually and the Y cursor measures the corresponding position of the waveform
Binary	Only available with digital channels option
Hex	Only available with digital channels option

Source

Cursors measurement source

Use the  knob to scroll though available options. Only channels or functions which are turned on are available.

1	chooses channel 1 for the measurement
2	chooses channel 2 for the measurement
3	chooses channel 3 for the measurement
4	chooses channel 4 for the measurement
Math f(t)	chooses the Math function for the measurement
Ref 1	chooses stored waveform Ref1 for the measurement
Ref 2	chooses stored waveform Ref2 for the measurement

Cursors

Cursor(s) selection

X1, X2	changes the active horizontal cursor
Y1, Y2	changes the active vertical cursor
X1 X2 linked	both horizontal cursors move simultaneously
Y1 Y2 linked	both vertical cursors move simultaneously

You can also push the Cursors knob, then turn the Cursors knob to select the cursor(s) to be adjusted. Press the Cursors knob to finalize the selection, or wait about 5 seconds for the popup menu to disappear.

`Units`

Cursor units

X units	For signals displayed on a time scale the X units can be: **Seconds** – shows X cursors in seconds, ΔX and 1/ ΔX **Hz** – shows X cursors as frequency relative to 0s and ΔX **Phase** – shows phase in degrees relative to 0 seconds and between X1 and X2. A 360^{o} reference must be set. **Ratio** – shows position in % relative to the 100% reference positions. For FFT the horizontal scale is frequency in Hz. Although the "X units" setting shows seconds the cursor measurements are in Hz.
Y units	For signals displayed on a time scale the Y units can be: **Base** – shows Y cursors in volts and ΔY in volts **Ratio %** – shows position in % relative to the 100% reference positions. For FFT the vertical scale is magnitude in dBV. The magnitudes of Y1 and Y2 are shown in dBV and the relative magnitude ΔY is shown in dB.

Cursor(s) selection

To select the cursor to be adjusted:

Push the Cursors knob; then, turn the Cursors knob. Press the Cursors knob to finalize the selection, or wait about 5 seconds for the popup menu to disappear.

Or:

Press the `Cursors` softkey; then, turn the Entry knob.

The `X1 X2 linked` and `Y1 Y2 linked` selections let you adjust both cursors at the same time, while the delta value remains the same. This can be useful, for example, for checking pulse width variations in a pulse train.

Cursor information

Cursor information

The currently selected cursor(s) display brighter than the other cursors. Cursor information is displayed in the right-side information area.

Cursors are not always limited to the visible display. If you set a cursor, then pan and zoom the waveform until the cursor is off screen, its value will not be changed. It will still be there when you return to its original location.

LEG1.14

Setup

Setup section

Default setup

Press `Default Setup` to setup the DSO with default values for the vertical, horizontal and trigger options. Default setup turns off all cursors, measurements and Math functions, and only channel 1 is displayed. Use Default Setup when you first turn on the DSO. A softkey to `Undo Default Setup` is available immediately after `Default Setup` is pressed.

Autoscale

Press `Autoscale` to let the DSO change the front-panel setup to try and display the signals. **It does not always give a useful result!** A softkey to `Undo Autoscale` is available immediately after `Autoscale` is pressed.

Waveform

Waveform section

Press `Acquire` to bring up the Acquire menu:

`Acq Mode`

Acquisition mode

Normal	displays the acquired signal
Peak Det	Not all acquired data points are usually displayed. Peak Det displays the peaks of acquired data.
Averaging	displays the average of repeated acquisitions
High Res.	averages sequential sample points

`# Avgs`

Number of averages

2	averages the last 2 acquisitions
…	# Avgs increases in binary sequence
65536	averages the last 65536 acquisitions

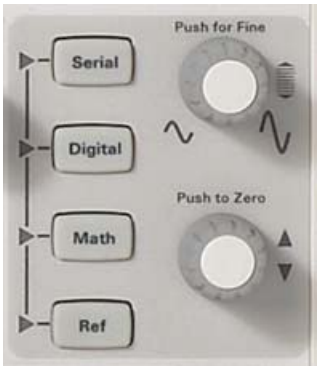
Press `Display` to bring up the Display menu:

`Intensity`

Display intensity

↻	Varies the brightness of the grid

Function



Serial and Digital options are not available on these oscilloscopes at UTS

Function section

Press `Math` to turn Math functions on and bring up the menu:

Function menu

`Function`

f(t)	options for Math function which is displayed on screen
g(t)	options for Math function which is not displayed on screen

`Operator`

+	adds signals from two specified channels
−	subtracts signals from two specified channels
×	multiplies signals from two specified channels
FFT	performs FFT on the specified channel

`Source 1, Source 2`

Selects the signals to be added, subtracted or multiplied.
Only Source 1 is specified for FFT.

FFT Menu

FFT menu

The following soft menus are displayed when FFT is the active Math operation:

`Span`

↻	Adjust the span of frequencies in the display. The span is the difference between the low frequency at the left end of the display and the high frequency at the right end of the display.

Frequency span

`Center`

↻	adjust the frequency at the centre of the display

Centre frequency

It is possible to set the centre and span to cover frequencies outside the range calculated by the oscilloscope but those sections of the display will be blank.

`More FFT`

	displays a sub-menu for additional FFT settings

LEG1.16

More FFT sub-menu

More FFT Sub-Menu

Window

FFT window

Hanning	window for making accurate frequency measurements or for resolving two frequencies that are close together
Flat Top	window for making accurate amplitude measurements of frequency peaks
Rectangular	good frequency resolution and amplitude accuracy, but use only where there will be no leakage effects
Blackman-Harris	not normally used

Vertical Units

FFT vertical units

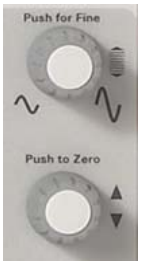
Decibels	Uses the logarithmic decibels scale for the magnitude of the FFT. This allows frequency components of widely varying magnitude to be displayed. The scale is in dBV which is dB relative to 1V RMS.
V RMS	Uses a linear scale. Frequency components with small amplitudes are not visible

Auto Setup

	Sets the frequency span and centre frequency to display from 0Hz to half of the sample frequency. Adjusts the vertical scale and offset to accommodate all currently calculated components.

FFT Vertical Scale

FFT vertical scale



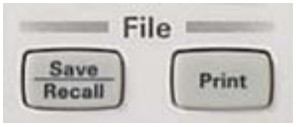
The upper knob is used to set the vertical scale of the FFT display. The scale setting is shown above the softkey labels.

The lower knob is used to set the vertical offset of the FFT display. The current offset value is shown above the softkey labels. The offset is the position of 0dBV relative to the centre of the display.

Reference waveforms

Press Ref to bring up the Reference waveform menu. The menu provides options for saving and displaying reference waveforms for comparison with live signal displays.

File Section



File section

The DSO has a USB port on the front panel. A USB Flash drive can be connected and data acquired by the DSO can be saved in various formats for use on computers.

Press `Save/Recall` to bring up the file menu:

`Format`

BMP(8 bit)	saves screen image in Windows bitmap format
CSV	Saves numeric data from active channels in Windows (Excel) "comma separated variable" format
-others	

File format

`Save to` – only available with USB Flash drive connected

↻	navigate the Windows file structure to specify the location to save the file
Press to go	Select the location specified

File location

`File Name`

	Allows you to enter a file name for the file to be saved. If no file name is specified the default "Scope_0.xxx" is used
Increment	The filename is numerically incremented for each file saved, e.g. "Scope_1.xxx".

File name

`Press to Save`

	Saves the data to the specified location in the specified format

Save file

LEG1.18

Tools Section

Tools section

The DSO has a basic inbuilt signal generator (Wave Gen). The signal is output from the BNC connector adjacent to the power button on the front panel. The Wave Gen button is illuminated in blue when the signal generator is operating.

Press `Wave Gen` to bring up the Waveform Generator Menu:

`Waveform`

Wave Gen waveforms

Sine	sinusoidal waveform
Square	square waveform (20% to 80% duty cycle)
Ramp	triangle, ramp, sawtooth waveforms
Pulse	pulse (square) waveform (~0% to ~100% duty cycle)
DC	DC, constant voltage
Noise	"random" signal with wide bandwidth

Various parameters which define a waveform can be set by selecting the appropriate softkey and adjusting the parameter using the knob. Not all parameters are available for all waveforms.

Waveform parameters

	Frequency	Amplitude	Offset	Duty/Sym	Width
Sine	✓	✓	✓		
Square	✓	✓	✓	✓	
Ramp	✓	✓	✓	✓	
Pulse	✓	✓	✓		✓
DC			✓		
Noise		✓	✓		

Instructions in these notes are relevant to software version 01.20.2011063000

Arbitrary Waveform Generator - Agilent 33210A with Option 002

The arbitrary waveform generator (AWG) front panel has the following layout:

AWG front panel

Front panel keys light up when on

Lighted keys indicate active keys or functions such as the currently active waveform. Most keys toggle on (lighted) or off.

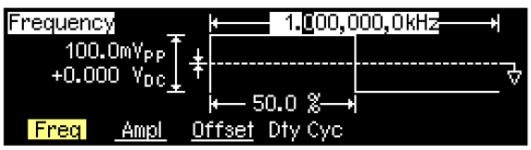
Output key

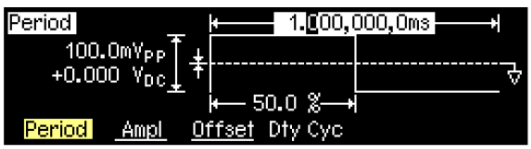
No signal is output unless the output key is lighted!

The `Graph` key toggles between *Graph Mode* (lighted) and *Menu Mode*.

In *Menu Mode*, the six softkeys allow you to select parameters and functions shown in the softkey menu at the bottom of the display. Some softkeys toggle between related parameters. For example, the left softkey toggles between `Freq` and `Period` below:

In *Graph Mode*, the softkeys work just as in *Menu Mode*, except that only one label is displayed for each key. You can still toggle between related parameters such as `Freq` and `Period`:



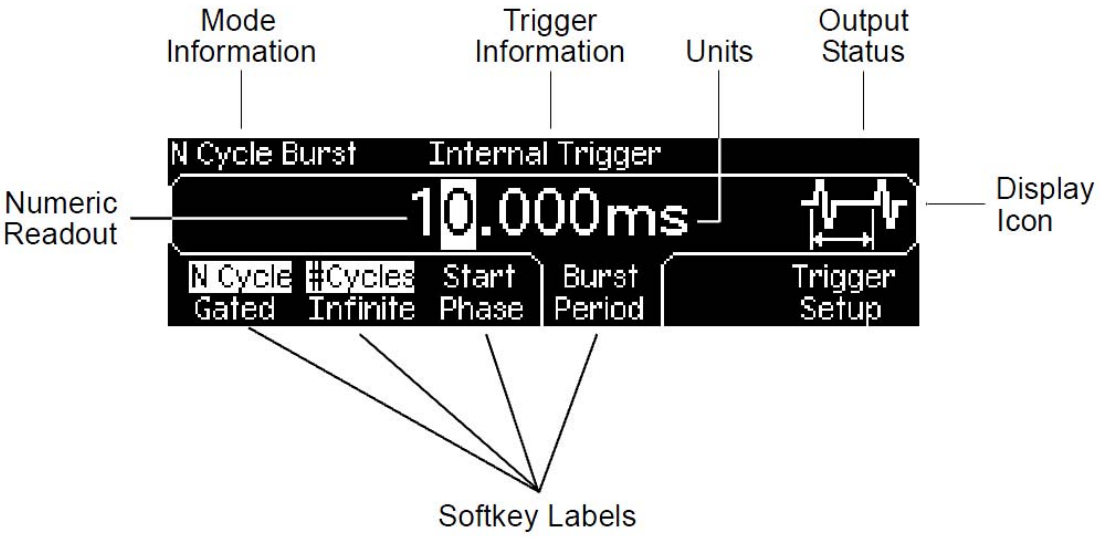


LEG1.20

Front Panel Display

Menu Mode

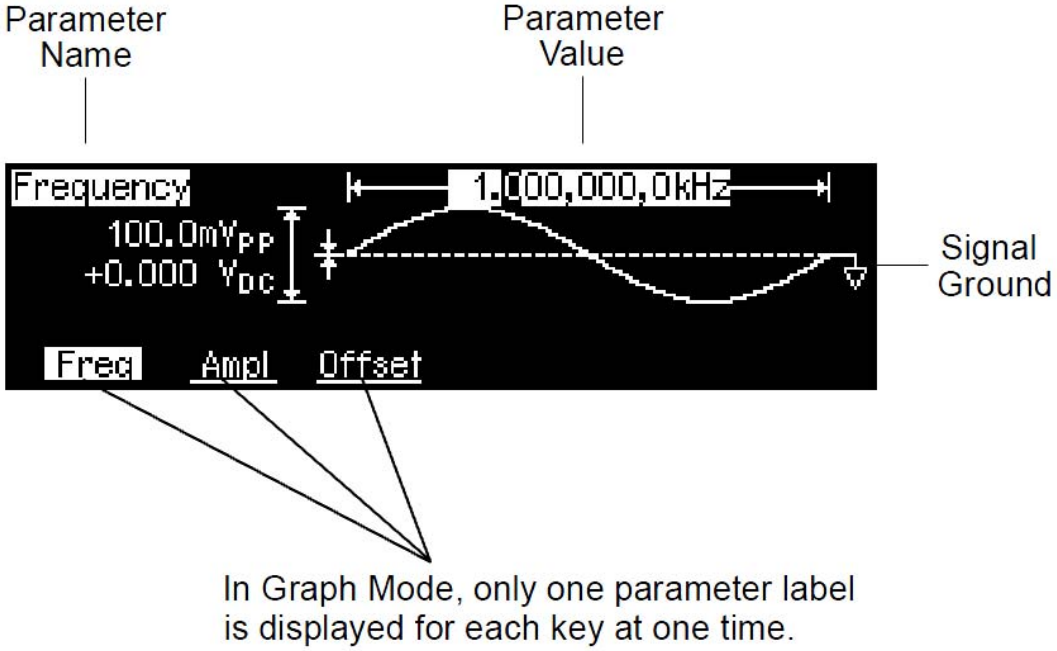
Front panel display in menu mode



Graph Mode

To enter or exit the Graph Mode, press the Graph key.

Front panel display in graph mode



Front Panel Number Entry

You can enter numbers from the front panel using one of two methods.

Front panel number entry using the knob and cursors

Knob and Cursors

1. Use the keys below the knob to move the cursor left or right.
2. Rotate the knob to change a digit (clockwise to increase).

Keypad

1. Key in a value.
2. Select a unit to enter the value.

To Use the Built-In Help System

The built-in help system is designed to provide context-sensitive assistance on any front-panel key or menu softkey. A list of help topics is also available to assist with several front-panel operations.

Getting help

1. View the help information for a function key by holding it down.

   OR

2. Pres the Help key to view a list of available help topics. This can be used to get help on the last message displayed, e.g. an invalid configuration.

LEG1.22

Setting up the AWG

Turn the power on

1. Push the white power button located on the lower left corner.
   The AWG will perform a self-test and will be operational in a few seconds.

Recall default settings

2. Press the `Store / Recall` button. Press `Set to Defaults`. Press `Yes`. This places the AWG in a known operating condition. The AWG defaults to Menu Mode with the sine wave function selected:

   Note: To protect any connected equipment, no signal is output until the `Output` key is pressed (lighted).

Select a waveform

3. Select a waveform type by pressing the appropriate key.

Set the frequency

4. To set the frequency, press the `Freq` softkey [to set the waveform *period* instead, press the `Freq` softkey again to toggle to the `Period` softkey]. Enter the magnitude of the desired frequency using either the keypad, or the knob and cursors. Press the softkey that corresponds to the desired units.

Set the output termination

5. Press the `Utility` key and select the `Output Setup` softkey. Press the `Load` softkey again to choose "High Z". Press the `Done` softkey.

Set the amplitude

6. To set the amplitude, press the `Ampl` softkey [to set the amplitude using a high and low level, press the `Ampl` softkey again to toggle to the `HiLevel` and `LoLevel` softkeys]. Enter the magnitude of the desired amplitude using either the keypad or the knob and cursors. Press the softkey that corresponds to the desired units. To change the units, press the `+/-` key to enter the numeric entry mode, then press the softkey that corresponds to the desired units. The displayed value is converted to the new units.

Set the DC offset

7. To set a DC offset, press the `Offset` softkey. Enter the magnitude of the desired offset using either the keypad or the knob and cursors. Press the softkey that corresponds to the desired units.

Enable the output

8. Connect a lead to the *Output* connector and press the `Output` key.

To Set the Duty Cycle of a Square Wave

1. Select the square wave function.

2. Press the `Duty Cycle` softkey. The duty cycle represents the amount of time per cycle that the square wave is at a high level (note the icon on the right side of the display).

3. Enter the desired duty cycle. The duty cycle range is 20% to 80%.

To Configure a Pulse Waveform

1. Select the pulse function.

2. Press the `Period` softkey and set the pulse period.

3. Press the `Width` softkey and set the pulse width.

4. Press the `Edge Time` softkey and set the edge time for *both* the rising and falling edges. The edge time represents the time from the 10% threshold to the 90% threshold of each edge (note the display icon).

LEG1.24

To Output a Stored Arbitrary Waveform

There are five built-in arbitrary waveforms stored in non-volatile memory, and four stored arbitrary waveforms (which can be given names).

1. Press the Arb key to select an arbitrary waveform. A temporary message is displayed indicating which waveform is currently selected.

2. Press the Select Wform softkey to bring up the arbitrary waveform selection menu.

3. Press the Built In softkey to choose from one of the five built-in waveforms: Exp Rise, Exp Fall, Neg Ramp, Sinc and Cardiac.

4. Press the Stored Wform softkey to choose from one of the four user-defined (and named) waveforms.

5. The waveform is output using the present settings for frequency, amplitude, and offset unless you change them.

To Create and Store an Arbitrary Waveform

1. Press the Arb key to select an arbitrary waveform. A temporary message is displayed indicating which waveform is currently selected.

2. Press the `Create New` softkey to start the waveform editor. While in the waveform editor, you define the waveform by specifying time and voltage values for each point in the waveform. When creating a new waveform, the previous waveform in volatile memory is overwritten.

3. Press the `Cycle Period` softkey to set the *time* boundaries for the waveform. The time value of the last point that can be defined in the waveform must be *less* than the specified cycle period.

4. Press the `High V Limit` and `Low V Limit` softkeys to set the upper and lower voltage levels that can be reached while editing the waveform. The upper limit *must* be greater than the lower limit. By default, Point #1 is set equal to the upper limit and Point #2 is set equal to the lower limit.

5. Press the `Interp` softkey to enable or disable linear interpolation between waveform points. With interpolation enabled (default), the waveform editor makes a straight-line connection between points. With interpolation disabled, the waveform editor maintains a constant voltage level between points and creates a "step-like" waveform.

6. The waveform editor initially builds a waveform with two points and automatically connects the last point of the waveform to the voltage level of the first point to create a continuous waveform. Press the `Init # Points` softkey to specify the initial number of waveform points (you can add or remove points later if necessary).

7. Press the `Edit Points` softkey to accept the initial waveform settings and begin point-by-point editing. The status line at the top of the display window shows the point number at the *left*, the time value of the current point in the *centre*, and the voltage value of the current point to the *right*.

8. Press the `Voltage` softkey to set the voltage level for Point #1 (this point is fixed at a time of 0 seconds). By default, Point #1 is set equal to the upper limit.

9. Press the `Point #` softkey and then turn the knob to move to Point #2. Press the `Time` softkey to set the time for the current point (this softkey is not available for Point #1). Press the `Voltage` softkey to set the voltage level for the current point.

10. Using the `Time` and `Voltage` softkeys, define the remaining waveform points.

11. Press the `End /Store` softkey to store the new waveform in memory.

12. Press the `DONE` softkey to store the waveform in volatile memory ***or*** press the `Store in Non-Vol` softkey to store the waveform in one of four non-volatile memory locations.

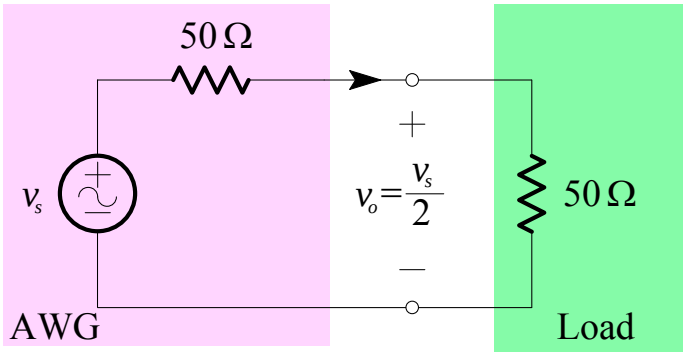
    You can assign a custom name to the four non-volatile memory locations.

Output Termination

The AWG has a fixed series output impedance of 50 Ω to the front-panel *Output* connector. You need to specify the load impedance that the AWG is driving. If the actual load impedance is different than the value specified, the displayed amplitude and offset levels will be incorrect. In other words, the displayed amplitude and offset levels reflect what would physically be measured at the output terminals under the specified load conditions.

The output termination (i.e. load impedance) value can be from 1 Ω to 10 kΩ, or High Z (open-circuit). The default is 50 Ω. The message line at the top of the display calls attention to output termination settings other than 50 Ω.

If you specify a 50 Ω termination but are actually terminating into an open-circuit, the actual output will be *twice* the value specified. This is because the AWG is expecting:



and so displays $v_o = v_s/2$. With no load the AWG output voltage will double to $v_o = v_s$, but the display will still show $v_o = v_s/2$ as though the output were terminated correctly.

We normally want the output termination to be High Z (the connections to the TIMS and DSO are a high impedance compared to 50 Ω).

1. Press the Utility key and select the `Output Setup` softkey.

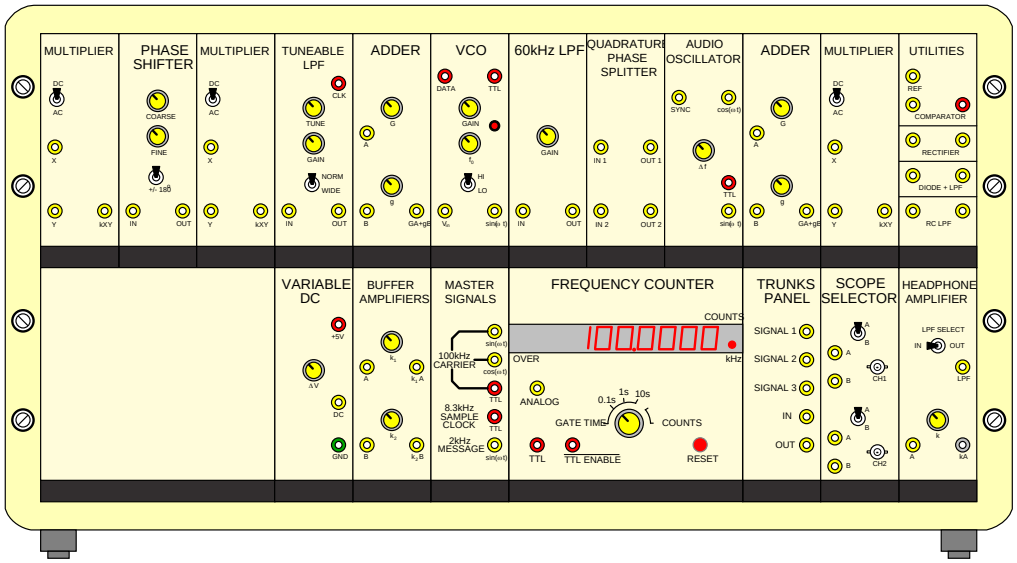
2. Use the knob or numeric keypad to select the desired load impedance or press the `Load` softkey again to choose "High Z". Press the `Done` softkey.

LEG1.28

TIMS Trainer

The Telecommunications Instructional Modelling System (TIMS) trainer is a modular piece of lab equipment, designed specifically for setting up and testing simple communication and signal processing schemes.

TIMS front panel



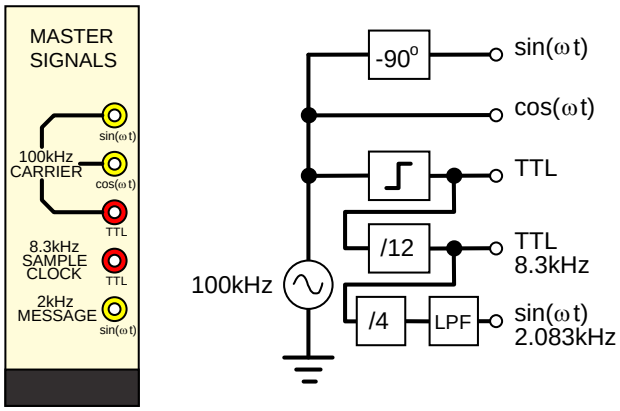
Inputs are always on the left of a module, outputs on the right.

Yellow terminals are analog, and red are digital.

Master Signals

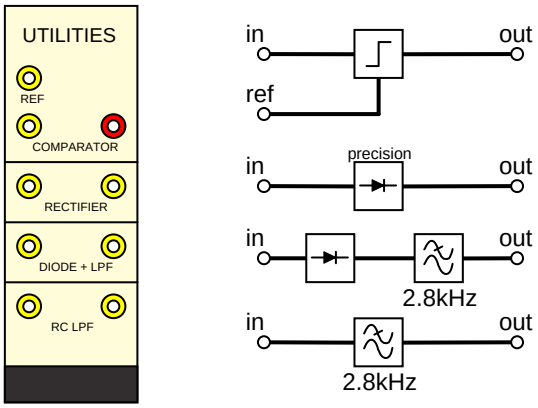
This module is used to generate various master signals. There are two sinusoids in quadrature (90° phase difference) with a frequency of 100 kHz. There are two TTL compatible (0 V to 5 V) square waves at a frequency of 100 kHz and 8.3 kHz. There is also a 2 kHz, 2 V amplitude, sinusoidal "message" signal.

Master signals module



Utilities

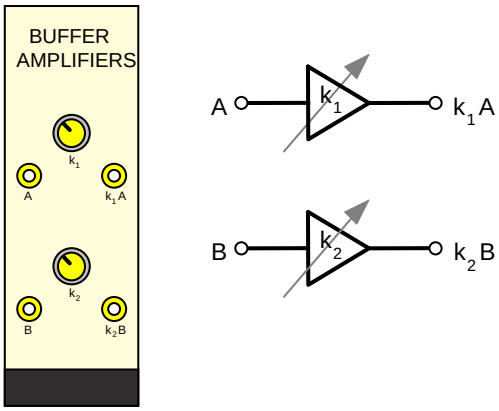
The utilities module has a comparator; a precision half-wave rectifier; a diode with lowpass filter for envelope detection; and a simple first-order *RC* lowpass filter. Both lowpass filters have a cutoff frequency of 2.8 kHz.



Utilities module

Buffer Amplifiers

These are used to buffer a signal (which prevents loading of the source circuit) and amplify it.



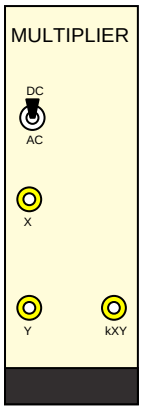
Buffer amplifier module

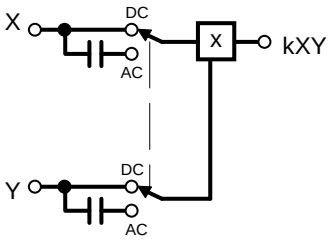
LEG1.30

Multiplier

These are used to multiply two signals together. We can multiply either the total signal (DC + AC) or just the AC component, depending on the position of the DC/AC switch. (DC stands for ***D***irect ***C***oupling, AC for ***A***C ***C***oupling).

Multiplier module

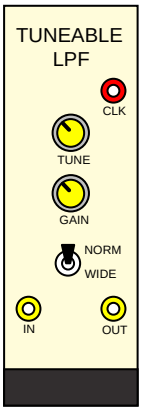


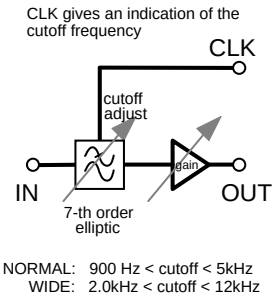


Tunable Lowpass Filter (LPF)

The tunable lowpass filter provides a variable cutoff frequency and gain control.

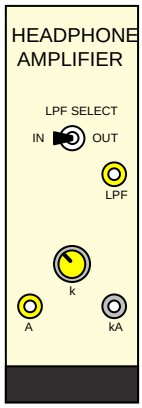
Tunable LPF module

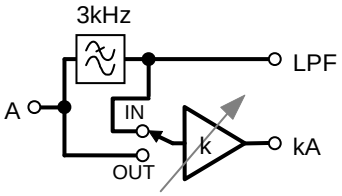




Headphone Amplifier

The headphone amplifier provides additional amplification and impedance matching for a set of headphones. It also has an optional lowpass filter which provides a cutoff frequency of around 3 kHz.

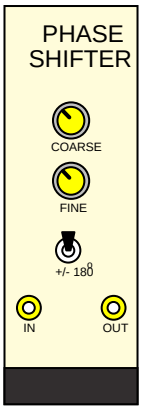


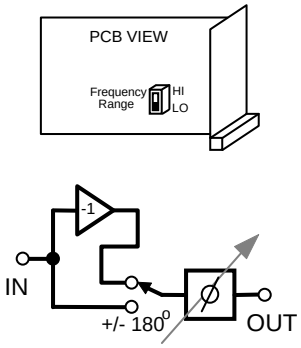


Headphone amplifier module

Phase Shifter

Used to vary the phase of a signal without affecting the amplitude. The signal can also be inverted.





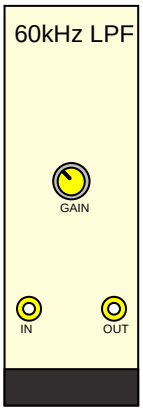
Phase shifter module

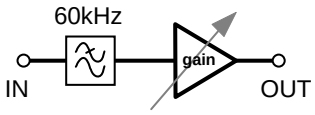
LEG1.32

60 kHz Lowpass Filter

Used as a nearly ideal lowpass filter. The passband gain is variable.

60 kHz lowpass filter module

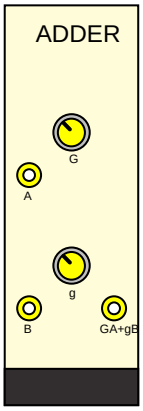


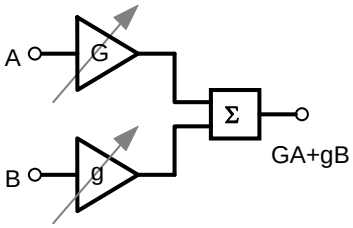


Adder

Used to add two analog signals. Each signal can be scaled before adding.

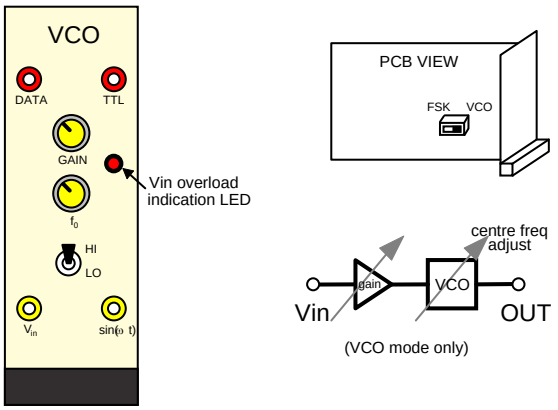
Adder module





VCO

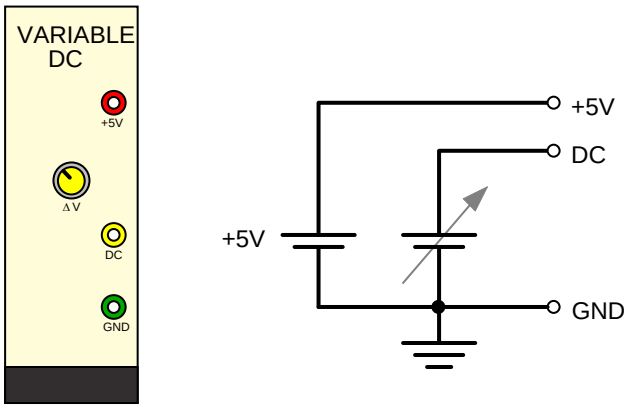
The Voltage Controlled Oscillator (VCO) produces a sinusoid with a frequency proportional to an analog input voltage. The centre frequency, f_0, is the VCO output frequency when no input is applied. The frequency sensitivity (V/Hz) is adjusted using the GAIN control. The overload LED indicates when the VCO cannot produce the "required frequency" due to the centre frequency setting, the gain, and the external input voltage overloading the internal circuitry.



VCO module

Variable DC

Provides a variable DC voltage – useful for adding an offset to a waveform and for measuring the VCO characteristic.



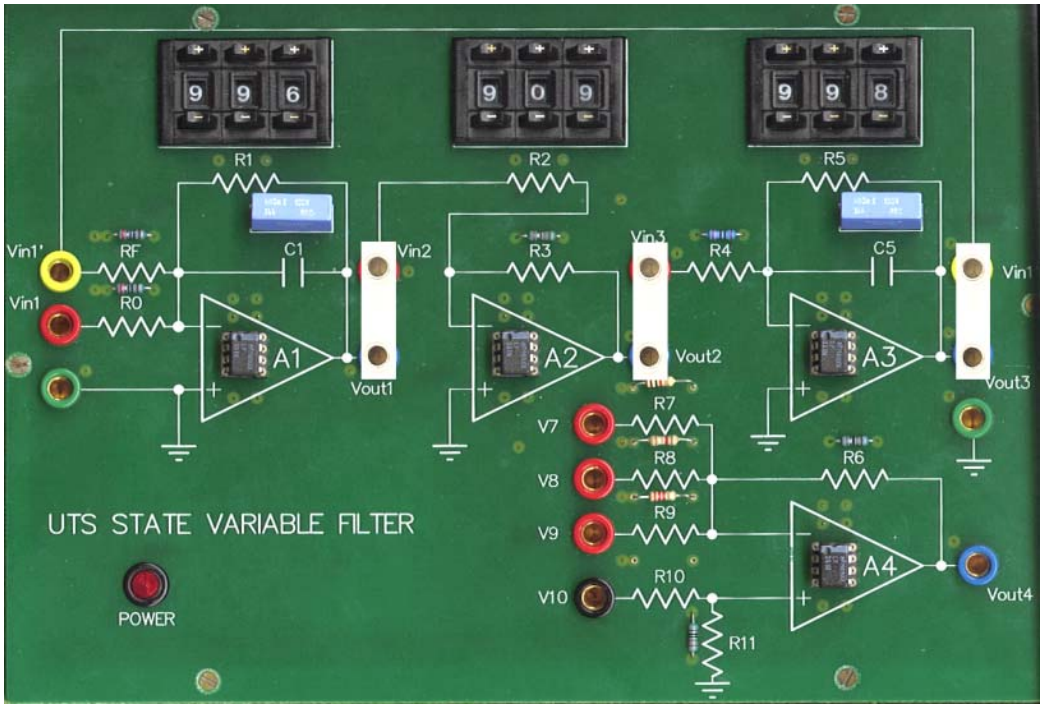
Variable DC module

LEG1.34

State Variable Filter

The state variable filter (SVF) is a versatile active analog filter, consisting of op-amps, resistors and capacitors. Due to its construction, we are able to isolate and connect parts of the filter using special links.

State variable filter front panel



A schematic of the implemented circuit is drawn on the overlay of the printed circuit board, making it easy to trace the signal paths.

There are three main parts of the amplifier, each one a simple op-amp circuit. From left to right they are:

Amplifier parts

1. first-order, real pole amplifier
2. gain stage
3. first-order, real pole amplifier

Links

There are links between each of the three stages, enabling individual parts of the SVF to be isolated. The links also provide the ability to build complex second-order transfer functions.

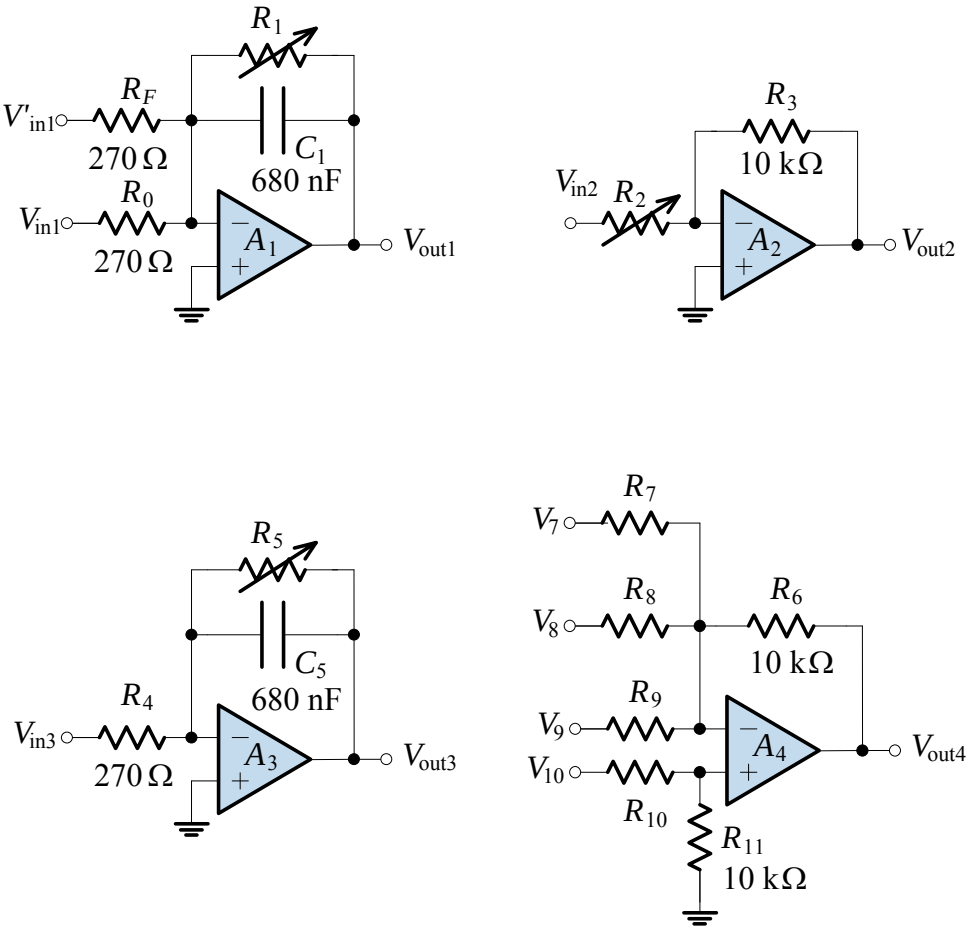
Summing amplifier

The fourth part of the SVF is a summing amplifier, with gains provided by choosing appropriate resistors.

The SVF needs power to operate. The switch is on the back, and power is indicated by the POWER LED.

A schematic of each of the four parts of the SVF is shown below:

SVF individual circuits



The push button resistors R_1, R_2 and R_5 are variable push-button resistors with the resistance ranging from 0 Ω to 9990 Ω in 10 Ω steps. **A 10 Ω fixed resistor is connected in series with each variable resistor giving an effective range of 10 Ω to 10 kΩ.**

SVF push button resistors

For example, if the push-buttons display 499 then the resistance is 5 kΩ: