plug & play instruments
oscilloscopes

Guided Tour

Welcome to the Cleverscope guided tour.

This tour introduces you to exploring signals using Cleverscope. These are techniques that you will use every day, and along the way we'll illustrate some of the standout features available to Cleverscope users.

We finish the tour with a list of important differences between Cleverscope and competing products.

Guided Tour

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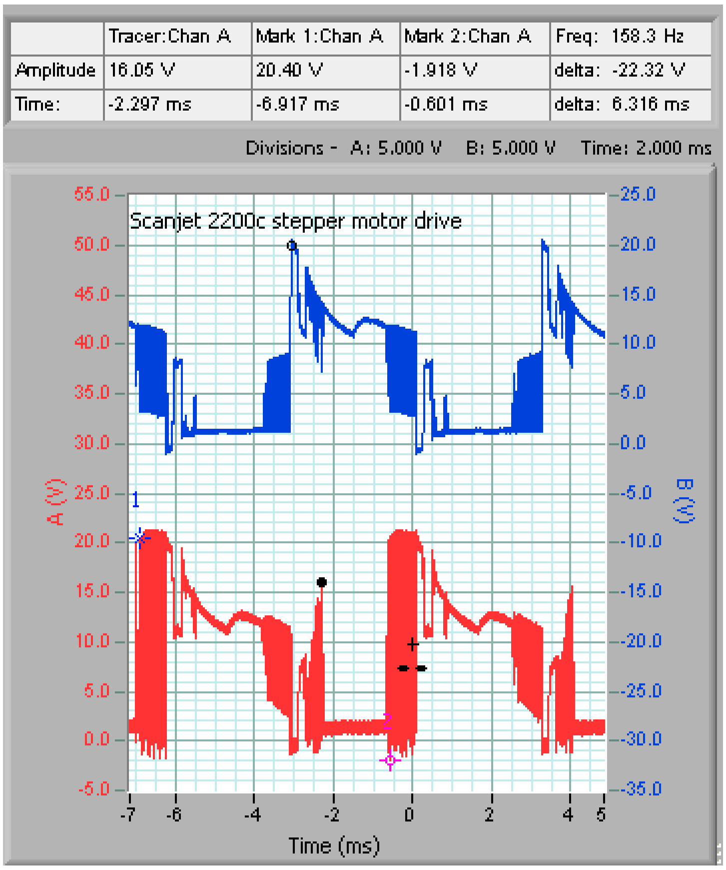
Exploring signals

Looking at analog signals in time

Stepper motor drives are commonly used to provide motion in all sorts of applications – scanners, printers, photocopy machines, and disk drives for example. Many modern high precision stepper motor drives control current on a pulse by pulse basis to ensure optimum stepping performance without resonance, to minimize radiated electrical noise, and to control speed. Verifying that a stepper drive is working correctly requires a measurement system that can look at a complete control cycle in detail.

As an example we look at the stepper motor winding signals for two of the motor connections of an HP Scanjet 2200 scanner. We are interested in the slew rate of the current controlled output, the correct pulse frequency, and the stability of the control system.

Here is the overview:



One control cycle lasts 6.3 ms.

Explanation

Further details of how you do it are included in this column.

Scope Graph setup

Set the scope graph amplitude and time axis to determine what you capture; the amplitude axis sets the scaling and offsets used to condition the measured signal and present it to the internal Analog to Digital Converter (ADC). In this example the A Channel has been conditioned to acquire a voltage range from –5V to + 55V. To maximize the amplitude resolution try to setup the axis to match the size of the signal you expect to capture.

The time axis sets the amount of signal captured before and after the trigger event. The trigger event is always at time 0. Here we have just over 7 msecs of capture before the trigger and 5 msecs of capture after the trigger. Note that the system will always capture at least 10 msecs of signal, so the post trigger capture may in fact extend out past the right hand edge of the capture graph.

Annotating the graph

You can annotate the graph using the  text tool. Click on the tool, and then on the graph where you want an annotation. Drag the little circle to move the annotation. Click somewhere else to place another annotation. The annotation is fixed to the currently active channel.

If you move the plot, the annotation will move with it.

Moving the tracer

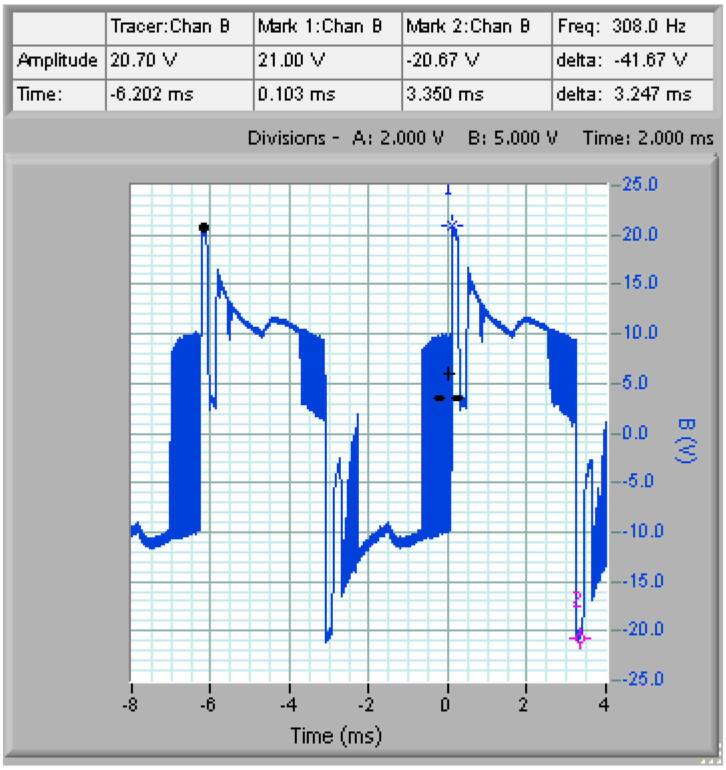
Move the tracer (the black blob) by moving the mouse or using the arrow keys. Make a marker by hitting 1,2 or the space bar, or double clicking. Read the values of tracer or markers from information area above the graph.

Copy and Paste

To copy and paste the graph into a report (as has been done here), click on the graph to be copied, and either type Ctrl C (for Copy) and then Ctrl V (for Paste) into the target document, or use Edit/Copy and then Edit/Paste in the target document.

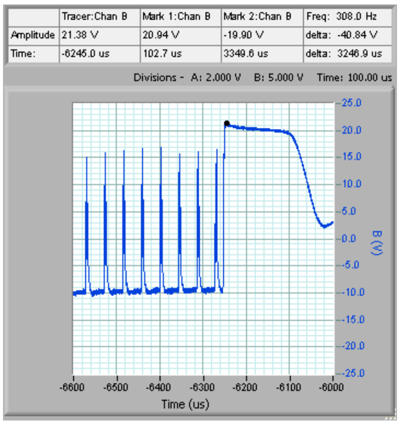
For our investigation we are most interested in the voltage impressed across the winding, rather than the individual winding voltages with respect to ground.

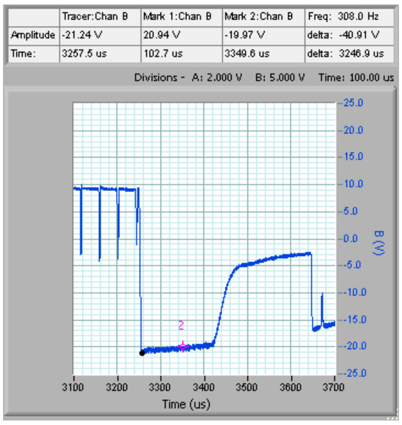
So we turn on Maths and measure A-B → B to find the voltage seen across the winding measured by the two probes:



The winding sees a total voltage of +/- 21V, which can seen to be relatively symmetrical.

Note that you can use the tracking graph to quickly navigate the captured signal. Here we moved the tracer from –6.2ms to +3.3 ms:

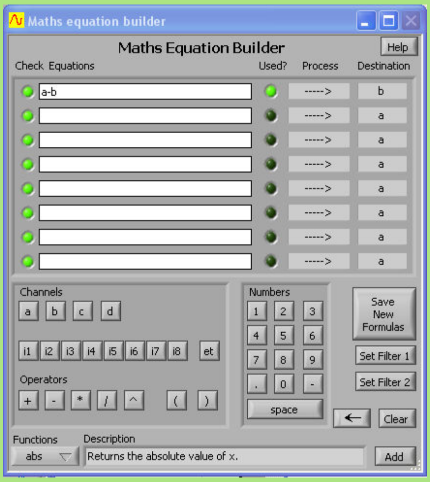




Entering a Maths Equation

Use Options/Display Maths Equation Builder to show the equation builder. Type in, or use the click buttons to form:

Equation	Used	Process	Destination
a-b		→	b



Click on 'Save New Formulas' to save the formula.

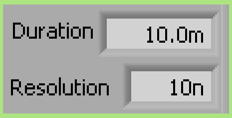
Enable the Maths Button on the Cleverscope Control Panel. Cleverscope will immediately update the B channel display with a-b.

You can turn on/off a channel by clicking on the Enabled buttons on the Cleverscope Control Panel.

Tracking Graph

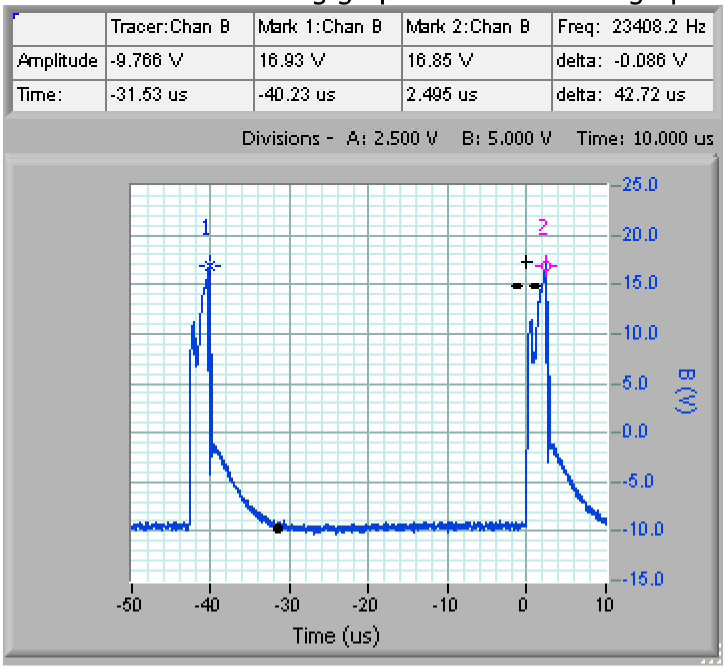
Move the tracer around the graph, and the tracking display will centre itself on the tracer. Make sure the tracking graph is displayed (Options/Display Tracking Graph) and that the graph is linked (Options/Tracking Graph is linked). To lock the tracking graph, hit the 'L' key while navigating the Scope Graph. The tracking graph will lock until you change it.

As you can see, the tracking graph axis can be completely different to those of the scope graph. You can zoom the graph over the total period given in Duration, and resolve down to individual samples with a time spacing given by Resolution. In this example you can resolve 10 ns anywhere in the 10 msec captured duration.



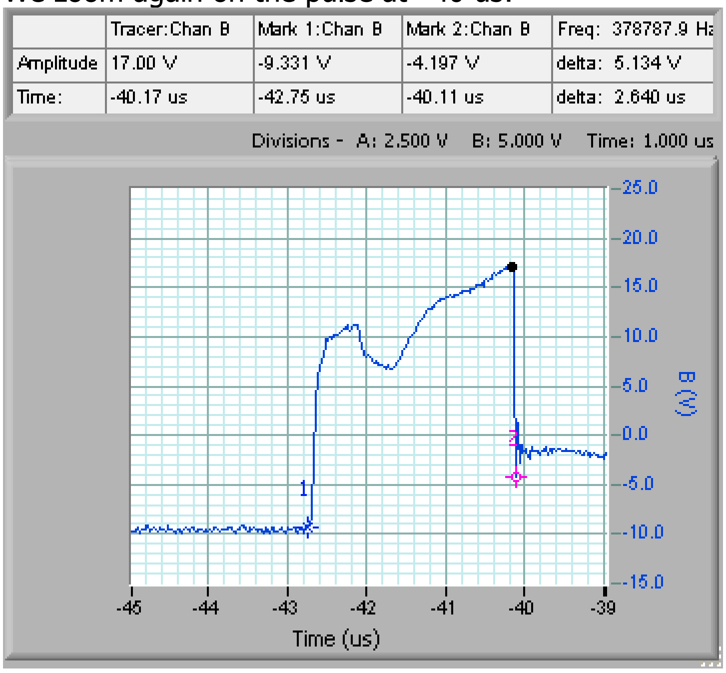
Common characteristics of the control system are:
- Pulse repetition rate
- Pulse slew rate
- Pulse amplitude

We measure each of these in turn below.
Here we use the tracking graph to zoom on the graph at 0 msec:



The pulse repetition rate is 42.72 us. The pulse swings +17V to –9.5V.

We zoom again on the pulse at –40 us:



We can see one positive going pulse lasts 2.64 us.

Zooming the graph
You zoom the graph in these ways:
1. Use the graph enlarge/reduce tools to enlarge or reduce the graph. For the time axis zooms in on the signal, zooms out on the signal. For the amplitude axis zooms in, and zooms out.
2. Use the Control Panel Tools to zoom on time, amplitude or both.
3. Use the keyboard commands to zoom on the marker

⇐ and ⇒ move cursor left right
Shift ⇐ and ⇒ move graph left and right
Control ⇐ and ⇒ change x scale up or down

⇑ and ⇓ move the selected graph up and down
shift ⇑ and ⇓ move the selected graph up and down
Control ⇑ and ⇓ change y scale up and down

How zooming works
Cleverscope keeps all the samples in the acquisition unit. When you zoom the graph, the Cleverscope application requests a new graph view from the acquisition unit. The acquisition unit finds the samples, and returns them, via the USB. The acquisition unit can keep up to 2 M samples in any one display buffer.

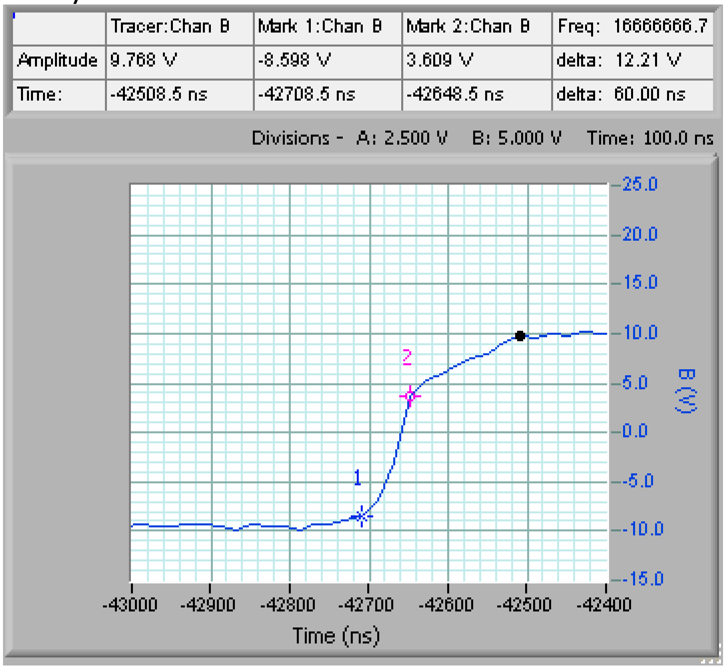
Placing markers
Markers are used to measure the time and amplitude of a time plot – or the frequency and amplitude for a spectrum plot. You place markers like this:
1. Move the tracer to the location of interest.
2. Place a marker by:
   - double clicking
   - pressing the space bar
   - pressing the 1 or 2 keys.

Measuring differences
You measure differences by placing two markers, and then reading the differences in the right most information box.

Freq: 378787.9 Hz
delta: 5.134 V
delta: 2.640 us

Here the time difference is 2.64 us.
You can measure differences between plots by placing the first marker, and then pressing the tab key to move from one plot to the next, and placing the second marker.

Finally we want to find the slew rate:



We can see the slew rate has two slopes – first slewing quickly with a rise of 12.2V in 60 ns, followed by a slower slew of 140 ns over 6.1V. Note that we can obtain all this information after a single capture of the waveform. We still get 10ns resolution, even though we captured more than 12ms of switching duration.

Normally, you would be verifying the unit's design, or test it. Using the design calculations, or testing values, you can verify that the unit being tested complies with your expectations.

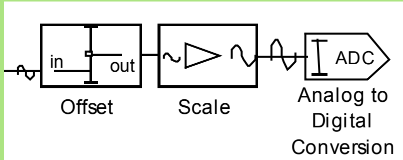
Looking at analog signals in amplitude

Cleverscope always scales and offsets the displayed signal amplitude range to match the Analog to Digital Converters (ADC) input range. This means that you always get maximum resolution, no matter what the display settings are.

A local university were using Exact Model 119 signal generators for lab experiments and wanted to characterize the performance of the unit.

Important characteristics are low harmonic distortion, and low spurious noise.

Analog signal scaling
Cleverscope always offsets, then scales the input signal so that it fits into the full dynamic range of the Analog to Digital Converter (ADC). This ensures that you make maximum use of the signal information.



As example, suppose the input signal was 42 mV in amplitude, biased to –1.6V, and you were displaying it on a 50 mV height graph, centred at –1.6V.

First Cleverscope offsets the input signal from –1.6V to 0V. The –1.6V offset is recorded for display purposes. Next cleverscope scales the 50mV full scale to 1V full scale (the ADC input range) by amplifying the signal 1000/50 = 20 times. The ADC digitises the input signal with full resolution.

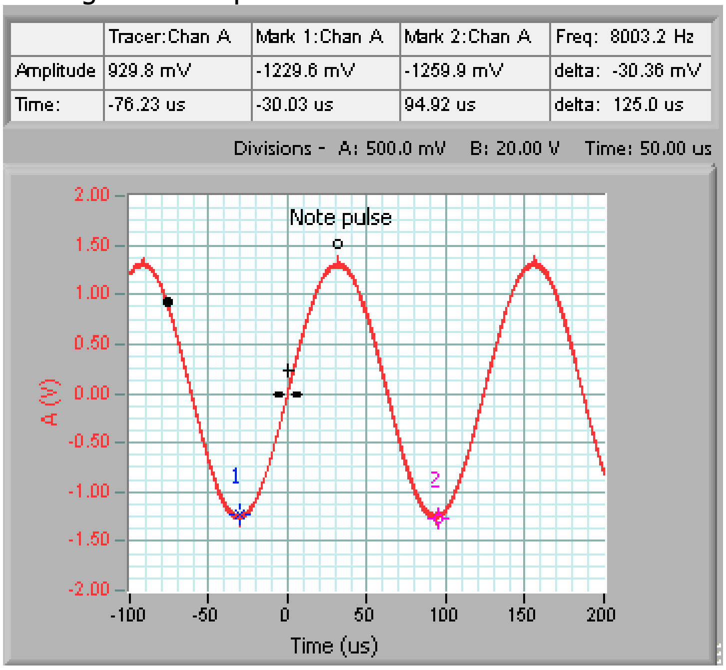
ADC dynamic range

Cleverscope uses a 10 bit ADC. This means that every measurement is digitised with a resolution of 1 part in 2^{10}, or 1 part in 1024. For our example above, the resolution on the 50 mV scale will be 50/1024 which is about 50 uV. The 42mV signal would result in 840 steps.

Discussion
Scaling and offsetting is exactly what standard oscilloscopes do. However, many of them don't have a very large offset range at the most sensitive scales. Cleverscope has an offset range at least twice as large as a very commonly used oscilloscope.

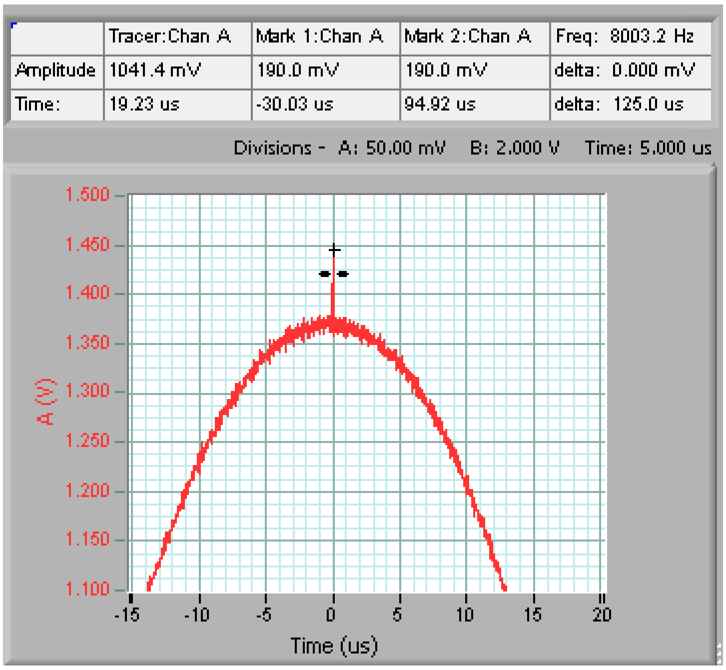
None of the surveyed PC oscilloscopes have offsetting. Instead the ADC just digitises a particular gain setting. For these oscilloscopes to capture a –1.6V signal they would have to use a +/-1.6V range (3.2V span). Further, most of these scopes are 8 bit, which means they would resolve 3200/256 = 12.5 mV. The 42 mV signal would result in 3 steps, far worse than Cleverscope. Even a 12 bit scope would have only 53 steps, still much less than the 840 steps resolved by Cleverscope.

The signal was captured:



Note the small impulses at the peak of the wave. The ADC range covers –2.0 → + 2V.

We can explore this more by triggering on the pulse:
Here we have enlarged the graph 10x to 50mV/div and 5 us/div.



The pulse is now quite visible. The ADC range covers 1.1 → 1.5V

Acquisition Methods
Cleverscope offers several different methods of acquiring signals.

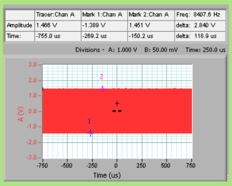
Two of the most commonly used are Peak Captured and Sampled. Mostly you will use Peak Captured sampling.

As you might imagine, we need to transfer the samples inside the Cleverscope acquisition unit onto the displayed graph. The graph is only a few hundred pixels wide (lets assume 240 for our discussion, but it could be up to 1400 on a large display), while Cleverscope stores more than 2 million samples for each captured signal. We do the transfer one of two ways:

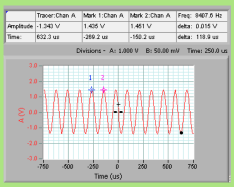
1. Sampled.
   We pick pixel count (240) samples evenly spaced out of the 2M samples. One sample every 83,333 samples, for example. This method will miss glitches, and can alias.
2. Peak captured.
   We find the maximum and minimum values for all the samples in the intervening 83,333 samples, and then display both of them. This method will not miss glitches or alias.

You can see in the captured wave to the left the small impulse on top of the wave form. The pulse turns out to be only 50 ns wide, but it is still displayed, even though one pixel represents 1.4 us. (300us/240)

Aliasing can be problem with sampled capture. Here is a 950 kHz signal captured with a time scale 1.5 ms wide:



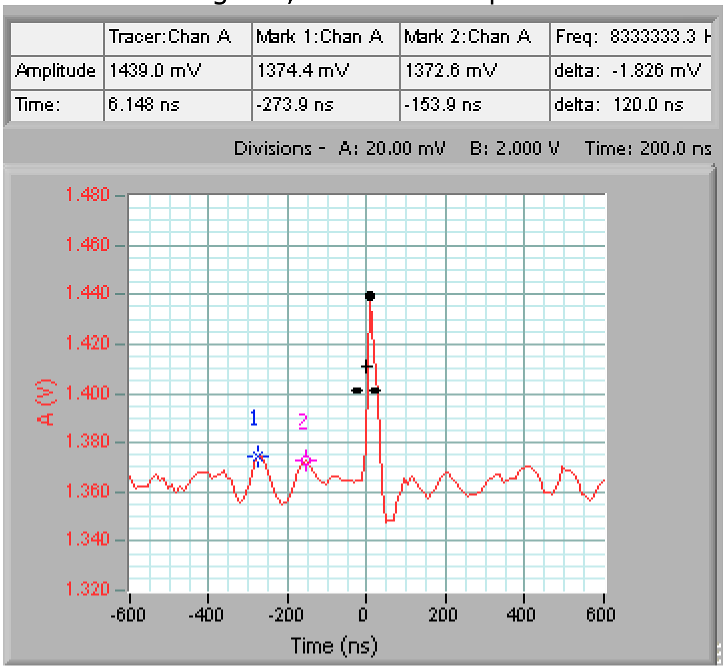
Peak captured – it's solid, no aliasing.



Sampled – we see an alias which is not real.

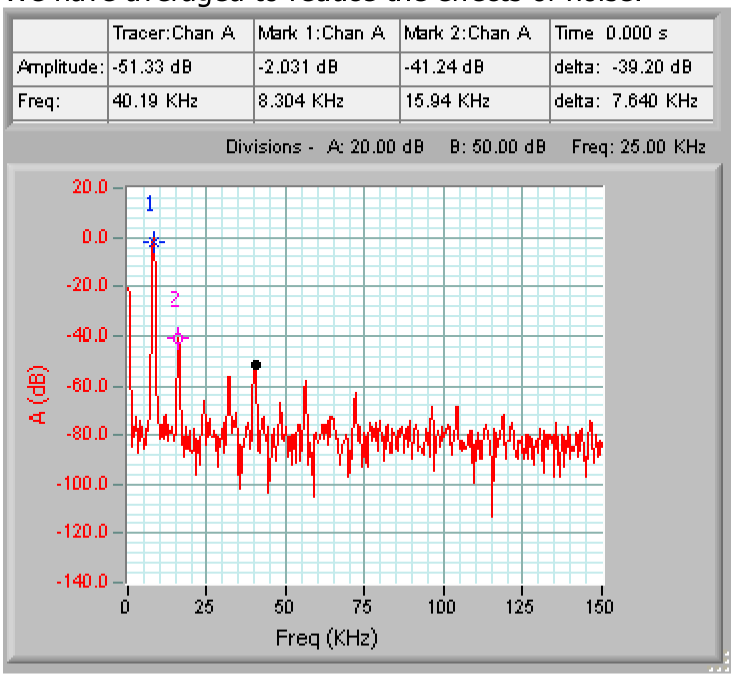
Other PC scopes don't do peak captured, and will alias.

Now we zoom right in, to look at the pulse.



We can see the pulse has an amplitude of around 70 mV. It's duration is about 50 ns. The ADC range now covers 1.32V → 1.48V. It's a matter of conjecture if this pulse is a problem or not – it has very low energy.

Now we check for spectral purity, by looking at the spectrum graph. We have averaged to reduce the effects of noise:



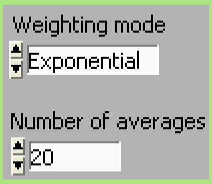
We see the second harmonic at –39 dB below the fundamental. The fifth harmonic is the next largest at –49 dB below the fundamental.

Averaging
Averaging is a very useful method for reducing the effects of noise, or seeing the long-term value of a varying signal.

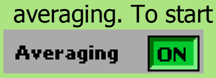
The averaging process can be done three ways:

1. Equal averaged
   We add up all the samples corresponding to one point in time, over successive captures, and then divide the sum by the number of captures. You get an output once that's done (ie not very often).
2. Exponentially averaged
   The current average is made up of a proportion derived from the current capture, with the balance from the previous average. Varying the proportion varies the time it takes to get a constant estimate. You get an output once per capture.
3. Peak captured.
   This applies only to spectrums. If the amplitude of a signal at a particular frequency is greater than the previous value, the new value replaces the previous value. Peak captured can be used to build up a transfer function, or find the total frequency content of a signal over time.

You select the type of averaging using Options/Averaging. For exponential averaging the proportion used is 1/the number of averages.



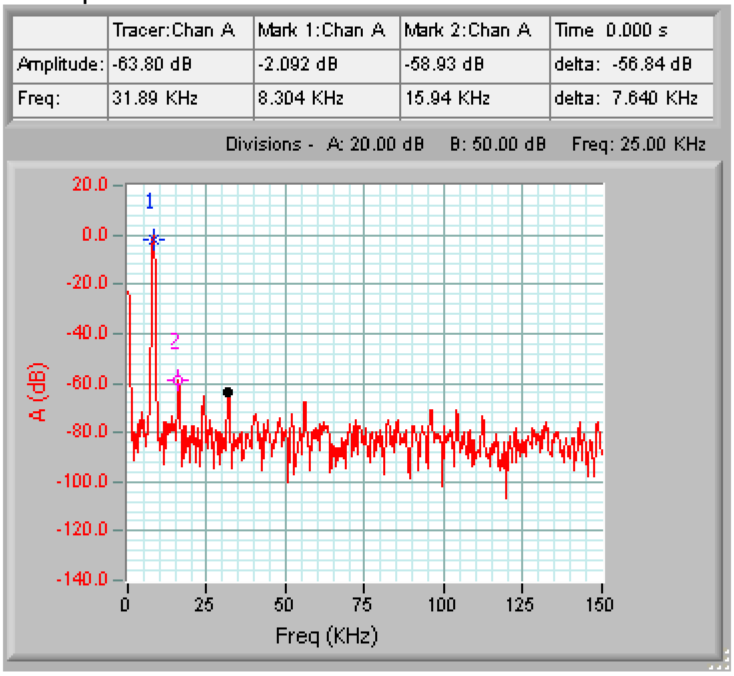
The number of averages doesn't apply to peak averaging. To start averaging turn it on with the averaging button on the control panel.



Because noise is random, and has an average value of 0, averaging will reduce the effective amplitude of the noise in each time sample. The amount of reduction is dependant on the number of averages – making this number larger, will reduce the noise more, but it will take longer to settle the signal being measured.

To reset the average to 0, use Options/Reset Average (or Ctrl R).

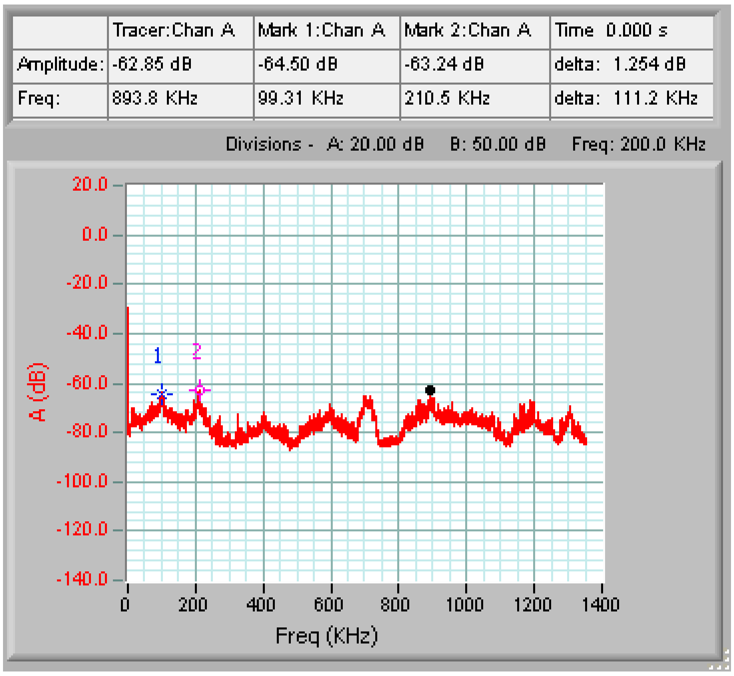
For comparison, here is the Cleverscope signal generator, outputting a comparable waveform:



	Tracer:Chan A	Mark 1:Chan A	Mark 2:Chan A	Time 0.000 s
Amplitude:	-63.80 dB	-2.092 dB	-58.93 dB	delta: -56.84 dB
Freq:	31.89 KHz	8.304 KHz	15.94 KHz	delta: 7.640 KHz

Here the second harmonic is –56 dB below the fundamental. The fourth harmonic is the next largest at –61 dB below the fundamental. The Cleverscope sig gen is about 17 dB better.

To examine sig gen output noise, we set the signal frequency to 1 Hz (leaving the amplitude as it was), and measure a window through the zero crossing. We increase the Cleverscope gain to 20 mV per division, and use peak averaging to get the maximum signal at each frequency.
Here is the Model 119 spectra:



	Tracer:Chan A	Mark 1:Chan A	Mark 2:Chan A	Time 0.000 s
Amplitude:	-62.85 dB	-64.50 dB	-63.24 dB	delta: 1.254 dB
Freq:	893.8 KHz	99.31 KHz	210.5 KHz	delta: 111.2 KHz

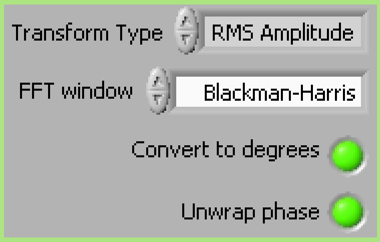
Peak noise is about –62 dB.

Signal Generator
Cleverscope includes an optional direct digitally synthesised signal generator. The signal generator synthesises sine, square and triangle waves, at a frequency between 0.2 Hz and 10 MHz. You can vary the amplitude over the range 0 → 5V p-p and the offset over the range –4→ + 4V.

The signal generator outputs samples at a 50 MHz rate, and uses a 5^{th} order modified Chebychev reconstruction filter.

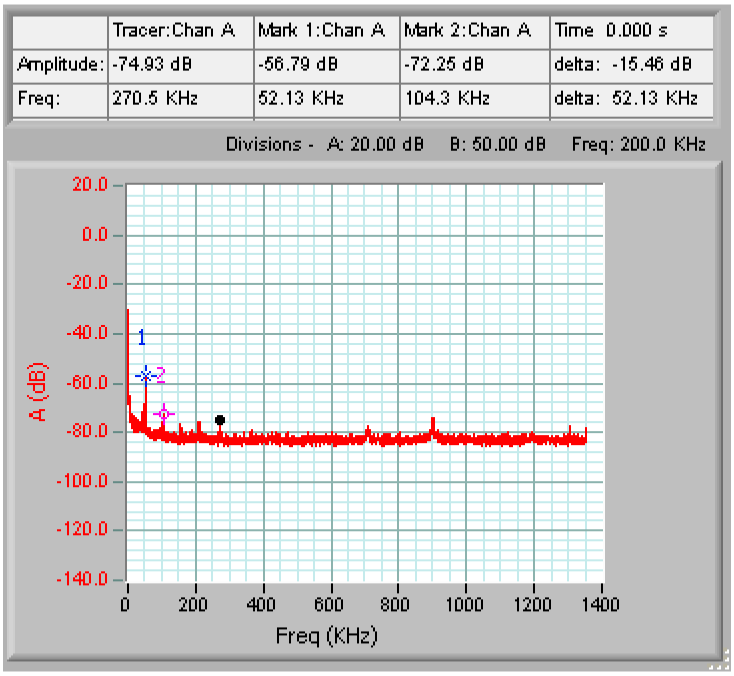
Spectrum Display
The spectrum display is turned on using Options/Display Spectrum Graph.

You can set these options, using Options/Spectrum..



Options are:
1. Transform Type
   For each transform type, a value is plotted at each frequency bin which is determined by the type of transform. Transform types are:
   • RMS amplitude: displays the equivalent RMS amplitude of a sine wave at the frequency of the bin.
   • Power: displays normalised power into a 1 ohm resistor.
   • Power density: displays normalised power into a 1 ohm resistor divided by the bandwidth of the frequency bin.
   • Gain/Phase – displays the Gain (Chan B/Chan A ratio, in dB) and Phase (phase angle between Chan B and Chan A) at the frequency bin
2. FFT window
   defines the window used to mitigate end point errors. There are 10 types of windows available.
3. Convert to degrees
   Applies to Gain/Phase. If true, displays degrees, otherwise displays radians.
4. Unwrap Phase
   Applies to Gain/Phase. If true, phase extends from 0 to 360 degrees. Otherwise it extends from –180 to + 180 degrees.

Here is the Cleverscope sig gen spectra, with the same signal:



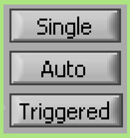
There is a spurious signal at –56 dB. However the rest of the signal has a noise floor somewhat below –80dB with just a few peaks intruding above that.

Spectral processing only runs if the spectrum display is displayed.

Averaging of spectrums are done in one of two ways:

1. Time domain averaging
   Time domain averaging gives the greatest improvement in signal to noise ratio. It runs when you have a stable trigger, and you use triggered or single capture.
2. Frequency domain averaging
   If there is no time domain trigger, and you use Auto triggering without a trigger, averaging is done in the frequency domain. A vector average (using both amplitude and phase) is carried out, so that signal to noise is still improved, but improvement will not be as good as the triggered average.

Trigger Controls



Use the trigger controls to select the type of triggering. Single is a single shot, based on the trigger condition being met. Auto free-runs (unless there is a trigger), while Triggered is just like single, expect that following a trigger and display, sampling for a trigger is automatically restarted.

You can set the trigger condition using the trigger panel on the Cleverscope Control Panel.

The most important values are these:

Set the slope for rising or falling triggers. Set the source appropriate to your application. The level can be set manually, or using the trigger cursors, to set a rising or falling trigger. The trigger cursors apply to the currently selected trigger channel. You can have different trigger levels for each of the trigger sources (A, B, Ext, or digital).

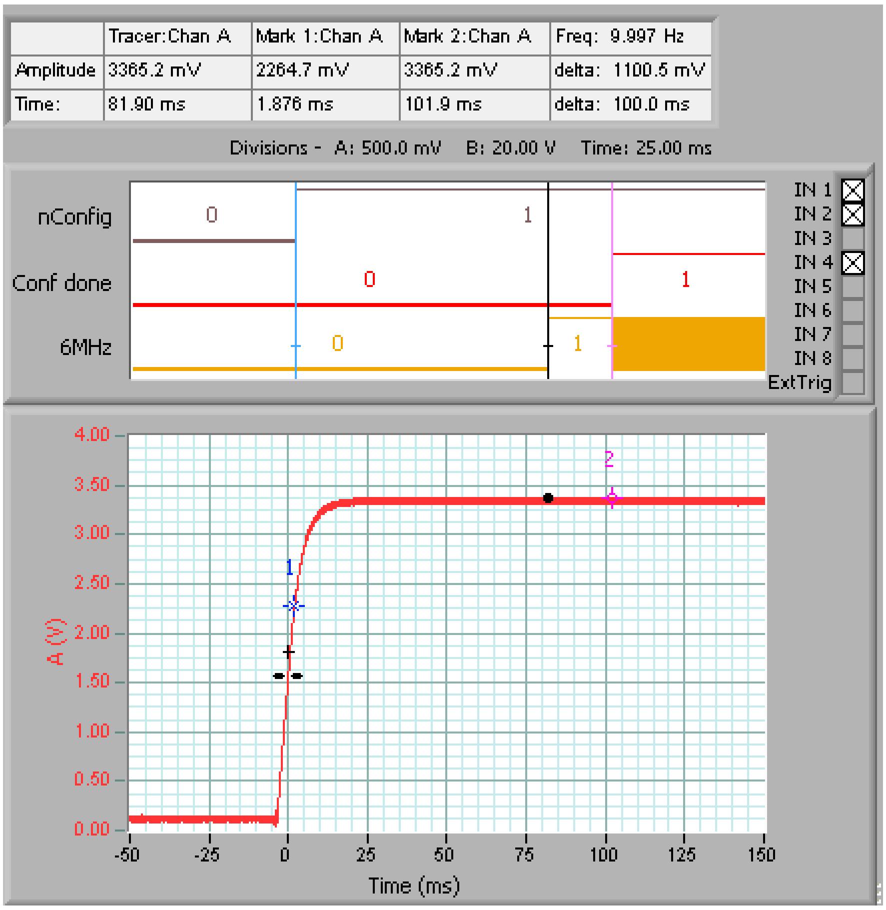
Looking at mixed analog digital signals

Most modern devices (such as cell phones, PDA's, music players, net devices, printers, scanners, and all manner of other electronic gadgetry) use embedded microprocessors or Field Programmable Logic Devices (FPLD's) to control the device. All require a power supply and signal conditioning to ensure correct start up and operation. Many devices include analog connections to the real world. Traditional oscilloscopes offer two or four analog channels, not usually enough to look at all the desired signals.

As an example we look at the power up sequencing of an Altera Cyclone FPLD. We are interested to see if there are any glitches in the power supply, and the turn on time of the system.

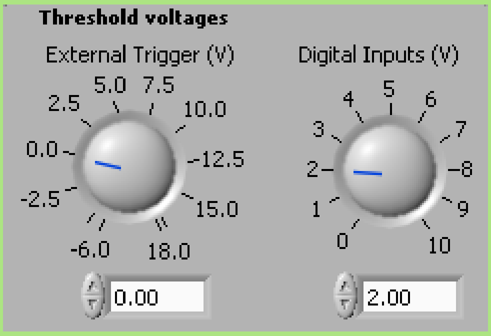
We captured the analog power supply, and three digital signals:

- NConfig – which forces configuration of the FPLD on a 0 → 1 transition
- Conf done – when high indicates that configuration is complete
- 6 MHz clock – this is a clock going to a USB device



We have placed markers at the nConfig transition, and at Config done. The tracer (the black dot) shows the point at which outputs were enabled. We captured 200 msec. Resolution is 100 ns.

Digital Signals
Digital Signals differ from analog signals in that they only have two states – low (0) and high (1). Cleverscope allows you to define the transition from low to high using the Options/Acquisition Details dialog.



A value of 2V suffices for most types of logic. However you can use the inputs with analog signals from filters and amplifiers and set the threshold as required.

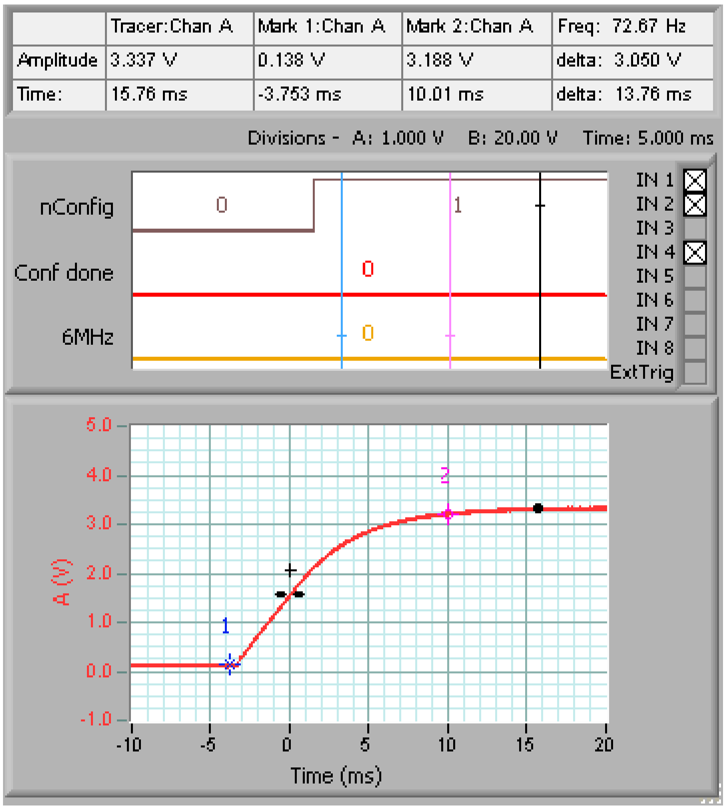
Digital signals are captured at exactly the same rate as analog signals, with a 10 ns sample period, and are time aligned to the analog signal. The digital signals include Inputs 1-8 and the External Trigger.

Displaying Digital Signals
You display the digital signals by using Options/Display Digital graph. Once displayed, resize the graph to get the amount of analog display you want. You can choose which digital signals to display by clicking on the check box. You can rename the digital signals using Options/Set Digital Labels, and set their colour.

We notice the following:

1. The power supply rise looks clean, without overshoots. We measure the rise time below.
2. The power supply voltage is 3.365V which is within spec for a 3.3 +/- 5% power supply.
3. The FPLD takes a total of 100 ms to wait for clock stability, configure and start outputting valid clocks etc.
4. We can estimate that the internal configuration process takes 20msec to run (from the point that the pin is enabled, to a clock being output).

Here we have zoomed in time on the rise:



We can see that the power supply rise time is 13.76 ms. The Altera Cyclone HW Handbook requires a power supply rise time from 100 ns to 100 ms. This requirement is clearly met.

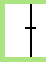
There is no sign of overshoot (the peak captured display would show it).

You can set the height of the digital graph between normal (as it is here) and double height by choosing

.

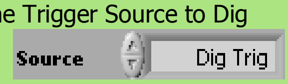
Digital Tracers and Markers

Notice that as you move the tracer the black tracer line on the digital display follows the analog tracer. Similarly the markers are mirrored to the digital graph, which is synchronized with the analog graph. If you want to pay particular attention to a digital input you can drag the threshold marker to the input of interest.

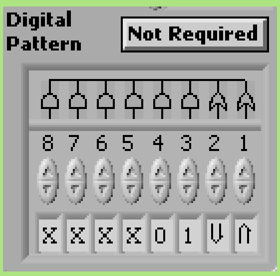


Digital Triggering

Digital inputs are displayed synchronous to the analog inputs when using analog triggers. In addition, the digital inputs can be used to initiate triggering. To trigger from the digital inputs, set the Trigger Source to Dig Trig. Next you need



to define the trigger. This is done using the Digital Pattern.



Each input is assigned a condition. X means don't care. The other values are a 0 (lo) value is required, a 1 (hi) value is required, a falling edge, and a rising edge. Next inputs are logically combined. means AND – all ANDed inputs must meet the condition to cause a trigger. means OR – any one of the inputs must meet the condition. In this example:

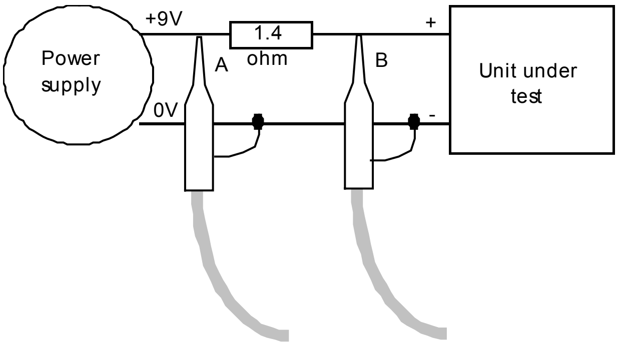
- either Input 1 has a rising edge, or Input 2 has a falling edge
- AND input 3 must be 1
- AND input 4 must be 0

You can also use the digital inputs to condition the analog trigger. If you use an analog trigger, and turn on 'Required' then the analog trigger cannot happen until the digital pattern is met. (Don't use edges in the pattern – the probability of a digital edge happening in the same sample as an analog edge is very small!)

Using mathematical functions

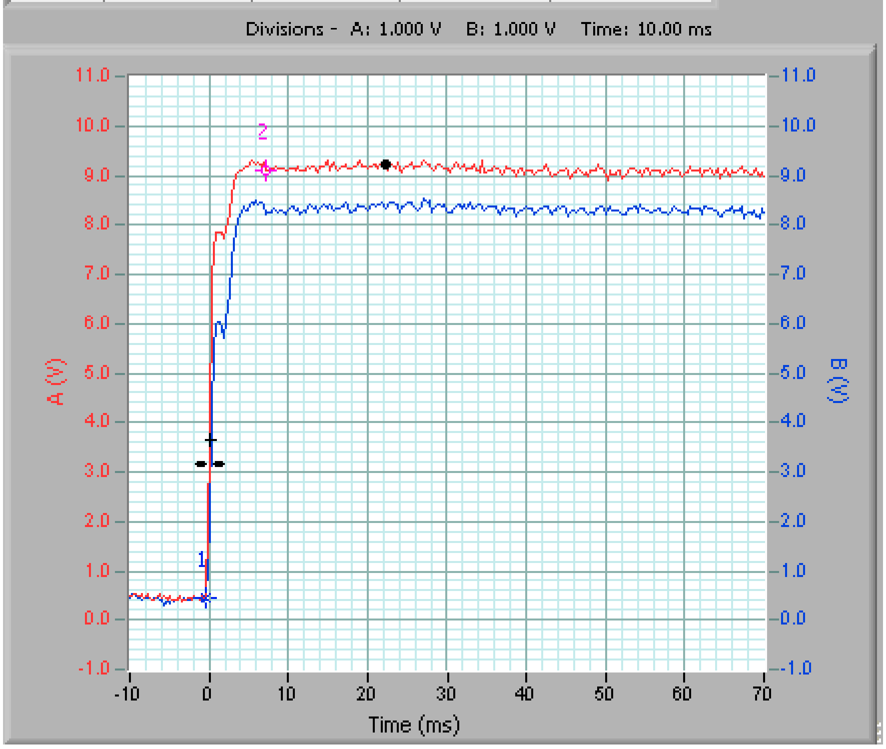
The Maths module can be used to enhance understanding of the signal being viewed.

As an example consider power consumption measurement. Here is a typical example – a power supply delivers 9V to a battery powered Unit Under Test (UUT). Our goal is to measure current, and power consumption, and arrive at the total energy needs of the UUT. To do this we use a series resistor (it could be a DC capable current clamp) to measure the current. Because the resistor is in the positive line we need to do differential measurements to see the current.



Here is a graph captured from a typical UUT starting up, configured as in the diagram:

	Tracer:Chan A	Mark 1:Chan A	Mark 2:Chan A	Freq: 133.3 Hz
Amplitude	9.222 V	0.472 V	9.082 V	delta: 8.610 V
Time:	22.19 ms	-0.313 ms	7.189 ms	delta: 7.501 ms



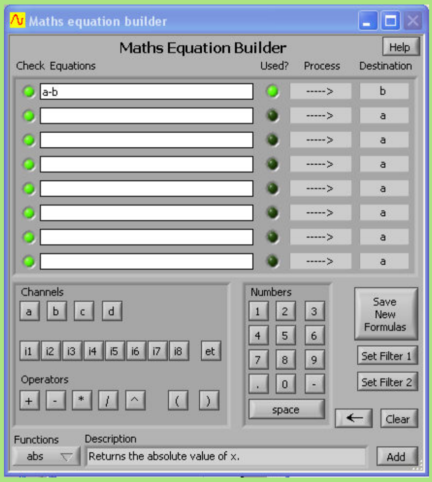
Mathematical Functions

The Mathematical Functions are very useful for visualising information that can be derived from the measured signals.

This section describes deriving first the differential voltage across a resistor, followed by conversion of that value to a current, then using a multiply deriving power, and finally by integrating the power, measuring energy.

Derivation is very useful in a number of other areas – for example using I and Q signals to demodulate base band signals, using 4 quadrant multiplication to simulate modulation and investigate the resulting signal bandwidth, using filters to estimate what the real world measurement of a conditioned sensor might be.

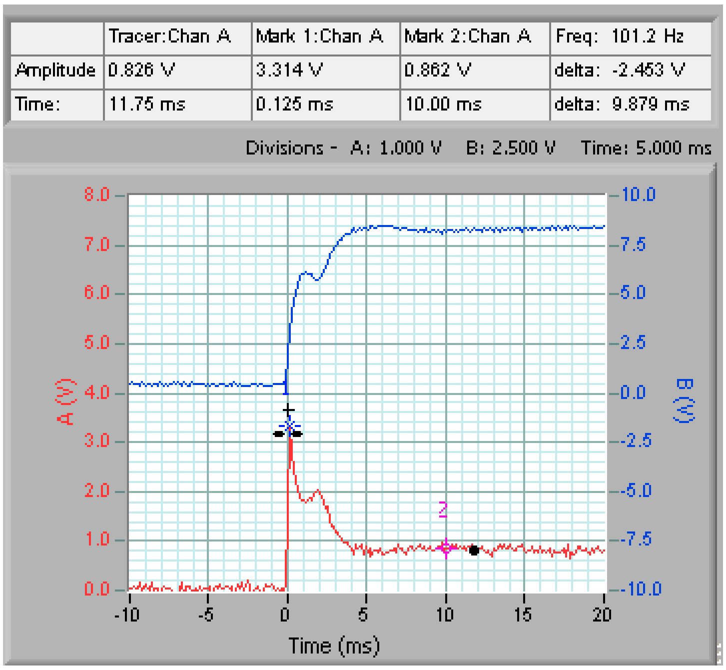
Remember to turn on Mathematical equations using Options/Display Maths Equation Builder. If you need help in how to use it, click on Help.



Click on 'Save New Formulas' to save the formula.

Enable the Maths Button on the Cleverscope Control Panel. Cleverscope will immediately update the displays to show whatever formula you have entered.

By using Maths, with A-B → A, we arrive at the following graph:

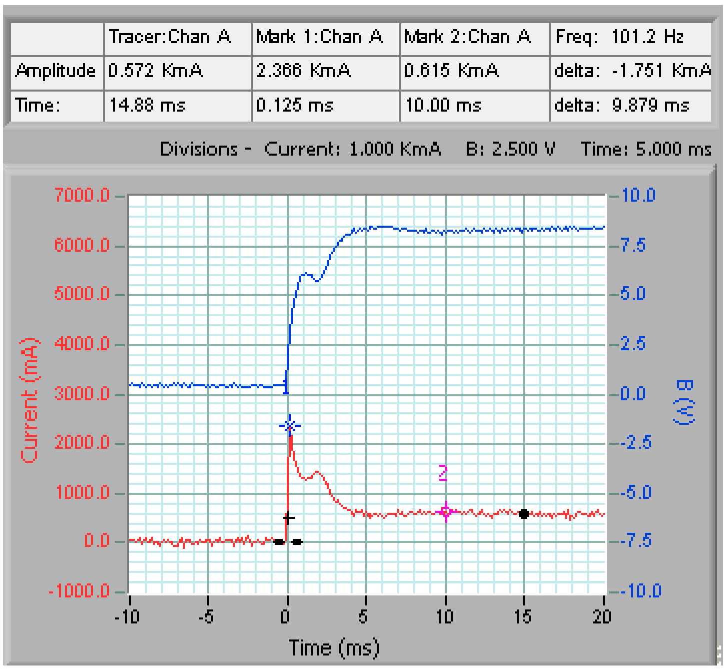


We can see the current demand was initially high, and then fell back following startup. However it would be useful to have this in mA.

From V = IR, and using a 1.4 ohm resistor, we can see that

I = V/R
= V x 1000 x 1/1.4 mA
= 714 V mA

So we add the x 714 into the Maths, and change the units and axis name:



Mathematical Equations

Enter the mathematical equation as

a-b

This equation subtracts each sample value in channel b at a particular time, from the sample value in channel A at the same time. Next it transfers it into Channel A.

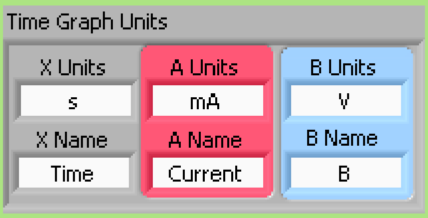
Channel B displays the actual voltage going into the UUT.

Hit the Save New Equations button to update the equation store. Ensure Maths is ON. The graph will update.

To convert to mA change the equation to read:

(a-b)*714

Change the units and axis name using the Options/Custom Units menu option, to change the A channel units and name.



Observe that units and names changed immediately on the graphs and information areas.

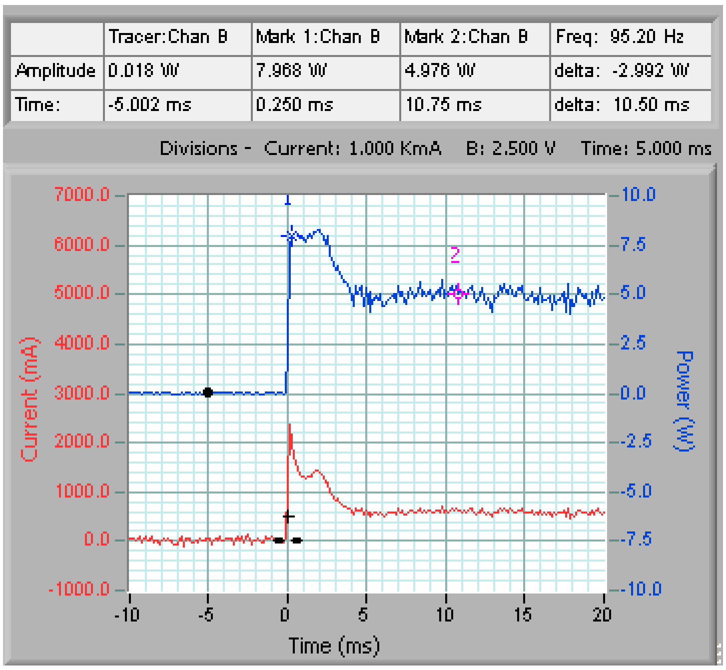
The graph is much more useful now – we can read the current off directly. We see the following:

1. The peak current demand is 2366 mA.
2. The stabilized current demand is 615 mA
3. The increased current demand lasts for about 5 ms.

The B channel shows the actual voltage going into the UUT. Many battery modules are rated in Ahr, which is the design continuous current consumption available for one hour of use. As an example a 9.6V (8 cell) Nicad battery pack might be rated at 700 mAHr, meaning that after one hour of constant current drain of 700 mA, the battery terminal voltage will have fallen to 80% of the full charge terminal voltage, and the battery will be nearly empty. When using a switch mode power supply, we are more interested in the power consumption, because the current will vary with terminal voltage. Assuming a straight line reduction in battery terminal voltage (ie an average of 90% of the fully charged terminal voltage), we can estimate the energy content of the battery in Watt Hr (or Joules, with constant conversion), and use this to calculate actual battery life.

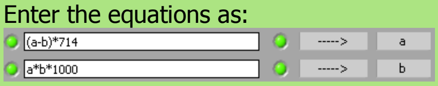
For the battery above, the capacity is
0.9 x 9.6 x 0.7 = 6 Watt Hour, or
0.9 x 9.6 x 0.7 x 3600 = 21.7 kjoule.

Again we can use Maths, first Multiply B x A → B to get watts in the A channel, and relabel the axis for power:



The peak power usage is 8W, while the normal power usage is 5W. If we ignore the initial power pulse, we could estimate the battery life at 6/5 = 1.2 Hours.

Enter the equations as:

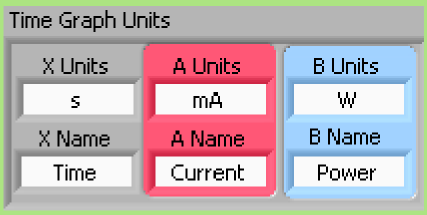


(a-b)*714
a*b*1000

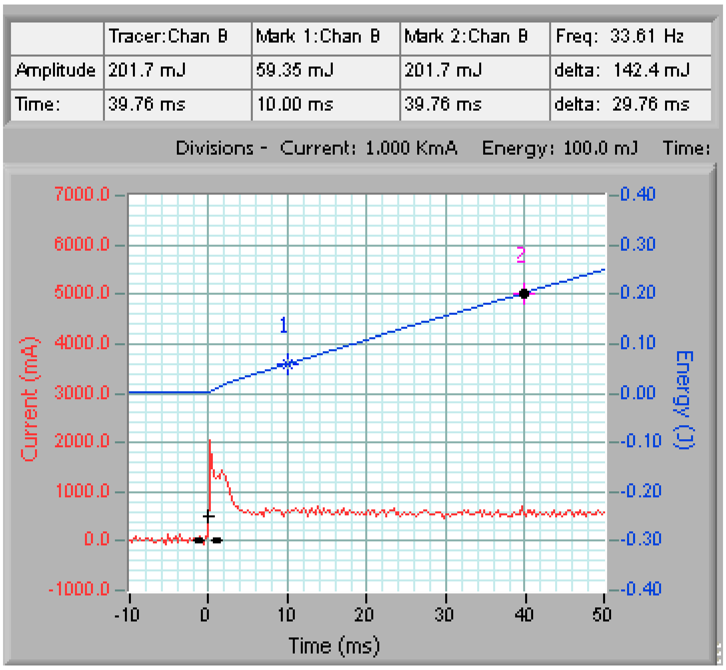
We include the *1000 because the current is in mA, and we want it in A to get W.

Notice there are now two equations. The first puts the current into channel A. The second equation runs after the first, and uses the new current values in A to calculate the power.

We change the units to be:



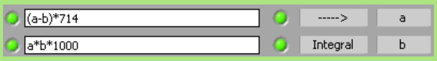
If the power consumption is varying markedly, we could measure the actual energy consumption, by integrating the power used over an appropriate period. This can be done with the integrating process applied in the Maths equation. Just to get a flavour, here is the graph above with an integral applied:



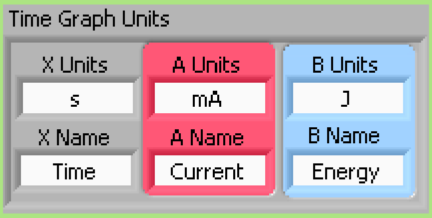
The axis have been relabelled to Energy (J), and shows energy consumed since start. We see the energy use between Markers 1 and 2 as 142.4 mJ, over 29.76 ms, or 0.02976/0.1424 sec/J. As a very rough estimate, battery life will be:

Life = 21700 (j) x (0.02976 /0.1424) (s/j) = 4,528 secs, or 1.26 hours.

Finally we calculate energy by evaluating:



Note the Integral is now turned on. We use the following units:

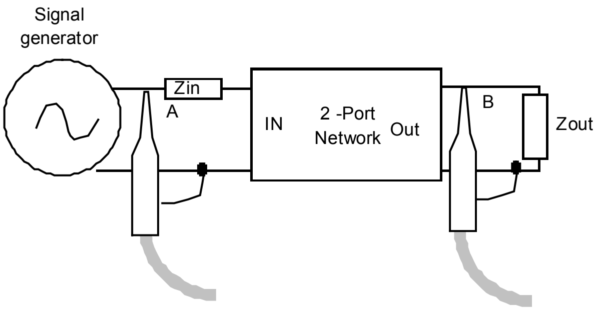


You can see here the great flexibility, and reduction in error, that can be achieved by using the mathematical equations, and custom units, to make the graphs far more meaningful than the raw measured voltages.

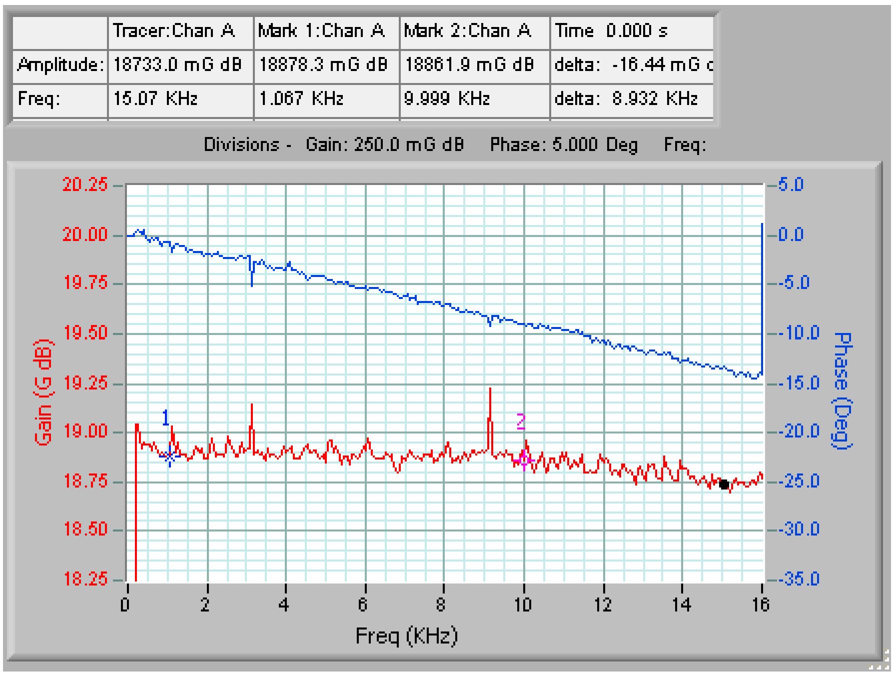
Using the transfer function response

Many analog systems can be characterized by a 2-port network, one port as input, and the other as output. Using Cleverscope you can measure this characteristic – attaching one probe to the input, and the other probe to the output. You will need common grounds at input and output. For many situations you can use the signal generator to provide the stimulus required to exercise the network over frequency.

Here is a typical setup:



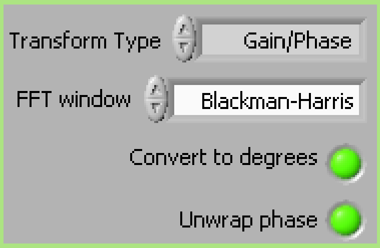
In our example we want to characterize the performance of an audio amplifier – in particular the frequency response. We connected up the amplifier as shown in the setup above, and swept the signal generator frequency from 100 Hz – 16 kHz. The gain/phase plot is shown below:



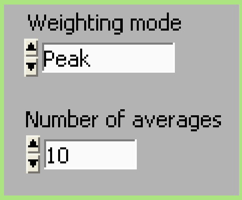
The gain is flat within +/0.2 dB over the 16 kHz frequency range, though there are two small increases in gain at about 3 and 9 kHz.

Transfer Functions
Transfer Functions are a variant on the Spectrum Display.

Choose Options/Display Spectrum Graph to show the spectrum graph. Next use Options/Spectrum.. to choose the Gain/Phase display, and set the display to degrees, and unwrap phase.

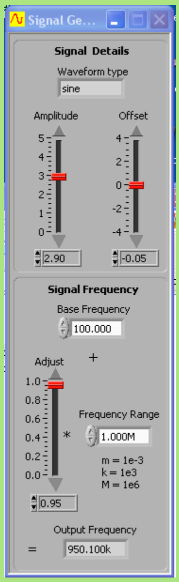


Next turn on Peak Averaging weighting mode, by using the Options/Averaging dialog



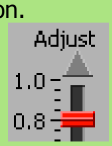
Make sure that Averaging is ON.

Now use a signal generator (such as the Cleverscope Signal Generator), to step from 100 Hz – 16 kHz.



Display the signal generator with Options/Display Sig gen Controls.

Set the Base Frequency to 100 Hz. Set the Frequency range to 16 kHz. Step the frequency over the range by clicking on the Adjust up button.



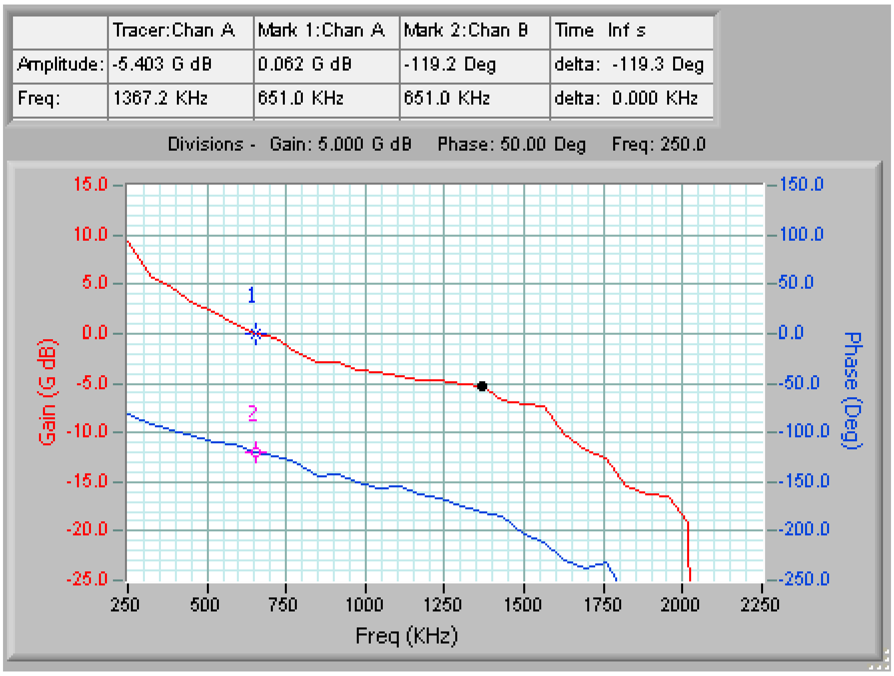
Set the amplitude and offset as required.

Note that the gain of the amplifier is +18.7 dB.

A common characteristic of an amplifier is the phase margin at unity gain. This is a measure of the stability of the amplifier. Using Cleverscope we find that the unity gain (0 dB) point is at about 651 kHz. Here is a plot of the frequency range 200 → 2000 kHz.

You can see that the phase shift at 0 dB is –119 deg. For a system to be stable, the phase shift must be less than 180 deg, and so this amplifier is stable, with a phase margin of 180-119 = 61 deg. Note that the phase shift becomes more than –180 degrees. The amplifier is therefore at least second order.

The tracer (the black blob) has been positioned at the point that corresponds to a phase shift of –180 deg. The Gain margin is –5.4 dB, and occurs at 1367 kHz for this amplifier.



Amplifiers are also characterized at the half power point, or –3 dB. This is called the bandwidth frequency. We can find this by finding the gain at the flat portion of the gain plot, and then find the frequency at which the gain is –3dB with respect to this.

Below we have found the portion of the graph for which this is the case.

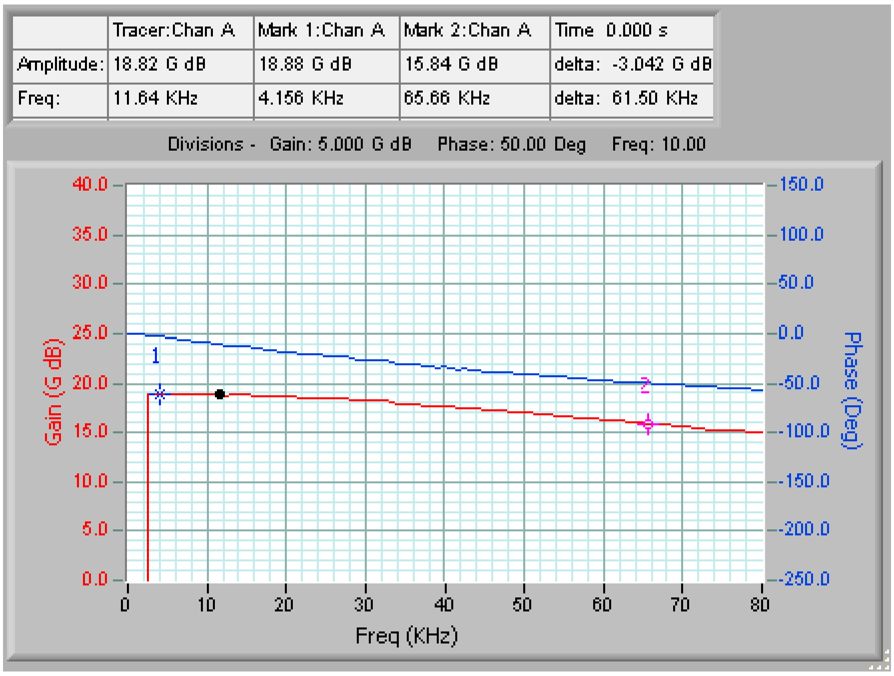
Sig Gen automatic scan
Sig Gen Automatic scanning of a desired bandwidth will be implemented shortly.

Repeat scanning as required. You may have to scan frequency in fairly small steps to get the required resolution to build up the peak averaged curve properly.

[The order of an amplifier can be expressed in multiples of 90 degrees.]

The gain/phase plot for the frequency range 2 kHz – 80 kHz shows the –3dB point. The gain is flat from 0 – 11.6 kHz, and then starts falling off. The –3 dB point is at 65.7 kHz.

We can see that the amplifier meets the requirements of an audio amplifier operating in the 0 – 20 kHz range. (At 20 kHz, the gain is down –0.25 dB, which is generally acceptable).



Once we have the Bode plot, we can work out some approximations. Naturally, these could be measured directly off the time graph, but it is useful to use these rules of thumb in many situations.

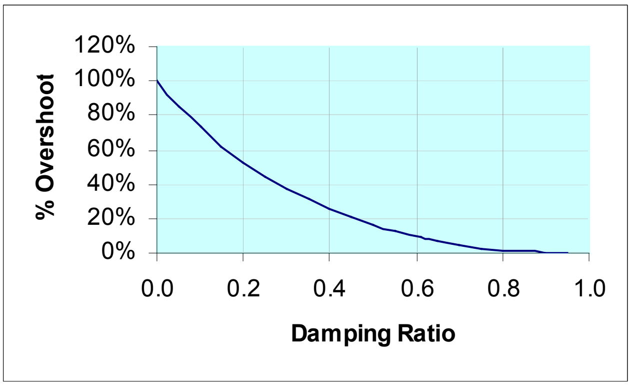
Firstly, the risetime (in a second order system, which most amplifiers are) is approximately 3.5/Bandwidth (bandwidth in Hz). For this system that equates to 3.5/11600 = 302 us.

Secondly, the phase margin is 61 deg. The damping ratio is defined as Phase Margin/90, which in this case is 61/90 = 0.68.
Using the second order expression

Om = $e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}}$ where ζ is the damping ratio
And Om is the maximum overshoot.

This expression is plotted below for damping ratios of 0 – 0.95.

Damping Ratio plot:



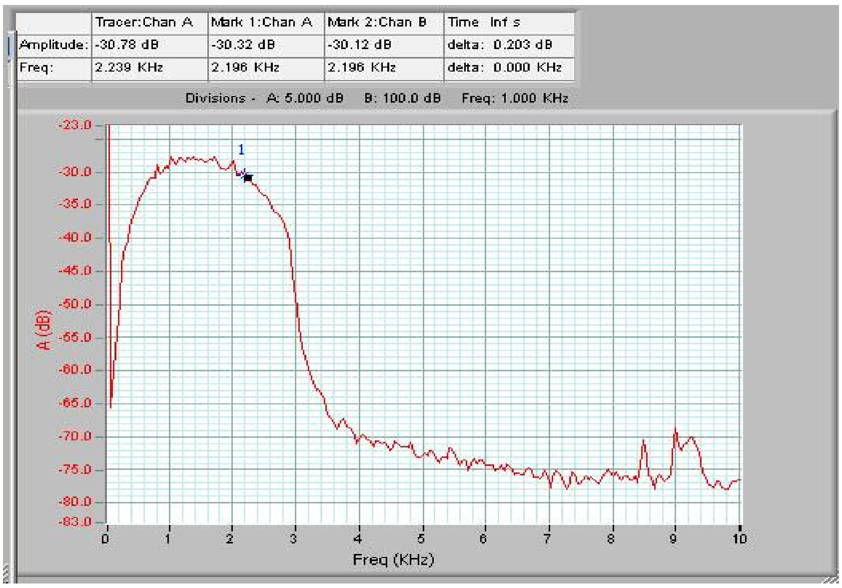
For our damping ratio of 0.68, the Overshoot is 5%.

These values can be used to validate the amplifier under test – either at design, or in production testing.

Using the spectrum analyser

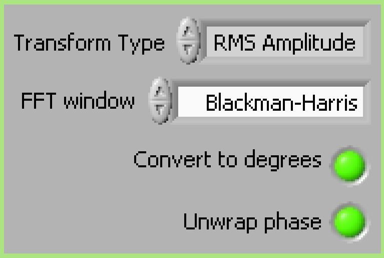
In many situations filters are used to reduce noise, equalize a sensor response, or limit spurious signals. One such situation is the passband response of the Intermediate Frequency (IF) filter in a radio transceiver. The filter is used to limit out-of-band signals which would degrade reception, or pollute other radio channels.

The spectral responses show the passband response of a typical communications transceiver (a Yaesu FT767-GX) with 2 different passband IF filters selected. Using a vacant radio channel, a signal with approximately constant spectral amplitude over the whole bandwidth (the common expression is 'white') was fed into the transceiver. The IF filter characteristic can be seen by averaging the received spectra over a number of measurements. Here is the standard, upper sideband, filter:



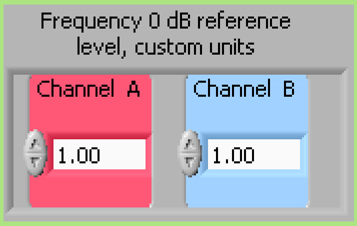
Spectrum Analyser
To turn on the spectrum analyser, use Options/Display Spectrum Graph.

Next set up the Transform Type to RMS Amplitude.



You can display the results in either dB or natural units using Options/Display in dB.

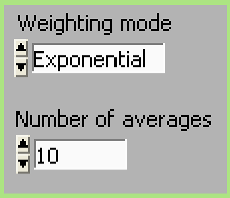
If you use dB you can set the reference level using Options/Custom Units, and then setting these values



Here the result will be in dBV. If you are display the power spectra, the reference can be used to set the 0 dB level for the terminating resistor you are using. As an example, suppose you wish to display in dBm, referred to 50 ohm. From P= V^2/R, V = √RP, with 50 ohms, and 1 mW, we get V = 0.224V.

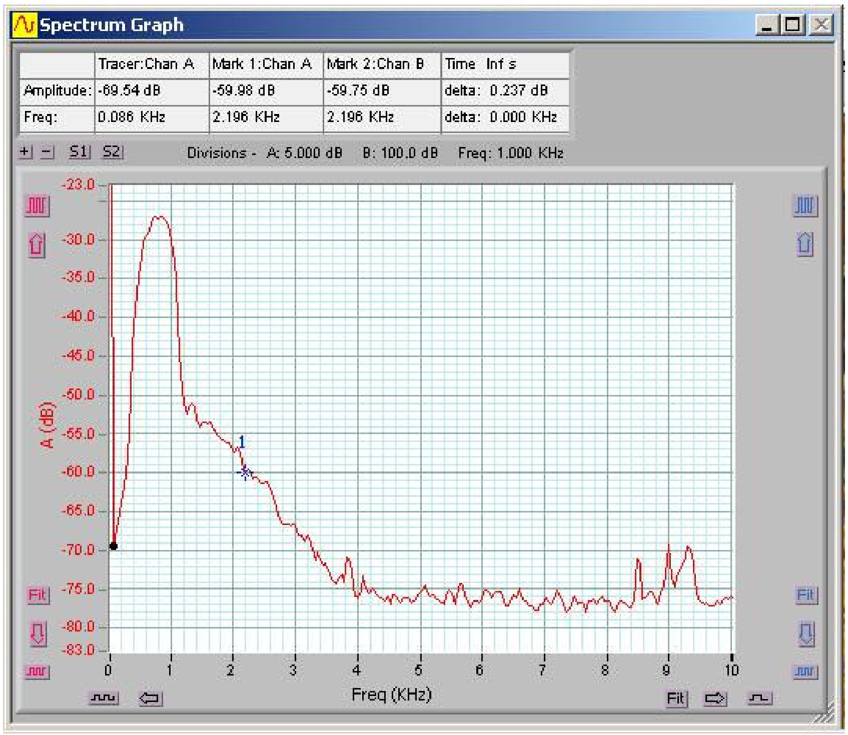
Thus we could set the reference to 0.224V, use Power as the Transform type, and set custom units to dBm.

We used exponential averaging. Set it up by using Options/Averaging



and make sure Averaging is ON.

And here is the Continuous Wave (CW) narrow band filter:



These filter characteristics allow comparison between receivers, and can be useful in validating the performance of the receiver.

Conclusion

Cleverscope offers tools to explore signals in the time and frequency domains, and to maximize the dynamic range of the signal being looked at. Cleverscope is quite capable of looking at mV level signals super-imposed on volt level backgrounds.

Cleverscope includes mixed signal acquisition, triggering and waveform viewing which is very useful when designing and debugging microprocessor controlled equipment.

Cleverscope include the mathematical resources needed to improve visualization of the underlying signal information.

Finally Cleverscope includes cut and paste to easily document the results of experiments and testing.

Conclusion

The Cleverscope system provides the following tools to ensure that you can easily explore and analyse the signals you capture:

1. A buffered signal store with 2M samples available for viewing.
2. Capture of analog and digital signals common in many types of equipment.
3. Software that maximises the duration and time resolution of the captured signal. More often than not you can achieve 20 msec of capture with 10 ns of time resolution.
4. Hardware that maximises the dynamic range and signal to noise ratio of the captured signal. This is achieved by offsetting and scaling the input signal to match the ADCs input range. In most cases you will get at least 60 dB of dynamic range.
5. Customs units and scaling to ensure that signals can be displayed in familiar, standardised units.
6. Mathematical equations to derive information from the input signals and visualize the information in a meaningful fashion.
7. Tools to annotate the graph, and zoom/pan it to obtain good displays of the input signal and document it.
8. Copy and paste into common office applications to improve record keeping, and test result documentation.
9. Two time graphs – one to give the big picture, and the other to examine the signal in detail.
10. Measurement tools to validate the signals.
11. Spectral displays, with a variety of transform types to find and view important spectral information.
12. Averaging tools to examine signals in the presence of noise, or to get the best estimate of signal amplitude.
13. Triggering in both the analog and digital domains to ensure capture of the signal.
14. and a whole lot more…..!

Comparison with other oscilloscopes.

This comparison only looks at key differentiators. For a more comprehensive comparison, look in the Newsletter section of www.cleverscope.com. Items in **bold** are best values.

Item	Tek TDS2012	Pico 3206	TiePie HS3-100	Cleverscope CS328
Analog Input FSD	20 mV – 50V	±100 mV – ±20V	±100 mV – ±40V	**20 mV – 80V**
Analog Channel bit resolution	8	8	8	**10**
Analog Input Offset	±2V:→200mV then ±50V	None	None	**±3.5V → 200mV then ±80V**
Number of digital channels	0	0	0	**8**
External Trigger	Yes	Yes – lose sig gen	No	**Yes**
External trigger sampled, stored and displayed?	No	No	No	**Yes**
Samples of storage, all inputs recorded	2.5k	500k	128k	**4000k**
Resolution on 2V offset signal	0.078 mV	15.6 mV	15.6 mV	**0.018 mV**
Tracking graph with independent time base	No	No	No	**Yes**
Dynamic Range	48 dB	48 dB	48 dB	**60 dB**
Sampling Rate, all channels being sampled, MSa/sec	**1000**	100	100	100
Self Calibration	**Yes**	No	No	**Yes**
Overload Protection	**300 Vrms**	±50V	±100V	**300 Vrms**
Earthed BNC for user/PC safety	**Yes**	No	No	**Yes**
User Units	No	Yes	Yes	Yes
Glitch resolution	**12ns**	None	None	**12 ns**
Peak Captured to eliminate aliasing	**Yes**	No	No	**Yes**
Anti-alias filter	**Yes – 20 MHz**	No	No	**Yes – 20 MHz**
Trigger delay	**Yes**	No	No	**Yes**
Mixed signal triggering	No	No	No	**Yes**
Signal Generator	No	Yes – lose ext trig	**Yes**	**Yes**
Sig Gen Range	-	100 Hz – 1 MHz	0.01Hz – 2MHz	**0.2Hz – 10 MHz**
Voltage Range	-	1V fixed sine/tri 5V fixed square	**0- ±12V p-p**	0 – 9V p-p
Voltage Offset	-	None	**0- ±12V**	±10mV – ±4.5V
Waveform type	-	Sine, square, tri	Sine, square, tri	Sine, square, triangle
Spectrum Analysis	Yes	Yes	Yes	Yes
Averaging	Yes	Yes	Yes	Yes
Mathematical equations	No	No	No	**Yes**
Math functions	-A, -B, A-B, A+B		-A, -B, A-B, A+B	**+ - * / sqrt, log, sin, cos, tan… integration, differentiation, filtering, multiple equations**
User Interface	320 x 240 LCD	Multiple MDI windows all contained in one window	One window	**Dual window with tracking function. Locate anywhere on desktop.**
Copy and paste into other document	Possible with extension module, slow	**Yes**	Yes, with save of image to disk, and load. Slow	**Yes**
Subjective view of ease of use	**Easy**	Moderate	Moderate	**Easy**
Price USD	Scope – 1786 Comms – 390 Total - $2176	$1456	$1386	**Scope – 1049 Sig gen plug-in 199 Total - $1248**

Disclaimer: These values are correct to the best of our knowledge on 1 June 2005. Cleverscope Ltd accepts no liability for errors or omissions.