

Using the lab instruments

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Our lab instruments

Not all of our labs have the same instruments. Depending on whether you're working in Beardslee or Discovery, these are the instruments you may encounter.

1. [Tektronix DMM4020 multimeter](#)
2. [Keithley 2110 multimeter](#)
3. [Tektronix PWS 4205 programmable power supply](#)
4. [Keithley 2230-30-1 power supply](#)
5. [RSR HY3002-3 triple output power supply](#)
6. [Tektronix AFG3022B arbitrary function generator](#)
7. [Tektronix MSO3012 dual channel oscilloscope](#)

Tektronix DMM4020 multimeter



DMM4020 multimeter features:

- Measures AC or DC voltage and current, frequency, period, continuity and diode test
- 5-1/2 digit resolution, autoranging
- Basic VDC accuracy 0.015%
- 200 mV to 1000 V with up to 10 μ V resolution
- 200 μ A to 10 A with up to 1 nA resolution
- 200 Ω to 100 M Ω with up to 1 m Ω resolution
- Capable of remote operation via USB or RS-232

List price: \$849

In this lab, we'll use the multimeter only for DC voltage, DC current and resistance measurements.

DC voltage or resistance



Continuity or diode test



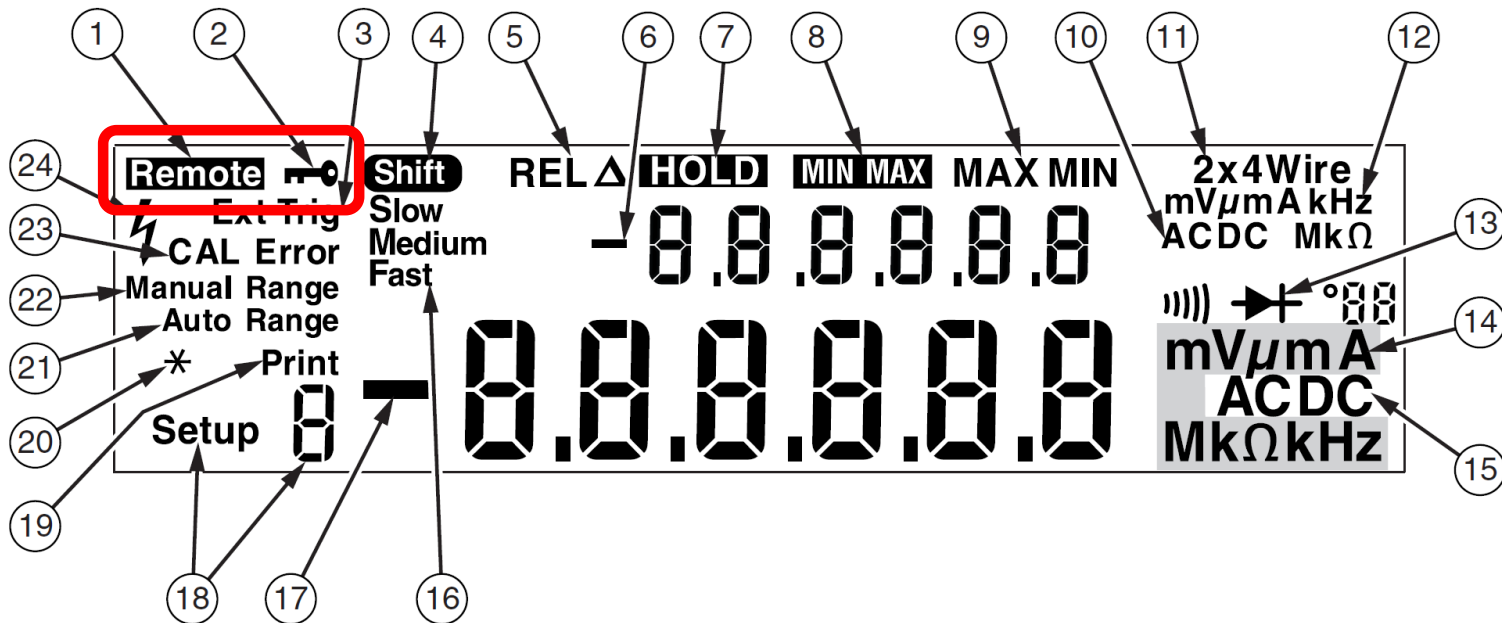
Toggles between continuity and diode test. In diode test mode, it measures the voltage across the diode.

DC current



If the buttons don't work

The usual problem is that it's set for remote operation.



Press the shift key to exit remote mode



Keithley 2110 multimeter



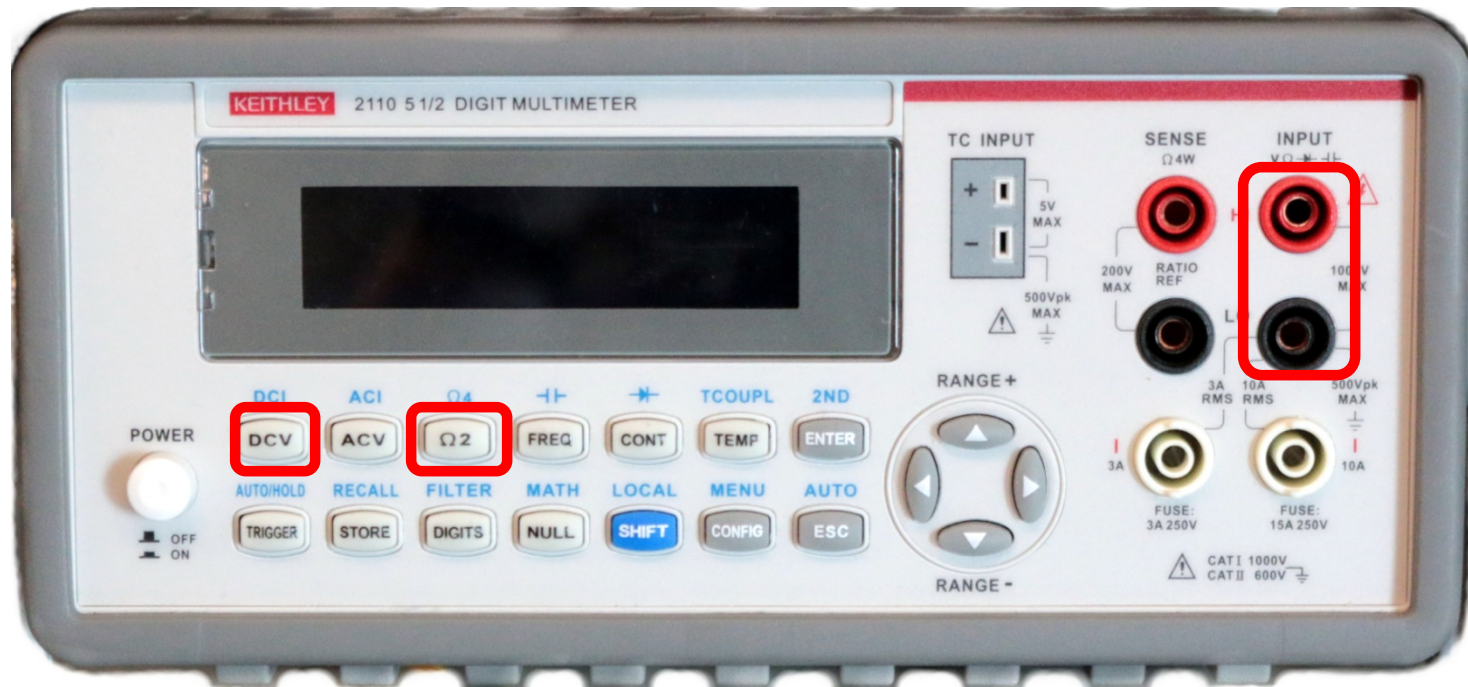
Keithley 2110 multimeter features:

- Measures AC or DC voltage and current, frequency, period, capacitance, continuity and diode test
- 5-1/2 digit resolution, autoranging
- Basic VDC accuracy 0.012%
- 100 mV to 1000 V with up to 1 μ V resolution
- 10 mA to 10 A with up to 0.1 μ A resolution
- 100 Ω to 100 M Ω with up to 1 m Ω resolution
- 1 nF to 100 μ F with up to 1.5% accuracy
- Capable of remote operation via USB or GPIB

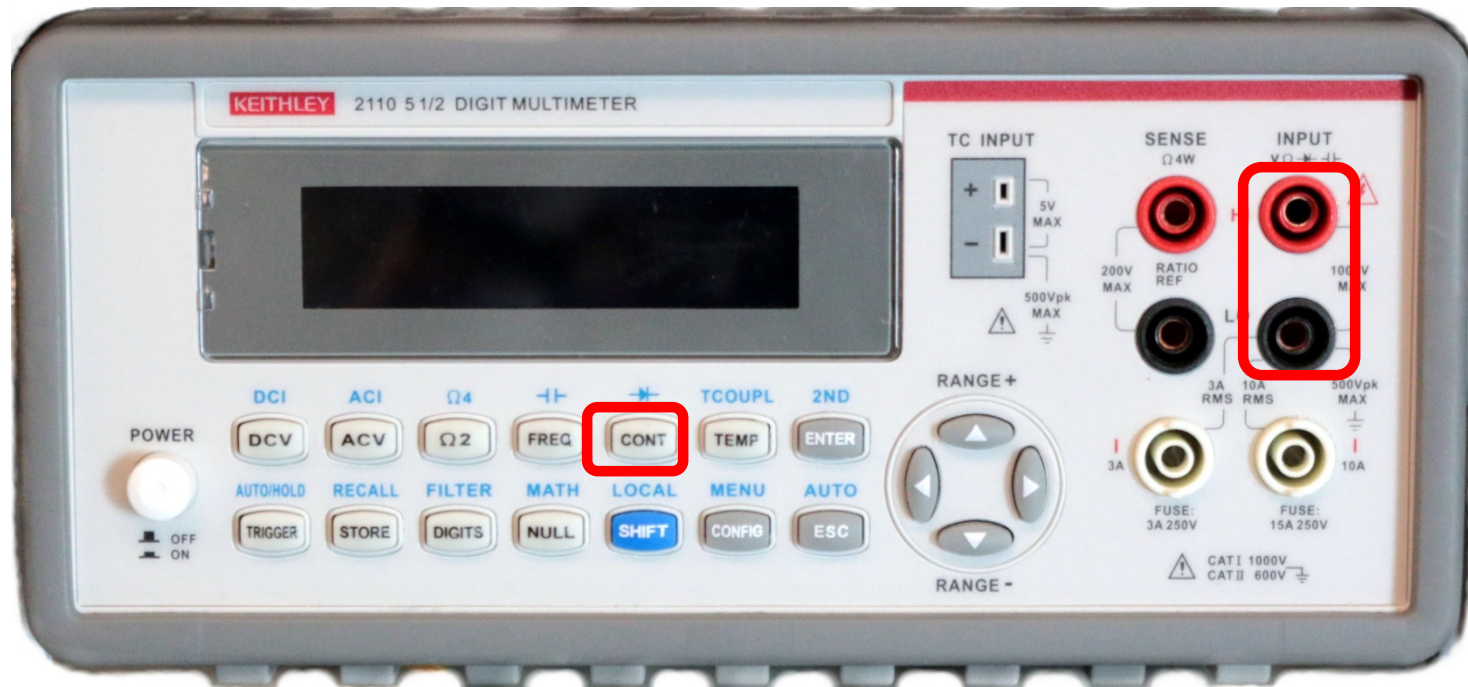
List price: \$620

In this lab, we'll use the multimeter only for DC voltage, DC current and resistance measurements.

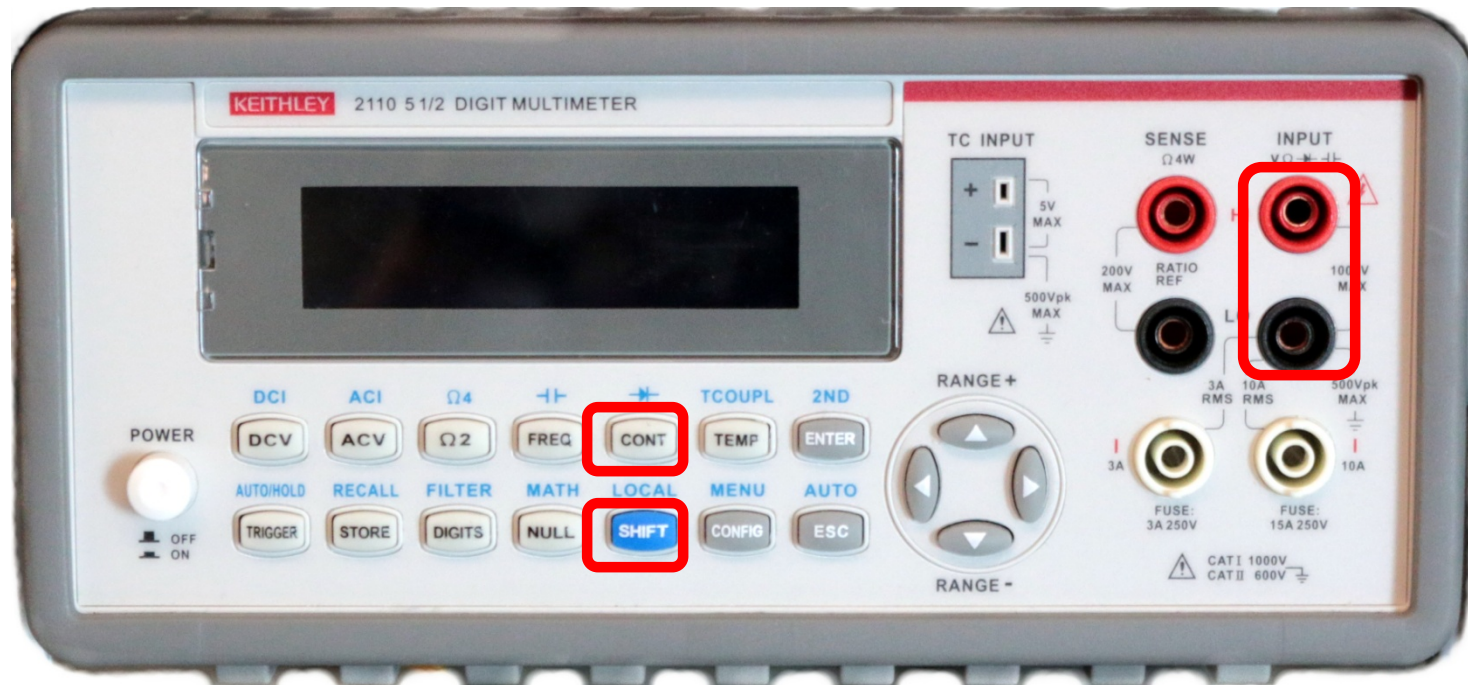
DC voltage or resistance



Continuity

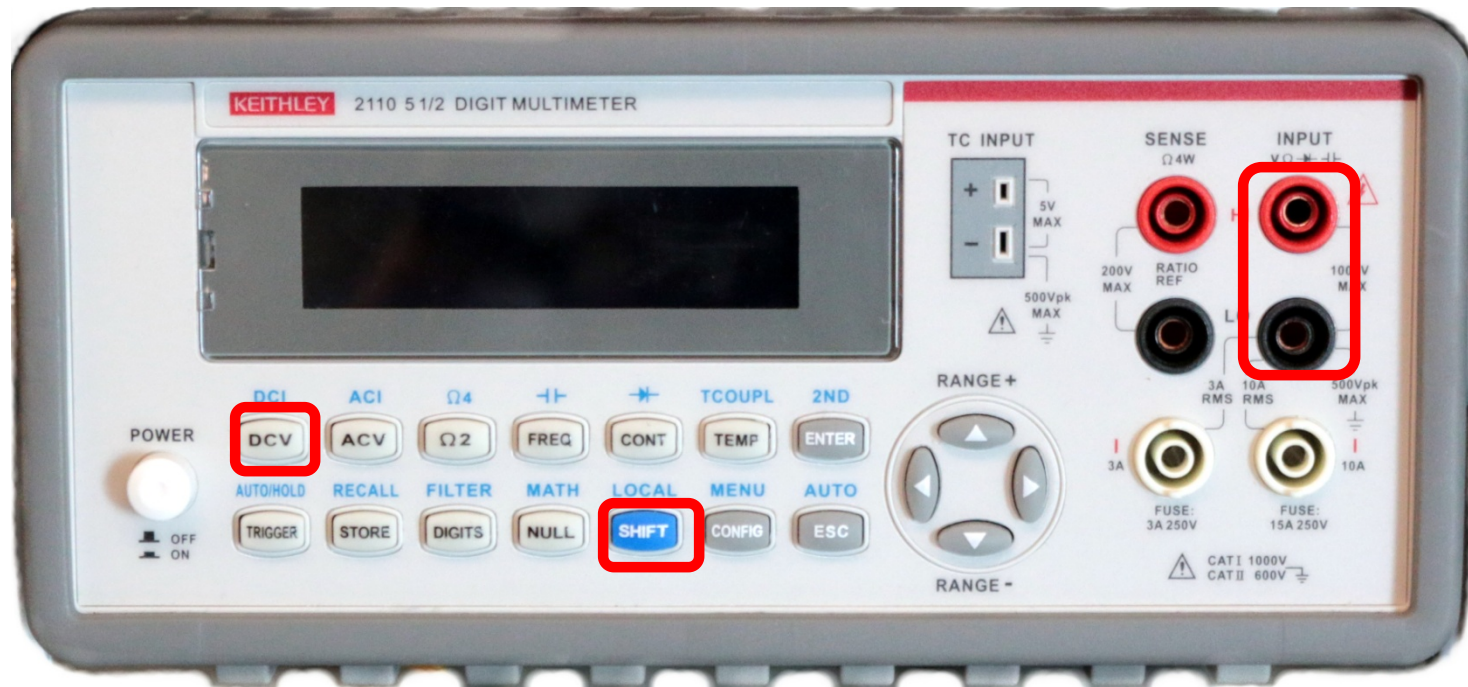


Diode test



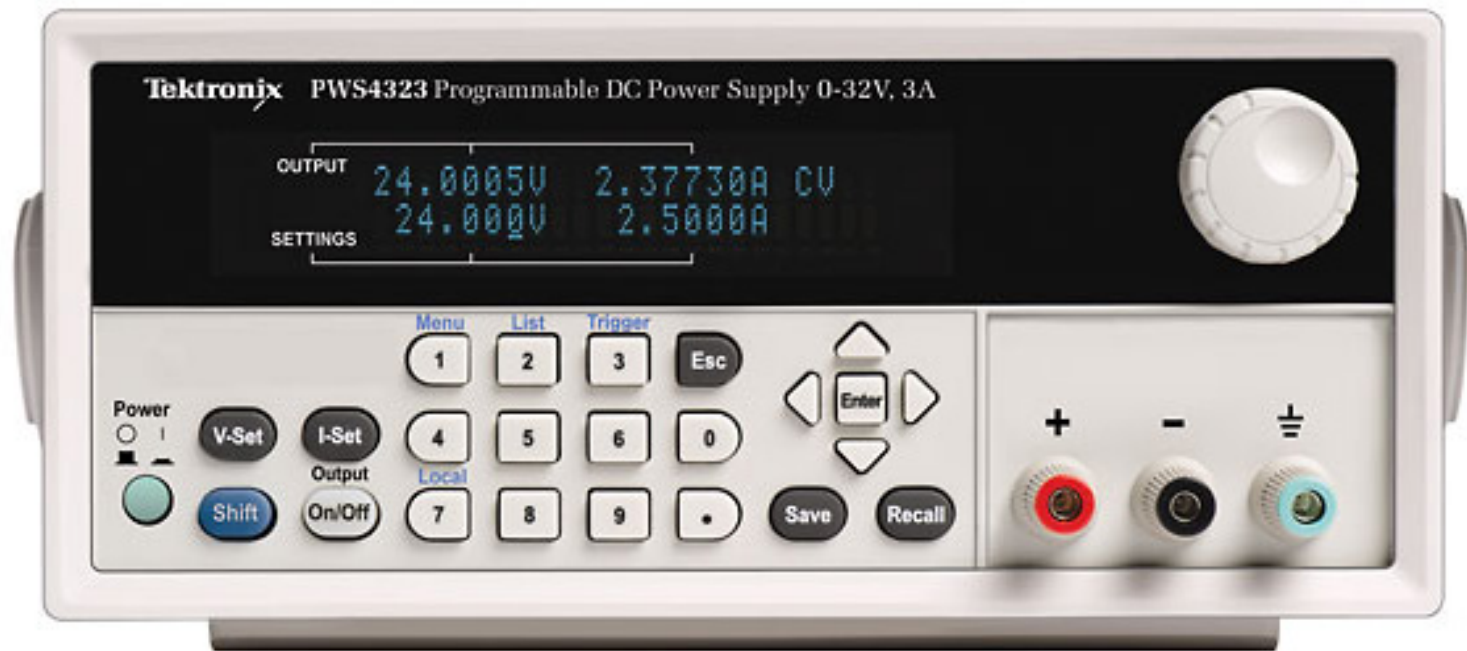
Press Shift, then Continuity.

DC current



Press Shift, then DCV.

Tektronix PWS 4205 power supply



PWS 4205 power supply features:

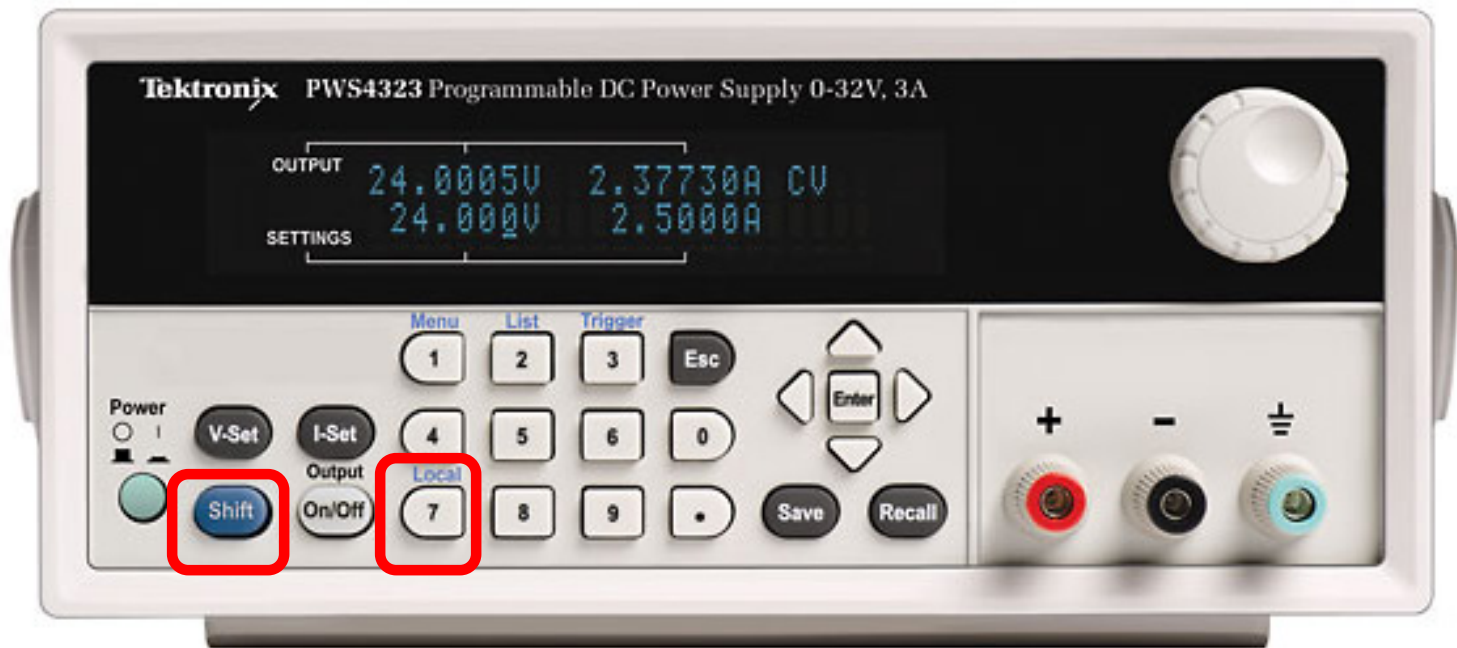
- Very high accuracy
- Keypad programmable
- Linear regulation
- One output
- Maximum 20 V at 5 A = 100 W
- Accuracy: 0.03% voltage, 0.05% current
- Less than 5 mVpp ripple and noise
- Capable of remote operation via USB

List price: \$904

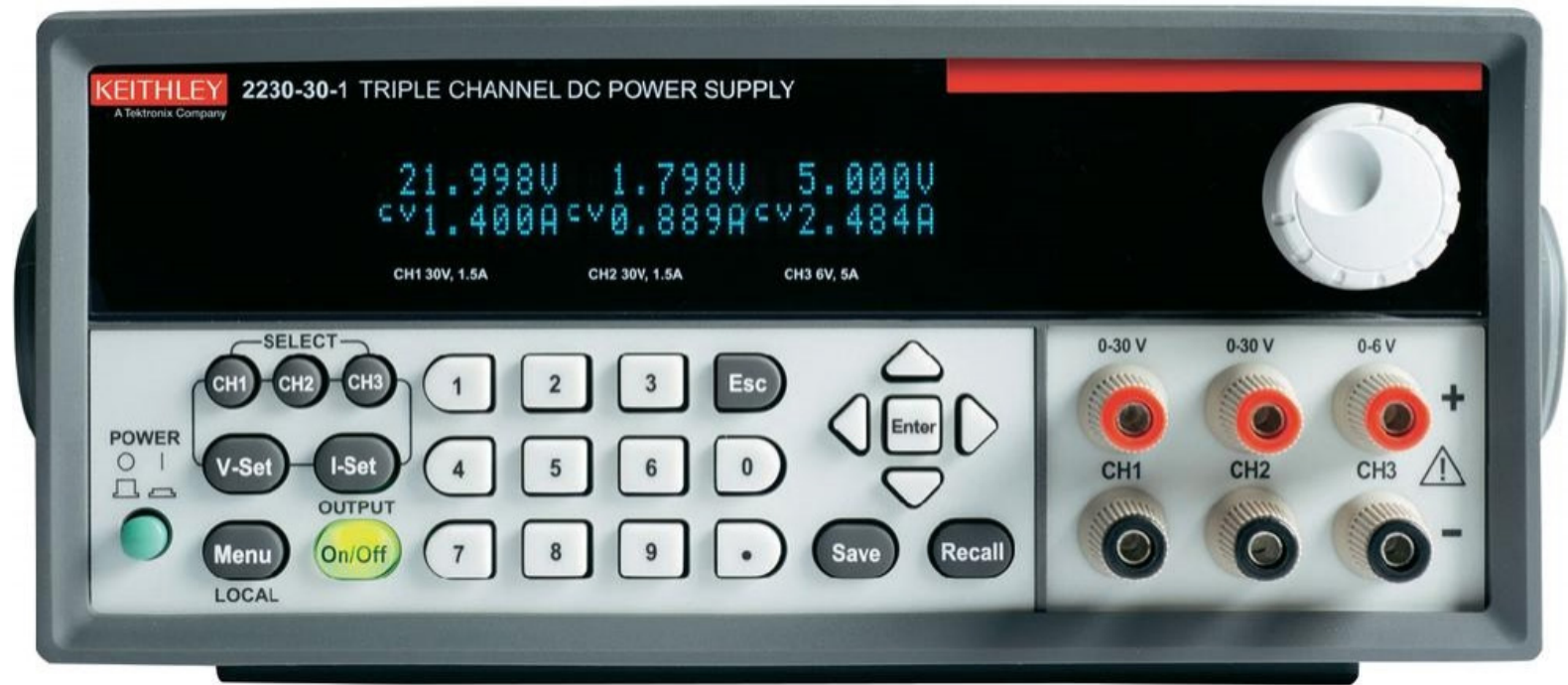
If the buttons don't work

The usual problem is that it's set for remote operation.

Press Shift-Local.



Keithley 2230-30-1 power supply



2230-30-1 power supply features:

- Very high accuracy
- Keypad programmable
- Linear regulation
- Two 0 to 30 V @ 1.5 A channels
- One 0 to 6 V @ 5 A channel
- Accuracy: 0.03% voltage, 0.1% current
- Less than 3 mVpp ripple and noise
- Capable of remote operation via USB and GPIB

List price: \$1190

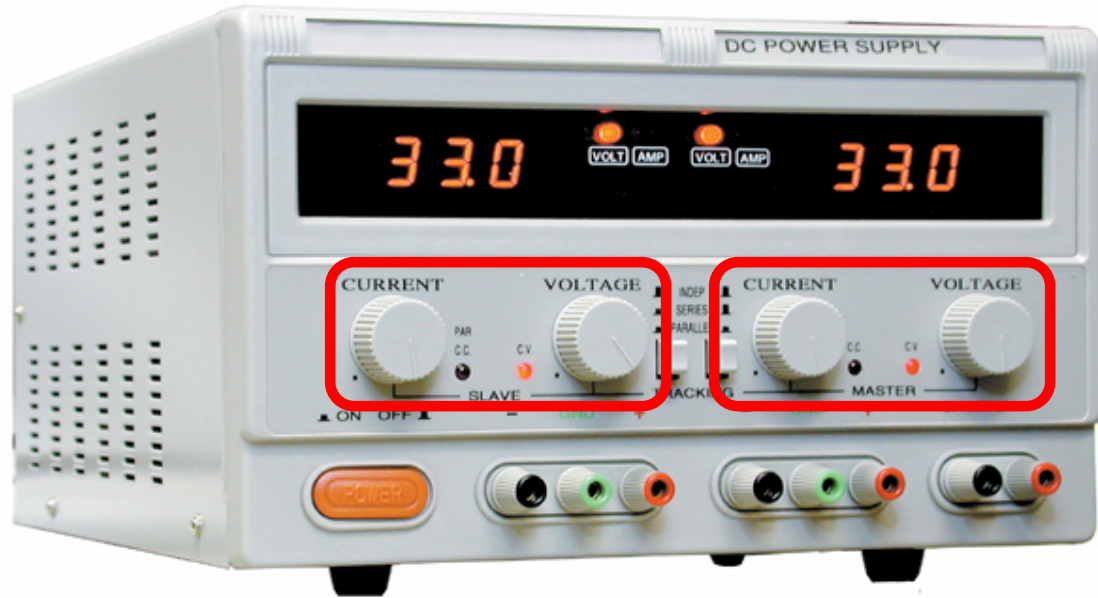
RSR HY3002-3 power supply



HY3002-3 power supply features:

- Two adjustable + one fixed 5 V output
- Fixed: 5 V at 3 A maximum
- Each adjustable: 0 to 30 V at 2 A maximum
- Ripple and noise 0.5 mVrms
- Meters can display current or voltage
- Independent, series and parallel modes

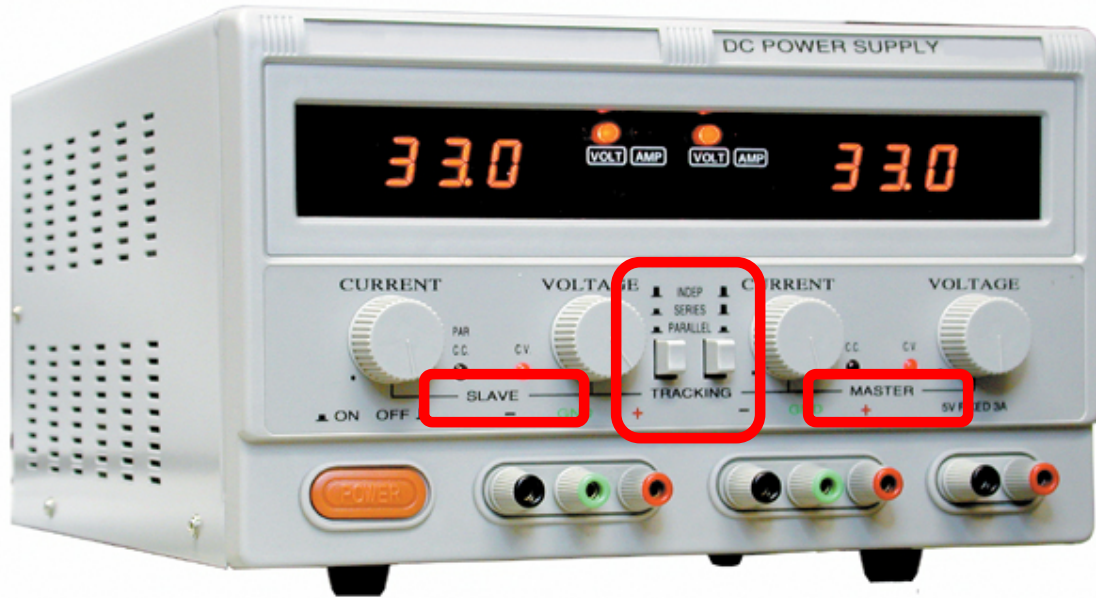
Typical price: \$160



Voltage knobs set *maximum* voltage.

Current knobs set *maximum* current.

If you short the supply or you have the maximum current set too low, the voltage drops.



Independent

Each supply can be adjusted independently.

Series

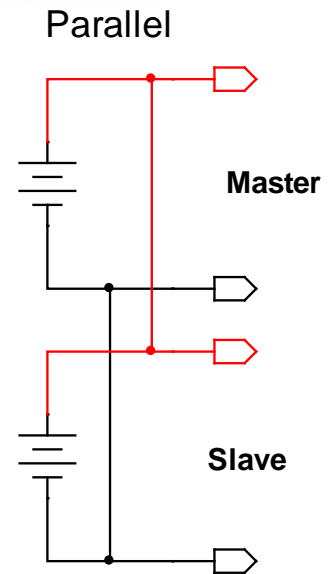
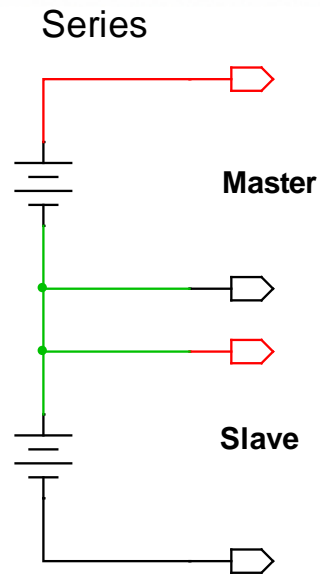
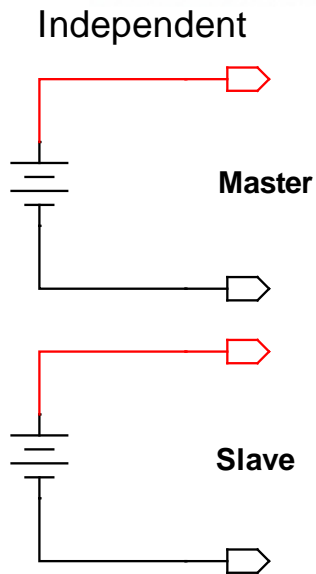
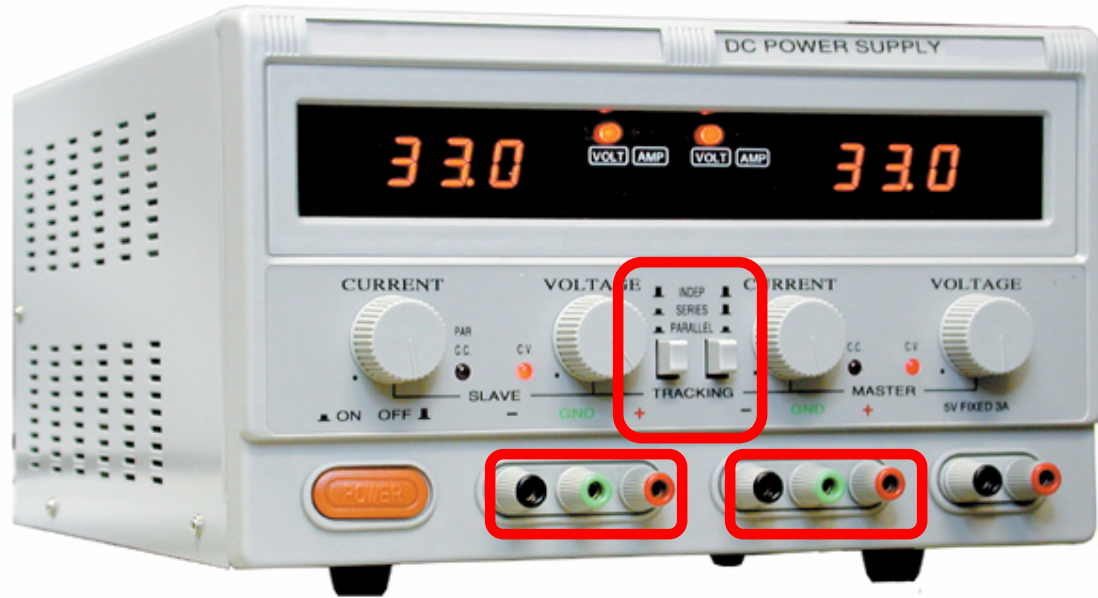
Both supplies controlled by the master.

Red on the slave connected to black on the master.

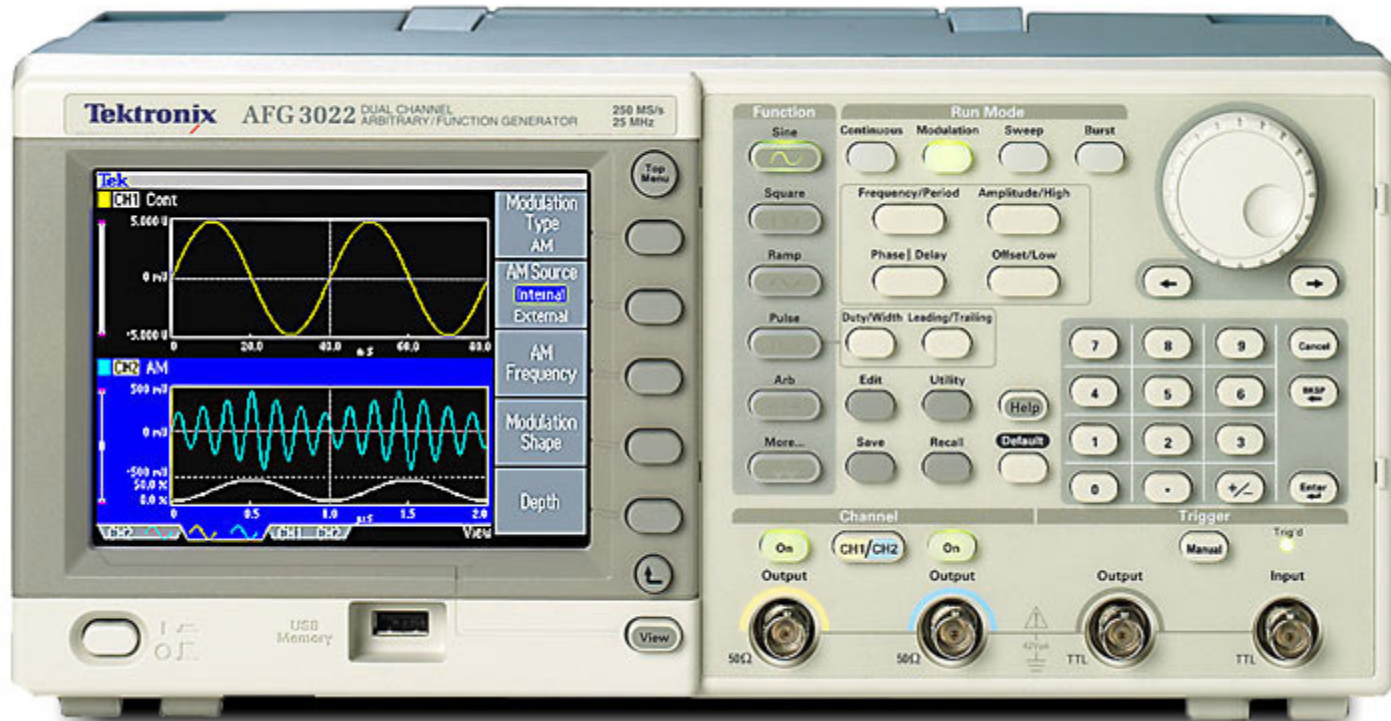
Parallel

Both supplies controlled by the master.

Red connected to red and black to black.



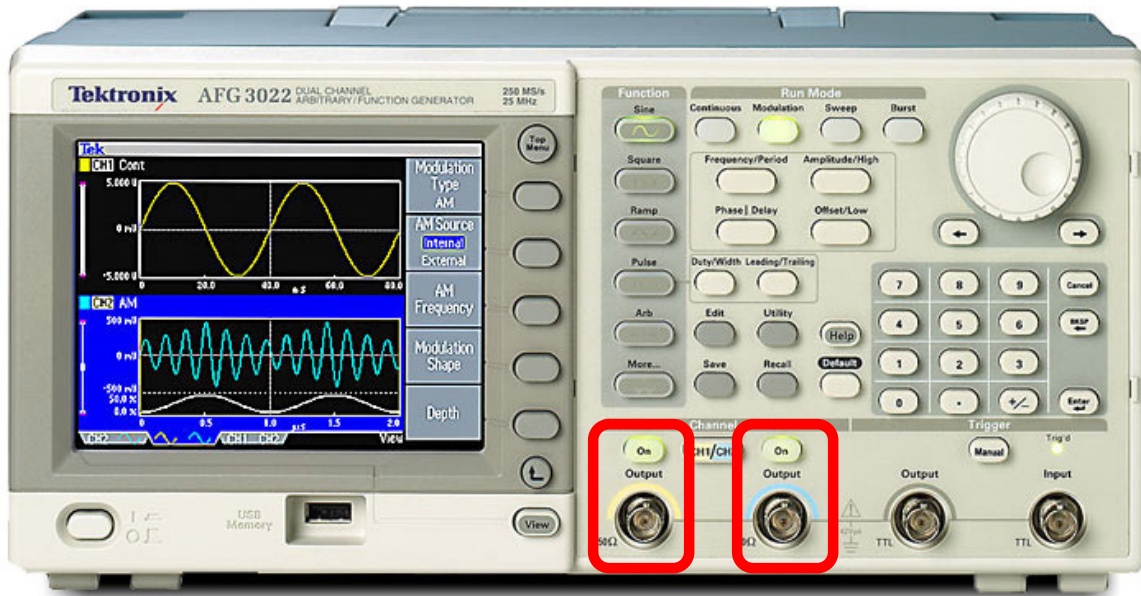
Tektronix AFG3022B arbitrary function generator



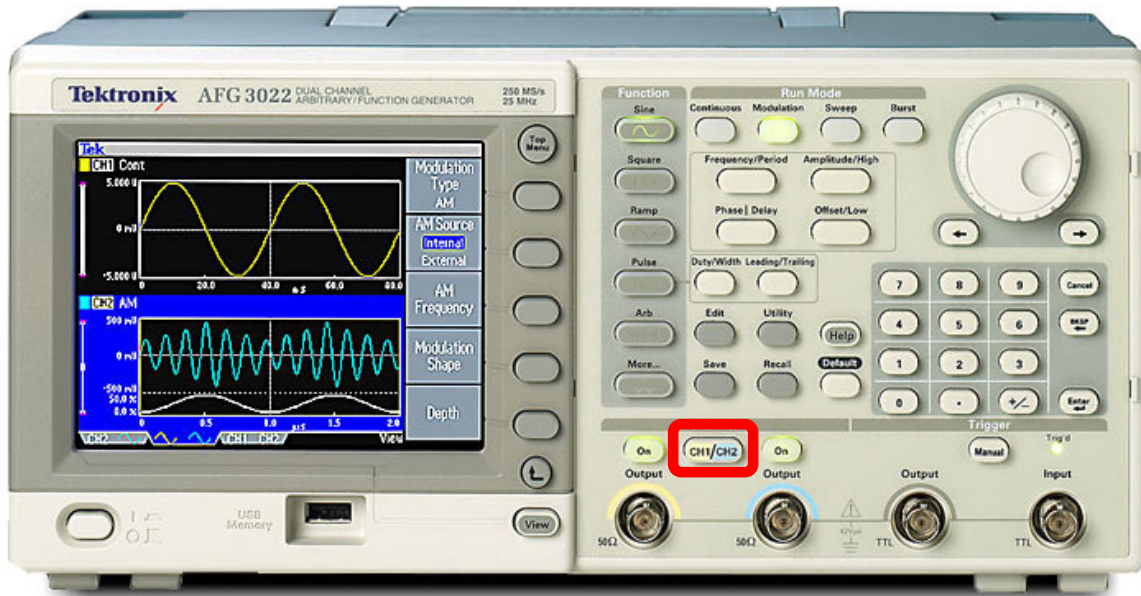
AFG3022B function generator features:

- Sine, square, triangle, pulse, ramp, DC, noise and arbitrary functions
- Maximum frequency 25 MHz
- Two channels
- Synthesized at 250 M samples/s, 14-bit resolution
- Output impedance 50 Ω
- LAN, USB and GPIB connection
- Screen and waveform capture to USB thumb drive

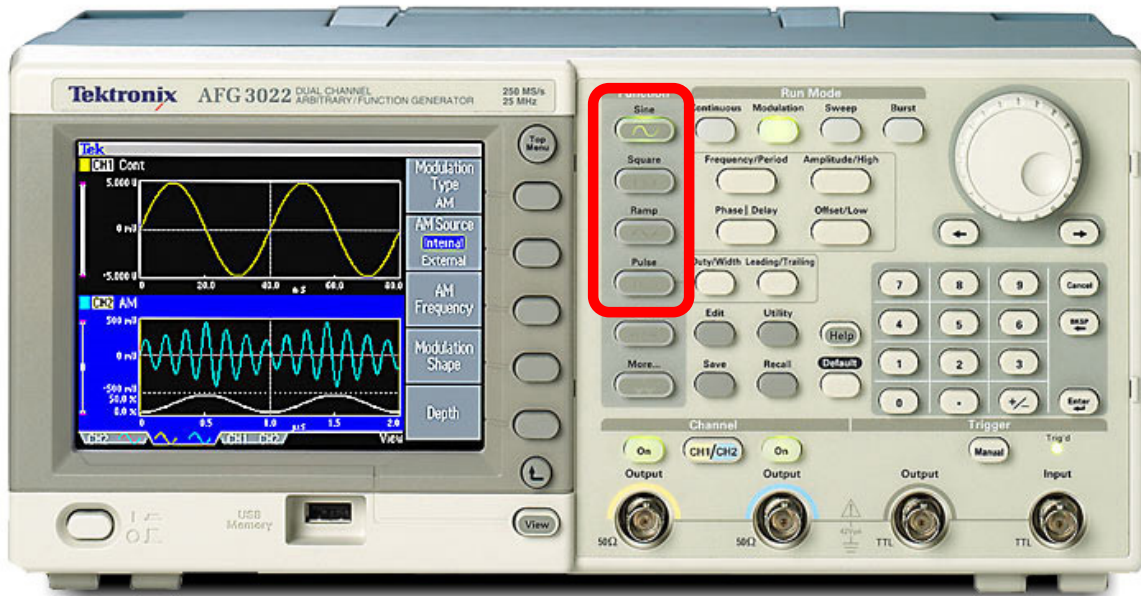
Typical price: \$2400



Each output channel is to be used with straight coax, not a scope probe and it has to be turned on.

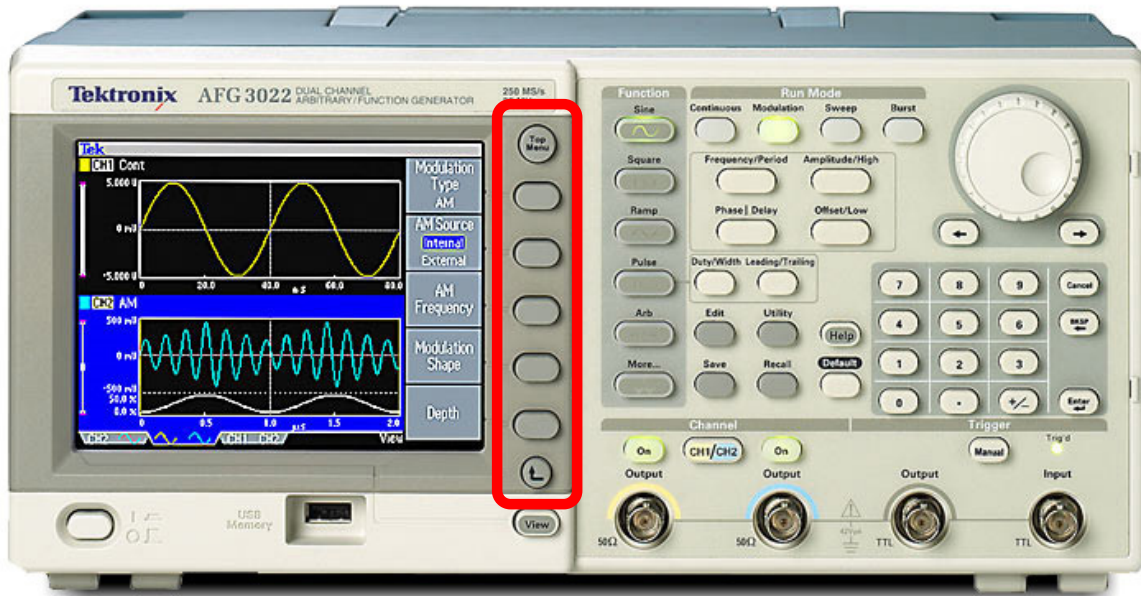


This button selects which channel you're programming.

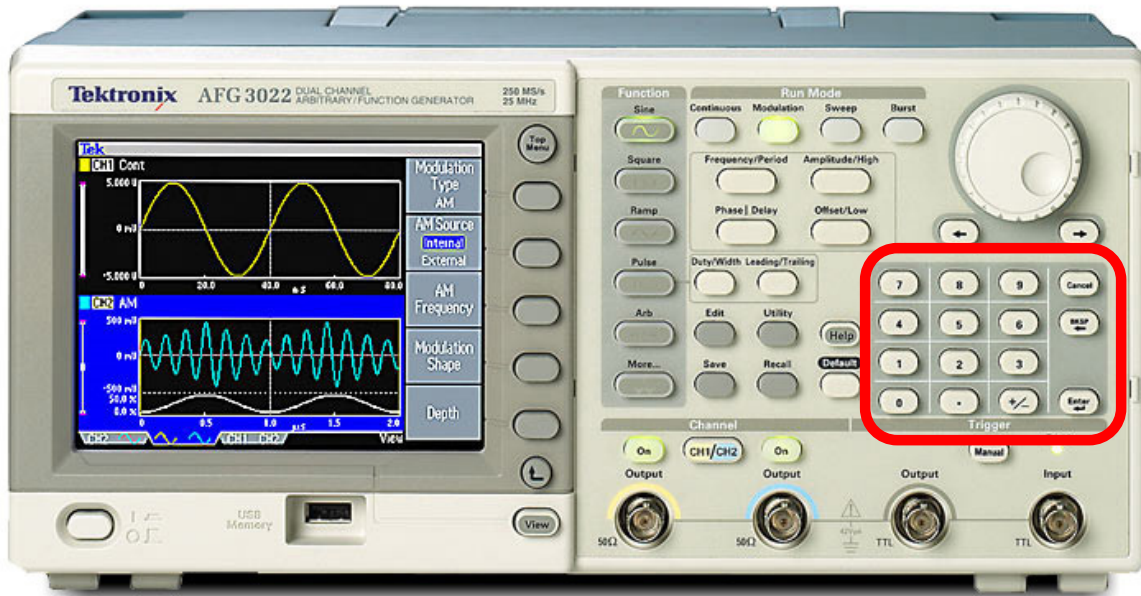


Sine, square, ramp and pulse functions.

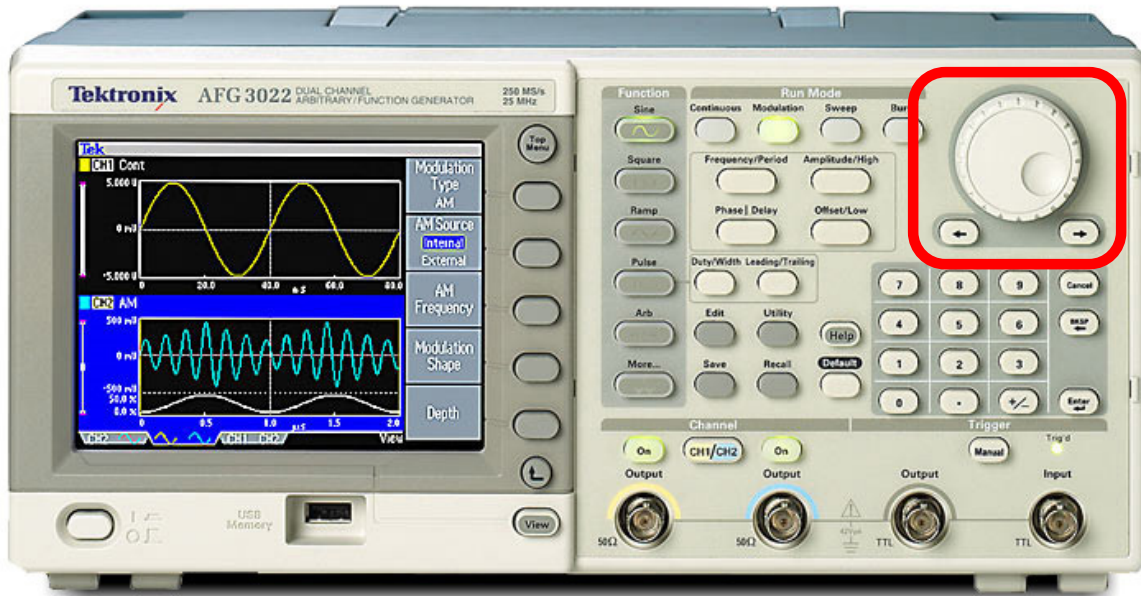
As square wave is exactly square. If it's not exactly square, it's a pulse.



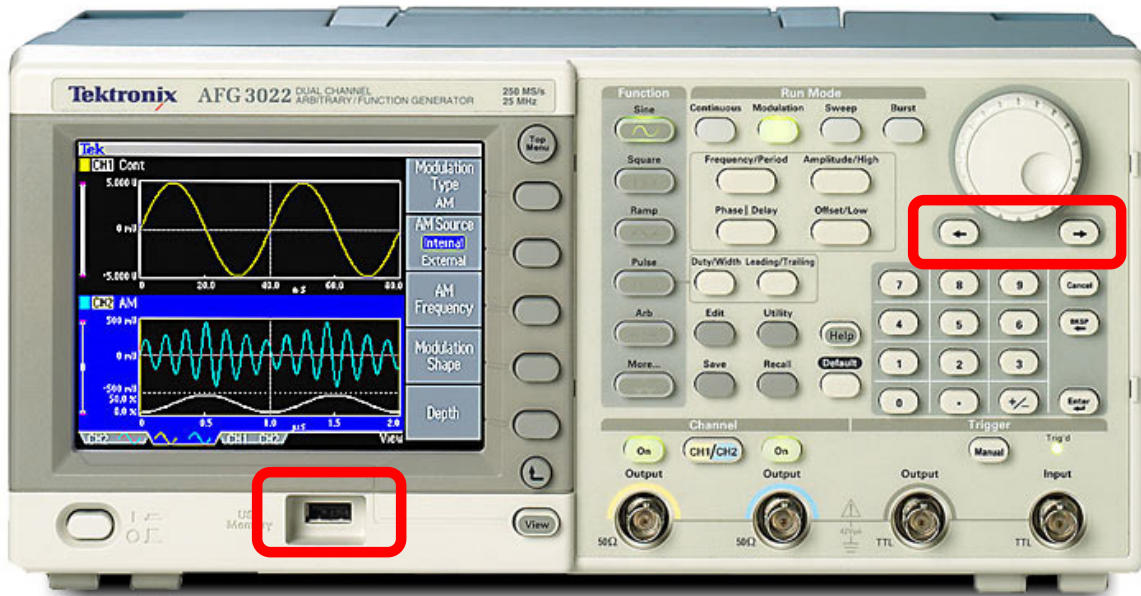
Buttons for the on-screen menus



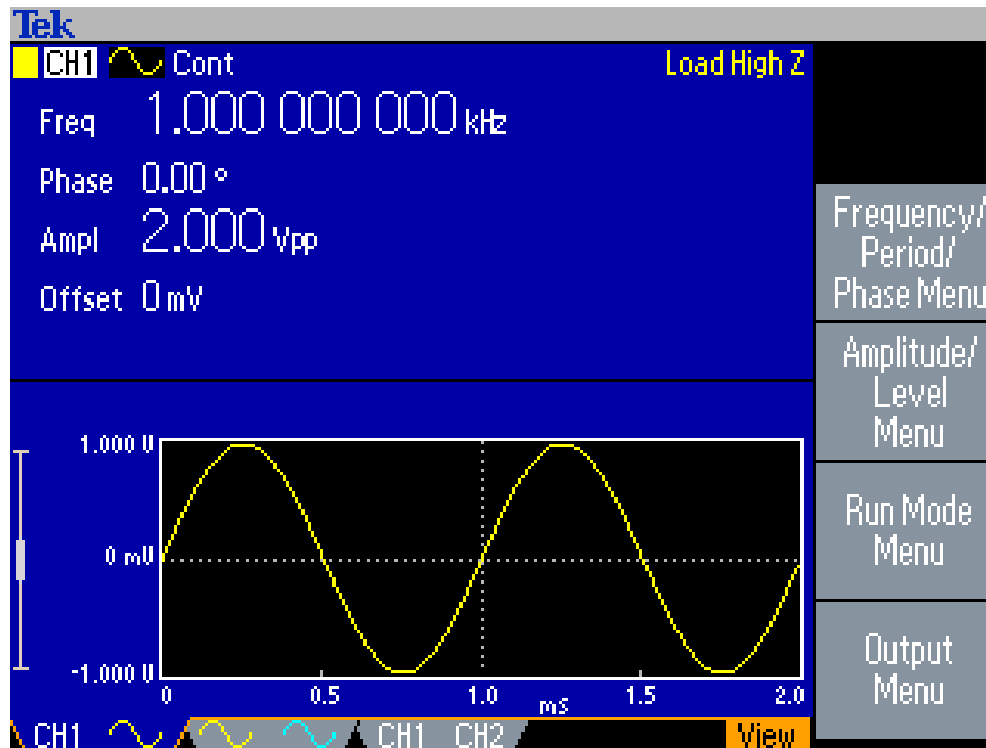
Keypad for direct entry of frequency or voltage.



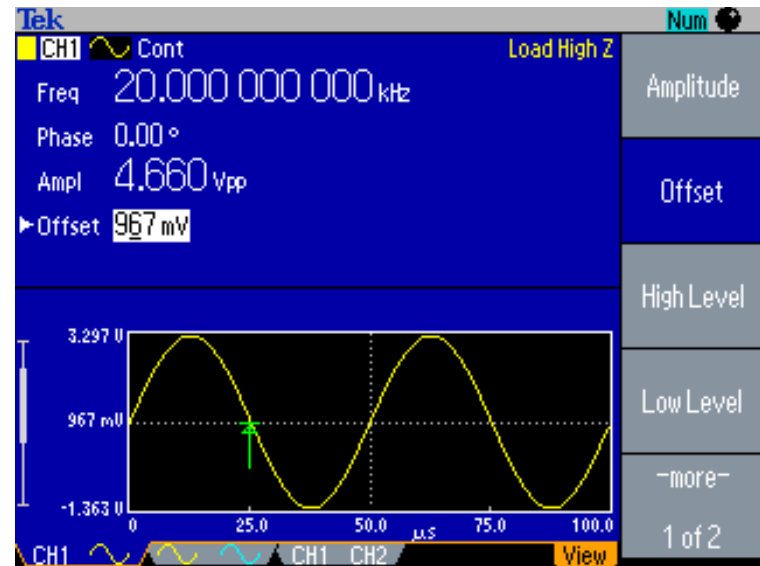
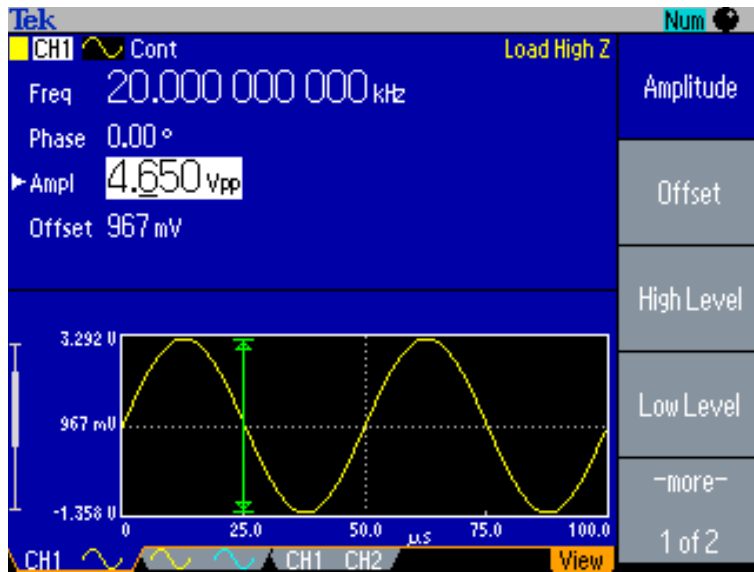
Wheel for dialing a frequency or voltage up/down.
Arrow keys to move the cursor.



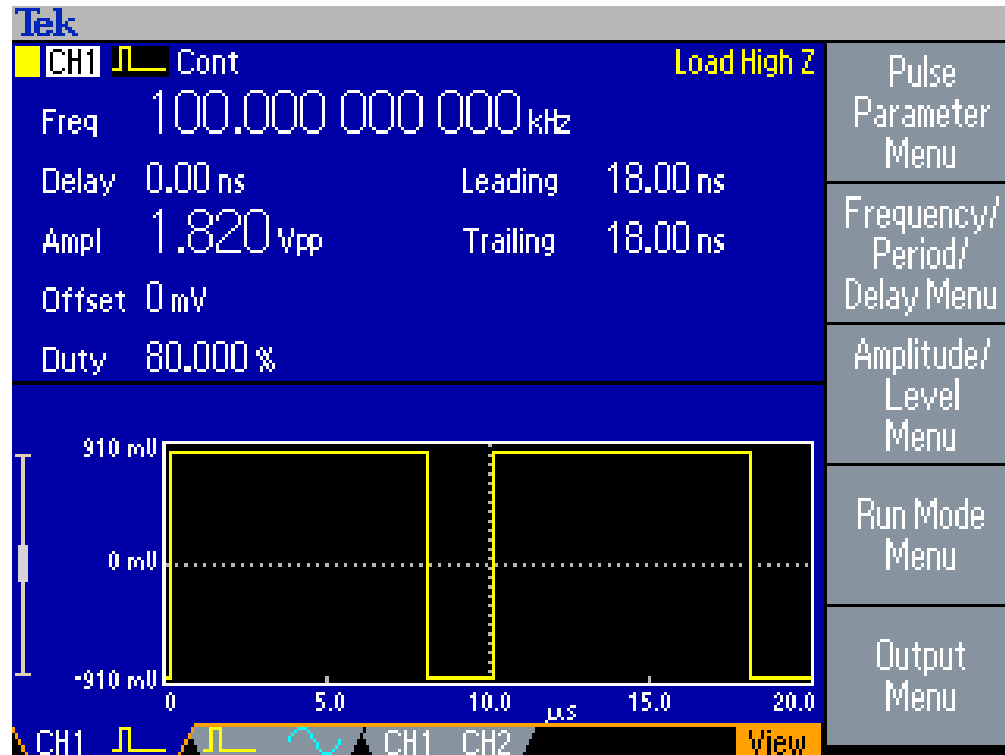
To capture a screenshot, insert a USB thumb drive and press (and hold) both cursor keys.



Top level menu for a sine wave.



Amplitude and offset menus for a sine wave.

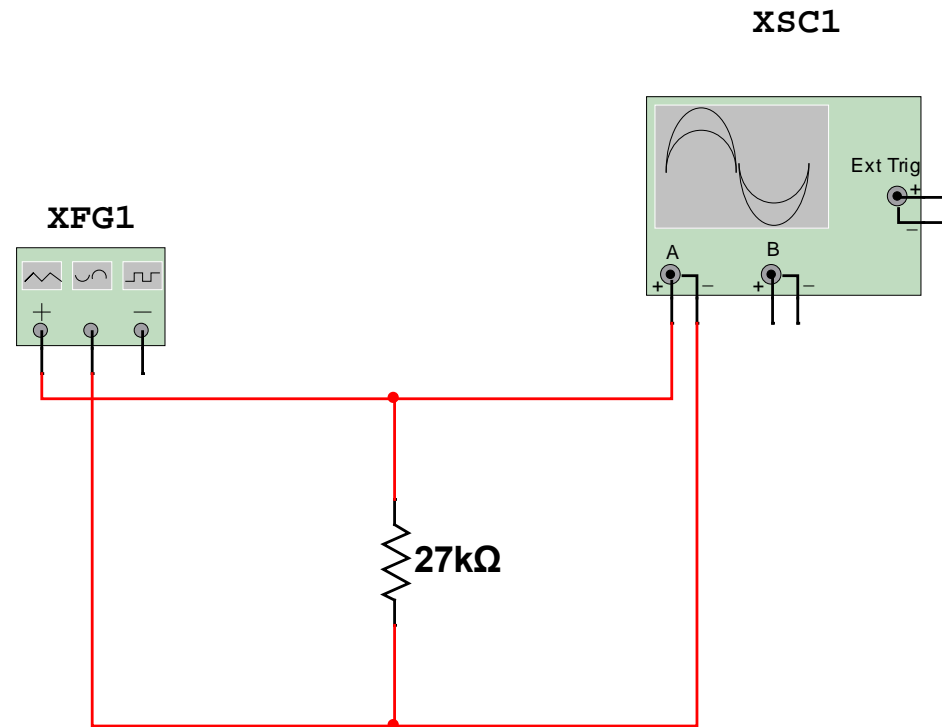


Top level menu for a pulse output.

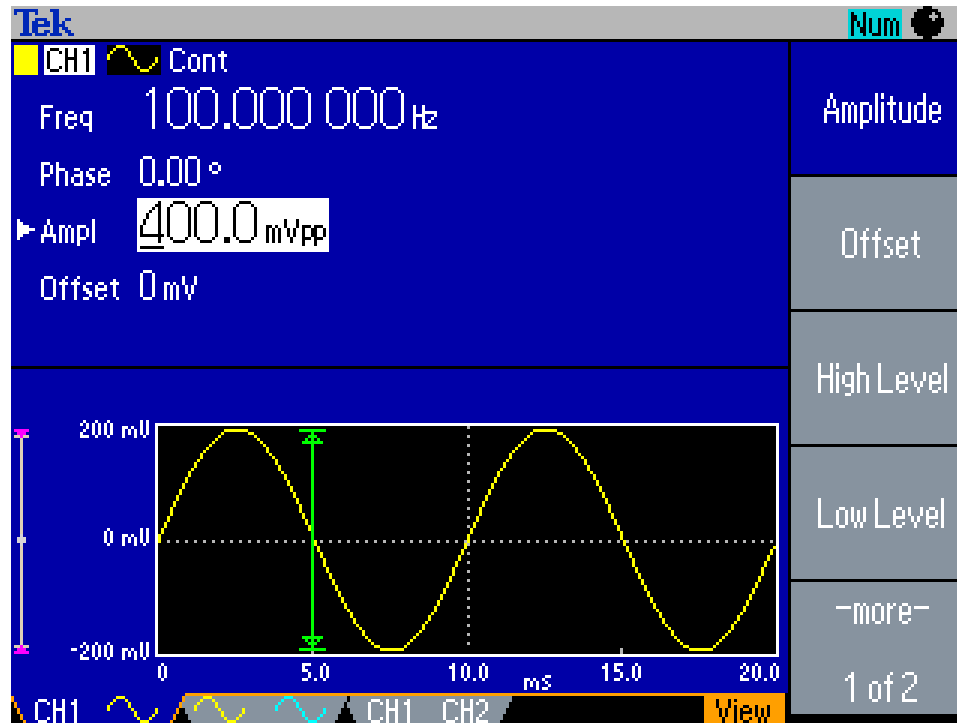
Never trust the function generator

- The display shows how the function generator was set.
- There's no feedback circuitry in there to ensure that what you asked for is what you got.
- *It doesn't measure the output.*

Example

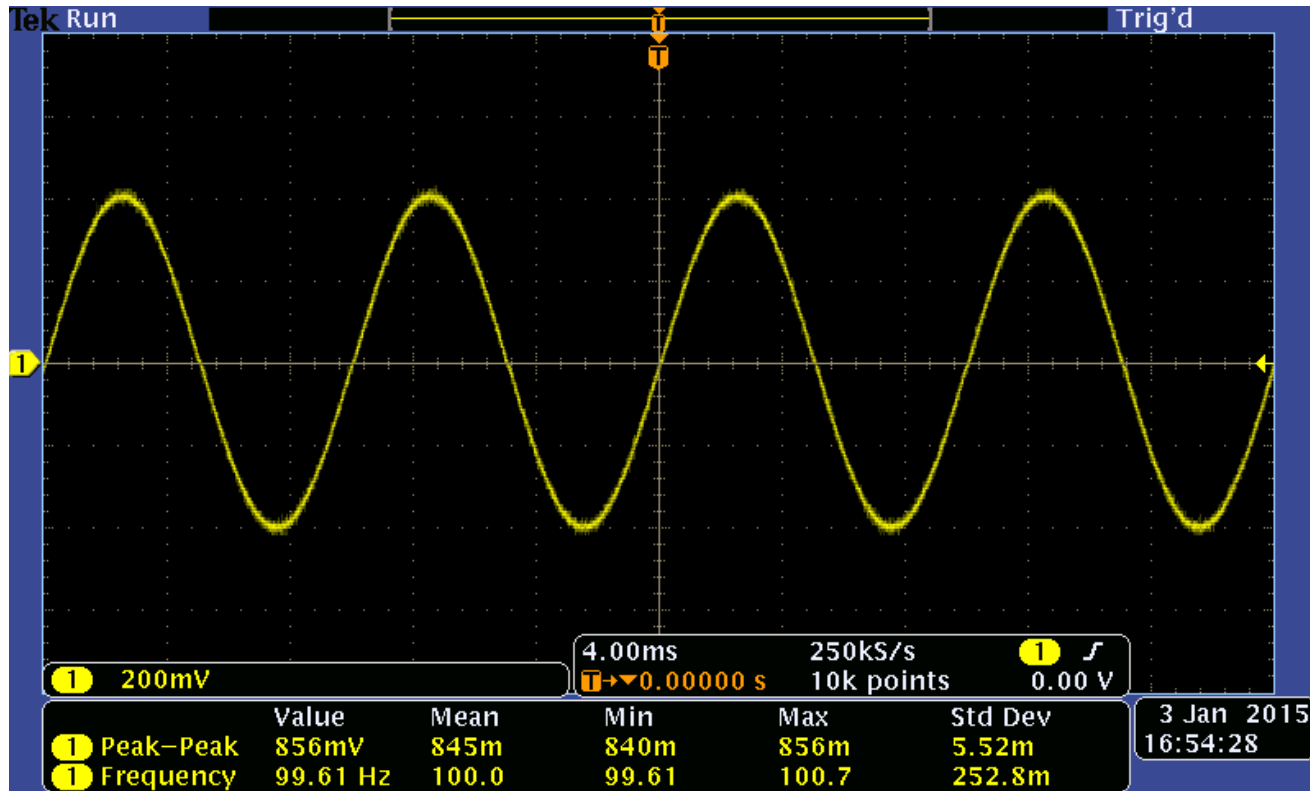


Here's what I set.



400 mVpp at 100 Hz

But here's what I got.

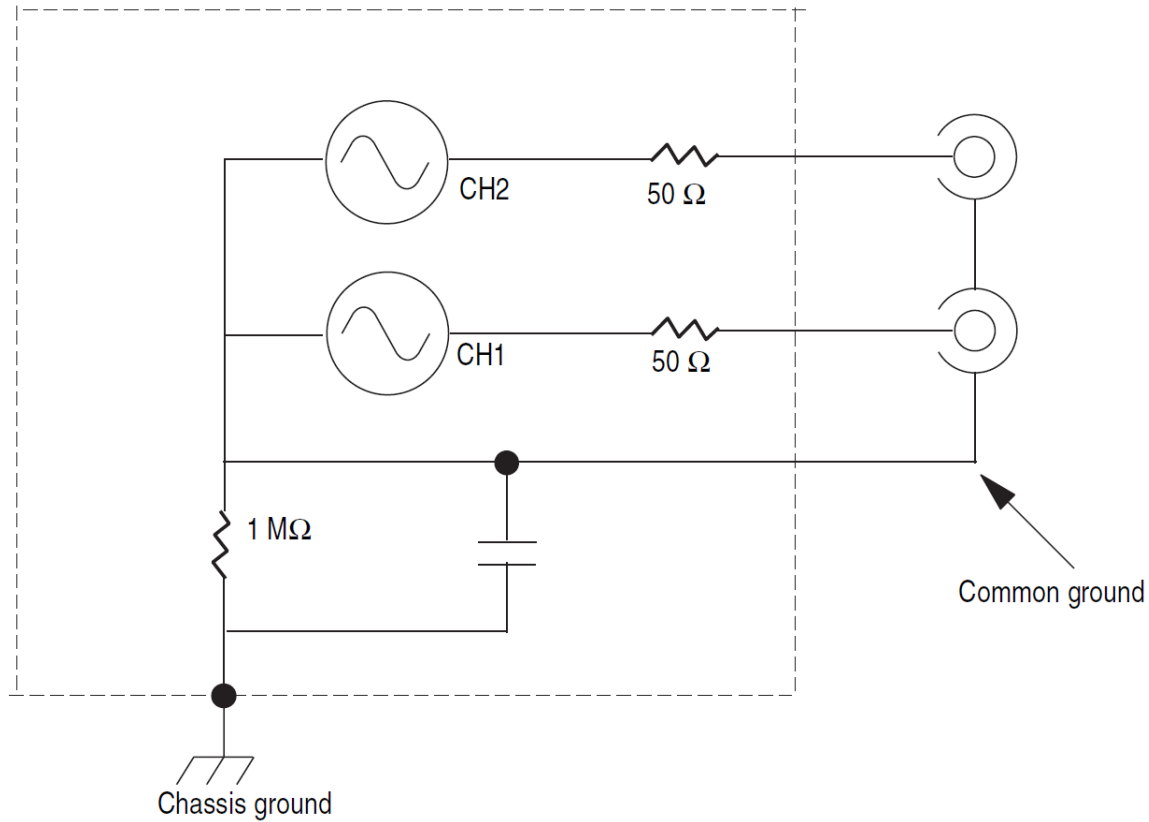


856 mVpp at 100 Hz

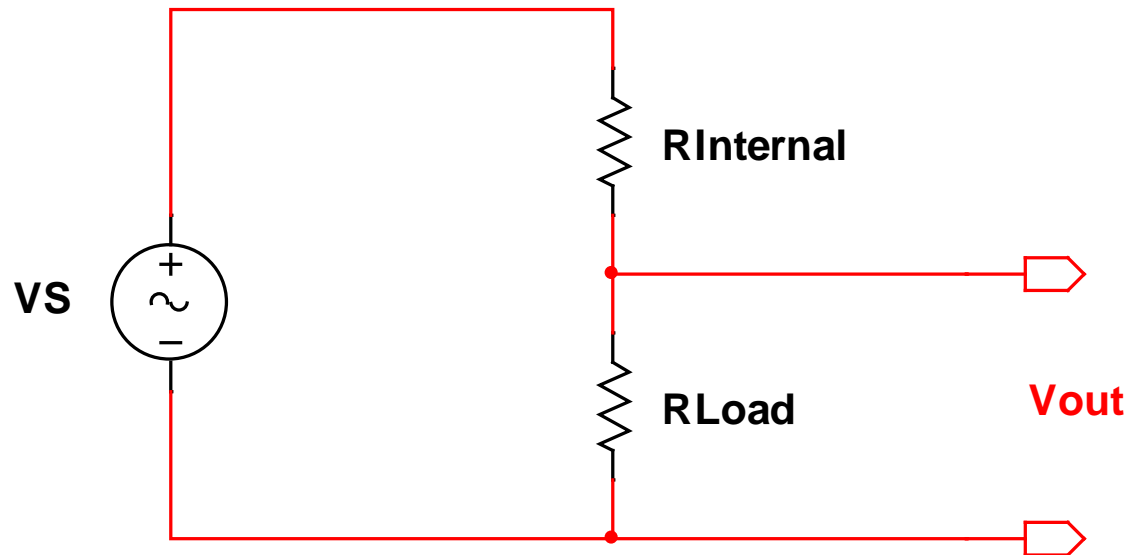
The reason it's wrong

- The function generator displays what it *expects* will be the output voltage *assuming* a 50 Ω load.
- If the load *isn't* 50 Ω , the display will be *wrong*.
- In most of our experiments, the load will have a fairly high impedance and the actual output will be ***roughly twice*** what's displayed.

The function generator has an internal 50 Ω resistance



It acts like a voltage divider.



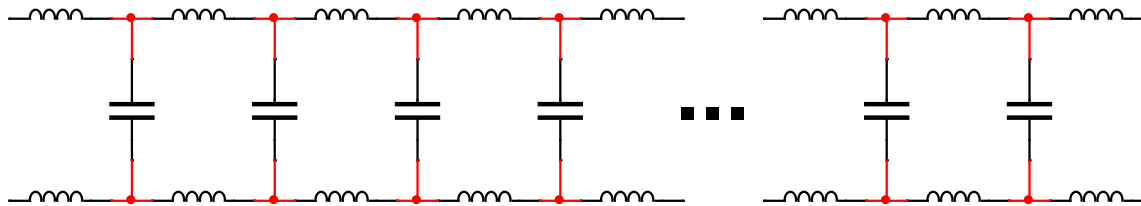
$$V_{out} = \frac{R_{Load}}{R_{Internal} + R_{Load}} * V_S$$

The reason it's 50 Ω

Because the function generator can produce RF signals, it was designed to drive 50 Ω coax, commonly used in RF for antennas and transmitters.

A little diversion on coax

Coax has the interesting characteristic that it can be modeled like this.

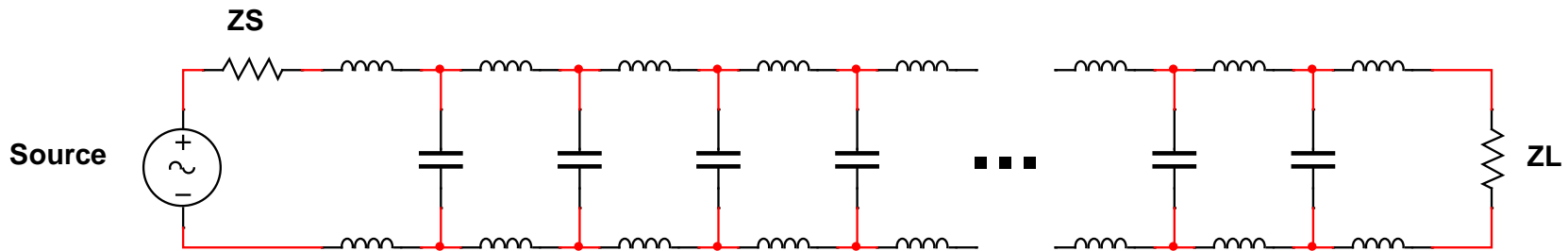


The signal propagates as power is passed from one stage to the next. Think of a ripple on a pond.

As you'll learn in 233, a circuit composed of purely reactive elements will be lossless. Power is dissipated only resistors.

This makes high quality coax a very low loss delay line, with some characteristic impedance Z_0 .

For maximum power transfer, the impedances should be matched: $Z_S = Z_0 = Z_L$



Because it's a delay line, if there's an impedance mismatch between the coax and the load, you get reflections.

The signal literally bounces back, the same way a ripple on a pond would if it hit a rock.

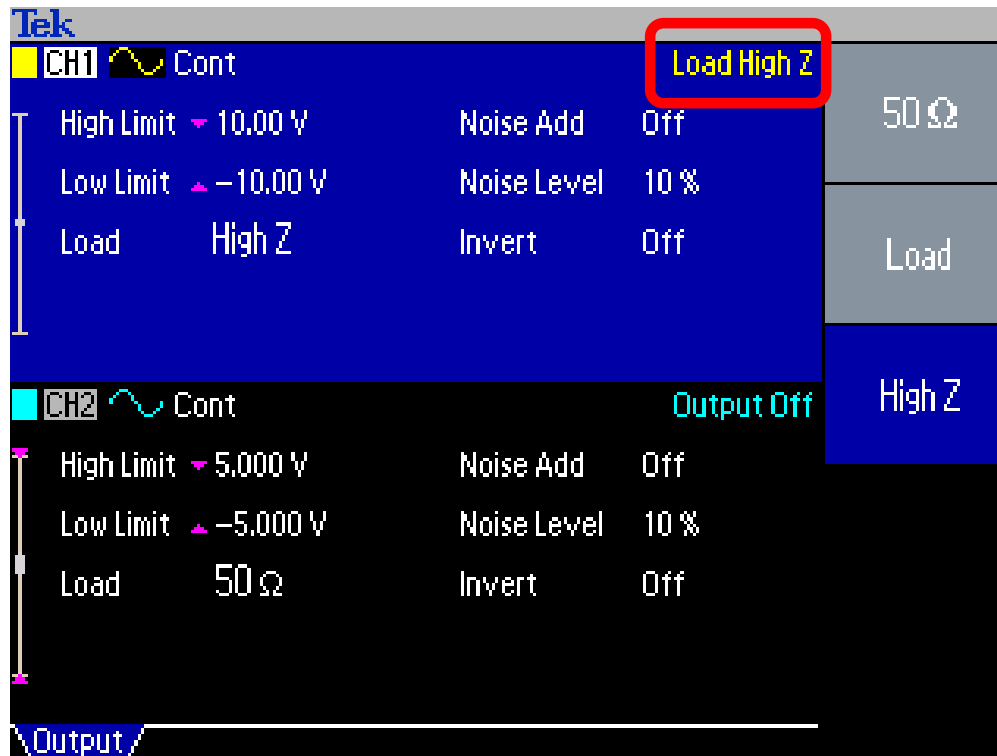
This creates standing waves and higher peak voltages at the source than expected.

Power that was intended to be transferred to the load is instead dissipated as heat in the transmitter, possibly damaging the transmitter.

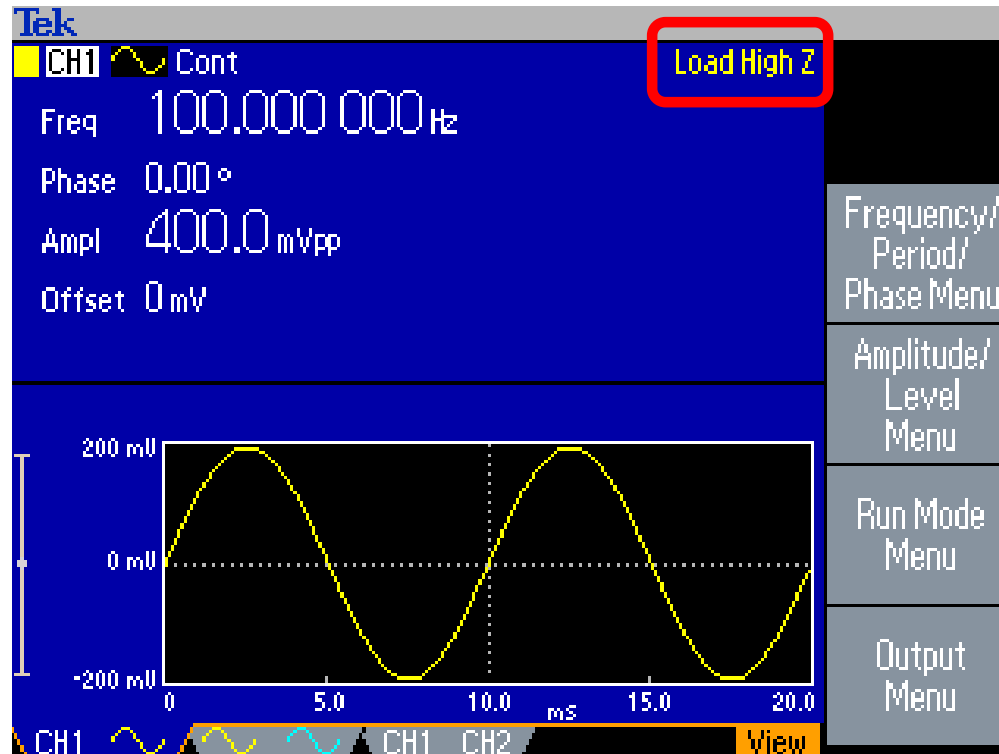
To avoid reflections, both ends of the coax must be terminated by $50\ \Omega$ loads.

Since one of those ends is the function generator, it also has to have an internal $50\ \Omega$ resistance.

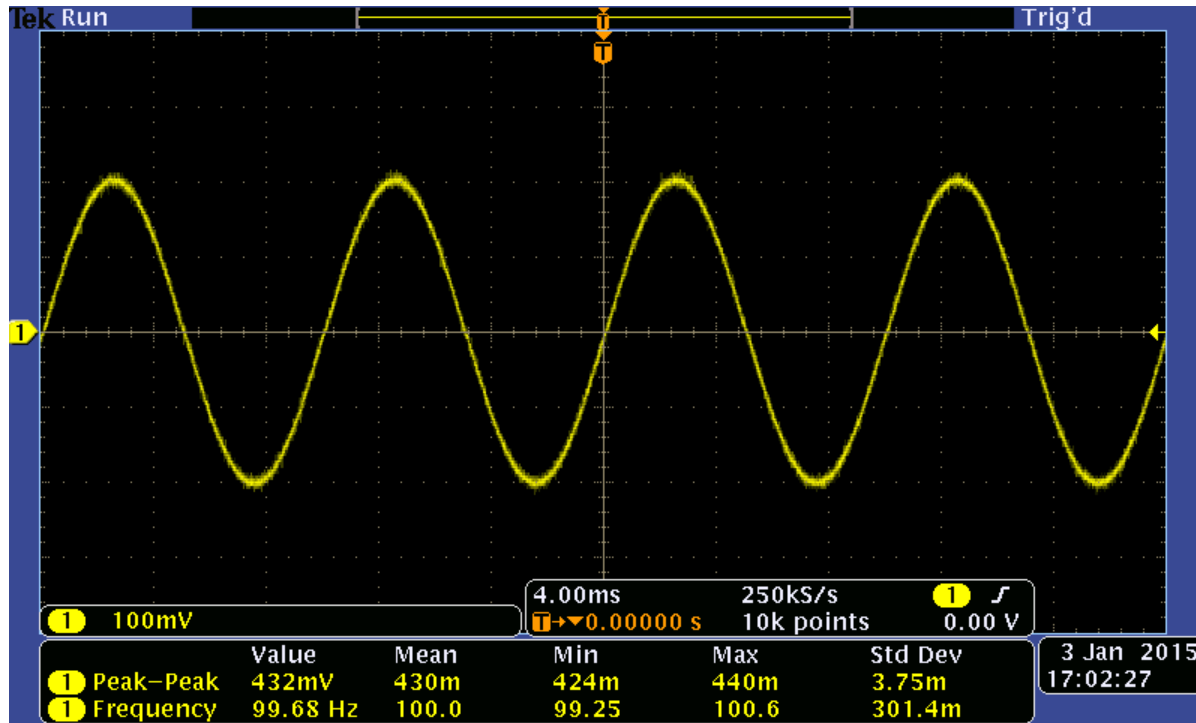
You can tell the function generator you have a “High Z” load through the output menu.



But that only changes the estimate it displays. It doesn't actually change the output.

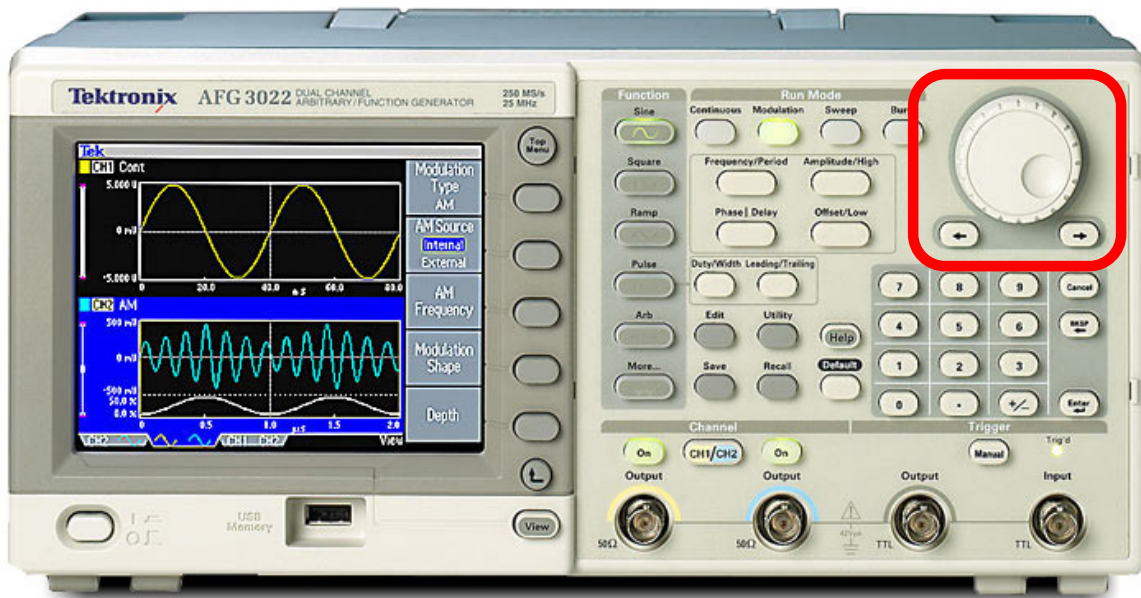


Here it is in High Z mode and reset for 400 mVpp output.



And now it's closer.

We asked for 400 mVpp and got 432 mVpp.



To get an exact value, e.g., 1 Vpp @ 1 KHz, you'll usually need to use the wheel to tweak the output while you watch the oscilloscope.

Only trust the oscilloscope.

It actually measures.

Tektronix MSO3012 oscilloscope



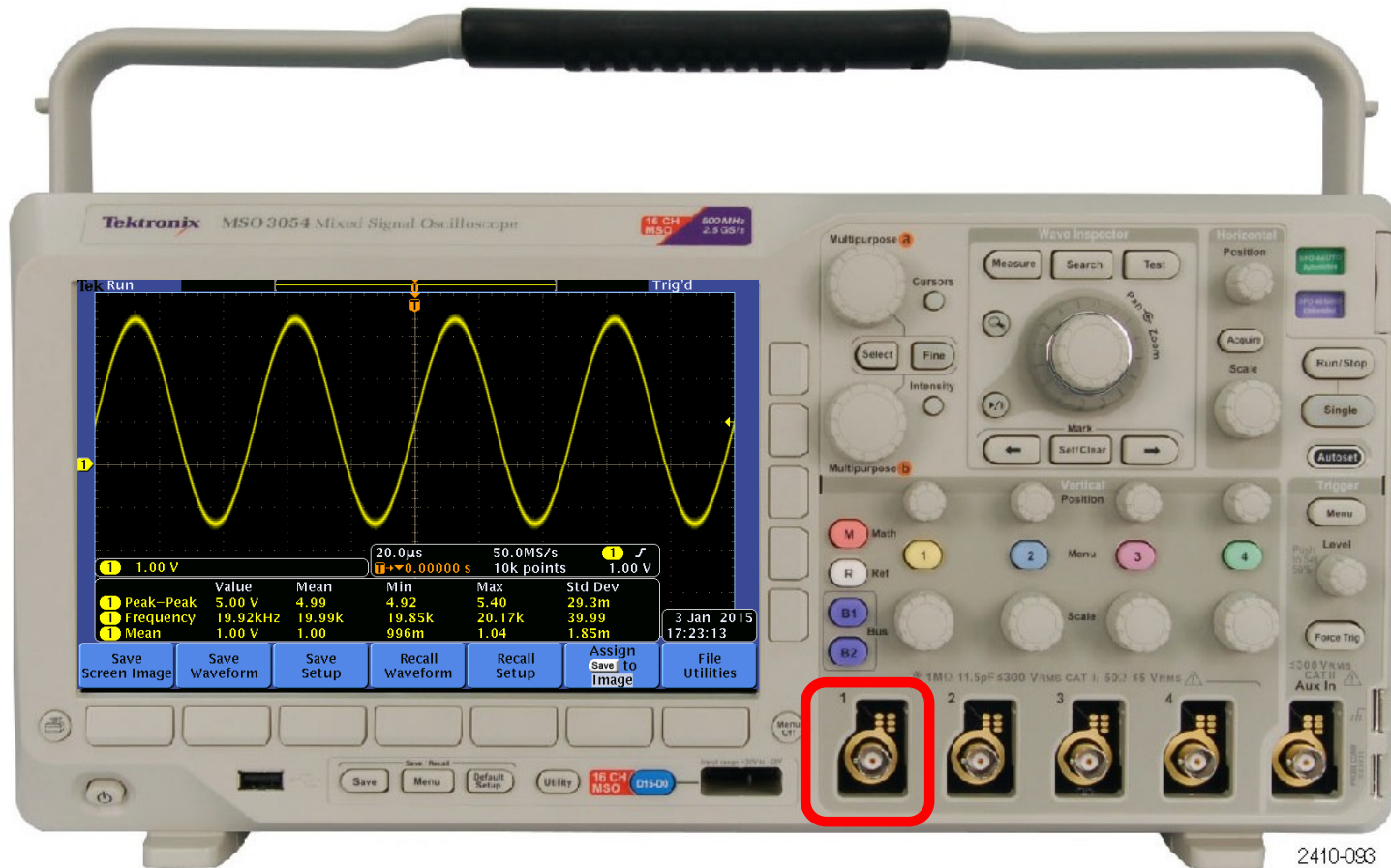
This photo is of the 4 channel version. Ours is the 2 channel version.

MSO3012 oscilloscope features:

- 100 MHz bandwidth
- Two digitized analog channels
- 16 digital channels
- 2.5 G samples/s
- 5 M sample recording
- On-screen measurements of Vpp, freq, min, max, etc.
- Screen capture to USB thumb drive or via Firefox

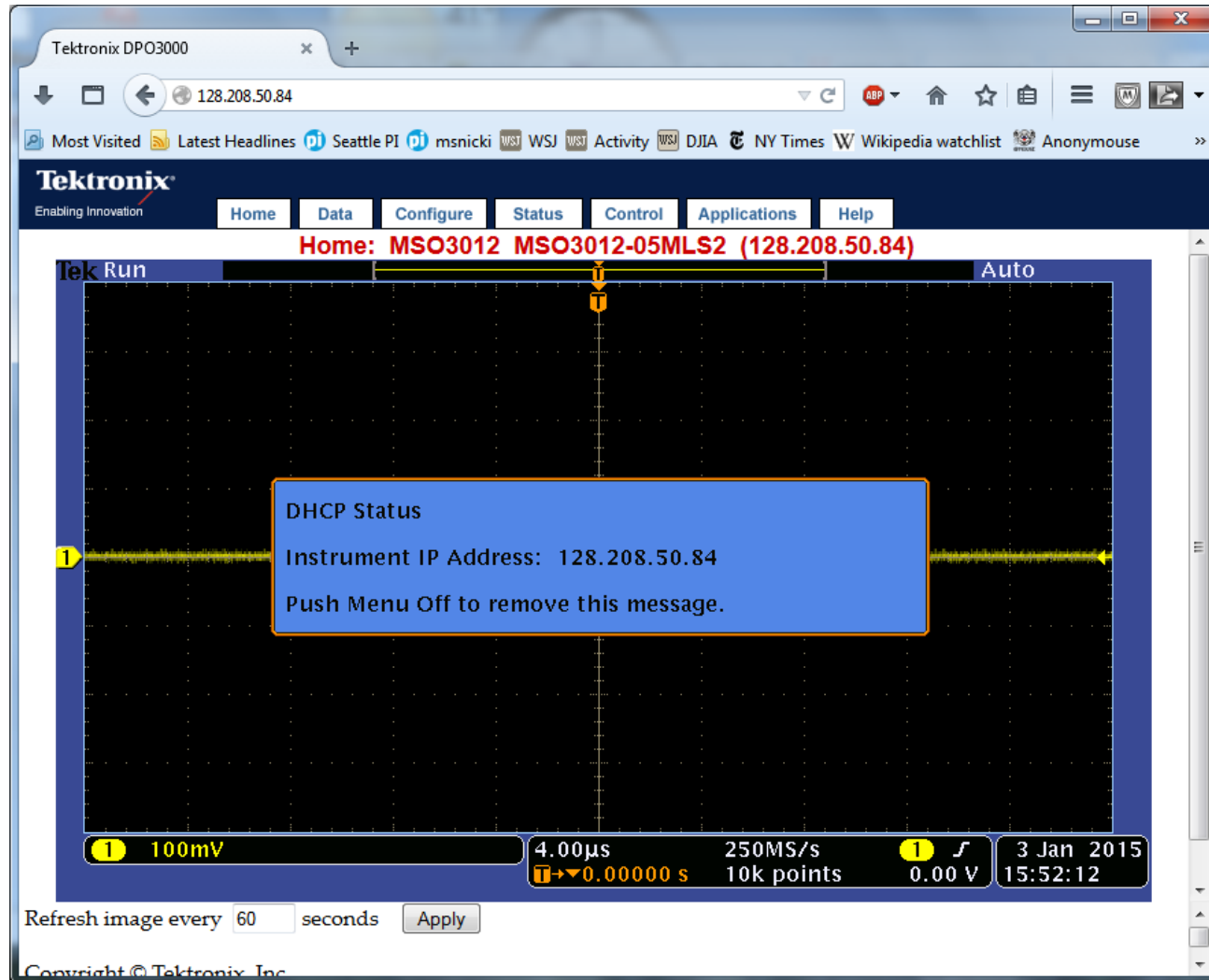
Typical price: \$4950

Please use only the boxy Tektronix oscilloscope probes with these scopes. They're keyed with a pin that tells the scope what kind of probe it is.

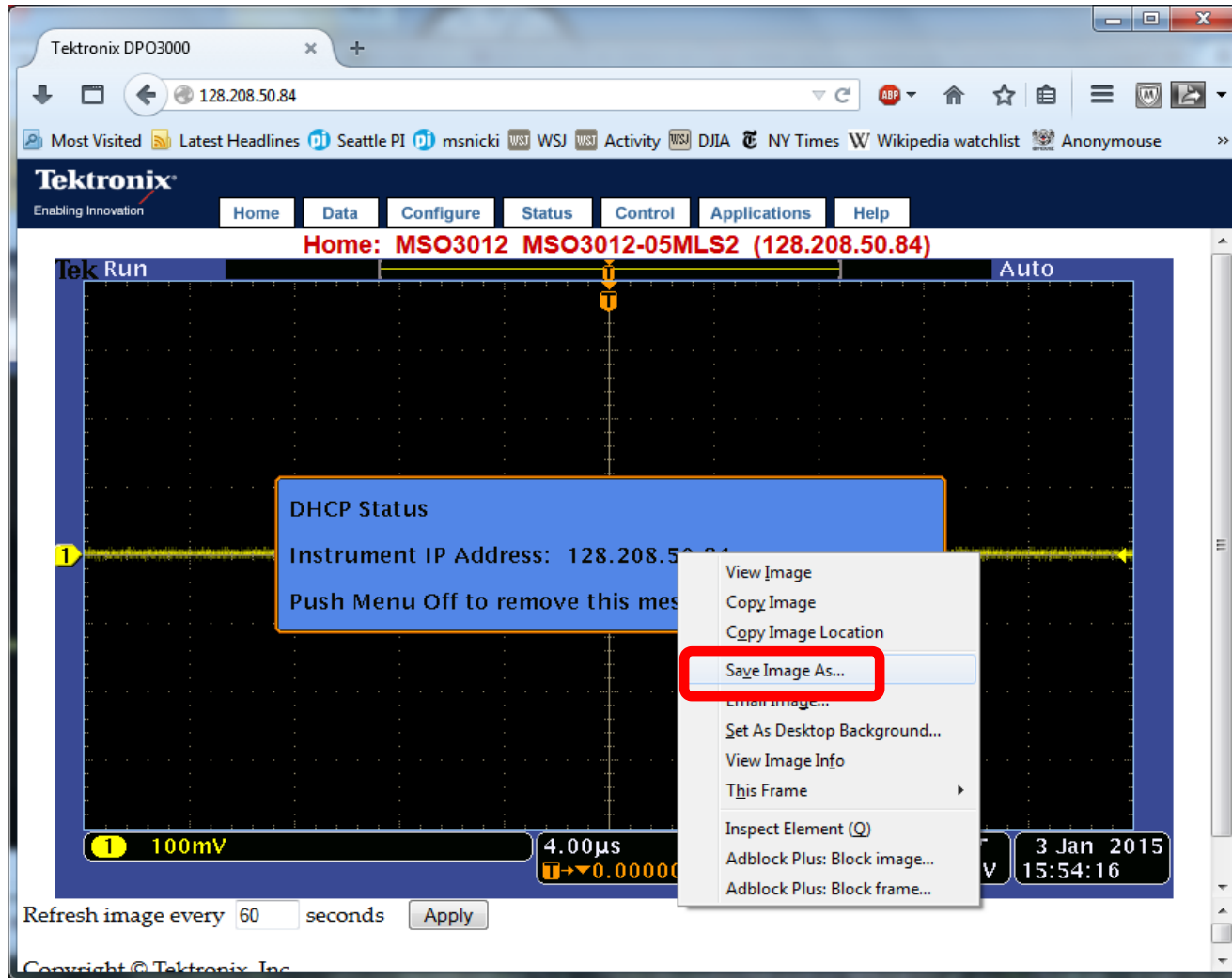


2410-083

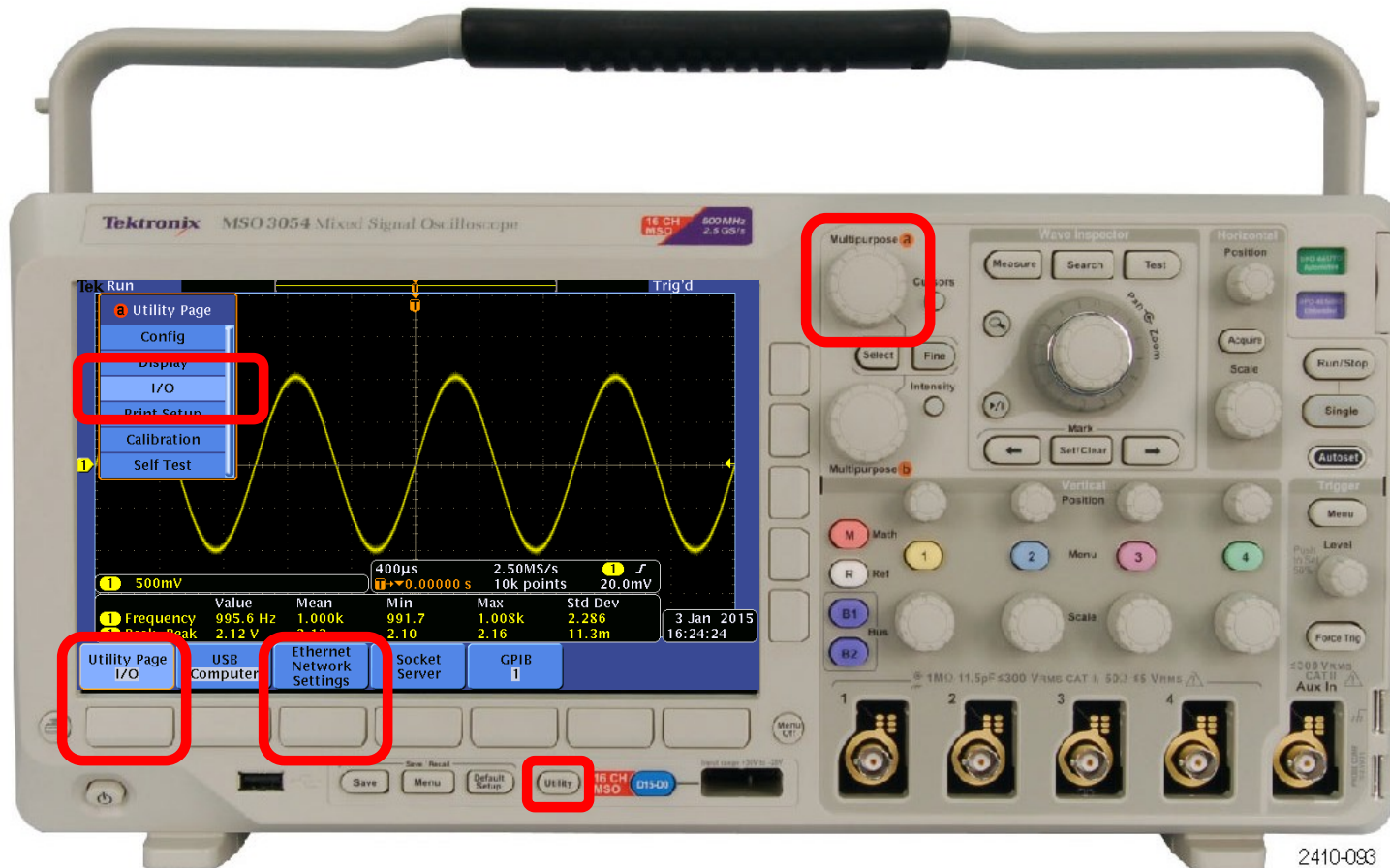
When it wakes up, it displays its IP address, which you can open with FireFox.



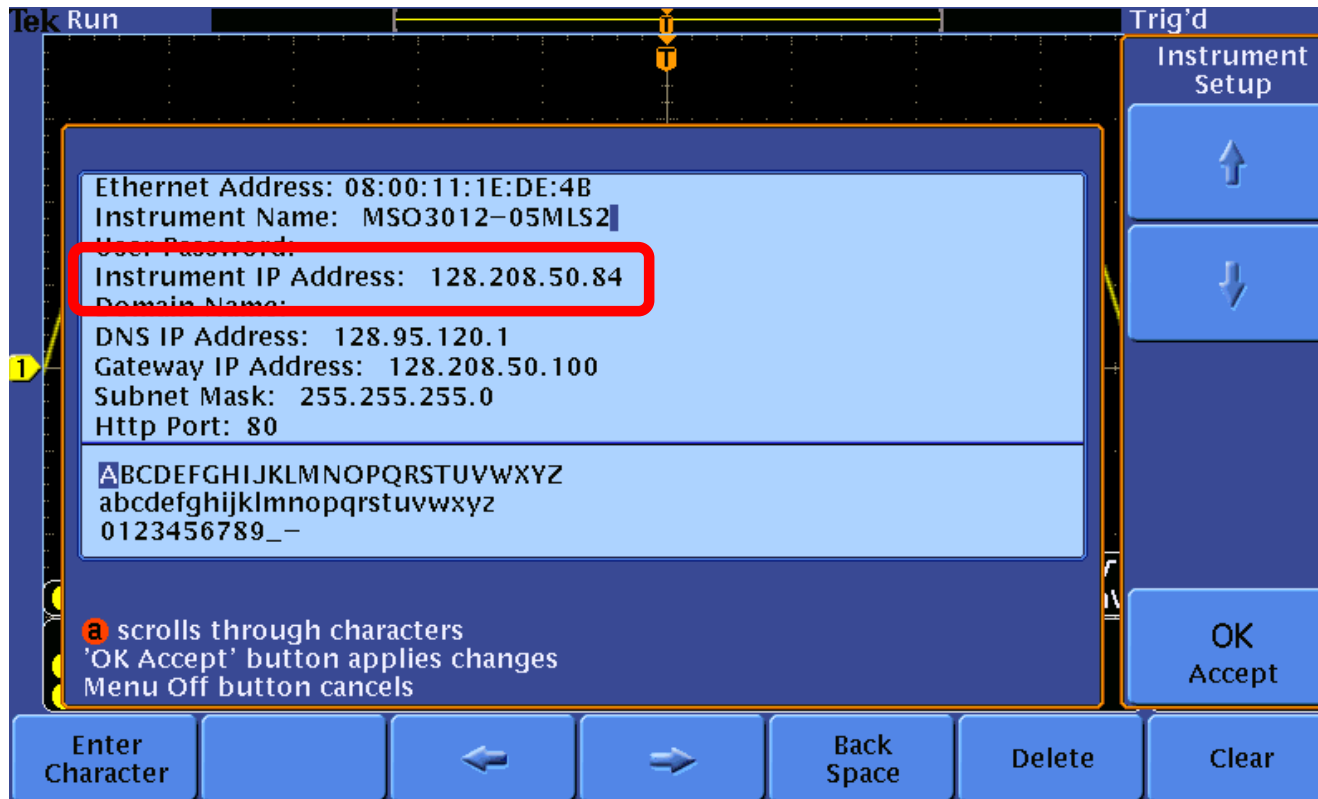
Save a screenshot under Firefox by right-clicking.



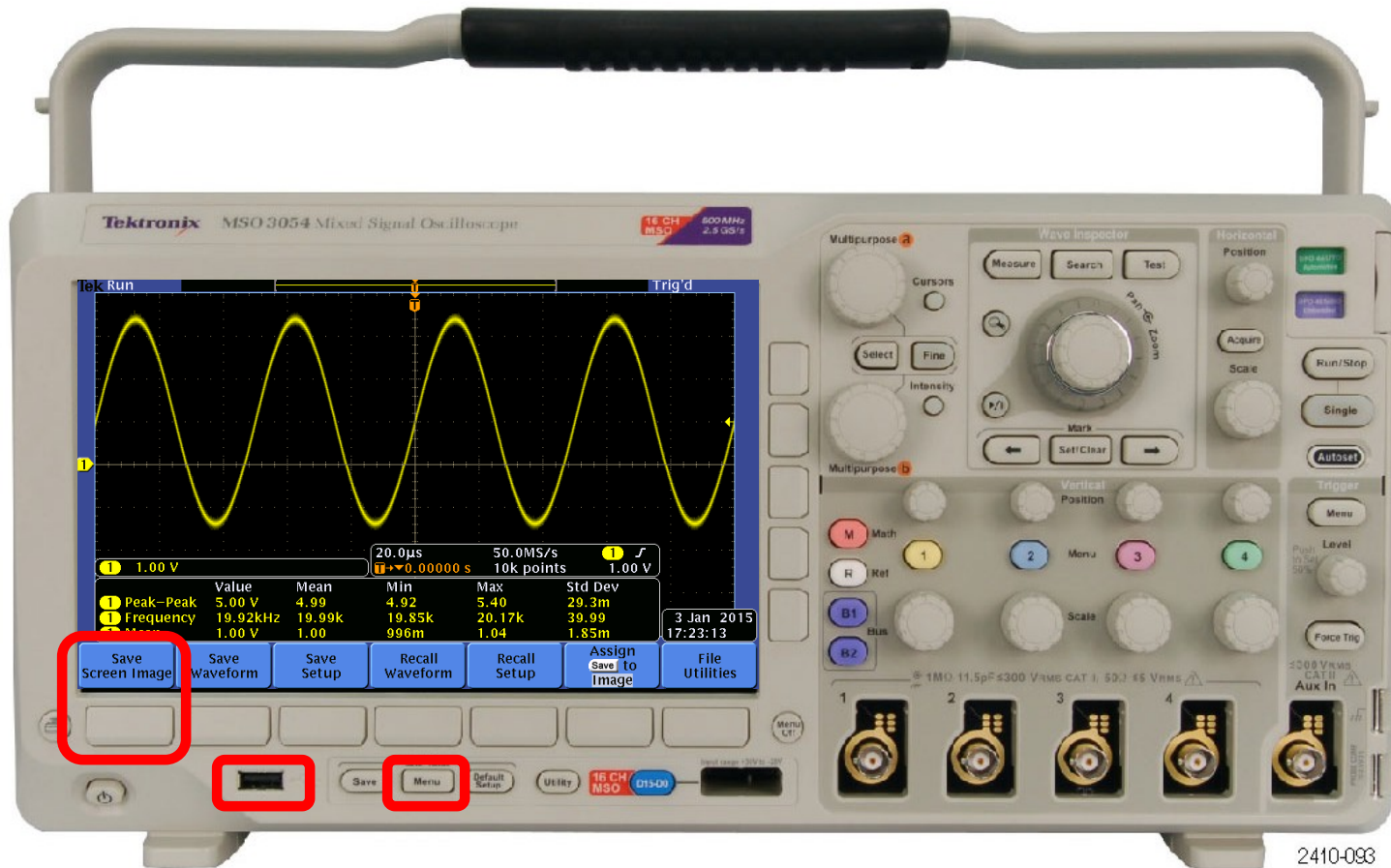
To find the IP address if you don't know it, press the Utility button, scroll with the A knob to I/O, then press Ethernet Network Settings.



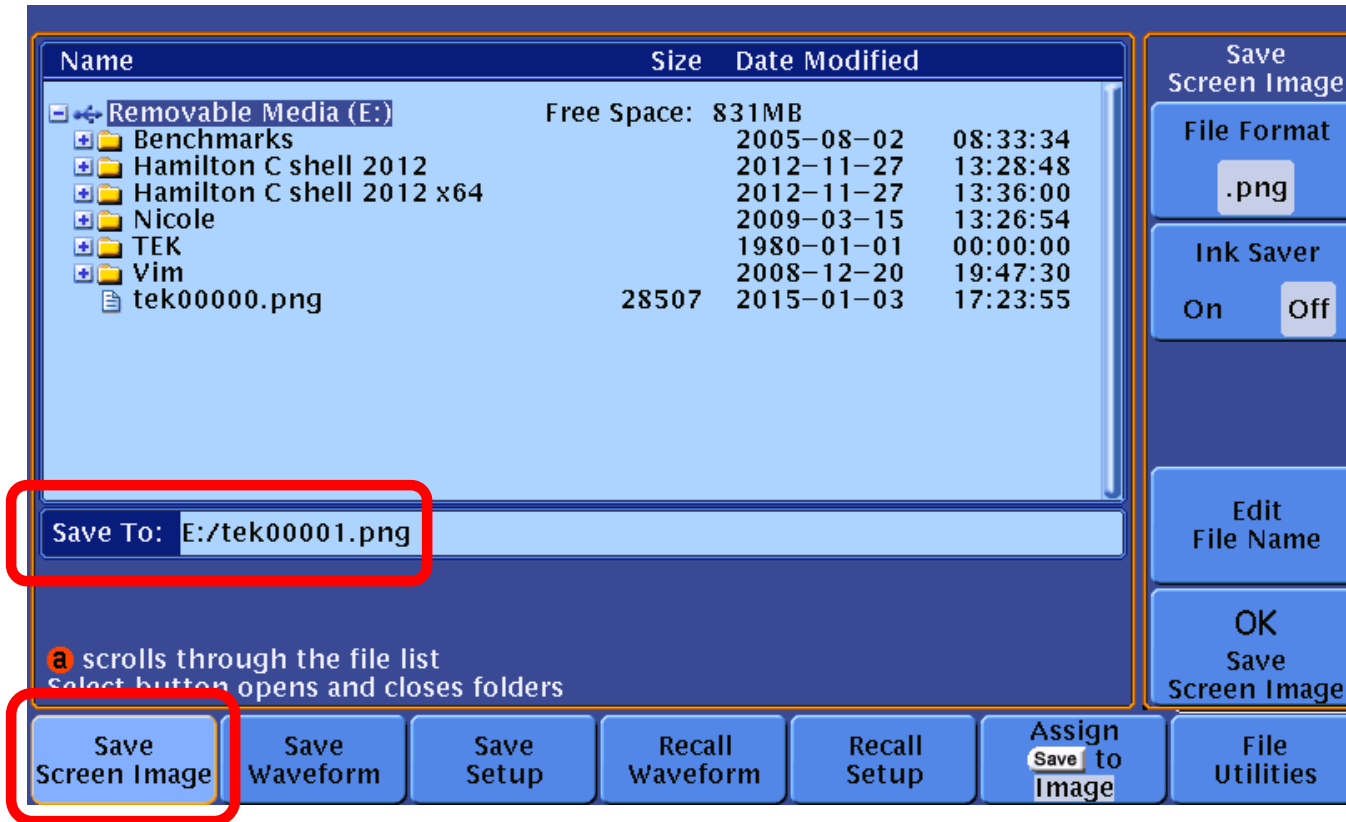
That brings up the Ethernet settings.



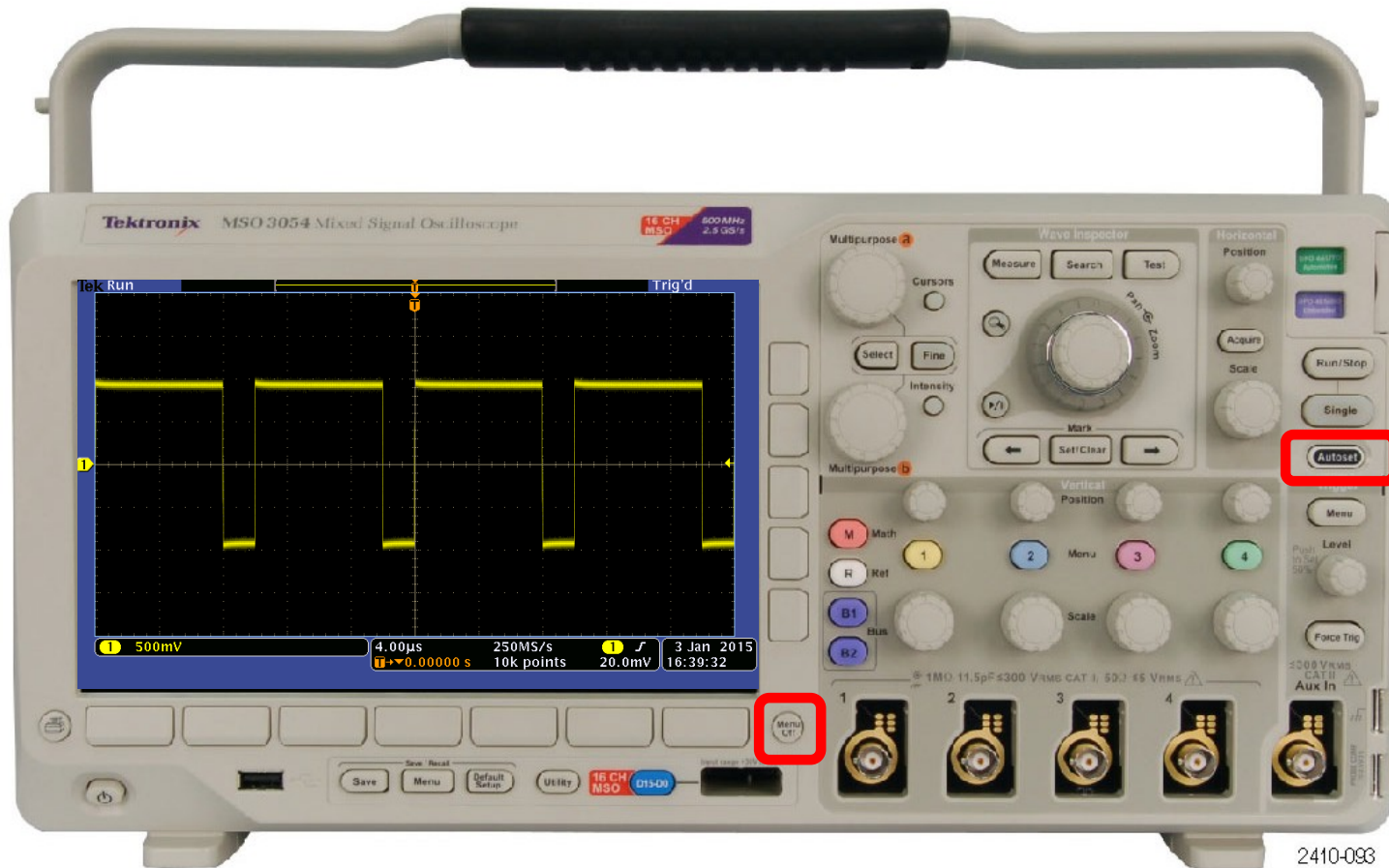
You can also save to a USB thumb drive by pressing Menu, then Save Screen Image.



This brings up a save menu.

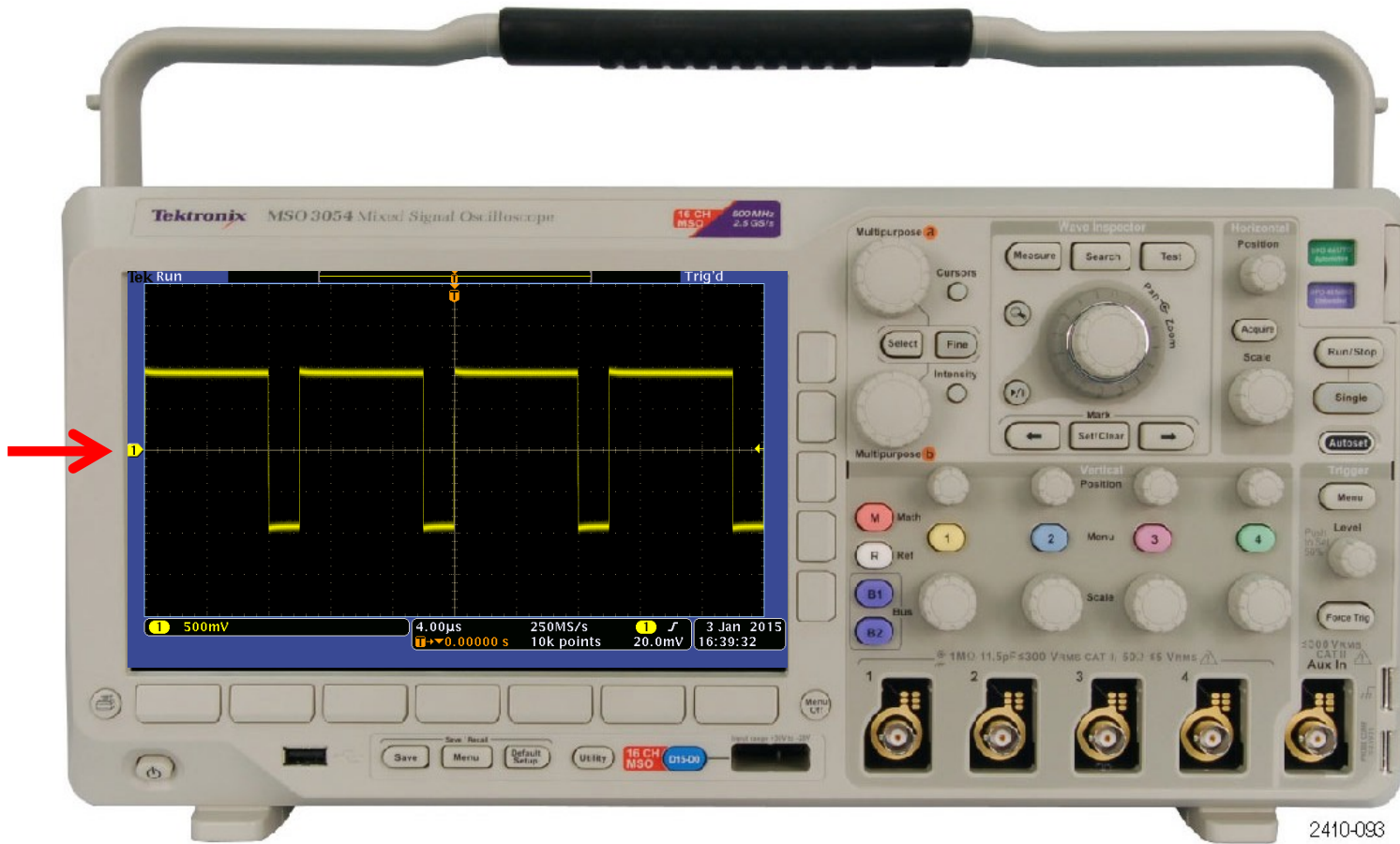


To display a signal on channel 1, press Autoset, then Menu Off.

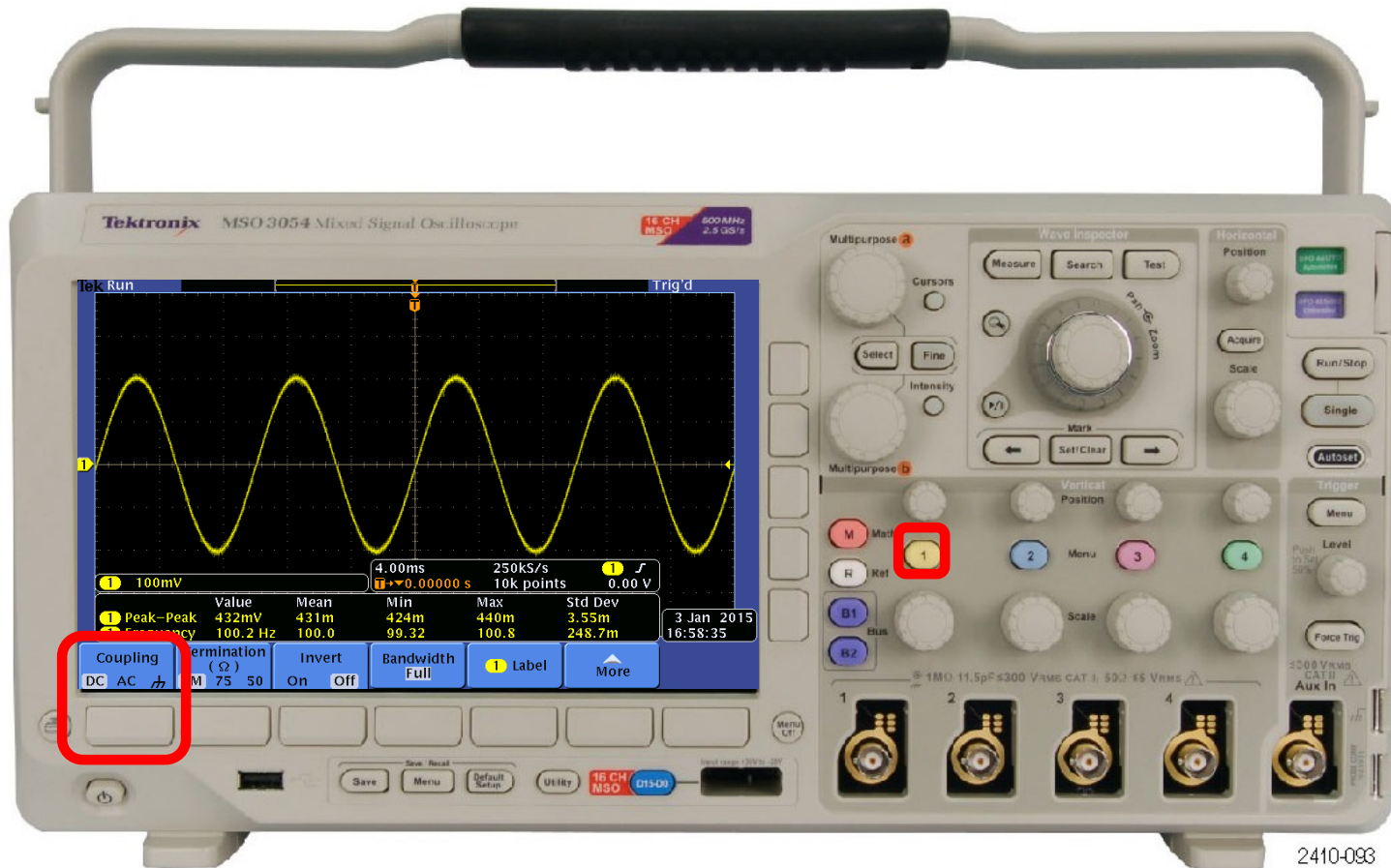


2410-083

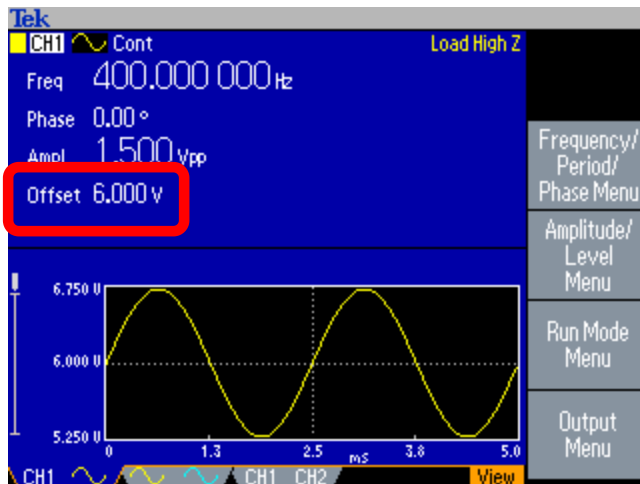
The **1** arrow on the left is 0 V for channel 1.



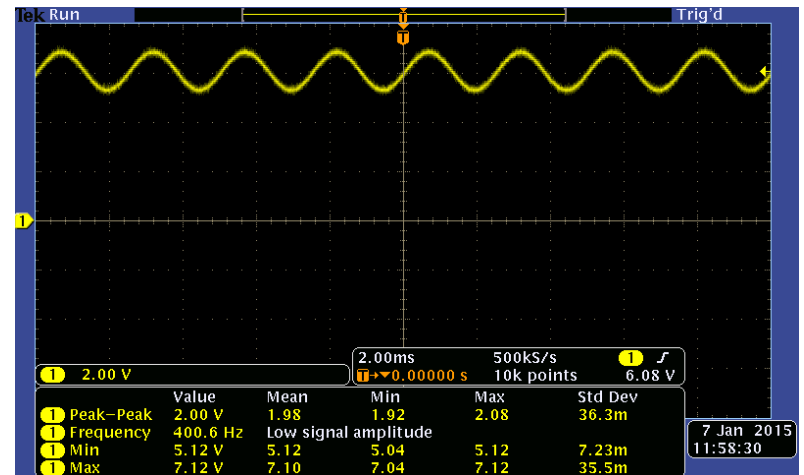
To change the coupling, press the channel menu button.



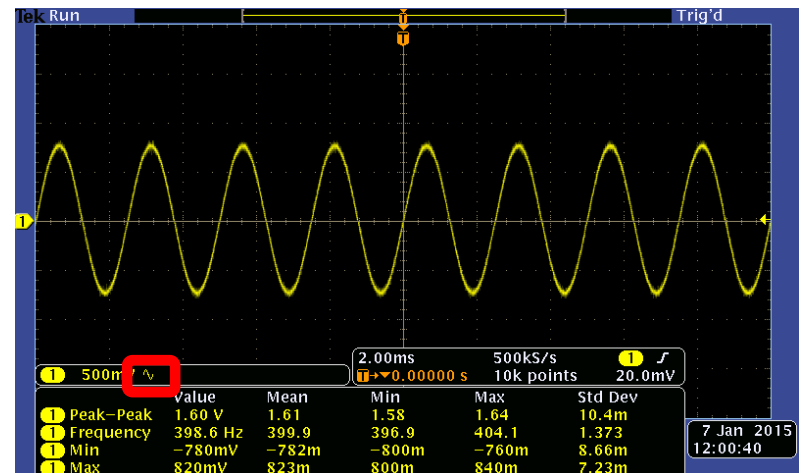
AC coupling filters out the DC component



1.5 Vpp 400 Hz +6.0 V offset

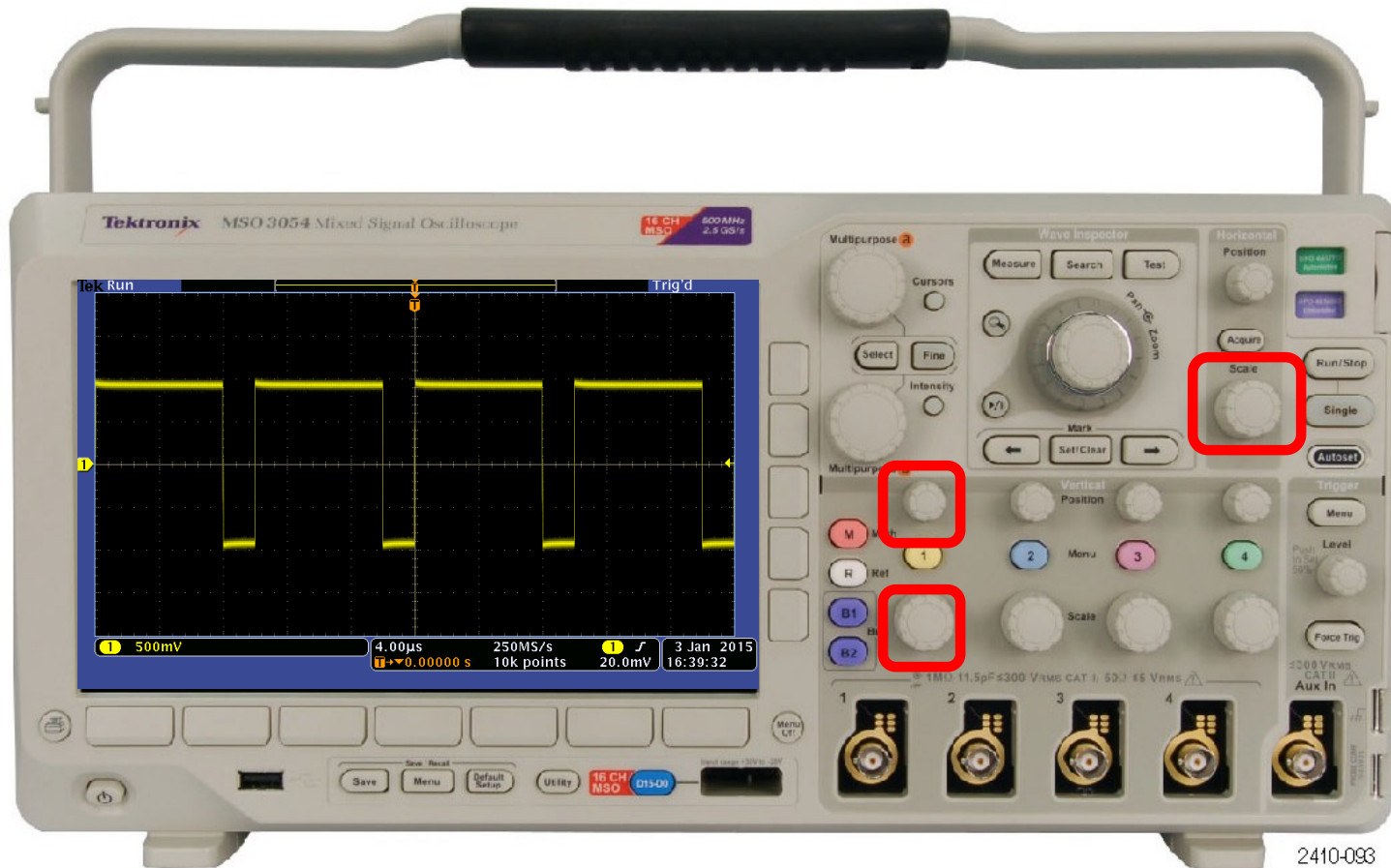


DC coupling



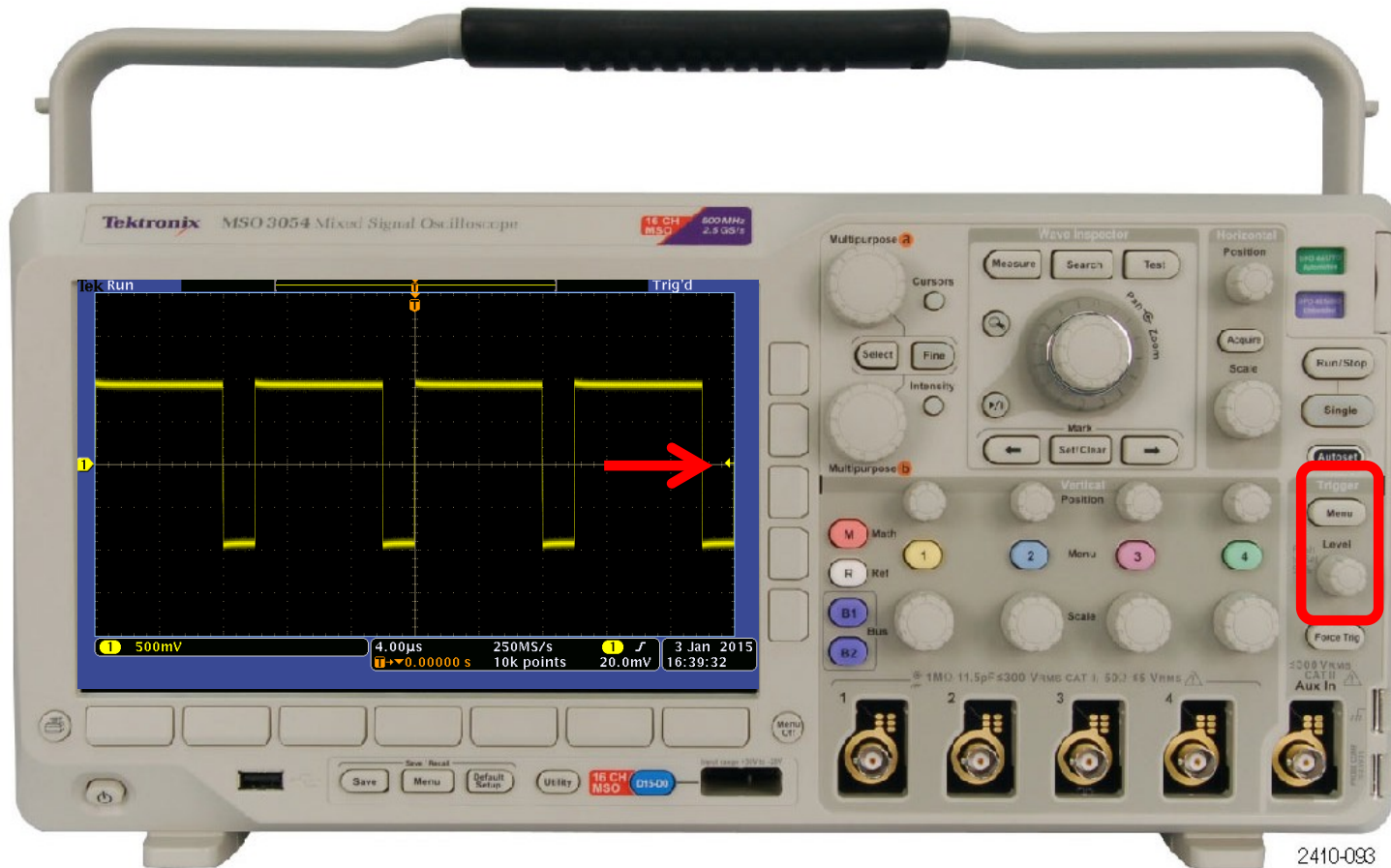
AC coupling

Adjustments for horizontal and vertical scales and vertical position.

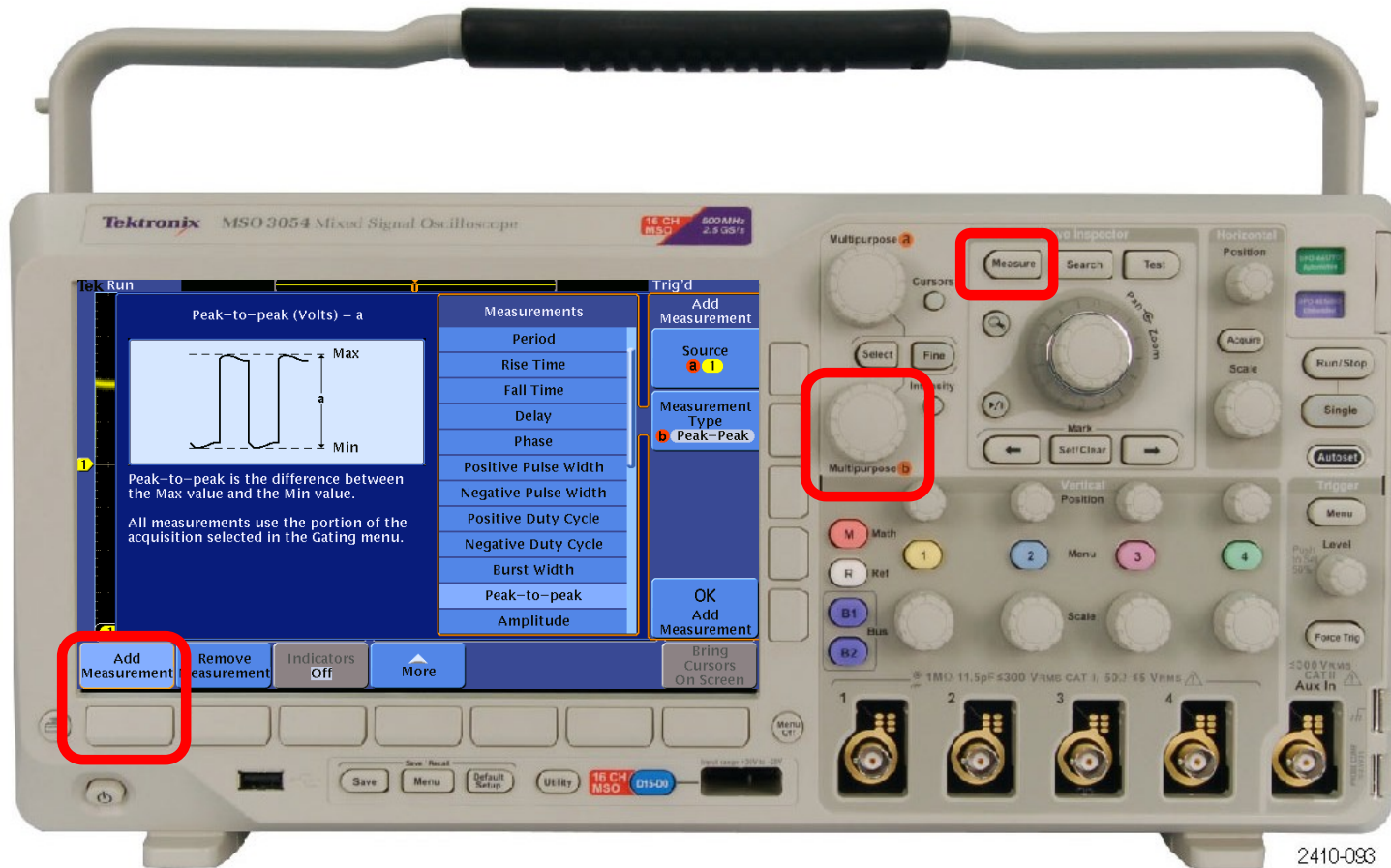


2410-083

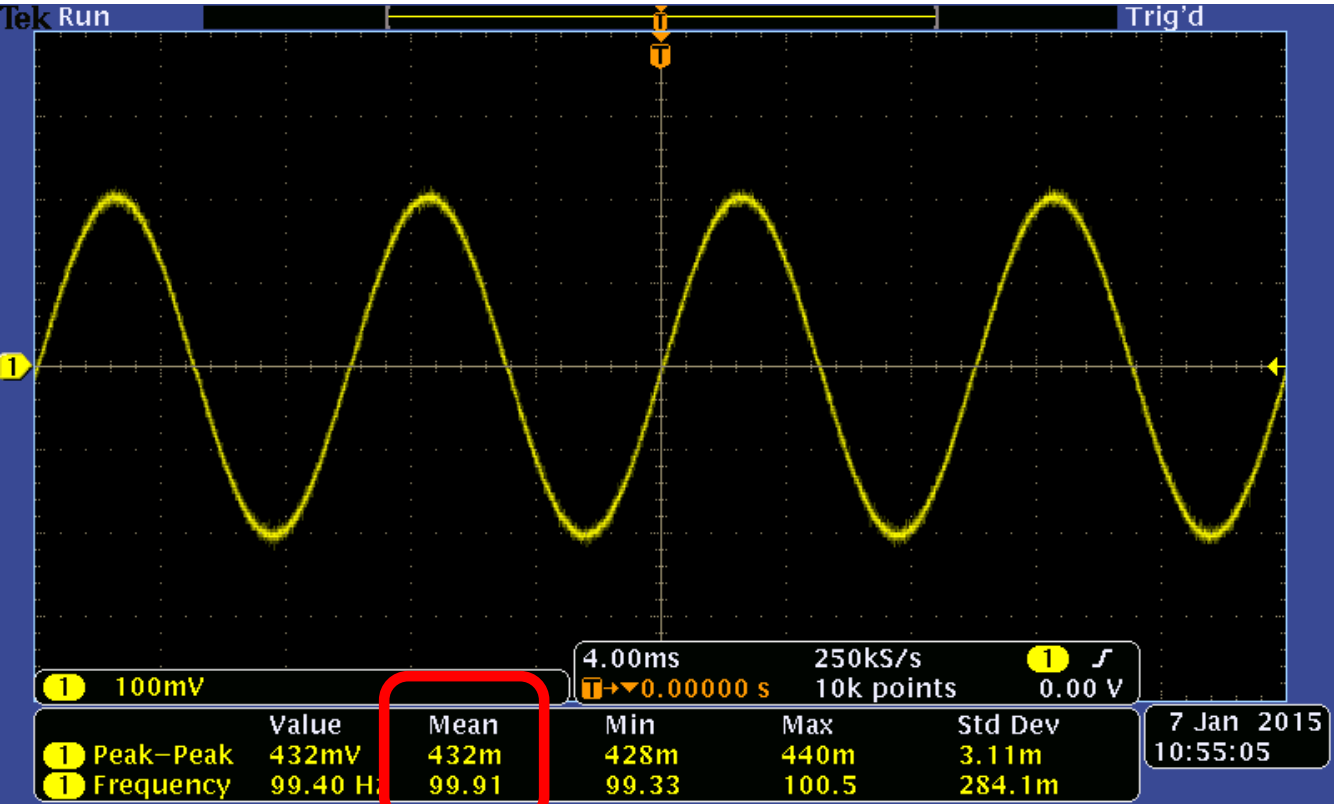
Adjustments to set the trigger level for recognizing the start of the cycle.



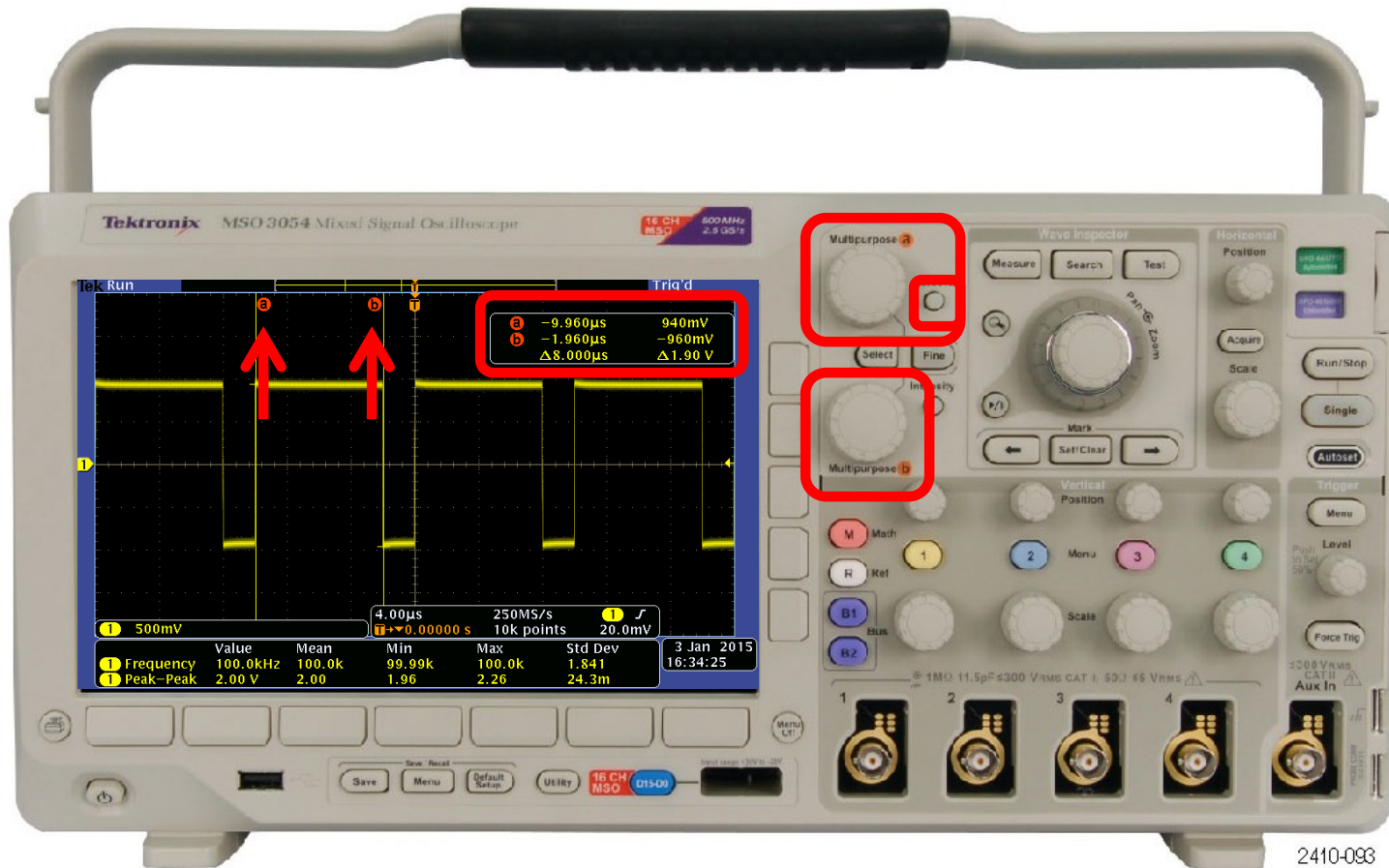
To add an on-screen measurement, press Measure, select Add Measurement, then scroll through the choices with the B knob.



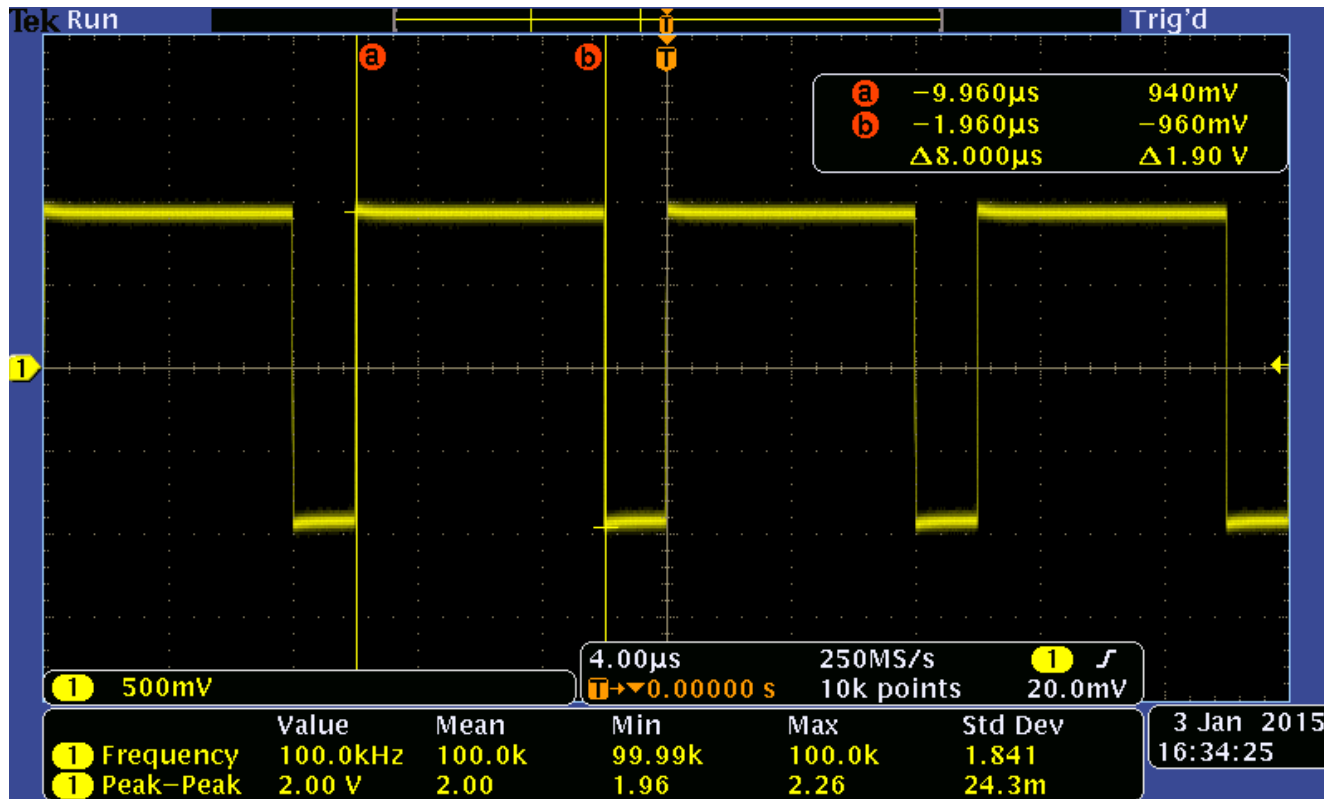
To get good measurements, wait until the mean values settle down.



To add cursors, press Cursors, then use the A and B knobs to adjust their positions.

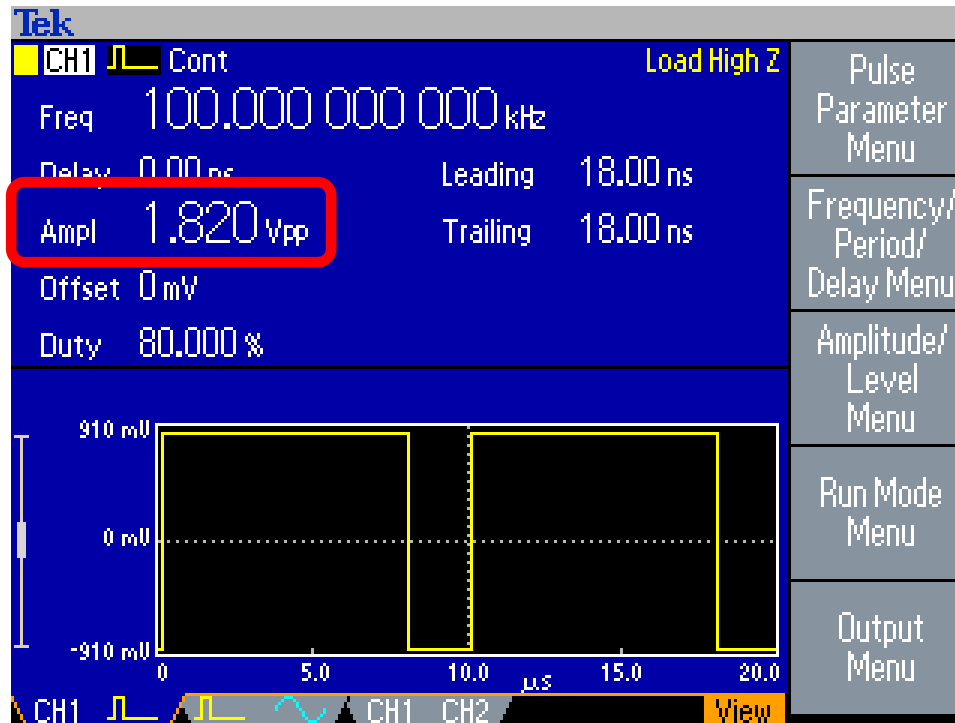


The desired result: A good screenshot with big, clear waveforms, helpful on-screen measurements and cursors and *no menus*.

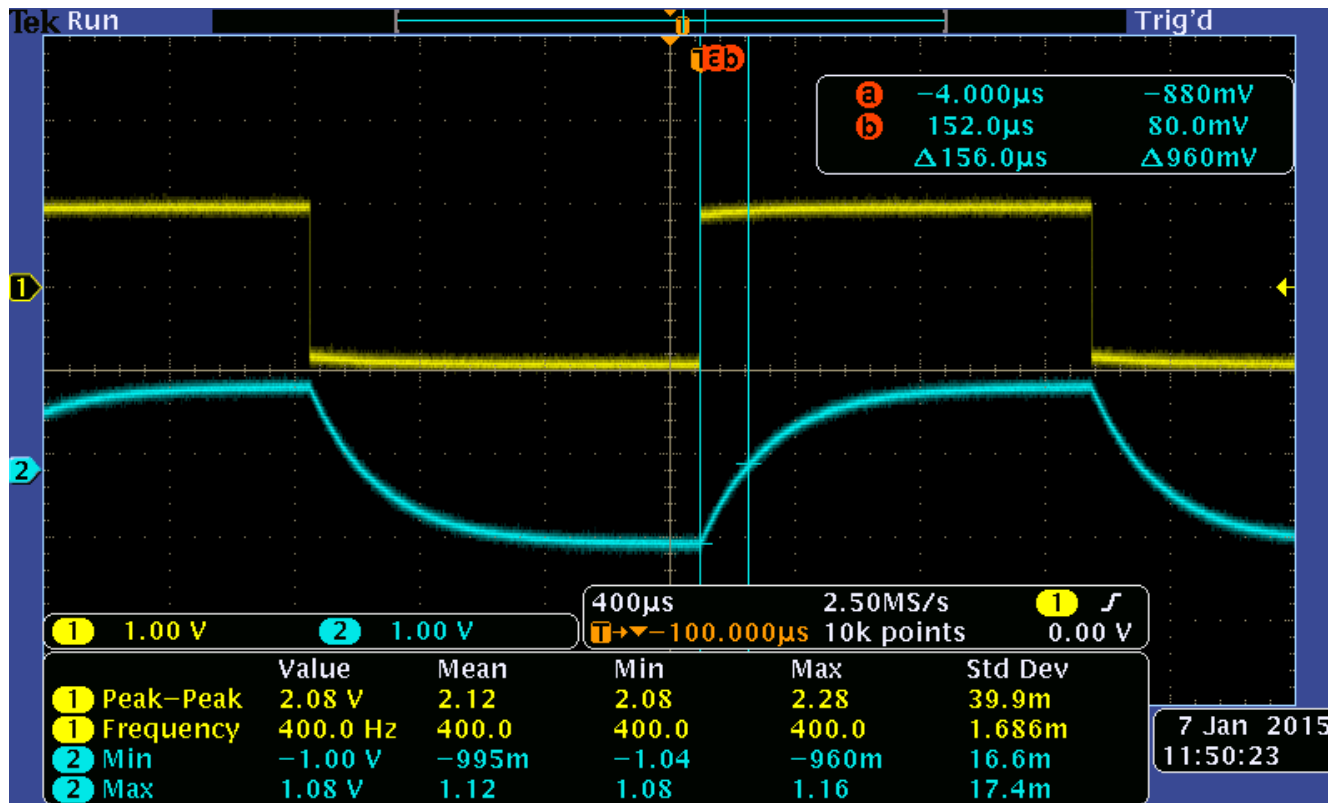


2.00 Vpp 80% duty cycle square wave at 100 KHz.

To get that, here's how the function generator was set.

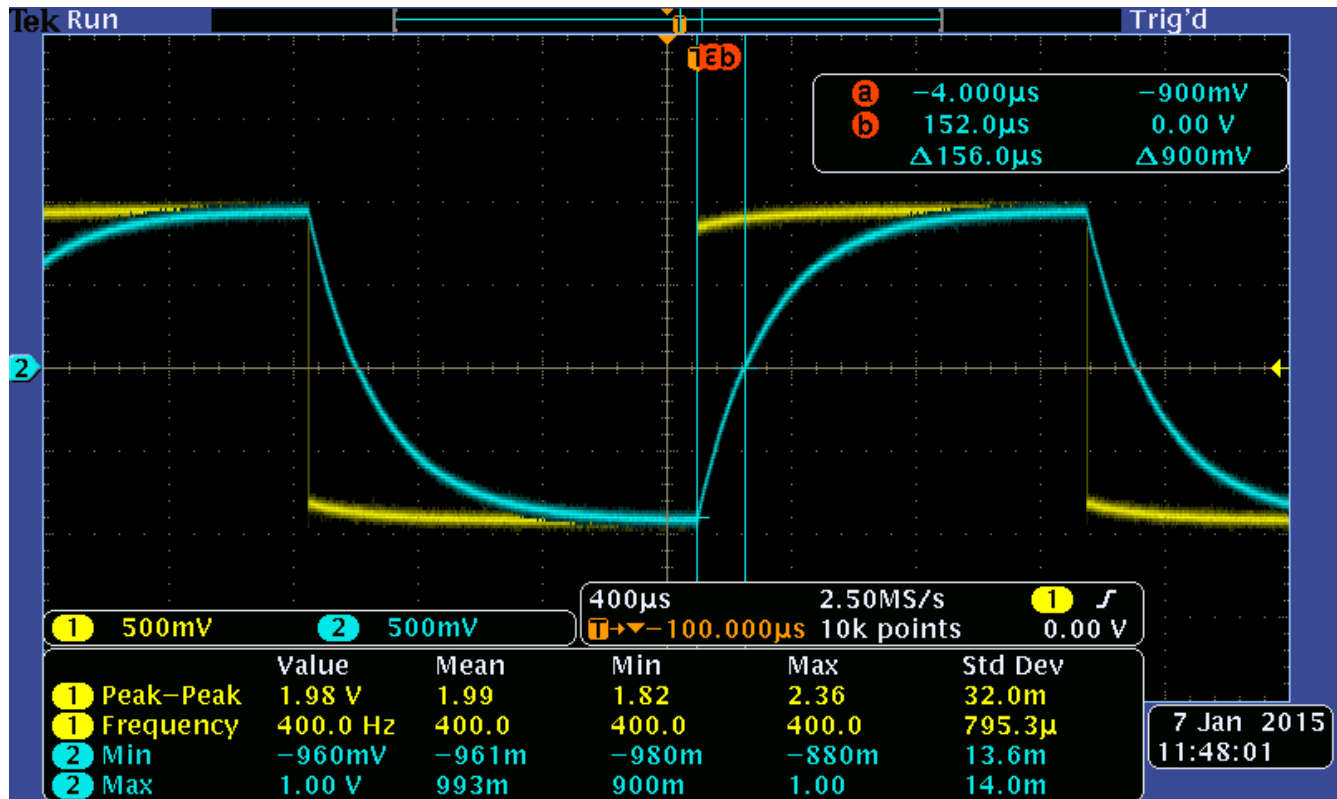


In most of your labs, you'll be comparing V_{in} on channel 1 with V_{out} on channel 2.

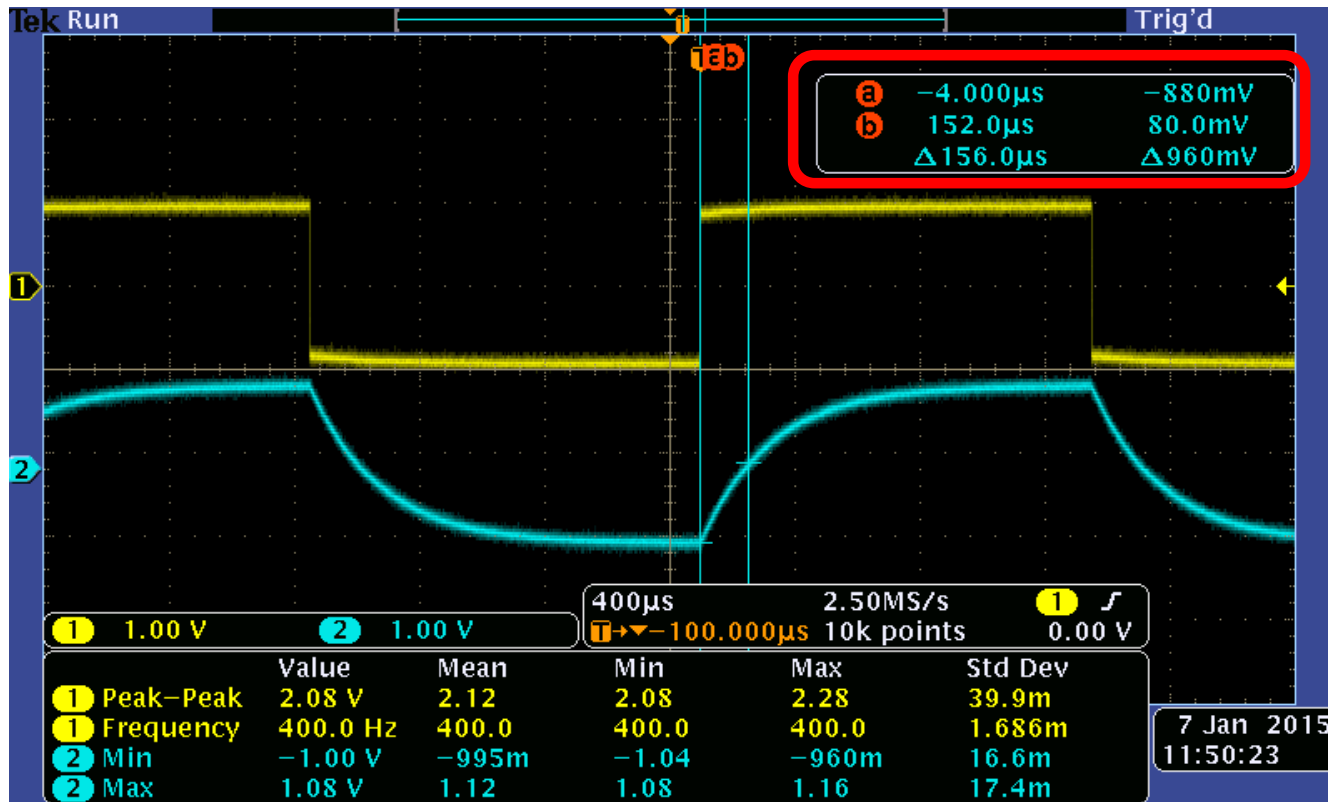


Here I've stacked the signals.

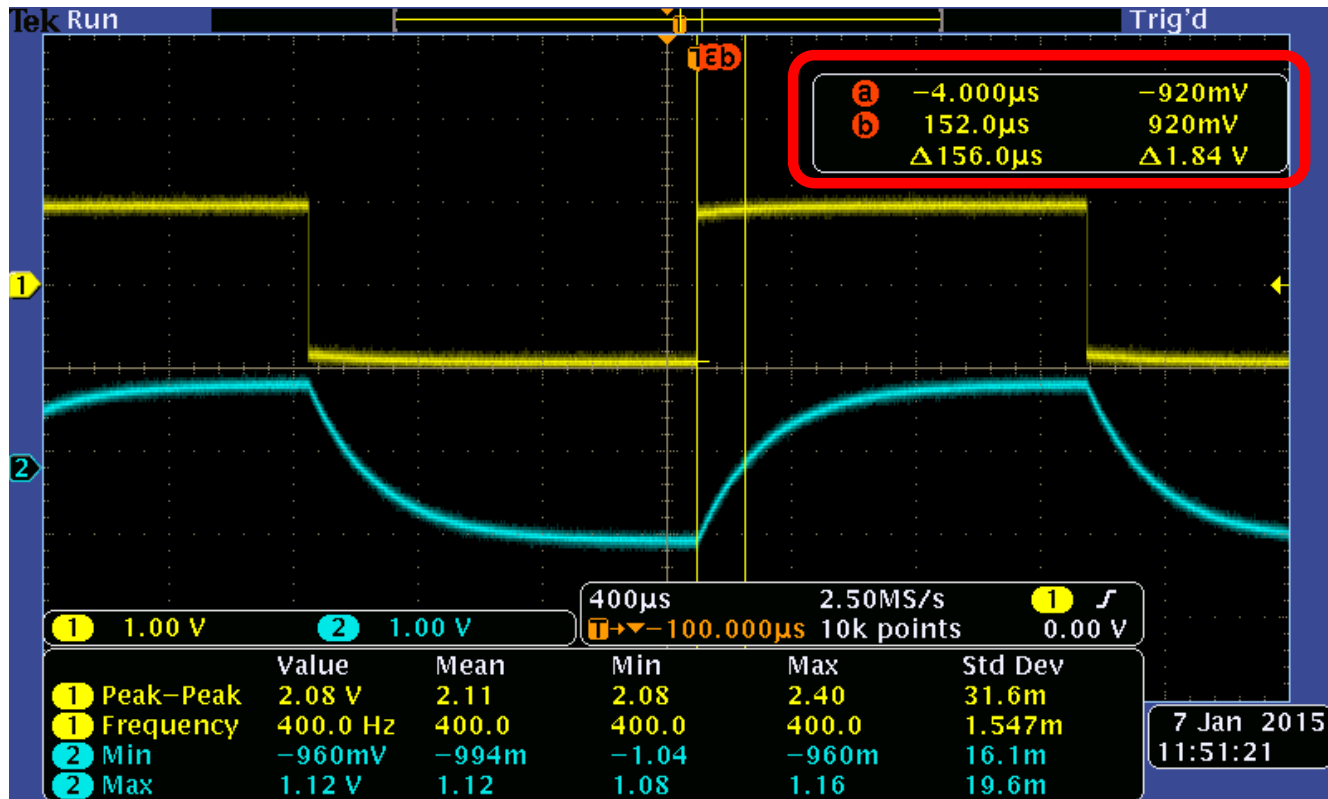
Here I've pushed them together for closer comparison.



The color of the cursor lines and info box tells you which signal is being measured.



Here's channel 1.



To switch the cursors between channels, press the channel menu buttons.

