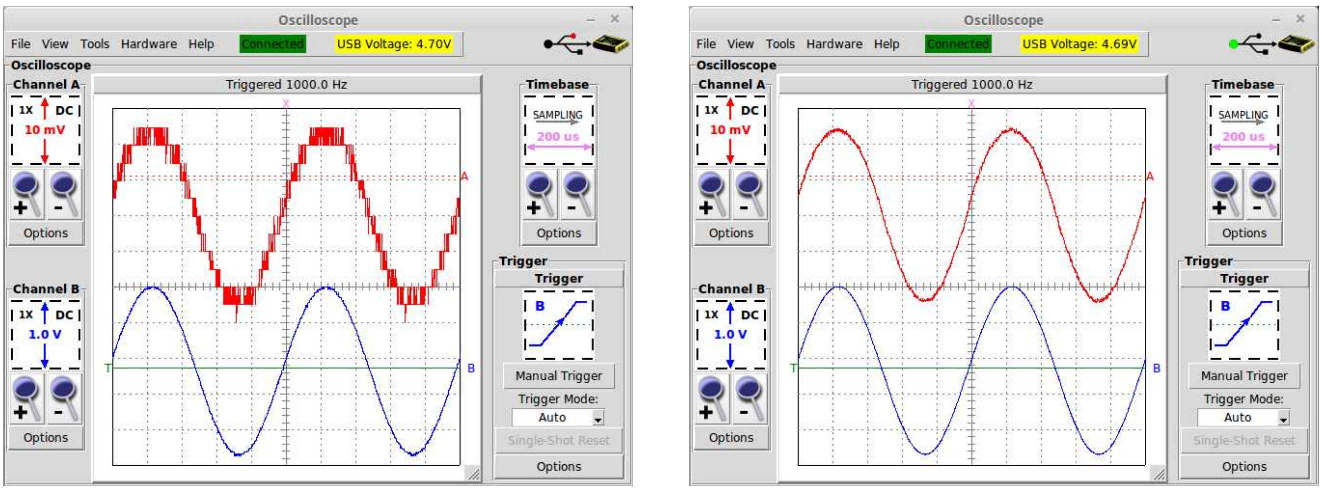
Waveform Averaging

Syscomp Electronic Design Limited
http:\\www.syscompdesign.com
March 23, 2016

When measuring low level signals, waveform average can be a very useful in extracting a signal from the noise. Figure 1 shows an example using the Circuitgear CGR-201.



(a) Averaging Off (b) Averaging x64

Figure 1: Small signal averaging

Averaging requires a solid trigger signal so the unattenuated signal from the generator was fed into channel B and the triggering source set to channel B.

The CGR-201 generator signal is rather large for this demo, so it was attenuated by a factor of 100:1 in a 1kΩ – 10Ω voltage divider. The attenuated signal was then fed into channel A.

The un-averaged signal in figure 1(a) is quite noisy: the signal is about 50mV peak-peak, the noise about 5mV peak-peak, for a signal-noise ratio of 10, or about 20db.

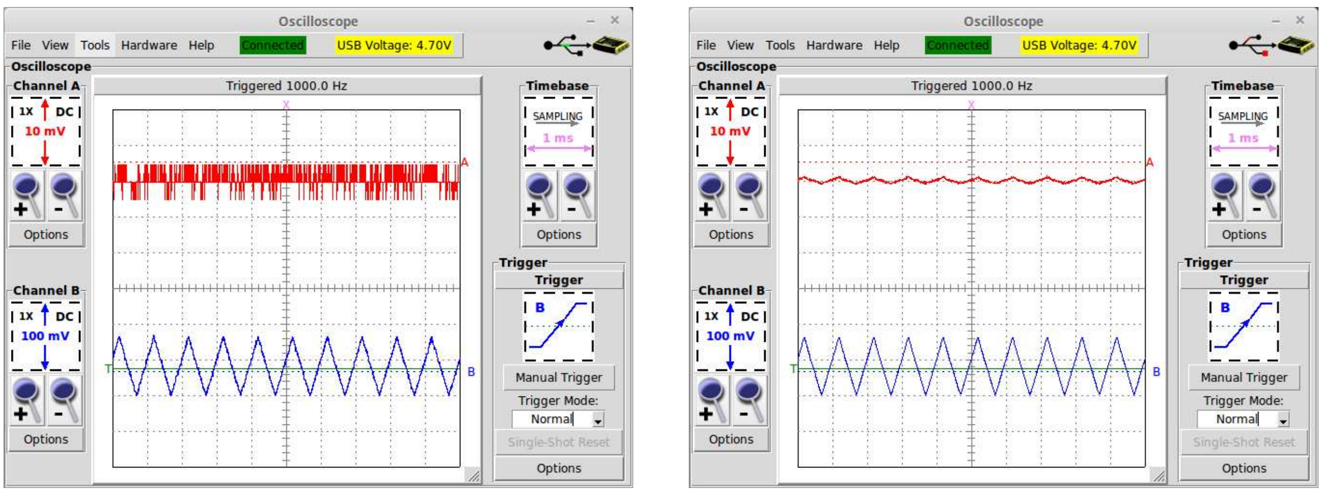
With averaging, the noise is much reduced. We can now determine more accurately that the signal amplitude is 47mV and the noise in the order of 1mV, for a signal-noise ratio of 47, or 33db. Obviously this is a huge improvement. Averaging extends the useful range of the oscilloscope into the small millivolt region.

There are some requirements for waveform averaging to work:

- The noise must be *random*, that is, *uncorrelated* with the signal.
- The improvement in signal-noise is proportional to the square root of the number of averages. In the CGR-201 software implementation, the range of adjustment is between 4 and 256 averages.
- The signal must be *repetitive* and steady state. A single-shot event will be lost in the averaging process. The signal cannot be changing in amplitude, frequency or harmonic content. (Slow changes are acceptable and the software will recalculate a new average if given sufficient time.)

- The scope must have a solid trigger signal so that the accumulation of the averages takes place accurately. In practice, the CGR-201 trigger mechanism is often robust enough to trigger off the noisy signal, so that's worth a try if you don't have a clean trigger signal.
- The averaged waveform can adapt to changes, but the rate depends on the number of averages. A large number of averages requires a (relatively) long time to adapt to changes.

One might expect a further requirement: that the noisy signal sweep through several levels of the A-D converter. Surprisingly, that's not necessary. In figure 2, the noisy signal is seen to be activating only two levels on the A/D converter. But the averaged signal recovers the full waveform quite nicely: it can be seen clearly (at small amplitude) in figure 2(b). The noise signal (also known as *dither* in this context) has the effect of creating the entire signal, even when the A/D converter is effectively using one-bit conversion.



(a) Averaging Off

(b) Averaging x256

Figure 2: Tiny signal averaging

Waveform averaging is commonly used in physics applications, where the instrument is referred to as a *lock-in amplifier*. For example, a light source is chopped (often with a slotted rotating wheel) and then passed through some unknown substance. The original chopping signal is used to trigger the oscilloscope. At the output of the unknown substance the low-amplitude chopped light signal is detected and then waveform averaged to bring it above the noise level. In this way, a very weak signal can be detected. The ratio of input to output amplitude of the light signal is a measure of the properties of the unknown substance.

Acknowledgement

Special thanks to Michael Goertz, who provided the averaging software routines.