

Single-Shot Capture using the DSO-101 Oscilloscope: Measurements on a Relay

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September 12, 2006

Introduction

The single-shot facility of the DSO-101 oscilloscope is ideal for capturing transient phenomena. In this paper, we use this capability to place an electro-mechanical relay under the microscope and investigate how current builds up in the armature, how the contacts close, and how they open.

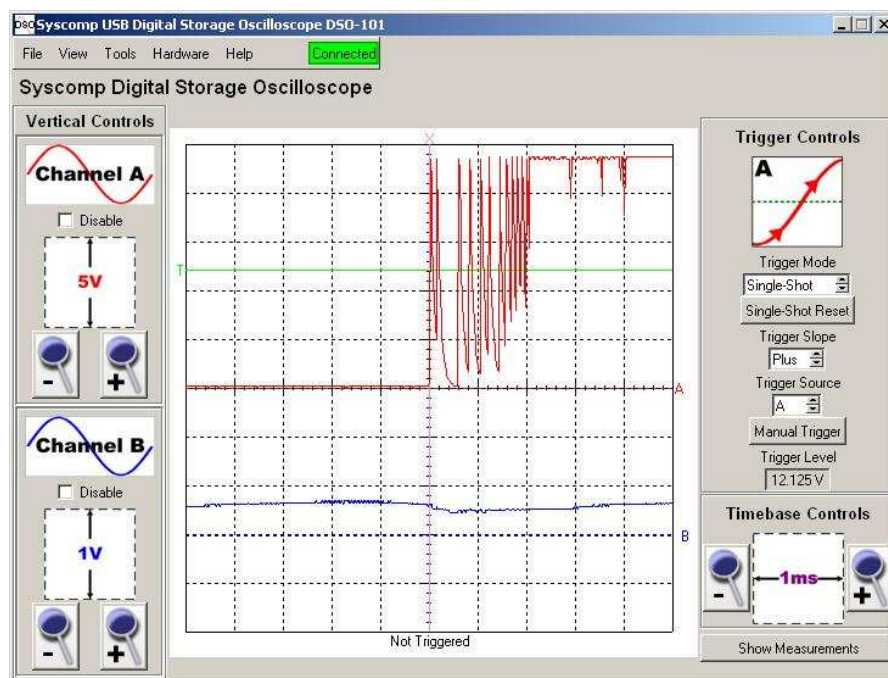


Figure 1: DSO-101 Digital Oscilloscope Screen

A Brief History of Oscilloscope Trigger Circuits

In order to appreciate the advantages of a digital oscilloscope, it's useful to know some of the history behind oscilloscope trigger circuits.

To produce a stable waveform display of a repetitive waveform the drawing of the trace must repeat from the same point in the waveform. Early analog oscilloscopes used a free-running astable multivibrator (oscillator) to generate the timebase. The input signal was applied to this oscillator in such a way as to pull the oscillation frequency into sync with the input signal. The *pull-in range* is quite limited, that is, the frequency of the multivibrator must be approximately equal to the frequency (or some integer multiple of the frequency) of the input waveform. This is a very crude technique and useless for non-repetitive waveforms.

Shortly after WWII, Tektronix invented the *triggered* timebase. The timebase starts its sweep when certain conditions are true of the input signal. For example, the trigger controls allow one to set the *level* and *slope* of the input signal to initiate a sweep. This gives the operator much improved control over the waveform display.

A triggered timebase can be arranged to display a single, non-repetitive waveform. The level and slope controls are set appropriately and the trigger circuit is *armed*. When the trigger event occurs, one sweep takes place. The trigger circuit must then be manually reset to enable another sweep. In a darkened room or using a *mask*, with the intensity at a high level, it is possible for an operator to see the event. Alternatively, an oscilloscope camera can be mounted in a light-tight enclosure while aimed at the screen. Then the shutter is locked in the open position. After the event has occurred, the shutter is closed and the film processed.

In order to see the event that caused the trigger, the oscilloscope vertical amplifier must include a *delay line*. The delay line complicates and adds significant expense to the circuitry.

Tektronix subsequently developed an *storage* cathode ray tube that could be used to record transient events. Storage oscilloscopes were expensive, especially those capable of recording at high speed.

Enter the Digital Oscilloscope

A digital oscilloscope such as the Syscomp DSO-101 is a much superior device for acquiring single-event waveforms:

- The horizontal trigger point can be moved between the left and right extremes of the display area, so that the signal can be observed both before and after the trigger point¹.
- The vertical amplifier does not require a delay line, which reduces size and cost.
- Trigger level and slope are determined by comparison of digital values, so triggering can be set very precisely.
- It's straightforward to generate a hardcopy record that can be printed, stored or incorporated into reports.

Trigger Controls

A screenshot of the DSO-101 oscilloscope is shown in figure 1 on page 1. To set up the oscilloscope for single shot capture:

1. Adjust the vertical gain control and display position for each channel so that the display is a suitable size. In the figure, channel A is adjusted into the upper section of the screen with a scale factor of 5 volts/div, channel B into the lower section with a scale factor of 1V/div.

¹Waveform acquisition takes place continuously, writing data into a circular buffer. When a trigger event occurs, the buffer contents are frozen and then written out to the display. The operator can select whether to display signal before, after and at the trigger event.

- Decide which channel will be the *trigger source*. In this case, channel A has a more abrupt transition, so that will more precisely locate the trigger point. Set `Trigger Source` to A.
- Adjust the trigger level (indicated by the T symbol and horizontal cursor) so that the signal passes through the trigger level at the desired trigger time. In this case, the trigger level is set to 12 volts, roughly half the peak signal on channel A.
- Adjust the trigger time (indicated by the X symbol and vertical cursor) so that the trigger point shows the section of waveform of interest. In figure 1 it has been moved to mid-screen.
- Set the `Trigger Mode` control to `Single Shot`. If possible, cause the event to occur, and the scope should capture the waveform. If necessary to expand or contract the display, adjust the timebase setting accordingly.
- Press `Single Shot Reset` to clear the display and arm the timebase for another capture,

The Circuit

We now show an example of single-shot capture at work: characterising the action of an electro-mechanical relay. The relay test circuit is shown in figure 2.

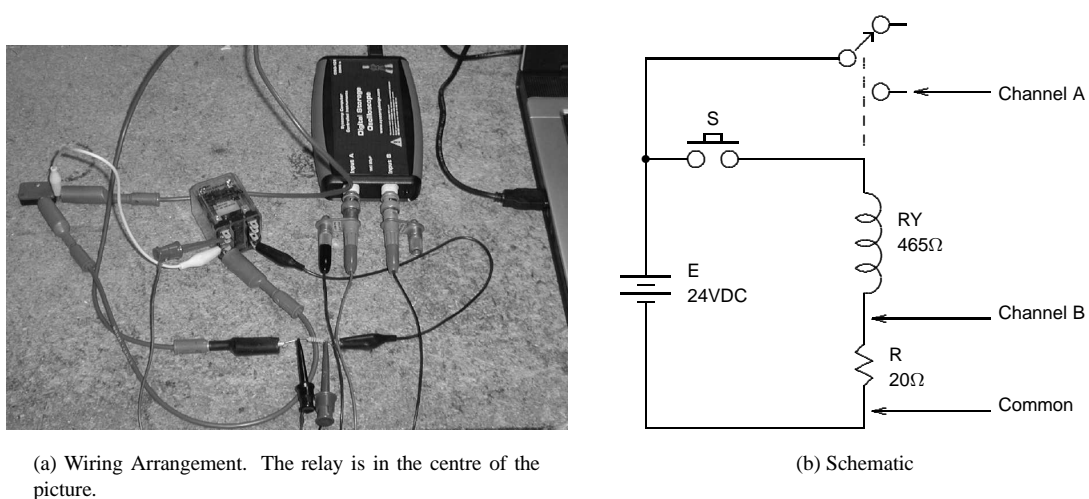


Figure 2: Test Circuit

The relay, Potter-Brumfield type KUP11D55, has a 24VDC, 465 Ω coil with DPDT contacts. The power supply E provides the necessary power. Switch S is operated by hand to cause the relay to actuate. Resistor R generates a voltage proportional to the relay current. Full current in the relay corresponds to 1 volt across this resistor.

The oscilloscope channel A views the output from a relay contact. In an ideal world, when the relay actuates this voltage should step from zero to 24 volts. As we'll see, that's not the case.

Oscilloscope channel B views a voltage proportional to the current in the relay armature. The relay armature is a coil of wire and we can expect that the winding inductance slows the rise of current.

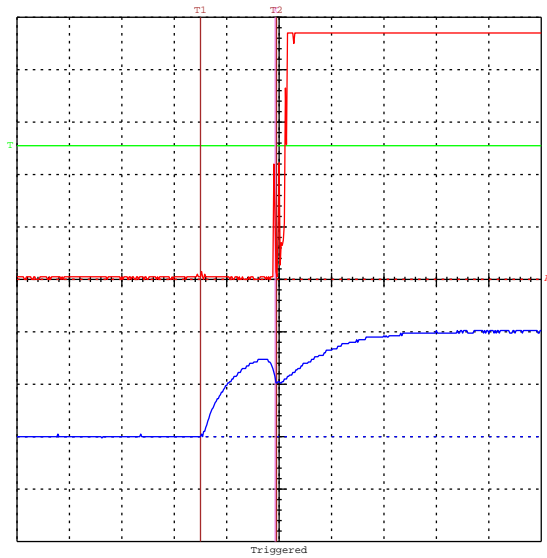


Figure 3: Channel A (upper trace): 5V/div. Channel B (lower trace): 0.5V/div. Timebase: 5msec/div.

Measurements

The lower trace of figure 3 shows the buildup of current in the relay as it closes. The most noticeable feature is the *notch* in the current waveform at the 7msec point. The upper trace shows that the contact closes at this point. The relay pole piece moves downward at that instant, reducing the reluctance of the magnetic circuit and thereby increasing the inductance. Once the relay is closed, the current resumes its upward climb to its peak value (51mA). Some contact bounce is evident in the upper trace.

The duration of contact bounce varied from trial to trial. The maximum interval between the first application of current to the coil to the final closing of the contact was found to be 17msec.

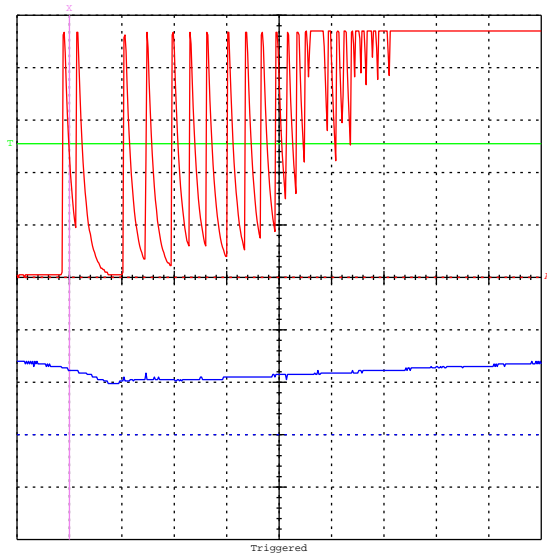


Figure 4: Contact Bounce on Closing. Vertical scales same as figure 3. Timebase: $500\mu\text{sec}/\text{div}$.

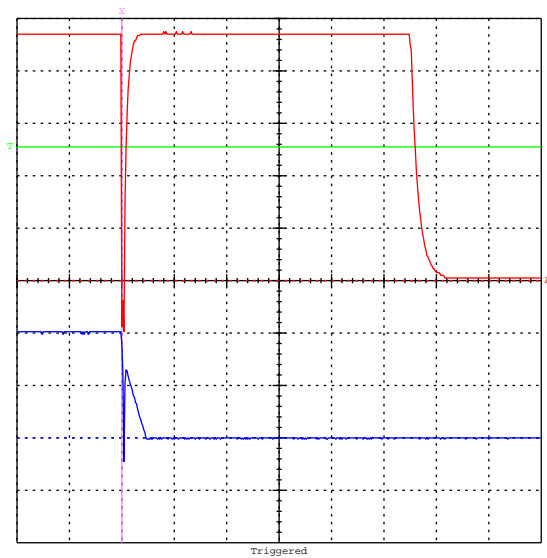


Figure 5: Contact Bounce on Opening. Vertical scales and timebase same as figure 4

Figure 4 shows an example of the contact closing bounce in detail. Typically, the contacts bounce for an interval of 3.6msec from time of first closure to final closure. This signal could not be used to actuate solid-state digital logic. A digital counter for example would happily count many of the bounce events as valid logic transitions. Furthermore,

a Schmitt trigger will not clean up this sequence since many of the bounce transitions extend across the full voltage range. The sequence could be cleaned up with a monostable circuit that includes a delay of somewhat greater than 3.6 milliseconds.

The relay contact opening sequence is shown in figure 5. The contact opens briefly at the instant current is removed and then loiters in the closed position for a further 3 milliseconds before the final opening. Again, this signal could not be used to actuate solid-state digital logic since there are at least two falling-edge transitions.

The DSO-101 oscilloscope excels in this type of application. It triggers easily, displays signals before and after the trigger event and allows convenient documenting of the results.

Note on the Diagrams

The waveforms were saved using the DSO-101 menu item `Tools -> Export to postscript`.

The postscript files were then incorporated into the L^AT_EX source code using the `\includegraphics` command.

Resources

Some general notes on the oscilloscope are available from Wikipedia:

<http://en.wikipedia.org/wiki/Oscilloscope>

Information on the Syscomp DSO-101 oscilloscope is available at:

<http://www.syscompdesign.com>.

Source code for the oscilloscope is Open Software. It is available under the GPL from Sourceforge at the Open Instrumentation Project:

<http://sourceforge.net/projects/oip>.