in practice

IAN WHITE, G3SEK

52, Abingdon Road, Drayton, Abingdon, OX14 4HP
Website: www.ifwtech.com/g3sek
E-mail: g3sek@ifwtech.com

HUMAN STORAGE SCOPE

IN YOUR APRIL article, how did you measure the pull-in and drop-out time of a relay?

EVERYTHING HAPPENS very quickly, in a few tens of milliseconds, and ideally you would use a digital storage oscilloscope which can 'freeze' such events for inspection at your leisure. Fortunately you can test relays with an ordinary non-storage scope, using your own persistence of vision and memory instead.

You don't need a scope for everyday amateur radio, but if you get drawn into fault-finding and digital electronics, you'll discover that there is absolutely no substitute. Many radio amateurs either know nothing about oscilloscopes, or else got stuck in the era of very basic scopes that are only good for giving a general impression of waveforms. But a 'laboratory' scope is a true measuring instrument: it lets you capture fast events, and *measure* both the voltages and timescales involved. A laboratory scope is a bit like a car - no matter who made it, or what colour it is, you can always expect the same basic features and facilities. A classic lab scope has:

- DC-coupled vertical (Y) amplifier, so that you can measure static or slowly-changing voltages, and a high input impedance so that the probe doesn't unduly disturb most circuits;
- Calibrated Y deflection (volts per centimetre of vertical movement on the screen) with many switchable ranges, so that you can make real measurements;
- Possibly two independent Y channels; most 'dual-beam' scopes generate the two traces by multiplexing the two Y-inputs into a normal single-beam tube;
- Horizontal (X) timebase with a wide choice of calibrated speeds (time/centimetre); and probably the option to input a second signal directly into the X amplifier for X-Y displays;
- Versatile triggering facilities so that you can start the X sweep from a particular feature of the Y waveform: rising edge or falling edge (useful for digital waveforms) or when passing a particular voltage level in either the rising or falling direction;
- Choice of repetitive sweep or a triggered single sweep;
- Sometimes a second timebase, so that you can delay the start of the main sweep for a controlled amount of time after the triggering event, or 'zoom in' on a selected portion of the waveform.

If you don't already have a scope like this, there are many bargains around, because today's professional buyers don't like the larger or older instruments [1] and they look too complicated for many amateur buyers. In fact they aren't as complicated as they seem, because all the controls relate to the basic functions listed above, so they will be much the same on any model. Once you've found your way around a particular front panel (which is not much harder than finding all the controls on a new car) it's not difficult to learn how to get the best out of a scope. Measuring the switching time of a relay is a typical example.

What you're going to do is trigger the timebase for a single sweep, and watch the relay contacts change over, with the brightness turned up so high that your eyes and brain can't help remembering what happened. **Fig 1** shows a simple way to hook-up the relay so that the contacts carry a DC signal that you can observe. The switch, S1, that you use to operate the relay will also trigger the single-shot sweep from the falling edge when S1 is closed.

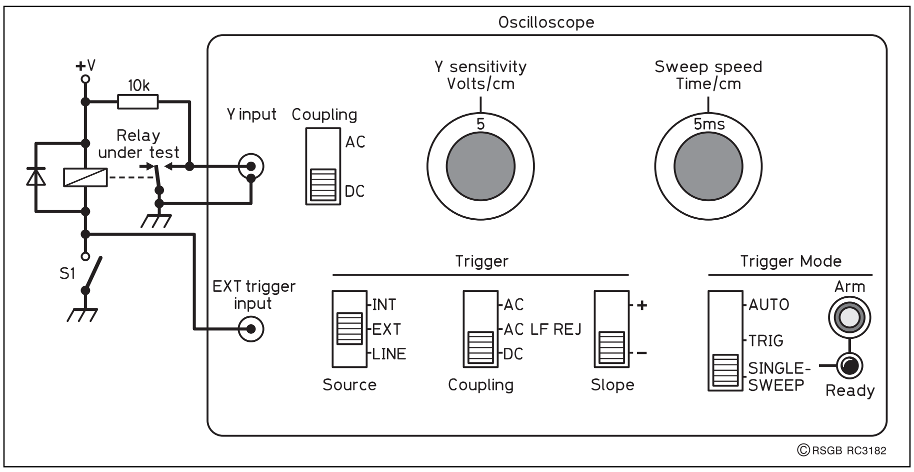

Fig 1: How to use a non-storage scope to measure relay changeover times. This diagram shows the key features which will be somewhere on the control panel of a typical laboratory scope.

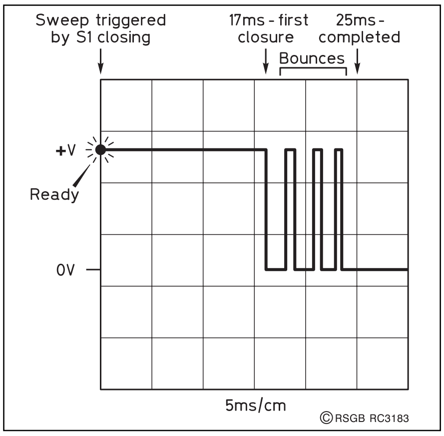

Fig 2: Typical contact closure trace from Fig 1.

With the input disconnected and the TRIGGER selector set to display a continuous trace, use the Y SHIFT to position the trace near the bottom of the screen. Set the Y SENSITIVITY to something like 5V/cm, and check that the trace moves up and down as you switch the relay. For most relays the SWEEP SPEED will need to be about 5ms/cm to see the whole event. Set the TRIGGER selectors to EXTERNAL input, DC coupling, SLOPE negative. With the relay switched off and SINGLE SWEEP selected, press the button to arm the sweep (probably a READY light will come on). Turn the brightness right up, and a very bright dot should appear at the left-hand edge of the screen. Use the X SHIFT control to position this on the left-most marker on the graticule. Now watch the screen carefully.

Switch the relay on, and watch the trace flick through. It should look something like **Fig 2**. You missed it! Well, everybody does, first time. Simply switch the relay off, press the button to re-arm the sweep, and do it again. This isn't a precision measurement, but after a few times you'll get a very clear impression of how long it takes for the contacts to close, and how much the contacts bounce after the initial closure. You'll also notice that the measurements vary, most likely because relays are not precision mechanisms and sometimes stick a little.

To measure the break time of the relay contacts, change the TRIGGER selector to SLOPE positive. You'll have to arm the sweep *after* having switched the relay on, or else the contact bounce in your switch will probably trigger the sweep before you're ready.

If you have trouble with reliable one-shot triggering, check the levels at the trigger input. This is where a dual-channel scope is convenient, because you can use the second channel to check the triggering waveform without unhooking from the relay contacts. In that case, select INTERNAL triggering, and the second channel as the TRIGGER SOURCE.

SWR ERRORS

A RECENT CHECK on my antenna with an MFJ-259B analyser showed an impedance (Z) of 53Ω. I thought this should be a good match for 50Ω coax, but the SWR was indicated as 2.0. It also said that the resistance was 42Ω and reactance 32Ω. Is something wrong with the instrument?

NO, THE INSTRUMENT is fine - the problem is your conception of how SWR is related to impedance (Z), resistance (R) and reactance (X). The formula relating SWR to R, X and the reference impedance Z_0 (usually 50Ω) is actually quite complicated. It's most easily written in terms of the reflection coefficient ρ (rho). As described in the March column, ρ is 0 for a perfect match, and 1 for a complete mismatch. SWR is related to ρ by:

$$SWR = \frac{1+\rho}{1-\rho}$$

R, X, Z_0 and ρ are related by:

$$\rho^2 = \frac{(R - Z_0) + X^2}{(R + Z_0) + X^2}$$

Let's plug in those measurements of R and X:

$$\rho^2 = \frac{(42-50)^2 + 32^2}{(42+50)^2 + 32^2} = 0.11$$

so ρ = 0.34 and

$$SWR = \frac{1+0.34}{1-0.34} = 2.0$$

The impedance Z displayed by the SWR analyser is computed from the usual formula:

$$|Z| = \sqrt{R^2 - X^2}$$

The computed value is actually |Z|, the *magnitude* of the complex impedance, and in this case the value is indeed 53Ω. So the MFJ-259B was correct in every particular.

There is a widespread misconception that SWR = Z / Z_0 but this example shows how untrue it is: |Z| is close to 50Ω but the SWR is actually 2.0. A little algebra will show that this simplified formula is true only when X = 0, ie when the load is non-reactive.

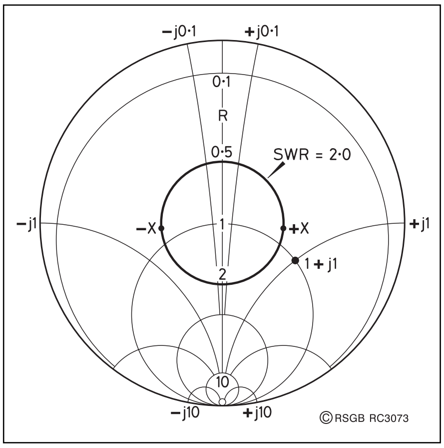

Fig 3: Smith chart representations of R = 42Ω, X = +32Ω or -32Ω - the SWR meter cannot distinguish because both impedances lie on the SWR = 2.0 circle. This is far from a perfect match to 50Ω (centre of chart) even though |Z| happens to be 53Ω.

Note that the same SWR would be produced by R = 42Ω and X = -32Ω. The SWR analyser actually measures ρ and |Z|, and then reverses the above formulae to compute SWR, R and ±X, so it has no way to tell whether the sign of X is positive or negative.

For a more visual viewpoint, let's look at this on a Smith chart - go back to the April 2001 column for a brief introduction. **Fig 3** shows the measured point plotted on the chart using values normalised to 50Ω: (R = 42 / 50, X = 32 / 50). As you can see, we're a long way from the centre so there's no way this impedance will be a good match to 50Ω. Fig 3 also shows the SWR = 2.0 circle passing through this point.

Finally, a correction to one statement in the April article. The scale of the central (R) axis is not logarithmic. As G0CPP has pointed out, the scaling is in fact proportional to the reflection coefficient ρ, because the 'map projection' used for the Smith chart is the magnitude and phase angle of ρ plotted in ordinary polar co-ordinates. I didn't mention the use of the Smith chart to plot phase angles or wavelengths along the transmission line, but if you look at a full chart you'll find that a complete rotation in phase angle is achieved in only half an electrical wavelength (180°). In other words, the phase angle of ρ changes twice as fast as the line length. This is because ρ is a *reflection* coefficient in a very literal sense - the rate of phase-angle change is doubled for the same reason that your reflection in a mirror moves towards or away from you twice as fast as you're actually moving.

WATERPROOF SEALANT

A USEFUL TIP from G4ERP, following-up the discussion in the July 2000 column.

"I HAVE BEEN using Unibond Waterproof All-purpose Sealant on electronic components for over 18 months now with no ill-effects. Unlike most sealants, it does not seem to cause corrosion - which would have been the case with acetic acid-based compounds as it has been used in a moist environment. There is a variety of colours. I use translucent. Also, it seems to have a good shelf life, unlike some of the non-corrosive compounds which refuse to set as they get older."

SMD ELECTROLYTIC POLARITY?

HOW CAN I tell the polarity of a surface-mount electrolytic capacitor? There seem to be several different packages, all differently marked.

THE DISTINCTIVE MARKING is on the *negative* side, as with most modern electrolytic capacitors. **Fig 4** shows a number of different package outlines, all with the negative side to the right. There is no consistent marking colour, but it always contrasts with the main body colour (eg white on a black body, or black on a brown or metal body). Some SMD electrolytic capacitors have a small metal can, which is always negative (as in larger electrolytics) and you can check continuity using an ohmmeter. The metal-can types are typically mounted on a small surface-mount wafer, which often has chamfered corners at the positive end. A few SMD electrolytics have no polarity marking but use the chamfer instead - again, this is at the positive end.

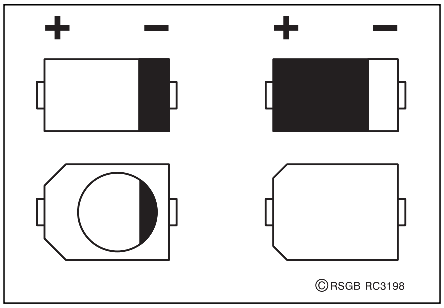

Fig 4: Typical polarity markings for SMD electrolytic capacitors. In each case the *negative* end is to the *right*.

NOTE

[1] I wouldn't buy a large and complex scope based on valves any more. Although 20 years ago I'd have killed for one of those blue monsters, they are all approaching 40 years old now, and are becoming very tricky to maintain. There are now enough good bargains around with solid-state electronics, which are generally more reliable and also definitely more compact.

The 'In Practice' website (see the previous page) contains a cumulative index from 1994-2001, and links to component suppliers, etc. ♦

If you have new questions, or any comments to add to this month's column, I'd be very pleased to hear from you by post or e-mail.

Please remember that I can answer questions through this column only, so they need to be on topics of general interest.