

# A new generation of Chatter Test System for improved performance

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**Abstract** - Electromechanical relays are unusual amongst passive components in that their very functionality is under threat from the shock and vibration of their application. Semiconductor manufacturers have it easy - integrated circuits shrug off shocks in excess of 200G whilst relay designers often struggle to ensure a 20G limit. Information about contact chatter during vibration is key to assisting relay designers achieve the maximum performance from their mechanical parts and is an area of relay testing that has languished un-loved, surrounded by 30-year old technology and held back by the apparent simplicity of the requirement - 'just look for a short pulses in the contact load circuit'. Chatter performance IS important and especially so when the relay is under threat from equivalent semiconductor parts.

This paper will show how Applied Relay Testing Ltd has given chatter measurement a complete 'makeover' resulting in a PC-based turnkey chatter detection system that has some novel features such as an input circuitry that accepts any contact load voltage from volts to hundreds of volts without reconfiguring and chatter monitoring logic which not only captures chatter events but actually counts and displays them, thus providing the relay engineer with quantitative information regarding the nature and severity of the failure. These new principles integrated together with automatic control of relay devices, load power supplies and vibration tables provide worthwhile throughput improvements in vibration testing.

## I. INTRODUCTION.

For well over a decade now Applied Relay Testing has been asked 'Can we produce a low cost relay contact chatter test system?' Each time we have declined due to the uneconomically high design cost for a low volume, low cost product. However the recent introduction of the Reflex 51 [1] has thankfully enabled us to re-use many pre-existing software and hardware building blocks in an easy to adapt architecture. The challenge was one of understanding the basic concepts of chatter detection and to improve upon some of the inherent weaknesses in the traditional approach to the device interface to provide an accurate, flexible and reliable solution. By capitalising on the power of modern complex in-circuit programmable logic devices we would be able to offer high reliability and vastly

enhanced flexibility over the traditional solution at an acceptable cost.

In order to understand the basic requirement for a chatter detector we started by looking at the MIL-STD-202F [2] monitor circuit shown in figure 1.

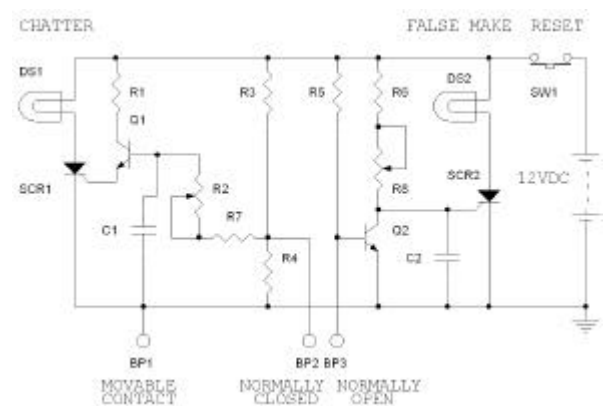


Figure 1 Monitor circuit for contact chatter and false closures.

This circuit shows a simple detector designed to monitor a single form C contact. From studying this circuit a list of its good and bad points could be drawn up as follows:

Good:

1. Relatively simple to understand and build.
2. Works on short device cable length with the 12 Volt DC contact load inherent in the design.

Bad:

1. Calibration is highly labour intensive as an adjustment is required for each measurement channel using a signal generator and an oscilloscope.
2. The single fixed DC contact load defined by circuit components, no AC load capability.
3. High susceptibility to noise pickup causing apparent relay under test (RUT) failures.
4. No ESD protection therefore easily damaged.
5. No indication of numbers of failures per contact. The only indication of failure is the lamps, assuming they too are working!

6. If the test is to be repeated with the relay in the energised/de-energised state the closed and open contact wiring must be swapped over and then re-calibrated.
7. Bandwidth issues on medium/long cable runs.
8. Potentially hazardous voltages present at detector input.

It was relatively easy to define a specification for a rather more sophisticated and much more user friendly test system. The key challenges identified were to address all the drawbacks of the standard circuit and in addition a wish list was created:

- To provide a wide range of software programmable detection filter settings from 1us to at least 20ms.
- To provide event counters to aid the user with failure analysis and reporting.
- To provide a software 'LEARN' mode to automatically configure the hardware using a known good configuration.
- To provide data-logging of test results.
- To provide a highly automated calibration process.

Our goal was to adapt the basic Reflex 51 relay life test system, (figure 2) for use as a chatter detector test system thereby reducing hardware design costs and thus the eventual sales cost. This unit provides us with the basic framework of power supplies, rack and system control interfaces, a basic calibration interface and miscellaneous relay coil switching capability which would all prove useful.

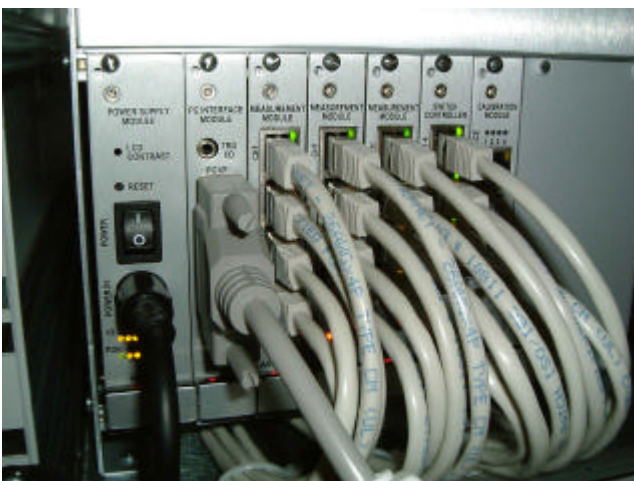


Figure 2 Reflex 51 relay life test system.

The Reflex 51 is controlled using a standard external PC via the parallel printer port. The PC provides an ideal low cost platform for controlling the system, recording test results and helps to minimise the complexity of the dedicated test hardware. The design of the Reflex 80 chatter detector test system could now be started.

## II. BACK TO BASICS

It was clear that we now needed to re-examine the device interface in order to address some of the limitations of the standard circuit. Figure 3 shows the interface between a relay contact under test and the standard chatter detector circuit (shown in figure 1).

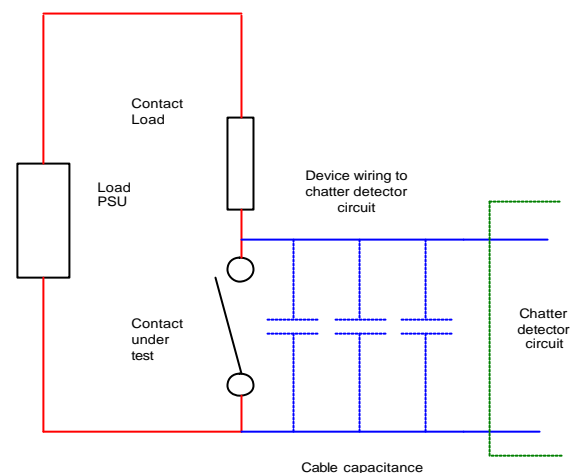


Figure 3 The standard device contact interface

The circuit diagram illustrates the stray capacitance caused by the wiring between the contact under test and the chatter detector. It is vital to assess the effects of the cable capacitance since it will have a dominant effect on the bandwidth of the contact pulses which any system would be able to detect.

If we assume for example a typical contact load of say 115V Volts at 100mA then, ignoring wiring resistances etc., a contact load resistor of 1150 Ohms would be required (using Ohms' Law). With several metres of cabling and with a capacitance of around 100 pF/m there can easily be many hundreds of picoFarads of cable capacitance. If we assume an effective cable capacitance of 300 pF then we can calculate the time constant as follows:

$$T = R \times C$$

where  $T$  = Time contact (seconds)  
 $R$  = Load resistance (Ohms)  
 $C$  = Cable capacitance (Farads)

$$\begin{aligned} \text{then } T &= 1150 \times 300 \times 10^{-12} \\ &= 345 \text{ ns} \end{aligned}$$

The MIL specification implies a timing measurement accuracy of  $\pm 3\%$ , therefore to achieve a 1us filter time constant this must be accurate to within  $\pm 30\text{ns}$ . Thus a time constant of over ten times this figure caused by the wiring alone is cause for concern. This has two major implications:

1. Any calibration of the system MUST be performed with the device wiring in situ.
2. Any movement of the cabling is liable to vary the cable capacitance and thus vary the time constant by several tens of nanoseconds thus requiring a system re-calibration.

In order to reduce the effect of cable capacitance a simple change to the circuit configuration is required. Figure 4 shows the solution to the problem.

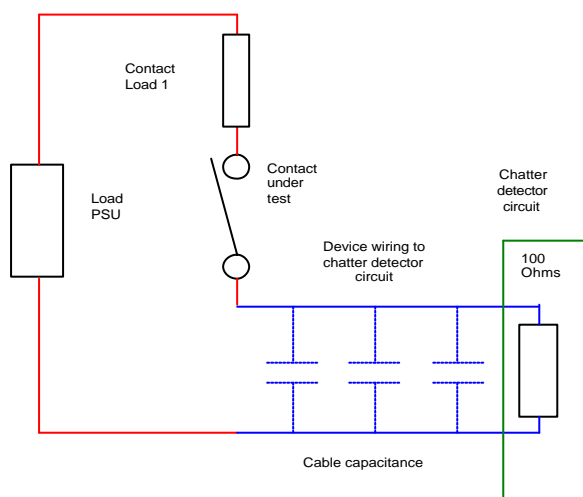


Figure 4 Improved device contact interface

By choosing the input impedance to be a close match to the cable impedance, typically around 100 Ohms, the effect of the cable capacitance is virtually eliminated. Another major benefit of the low input impedance of the detector is that the intrinsic noise immunity is greatly improved. This means that the likelihood of an erroneously reported device failure due to electrical noise pickup is reduced. With a low impedance front end additional ESD protection devices can be easily incorporated with little impact on the circuit performance.

Furthermore, now that the detector is sensing contact current rather than contact voltage we can ensure that the voltages present on the cabling from the load/ RUT to the detector is no longer potentially hazardous. In fact the

performance of the detector is now largely independent of the contact load voltage.

Note however that the input impedance of the detector must now be included in the calculation of the contact load resistor as follows:

$$\text{Load Resistor} = \frac{\text{Contact load voltage} - 100}{\text{Contact load current}}$$

For higher load current requirements where the load resistor would be less than 100 Ohms, a shunt resistor can be fitted as shown in figure 5.

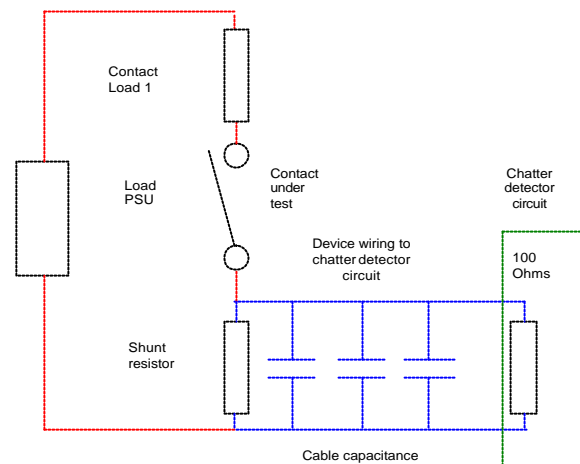


Figure 5 High current device contact interface

### III. PROGRAMMABLE FILTERING

The next issue we needed to address was to provide software programmable filter settings. The MIL specification calls for filter time constants of 10us, 100us, 1ms, 5ms and 20 milliseconds although we were aiming to broaden this range to typically 1us to 25ms.

It was necessary to look very closely at possible error mechanisms in order to obtain the MIL specification  $\pm 3\%$  timing accuracy. Only 30 nanoseconds of timing error would be permitted if we were to achieve our goal of a minimum filter time constant of 1 microsecond.

To keep the circuitry as simple as possible it was decided to create the 1 microsecond time constant using an analogue RC filter circuit. The design incorporates a digital potentiometer IC (see figure 6) rather than a more conventional manually adjusted version thus ensuring the calibration procedure could be made automatically.

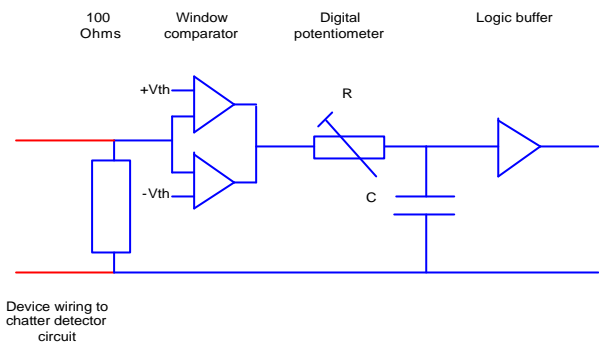


Figure 6 Simplified chatter detector input circuit

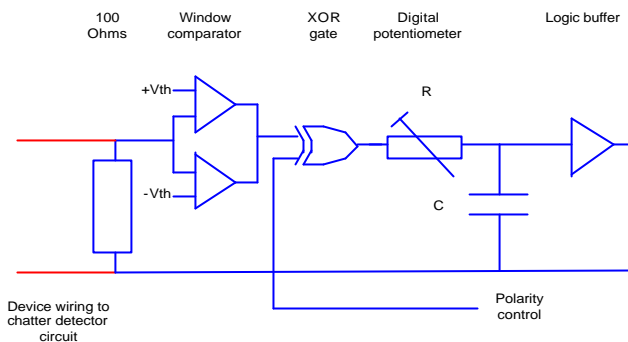


Figure 7 Updated chatter detector input circuit

A high speed window comparator circuit provides the ability to program accurately a minimum contact current threshold level at which the system will detect contact activity with both DC and AC load voltages.

In order to fulfil the requirement of offering software programmable filter time constants, it was necessary to provide a simple digital filter which was fed from the 1us output. In practice we were limited to a maximum time constant of 255us. By adding a second RC filter with a 100us time constant, we were able to extend the operating range to in excess of 25 milliseconds. This extra hardware ensured that there was enough capacity remaining in the logic core for an additional 8 bit counter per contact channel in order that we can record up to 255 contact failure events per contact channel. Although not strictly necessary we felt this could be a useful debugging tool for the end user.

It was clear that the filter performance would change according to whether the input waveform was a positive or negative going pulse, i.e. a normally closed contact opening or a normally open contact closing. This is because the time constant is defined as the time for the voltage across the capacitor to fall to 36.8% (1/e) of its original value or to charge to 63.2% of its full value. Since the input switching thresholds of the logic buffer do not match these levels we had two choices:

1. To have separate calibration values for negative and positive going contact pulses.
2. To add a simple exclusive OR (XOR) logic gate before the RC filter to ensure the pulses were always present in one polarity.

We decided to implement option 2 thus simplifying the calibration procedure since we can read back the initial rest state of the contact prior to starting the chatter measurement. Figure 7 shows the updated input circuit configuration.

#### IV. AC LOADS

Thus far all work had been carried out using a DC load power supply; however we still had to consider the effects of contact measurement with AC signals. It is clear that AC would cause a problem since each zero voltage crossing is indistinguishable from an open contact closing. It is therefore necessary to introduce a gating or detector enable pulse which can inhibit the detector during this time. Figure 8 shows this detect enable pulse which is generated from the load power supply voltage.

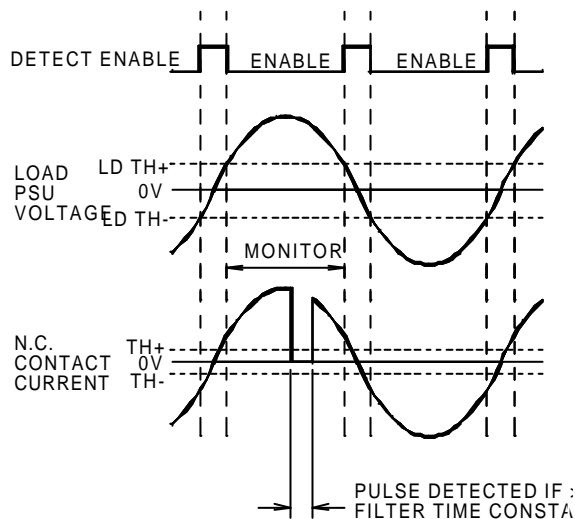


Figure 8 AC load waveforms

The chatter detector must therefore include a load voltage monitoring input for this purpose and also provide a load polarity signal which is used to control the XOR gate shown in figure 7.

An arbitrary function generator was programmed with sine waves superimposed with pulses of varying pulse widths to confirm the correct identification of the pulses exceeding the programmed filter widths.

V. THE REFLEX 80

Figure 9 shows a photograph of the Reflex 80 chatter detector test system fitted with eight 16 channel chatter detector modules. Our focus now moved to the software design.



Figure 9 The Reflex 80 chatter test system

The user interface, shown in figure 10, indicates the status of up to 128 device channels which can be displayed simultaneously (corresponding to up to eight 16 channel chatter detector cards which may be installed in any one system). Individual contact channels can be easily activated or deactivated as required to simplify the display.

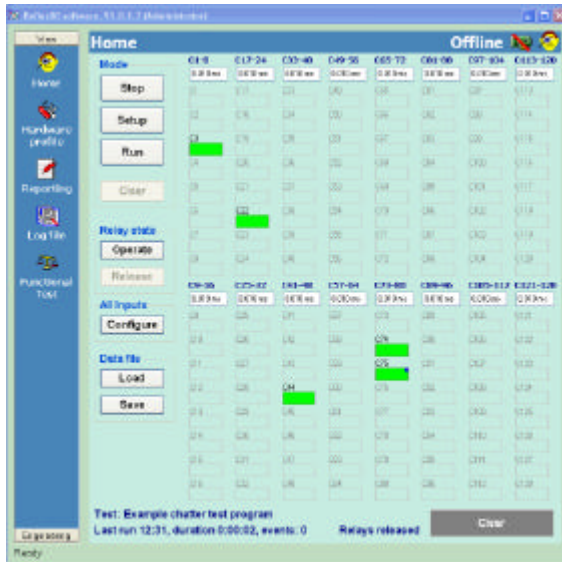


Figure 10 The basic User interface

The system may be run in any one of three distinct modes:

1. Set-up mode
2. Learn mode
3. Run mode

In 'Set-up' mode (figure 11) the user can observe contact activity dynamically while the devices are being connected. During this time data is not being logged to disk but the graphical display is constantly updated to show any failing contacts. Any contact failure counts are reset on a regular basis and then resume counting until the failure mechanism has cleared. Thus faults such as those due to incorrect device wiring or poor device contacts on the test fixture can be rectified as required prior to the start of the test sequence.

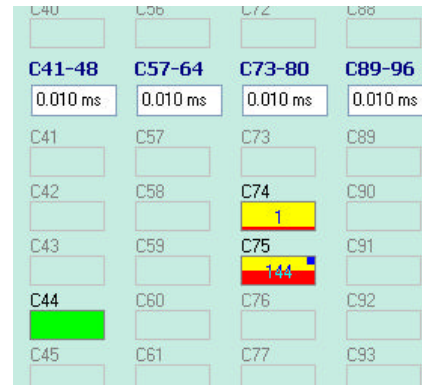


Figure 11 Software running in 'Setup' mode (exploded view)

'Learn' mode vastly simplifies the device configuration process. In this mode the system automatically detects all open and closed contacts before testing commences such that any deviation from this state (exceeding the programmed filter setting) is deemed a failure and the event recorded. The operator can choose to edit manually this configuration if required otherwise no further user interaction is necessary.

Finally the user will perform the chatter test in 'Run' mode. This mode operates in much the same way as the 'Set-up' mode, constantly monitoring the device contacts for failures. However if the failure count on a contact should exceed 255, the display simply indicates '>255'.

As with all Applied Relay Testing products, full data logging is supported along with powerful automated report generation tools (figure 12). The test results and conditions can be logged to disk for maximum product traceability.



Figure 12 A sample test report

VI. CONCLUSION

This paper has detailed the process of creating a new product, the Reflex 80 chatter test system, with a minimum of hardware and software design effort. The fundamental architecture of the classic test configuration has been challenged in order to address its limitations resulting in a superior configuration which has eliminated many of the design weaknesses of the original approach.

The resulting system has not only resulted in a unit with a more flexible load capability but one which requires far less manual intervention than previously encountered whilst providing an automated data logging and test report generation.

VII. ACKNOWLEDGEMENT.

Applied Relay Testing Ltd wishes to thank Mr. Bach Pham and Mr. Mark Mumma at Leach International for their valuable assistance during the creation of the Reflex 80.

VIII. REFERENCES.

[1] B.J.Frost “All You've Ever Wanted In a Relay or Switch Tester” *Proc. of the 53<sup>rd</sup> relay conference, NARM, April 2005*

[2] Dept. Of Defense “Test-circuit B; Monitor circuit for contact chatter and false closures” *Military Standard, Test methods for electronic and electrical component parts, MIL-STD-202F, Method 310 figure 310-3, April 1980*