AN090308: Reflex 40
An Advanced Test Solution for Relay Stick, Miss and Functional Testing

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I. ABSTRACT

Stick and Miss Testing is an important facet of relay test schedules yet can be a challenging test to perform. Fixturing, cabling and equipment measurement issues all conspire to introduce erratic test failures that masquerade as device faults. These issues increase exponentially as test cycle rates go up rending older equipment less and less suitable for the newer smaller geometry relays. Testing is further complicated when working at the mill volt contact levels intended for small, fast devices such as MEMS and reed relays. With test cycle durations that can rise to billions of cycles, equipment that is sure-footed in this terrain is essential.

This paper will show how Applied Relay Testing Ltd has given Stick, Miss and Functional testing a complete 'makeover' resulting in a turn-key test system that has fully automatic pre and post-test Operate and Release Voltage measurement, visual relay device cycle programming and a flexible load architecture that offers capability from mill volts to hundreds of amps. The system is highly scalable from a few simple laboratory 'look-see' channels through to high channel-count production installations. New test and programming techniques are allied with built-in self-test and Microsoft Office compatible exporting and reporting, these features combining to provide a worthwhile boost in productivity over older equipment".

II. INTRODUCTION

Since the mid 1990's Applied Relay Testing has been manufacturing relay life test systems, initially introducing the RT96 aimed at telecom relay testing and later the Reflex 50 and Reflex 51 for general purpose testing. These systems provide comprehensive analysis of the contact resistance or voltage drop for each contact operation. However these systems are naturally more complex than that required for stick and miss testing, where the voltage dropped across a contact is compared with pre-defined voltage limits. In this case the contact measurement circuitry can be simplified thereby reducing the manufacturing costs and consequently the final sales price. As we move further into this cost sensitive climate all aspects of the relay manufacturing process have come under the spotlight, with the cost of the test equipment being no exception.

Figure1 identifies the traditional stick and miss detector architecture.

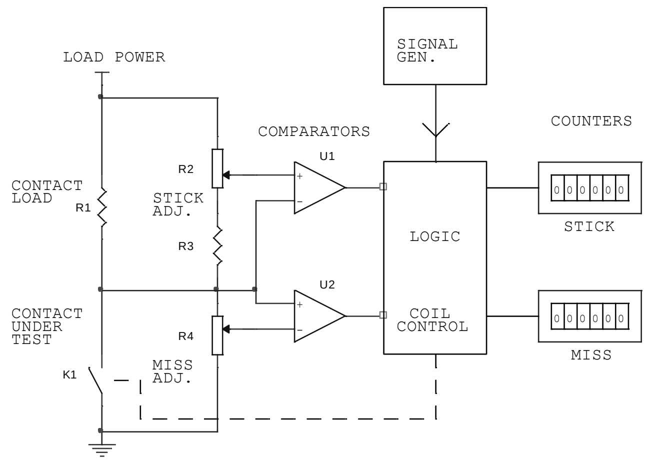


Figure 1: Simplified Stick and Miss Architecture.

This circuit shows a simple comparator based detector designed to monitor a single form ‘A’ contact. The divider network formed from resistors R2-R4 provides the stick and miss failure thresholds, e.g. 95% and 5% or 90% and 10% of the applied contact load voltage [4]. Further logic circuitry is required to condition the stick and miss signals to ensure failures are only detected during the required monitoring periods, e.g. 40% of each on and off state.

Analysis of the simple stick and miss detector architecture identifies a number of limitations, these being:

- Manual adjustment of stick and miss threshold.
- Manual data-logging of counter output required by the operator.
- No protection against shorts between device contacts and coil pins.
- Maximum cycle rate limited by mechanical counter response time.
- Cycle rate configured by an external signal generator.
- Poor accuracy with low level loads due to comparator offsets.
- No automated pull-in or drop-out test capability.

III. STICK AND MISS DETECTOR DESIGN

The first issue we addressed was that of the poor threshold level accuracy due to the input offset of the detection comparators. Typically comparators will have an input offset of around 4mV which can be largely ignored with high level contact load voltages. However with low level loads such as 30mV/10uA a miss threshold of around 3mV (10% of applied contact load voltage) would clearly be a problem given the inherent 4mV comparator offset. The addition of a pre-amplification stage can reduce the effect of this offset to acceptable levels, as seen in figure 3.

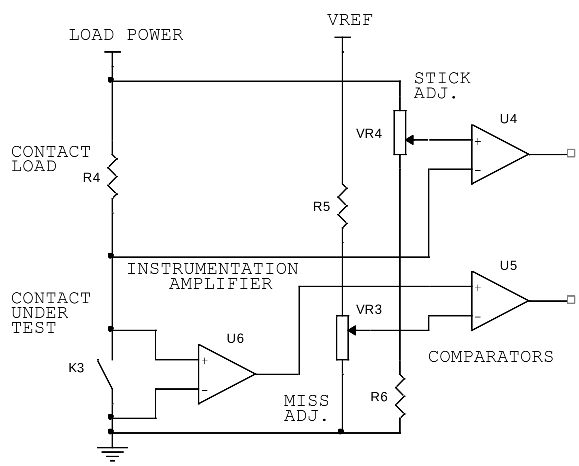


Figure 2: Additional amplification.

If we assume a precision amplification stage with a gain of 100 has been added, this will typically have an input offset of say 50uV which when combined with the output offset may result in a maximum offset of around 5.1mV. The miss detection threshold voltage would now be 100 x 3mV = 300mV relative to the amplifier output level. The 4mV of comparator offset will increase the total measurement error to 5.1mV + 4mV = 9.1mV. This is now only 9.1/300 = 3% error (approx.).

In the example configuration shown in figure 2, the amplification has only been added to the miss detection comparator for two reasons:

- Miss detection voltages are typically only around 5-10% of the load voltage compared with stick, which is around 90-95% of the load voltage.
- Allows a fixed gain amplifier to be used, which would otherwise saturate during the stick measurement.

Figure 3 shows a simplified view of the Reflex 40 stick and miss detector front end, with the addition of a precision programmable gain amplifier (PGA) and a digital to analogue converter (DAC). By using a DAC to program the threshold level and a PGA to configure the optimum gain to the comparator, this simple circuit can be utilised for both stick and miss detection.

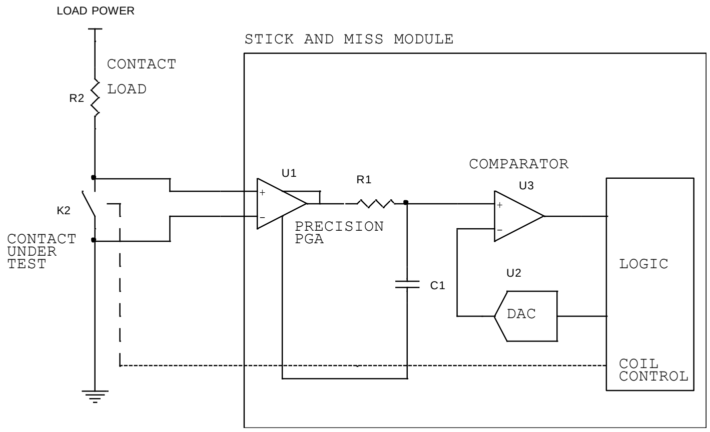


Figure 3: Simplified Reflex40 stick and miss detector

External voltage protection circuitry can be added if required to prevent damage to the measurement or contact load circuitry in the event of a short between the coil and contact pins (as seen in figure 4). A clamp voltage sense monitor signal provides an over voltage flag which can be used by the control logic to disable the coil power supply under fault conditions.

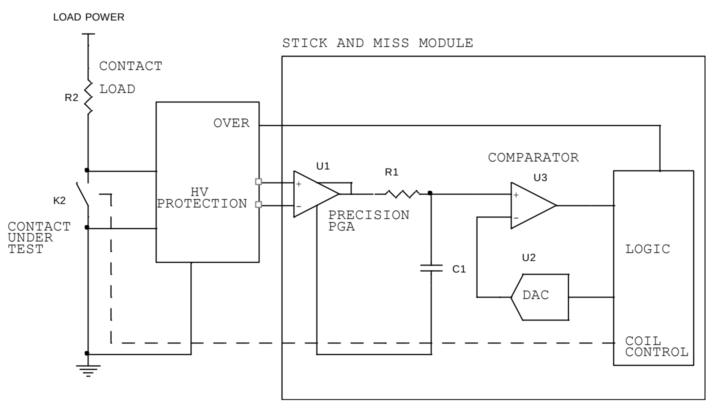


Figure 4: The Reflex 40 device contact interface

A key requirement of the system was to dispense with the need for an external frequency generator to control the cycle rate and duty cycle of the relay coil switching, thereby reducing the size and cost of the system. For low cycle rates of a few Hertz the system timing could be controlled by the host PC. However with more complex configurations with each stick and miss module running autonomously this would put a heavy burden on the host PC. By employing the latest low cost FPGA technology the timing could be moved from the PC into the Reflex 40 hardware. This vastly reduced the burden on the PC allowing it to act as a data collection and display tool. The benefits of this change are to improve the responsiveness of the PC since the system software no longer puts such heavy timing demands on the multi-tasking Windows operating system. This also allows us to extend the operating cycle rate to several kilo Hertz which would encompass reed and MEMS testing.

The FPGA also eliminates the need for manual data-logging of stick and miss failures and elapsed cycle counts as all the counters are now implemented within the FPGA fabric, allowing the host PC to interrogate all counter values in real time and automatically perform the necessary data-logging. This not only eradicates any human data-logging errors, but also reduces labour costs. Counter sizes are only limited by the overall FPGA architecture and the designer’s hardware description language (VHDL) implementation. In today’s market FPGA devices are readily available as multi-million gate resources, so counter sizes are no longer a stumbling block within this application.

IV. PULL-IN AND DROP-OUT TESTING

A typical requirement for a stick and miss test system is that it should also be able to perform pull-in and drop-out measurements [2], since these are often required as part of the relay screening process [1]. A ramping voltage is applied to the device coils whilst monitoring the contacts. When all devices have been operated or a programmed voltage limit has been reached, the coil voltage is then ramped back down again looking for a change in contact state, so that both operate and release voltages for each device can be determined.

This testing requires an accurate coil voltage to be applied across the device contacts so that operate and release voltages can be correctly deduced. A full four terminal Kelvin connection should be made as close to the device coil pins as is practical. However when performing stick and miss testing the Kelvin connection must be made upstream of the coil switch since the four terminal connection should be made at all times to prevent unwanted power supply transients being generated. It was necessary therefore to ensure that the Reflex 40 included a coil switching matrix, allowing the Kelvin connection to be moved as required depending upon whether the system is performing stick and miss or pull-in and drop-out testing.

V. COIL SWITCHING

In certain life test applications [3] it may be necessary for the device relay coil to be switched asynchronously with the power supply for ac loads. Although programmable power supplies usually feature an output switch, we cannot use this feature since they are invariably mechanical and would therefore be a reliability issue.

A simple transistor or FET switch can be used for switching DC coils when placed in series with the coil power supply output terminals. Normally AC coil switching can be achieved by using mercury wetted relays. This is no longer a long term solution due to the increasing pressures to eliminate hazardous chemicals since the introduction of RoHS directive. Use of SCR or TRIAC based solid state relays (SSR) relays are not suitable due to the zero crossing switching behaviour of these devices. Even the so called random SSR are only ‘random’ when switching on, the switches turn off at the zero voltage crossing.

PhotoMOS relays are available with high voltage - low/medium current or low voltage high current AC switching elements but they have relatively slow turn on and turn off times, typically of a few milliseconds. These limitations meant that they were not well suited to a general purpose solution capable of high switching speeds.

Applied Relay Testing already produced a high speed DC switching element, with switching times in the order of 1 us, designed for general purpose coil and load switching within the Reflex 51 and Reflex 80 test systems. This uses a parallel configuration of an optically isolated MOSFET switches. The internal body diode inherent in MOSFET switches would preclude this type of switch from being used to switch an AC coil voltage. Figure 5 shows a simplified schematic of the DC switching element.

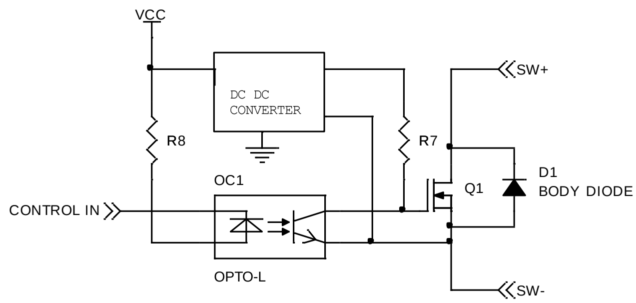


Figure 5: Simplified DC switch schematic

Using the architecture found in AC PhotoMOS relays, the solution to an AC switch can be achieved by placing two DC switching elements back to back as shown in figure 6.

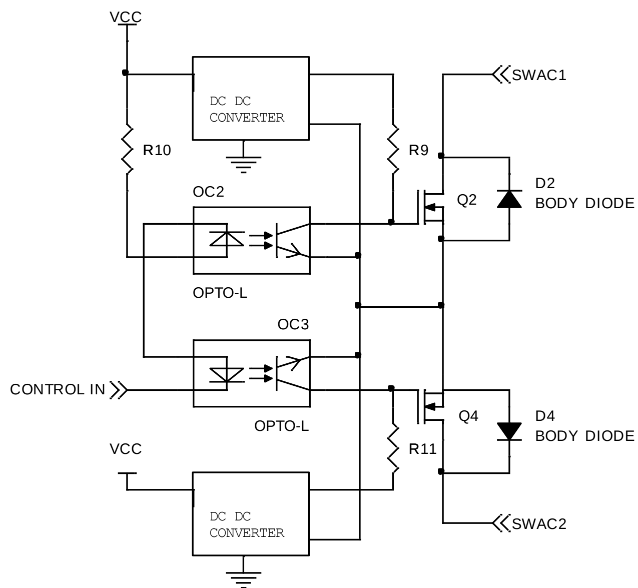


Figure 6: Simplified AC switch schematic

The resulting switch module provides a fast and truly random switch suitable for asynchronous AC switching. By changing the MOSFET output stage a wide variety of voltage and current options can be easily created to suit a particular application. Additional output protection components have been included (not shown) to prevent damage from over voltage spikes which may occur when switching inductive loads such as relay coils etc.

VI. THE REFLEX 40

Figure 7 shows a photograph of the Reflex 40 stick and miss test system. The unit is split into two sections, the upper section houses the load and measurement modules and the lower section the coil switching matrix and system power supply.

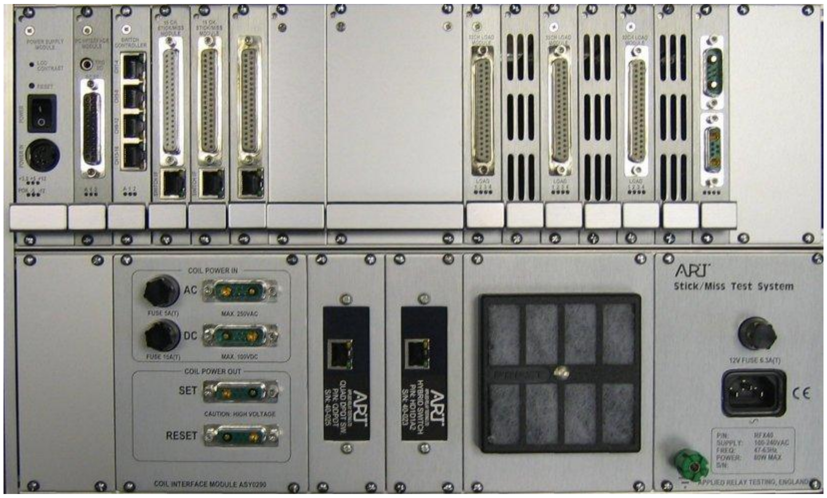


Figure 7: Reflex 40 Stick and Miss Test System

Up to eight 16 channel stick and miss measurement modules can be installed in the system enabling the user to test up to 128 contact channels for both stick and miss. Optional load cards provide software controlled selection of the contact loads suitable for use with load currents in the 10uA – 100mA range. In order to reduce errors due to thermal EMF offsets it was decided that the low level load would not be switched, instead the low level load is always in circuit thereby eliminating the need for load switching relays designed specifically for low thermal EMF applications. This simplification has allowed the load card to be designed with 32 channels and 4 load options per channel. The airflow is ducted air to ensure that there is adequate cooling maintained when the high level loads are selected.

VII. SOFTWARE CONTROL

The major features of the software implementation are:

- Provides testing for contact Stick and Miss faults and Operate and Release voltages (Pull-in and Drop-out voltage) on non-latching and latching relays of any contact construction.
- Operate and Release voltage can be tested at any number of specified intervals during the Stick and Miss test run, making it possible to see the actual trend of wear-out mechanisms during life.
- Operate and release voltage results are ‘by contact’ as well as ‘by device’ making it possible to provide engineering feedback on contact matching.
- A simple ‘Microsoft Outlook-style’ interface provides access to the major program features.
- A clear, customisable operator interface screen showing the current status of the test, including each device and contact.
- ‘Operator’, ‘Supervisor’ and ‘Administrator’ user levels and passwords to control access to each feature.

- A WYSIWYG fixture editor that permits the operator to quickly assign part numbers to devices for traceability.
- 'Batch' execution of multiple tests to permit long periods of unattended operation.
- A built-in report generator producing Microsoft-Word compatible report documents.
- A built-in log record of all user activity, test actions and system errors providing full machine traceability.
- Built-in hardware self-test and calibration functions and traceability.
- A machine and operator utilisation log.
- An architecture that is flexible to suit a wide range of numbers of hardware channels.

The Reflex 40 software is usually displaying its 'Home' page as shown in Figure 8 below:

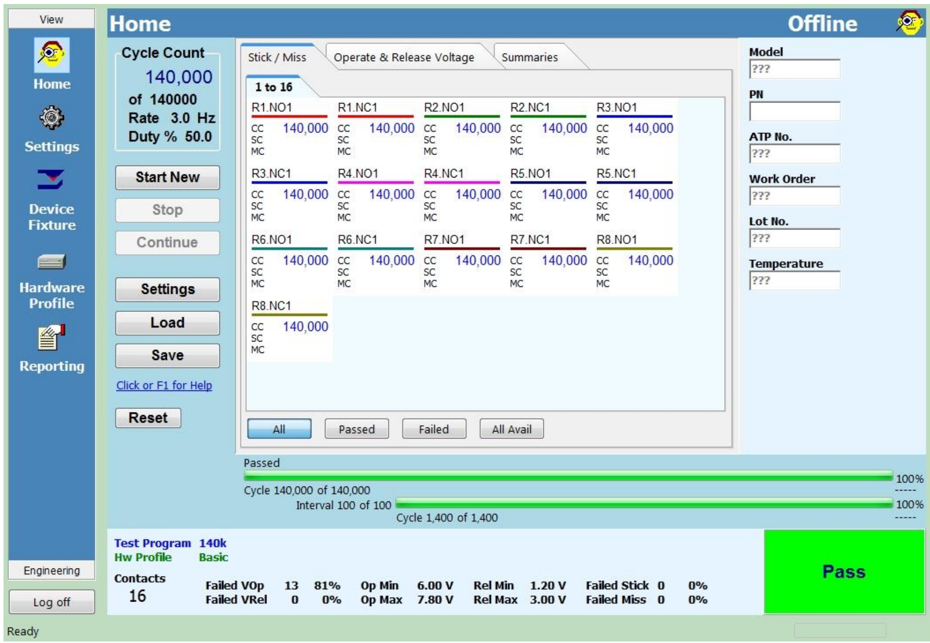


Figure 8: Reflex 40 Home Page.

Figure 8 shows the end of a 140,000 cycle test with no stick and miss failures. The display comprises of an icon panel at the left which switches the display between various 'page' views. The 'Home' view is designed to be an overview of the test settings and results. The page control at the centre is shown switched to its 'Stick/Miss' tab which displays a view by individual contacts with each relay device shown in a specific colour. Filter buttons allow the user to switch the views between all contact results or only the contacts that have passed or failed.

The area designated for viewing contact results has been designed to expand and contract automatically with the available screen size such as to always have the full amount of actual contact data visible, thus on a suitable screen it is usual to be able to display large number of contacts at a glance without touching the mouse or keyboard.

There are other tabs which provide access to the operate and release voltage results and a combined ‘Summaries’ view of all test results by device rather than contacts, as shown in figures 9 and 10 below.

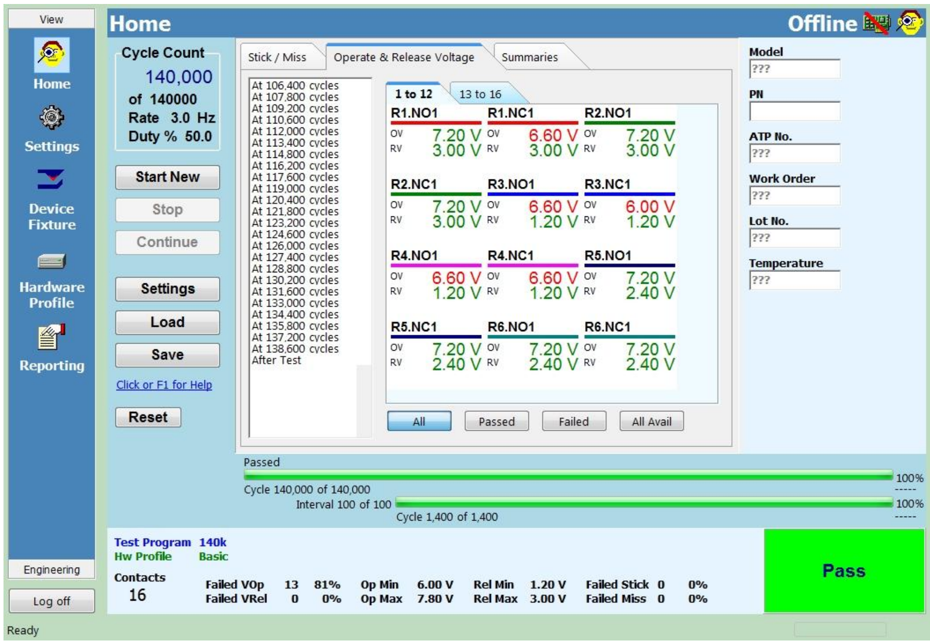


Figure 9: Operate and Release Voltage Results

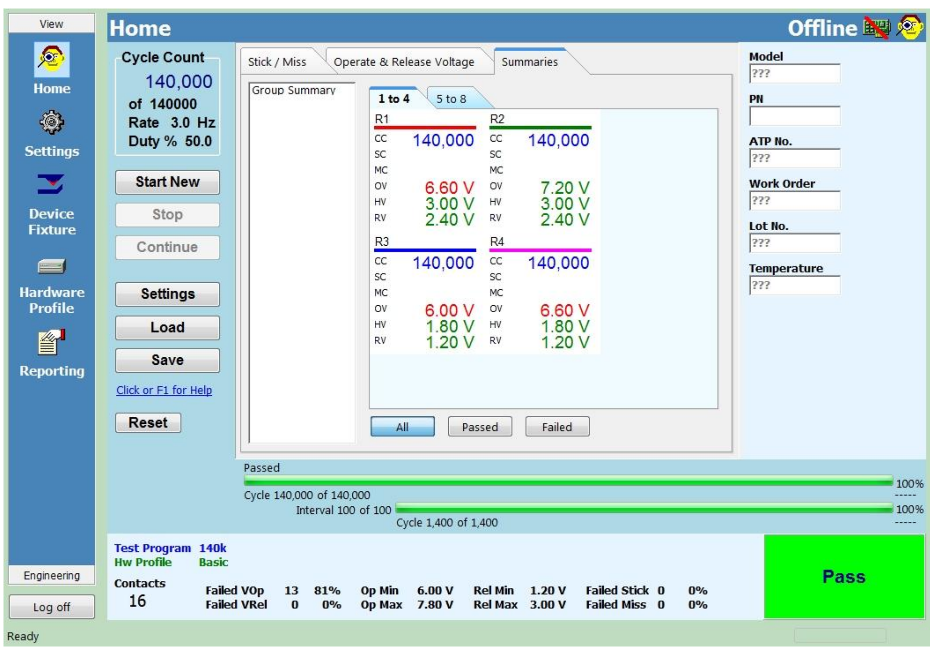
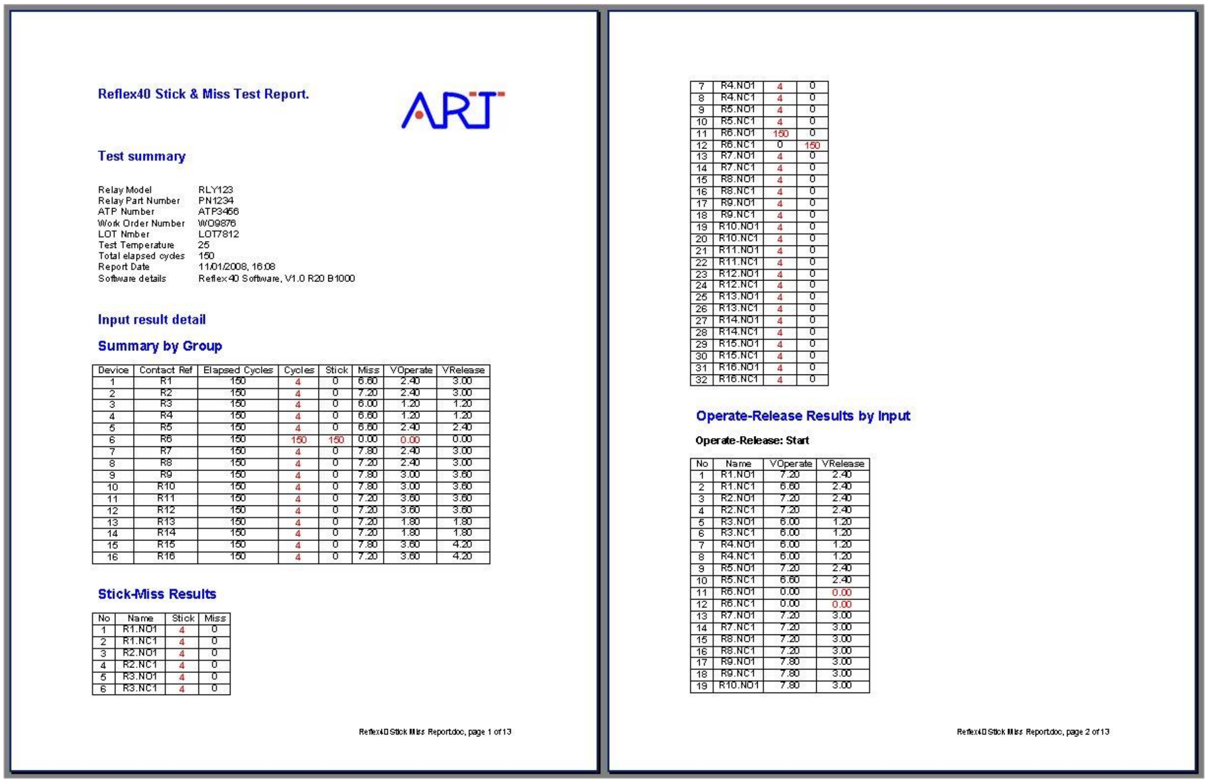


Figure 10: Combined Results Summaries

A typical test run comprises of a specified number of stick and miss test cycles (140,000 in the example above) split into a number of programmable test ‘intervals’ (100 intervals in the example above). If an operate and release voltage test is specified then at each of these intervals the system will pause it’s stick and miss testing and enter a short test phase to measure the operate and release voltages of all contacts. The result data is recorded and the stick and miss testing resumes. This process is repeated for each of the intervals until the test is completed (or until specified failure criteria are met such as ‘stop on stick failure’ etc).

At the end of the test (or during a test pause if required) the user can produce a test report. An example of such a report is shown in Figure 11.



Reflex40 Stick & Miss Test Report.

Test summary

Relay Model	RLY123
Relay Part Number	PN1234
ATP Number	ATP3456
Work Order Number	WO9876
LOT Nmber	LOT7812
Test Temperature	25
Total elapsed cycles	150
Report Date	11/01/2008, 16:08
Software details	Reflex 40 Software, V1.0 R20 B1000

Input result detail

Summary by Group

Device	Contact Ref	Elapsed Cycles	Cycles	Stick	Miss	VOperate	VRelease
1	R1	150	4	0	6.60	2.40	3.00
2	R2	150	4	0	7.20	2.40	3.00
3	R3	150	4	0	6.00	1.20	1.20
4	R4	150	4	0	6.60	1.20	1.20
5	R5	150	4	0	6.60	2.40	2.40
6	R6	150	150	150	0.00	0.00	0.00
7	R7	150	4	0	7.80	2.40	3.00
8	R8	150	4	0	7.20	2.40	3.00
9	R9	150	4	0	7.80	3.00	3.60
10	R10	150	4	0	7.80	3.00	3.60
11	R11	150	4	0	7.20	3.60	3.60
12	R12	150	4	0	7.20	3.60	3.60
13	R13	150	4	0	7.20	1.80	1.80
14	R14	150	4	0	7.20	1.80	1.80
15	R15	150	4	0	7.80	3.60	4.20
16	R16	150	4	0	7.20	3.60	4.20

Stick-Miss Results

No	Name	Stick	Miss
1	R1.NO1	4	0
2	R1.NC1	4	0
3	R2.NO1	4	0
4	R2.NC1	4	0
5	R3.NO1	4	0
6	R3.NC1	4	0
7	R4.NO1	4	0
8	R4.NC1	4	0
9	R5.NO1	4	0
10	R5.NC1	4	0
11	R6.NO1	150	0
12	R6.NC1	0	150
13	R7.NO1	4	0
14	R7.NC1	4	0
15	R8.NO1	4	0
16	R8.NC1	4	0
17	R9.NO1	4	0
18	R9.NC1	4	0
19	R10.NO1	4	0
20	R10.NC1	4	0
21	R11.NO1	4	0
22	R11.NC1	4	0
23	R12.NO1	4	0
24	R12.NC1	4	0
25	R13.NO1	4	0
26	R13.NC1	4	0
27	R14.NO1	4	0
28	R14.NC1	4	0
29	R15.NO1	4	0
30	R15.NC1	4	0
31	R16.NO1	4	0
32	R16.NC1	4	0

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Operate-Release Results by Input

Operate-Release: Start

No	Name	VOperate	VRelease
1	R1.NO1	7.20	2.40
2	R1.NC1	6.60	2.40
3	R2.NO1	7.20	2.40
4	R2.NC1	7.20	2.40
5	R3.NO1	6.00	1.20
6	R3.NC1	6.00	1.20
7	R4.NO1	6.00	1.20
8	R4.NC1	6.00	1.20
9	R5.NO1	7.20	2.40
10	R5.NC1	6.60	2.40
11	R6.NO1	0.00	0.00
12	R6.NC1	0.00	0.00
13	R7.NO1	7.20	3.00
14	R7.NC1	7.20	3.00
15	R8.NO1	7.20	3.00
16	R8.NC1	7.20	3.00
17	R9.NO1	7.80	3.00
18	R9.NC1	7.80	3.00
19	R10.NO1	7.80	3.00

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Figure 11: Example Test Report

The report shows the full detail of the overall test settings, the stick and miss counts and the operate and release voltage results with any failures specifically highlighted. For further flexibility in distribution and printing, the report is produced directly in a Microsoft Word format. A further useful feature is that for working with reports and developing test programs, the Reflex 40 software can run in an off-line mode on any PC to load and save test programs and produce reports as required.

To make the machines use as straightforward as possible the operator loads a pre-written test program that specifies all of the electrical parameters and interval settings, but often has to manually enter individual serial numbers for each device. To make this as easy as possible a graphical ‘fixture editor’ has been provided as shown in figure 12 below.

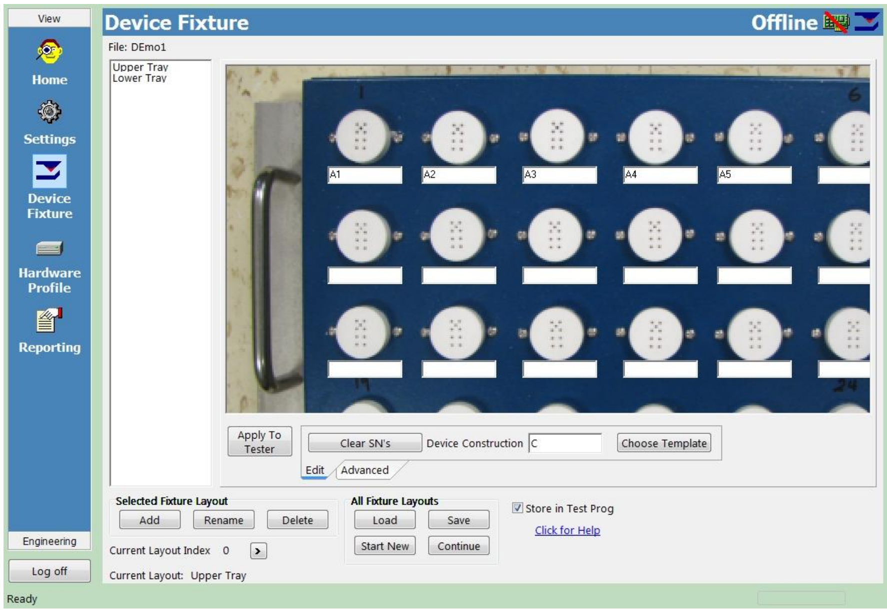

Figure 12: Graphical Fixture Editor

This fixture editor is customisable to show a photograph of the real test fixture layout but has edit controls (the white boxes) overlaid upon it to allow the operator to type in the actual device serial number for that position. This technique helps to reduce possible errors in mismatching a serial number and device. Since the system is contact-based by test channel, the software is able to allow very flexible device constructions from a simple Form-A single contact through to devices with many tens of contacts if required.

The fixture editor also supports running multiple tests in ‘batch mode’ using multiple fixture layouts and serial number groups. During this mode, the end of a stick and miss test ‘fires’ a programmable software ‘event’ that can be used to re-configure external hardware, for example to select another fixture. The software then automatically initiates the start of another test. The process repeats for as many fixture layouts as are specified. This technique dramatically increases the productivity of such a system with unattended operation possible for very long periods.

To support this operation and to provide full traceability of user and test events, a detail log file record and viewer is built into the Reflex 40 software. This log records detailed information about all aspects of the system including hardware status, user logs and any errors.

Hardware control is provided by a ‘hardware profile’ which maps operations such as power supply control on to generic test program ‘events’. This makes it possible to tolerate a range of hardware implementations depending on the required application and device fixturing.

VIII. CONCLUSION

This paper has detailed the process of creating a new product, the Reflex 40 stick and miss 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 traditional approaches.

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 environment.

IX. 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.

X. REFERENCES

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