AMETRIX INSTRUMENTS

Application Note 3

Relay Leakage Testing with the AMETRIX Model 101 Picoammeter

Glenn Fasnacht, President, AMETRIX Instruments
gfasnacht@ametrixinst.com

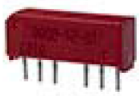
I. Introduction

The AMETRIX® Model 101's highly sensitive 2 nA range with 1 fA resolution places extreme demands on its calibration system. The system must ensure minimal additional errors, some of these errors are due to surface and bulk leakage across and through open relay contacts. These errors must be considered, and to do so they must be quantified. Parasitic leakage resistance values must be high enough that the relays have minimal impact on the uncertainty of the calibration.

Relay manufacturers' specs are usually warranted minimums, and frequently are much lower than actual performance. Without proof, I suspect that they are sometimes chosen to ensure that they look competitive in the marketplace, but that is about all.

This is a report summarizing the results of testing a sampling of reed relays, and the variation among samples was huge. Because my sample sizes are small this is not an endorsement of any one manufacturer or relay. The variation among samples may be due to the manufacturer or may simply be due to lot-to-lot variation, component age, construction method, or many other factors. The purpose of this report is to show that there is variation among parts and that these methods are good tools for further investigation. Also note that this report it is the result of testing the relays that were at my disposal, and the best relay for a given application is the one with the best characteristics for that application; critical characteristics other than electrical ones may include cost and availability. By the way, some of these parts have been in my box of reed relays for a few decades so this report is not a condemnation of any one's relay.

The relays tested were:

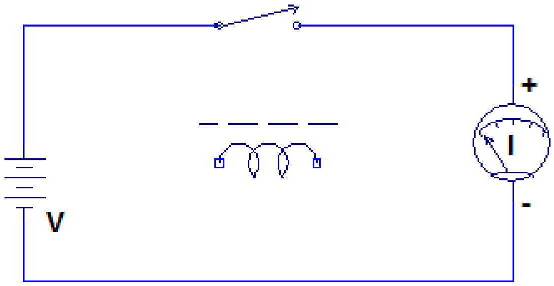
Reference	Mfgr	Model	Description	Picture	Other
RlyA	Hamlin	HE3621 A0500	An encapsulated reed with 5 V coil		Cost: $0.99/100 Delivery: Stock
RlyB	Meder	SIL05-1A72-711	An encapsulated reed with 5 V coil Same footprint as the Hamlin		Cost: $2.70/100 Delivery: Stock
RlyC	Coto	1203-0145	An un-encapsulated reed with 5 V coil and guard Totally different footprint from other relays under consideration		Cost: $25.90/250 Delivery: 10-12 weeks
RlyD	Coto	9002-0005	An encapsulated reed with 5 V coil and guard Similar footprint as the Hamlin and Meder but with guard pins		Cost: $2.95/100 Delivery: Stock

II. The Tests

A. Test Description

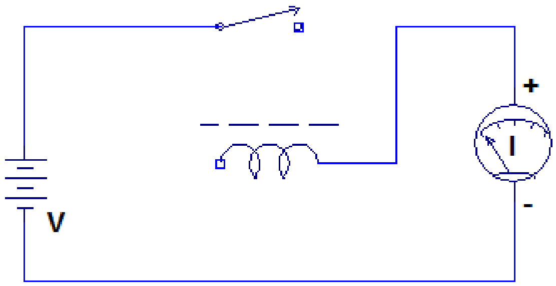
Three tests were performed:

Test A measured the leakage from the contact-to-contact of the open switch. For the un-encapsulated reed relay this leakage is primarily the glass, but for the encapsulated ones it is primarily the epoxy fill.



test A

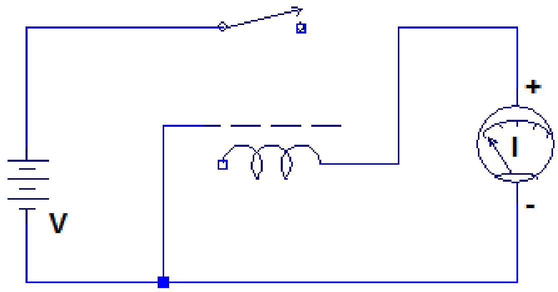
Test B is switch-to-coil leakage. By the way, with assembly method I expected there to be lower insulation resistance, i.e. higher leakage, than contact-to-contact.



test B

Test C is switch-to-coil leakage on reed relays with a grounded guard. The guard should reduce both leakage and capacitive coupled coil to contact charge injection when the 5 V is applied or removed from the coil.

Both the switch contact-to-contact and switch-to-coil leakage paths affect the accuracy of a low current calibration system.



test C

III. Equipment

The voltage source is the low-voltage bias output of an AMETRIX Instruments' Model 101 Picoammeter. This was chosen because it has good short-term stability, low noise, and good Mains isolation, resulting in low common mode current.

The Model 101 was on the 2 nA full scale range.

The relay under test (RUT) was placed inside an aluminum box for shielding, ***figure 1***.

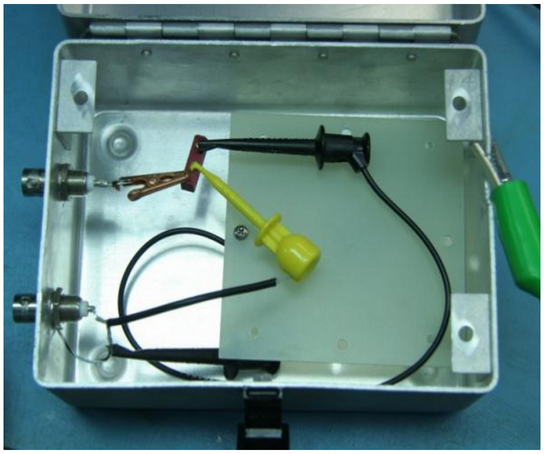


figure 1

The box had two BNCs; one for the voltage source, one for the ammeter. The voltage source had the yellow grabber and the ammeter the mini-alligator clip. The black grabber was connected to ground and connects to the shield of the RUT. The green alligator clip on the right was connected to Earth ground to reduce mains pickup.

The box's lid was clamped closed during testing.

IV. Measurement and Fixture Induced Uncertainty

Two initial tests were performed to estimate the limits of the testing uncertainty.

To determine the effect of turning on the test voltage, with no RUT installed but the clips in the same relative position, data were acquired and at the tenth measurement of the acquisition the voltage supply was changed from 0 V to +10 V.

For this and other plots, time is in seconds and current in amperes. ***Figure 2*** shows about a 400 fA jump due to parasitic cable capacitance and test fixture leakage.

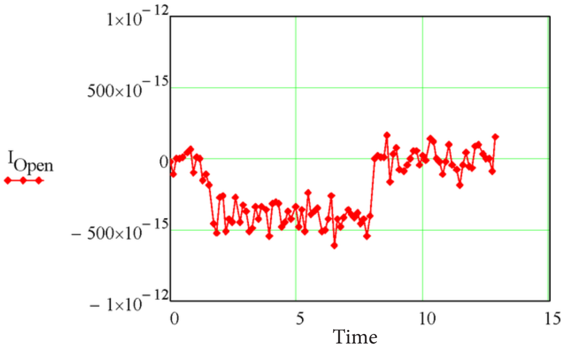


figure 2

This was the current flow with a 10 GΩ resistor inserted between the voltage source and the ammeter; 1 nA as expected.

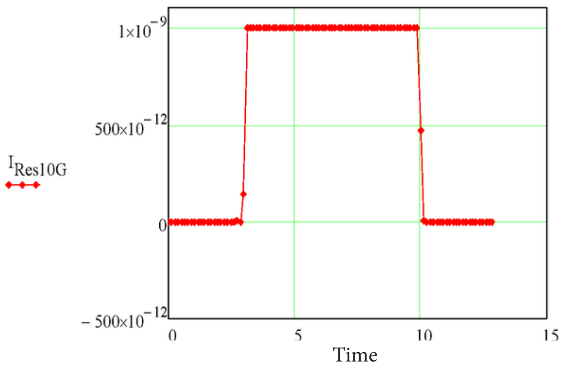


figure 3

Figure 4 is the top of ***figure 3*** expanded, and one can see a nice clean rise with minimal overshoot. The fall was just as clean. Note the vertical scale is only 2 pA/division.

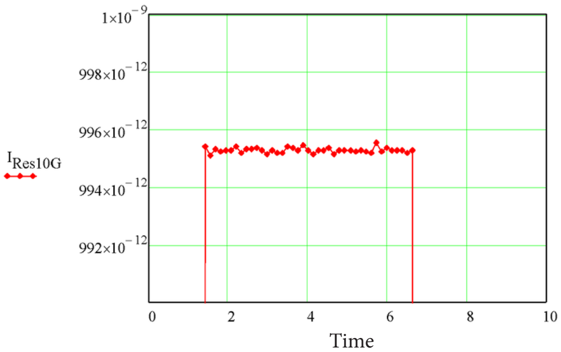


figure 4

This resistor test was performed to ensure that measurements of the relays would be trustworthy.

While this report makes the measurements appear to be easy, there was a fair amount of trial and error applied to eliminate mains noise pickup and noise due to mechanical vibration.

Some example plots from the previously defined tests on real relays:

These tests all involved starting with 0 V applied, and after about one second jumping to +10 V, and after about six more seconds returning the voltage to 0 V. This is not simply turning the calibrator output off but setting it to 0 V; this ensures a low impedance path to discharge any DA.

Figure 5 is the result for a high DA relay. One can easily see the spikes where the DA is charged and discharged.

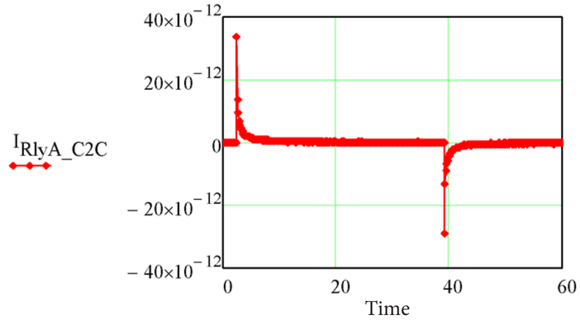


figure 5

Figure 6 is the bottom of ***figure 5*** expanded. The difference between the pre-10 V pulse and the settled post-10 V pulse is due to leakage resistance, and this was about 250 TΩ. Averaging of pre- and post-pulse measurements was necessary to reduce the effects of noise in the calculation.

Note how low these currents are, and how long it takes the current to drop to a steady state. This long time is due to these extremely low currents and due to the real-world characteristics of the relay.

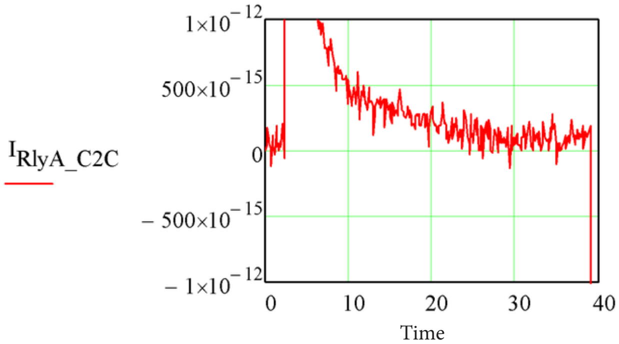


figure 6

The extreme cost due to long test times is why relay manufacturers don't perform such tests on every relay.

This is true for more than just relay manufacturers, this is also why the $0.39 CMOS opamp, with a typical bias current of 100 fA has a guaranteed maximum of 10 nA. Guaranteed specs are 100% measured in production and to measure 100 fA on that opamp would raise the price $2.49. To keep their price low, they test to the higher current but the lower typical is ensured by design and sample testing.

While not 100% tested during production on most of these parts, these test are performed in the lab during development and for quality assurance purposes, and there the time is taken to ensure that their design and process is under control.

What about the apparent exponential decay seen in ***figure 7***? This looks like a simple RC time constant, but it is not. It is rather typical of dielectric absorption; multiple RC time constants combined.

The red trace is a plot of the data from ***figure 5*** imported into Linear Technologies LTSPICE. The blue overlapping is the result of my model of the relay, attempting to tweak the model to agree with the measured.

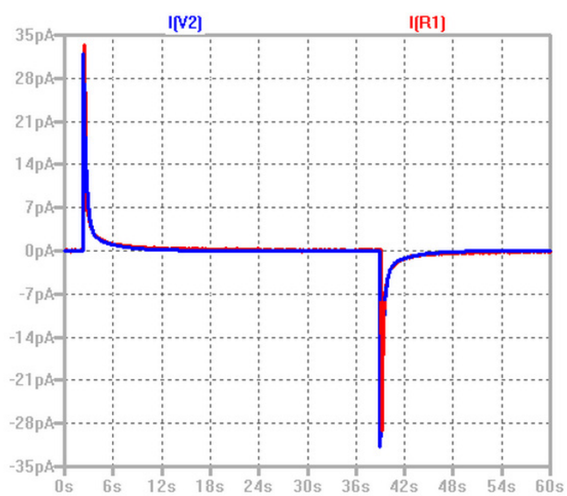


figure 7

Figure 8 is the model that was used. As the reader can see, the resistances are extremely high and the capacitances are extremely low.

This is why a 10 V supply and a picoammeter were needed to make the measurements.

Wikipedia offers a more in depth description of dielectric absorption (DA).

http://en.wikipedia.org/wiki/Dielectric_absorption

While plots of measurement data provide great insight into a given relay's performance, they are not well suited for making comparisons among many relays. To that end, a few comparison characteristics were developed:

Peak DA—the difference between the peak current charging the DA capacitors, and the settled value.

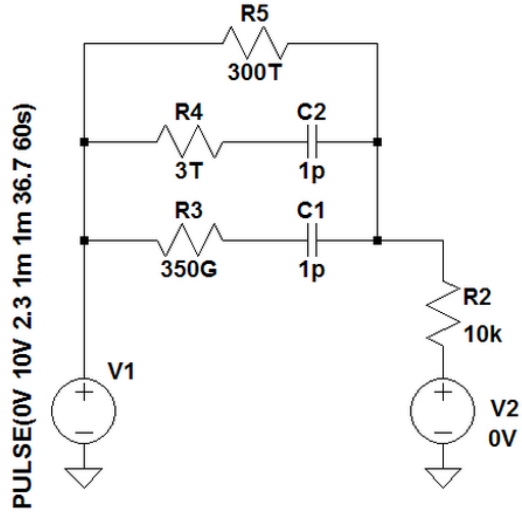


figure 8

Leakage resistance—100 V divided by the difference between the initial 0 V current and the settled 100 V current.

These two characteristics should make it easy to spot significant differences among relay manufacturers and models.

V. Results

Notes:

Relay	Switch contact-to-contact resistance (TΩ)		Switch-to-coil without guard resistance (TΩ)		Switch-to-coil with guard resistance (TΩ)	
	leakage	DA	leakage	DA	leakage	DA
RlyA	49	2.6	6.8	0.73	no guard	no guard
RlyB	180	49	91	22	no guard	no guard
RlyC	420	190	310	130	15000[1]	5200[1]
RlyD	190	19	410	15	1100	89

The resistance was so high it was lost in the noise.

For comparison, I measured the isolation of the PCB. Note that there is 2.2 nF of COG ceramic capacitor between the two sides being measured, the isolated and non-isolate side. DA was 0.03 TΩ and leakage was 2.2 TΩ, so the PCB is also a major contributor that must be considered.

VI.Comments

There are huge differences in the performance among relay manufacturers and models, as well as availability and prices.

Also, remember, these results are from a sample size of one, which is rather shaky ground upon which to base a decision. It may be good enough to give direction to future testing, but one is cautioned against making a decision on this one set of measurements. Also, there is a plethora of other models by many other manufacturers one might consider.

If the lowest cost and most readily available device is adequate it may be foolish to spend more. On the other hand, if these characteristics matter in your circuit, measurements like these can save many problems.

Lastly, other circuit parameters, like the PCB, may have hidden parasitic characteristics that dominate such that the non-ideal relay may be the least of one's worries.

These measurements helped me make an informed choice for my particular application.

AMETRIX Instruments
1 (216) 200-6405
sales@ametrixinst.com
techsupport@ametrixinst.com
8984 Darrow Rd Suite #2-110
Twinsburg, OH 44087