SUPPORT NOTE

SN-149

Eliminating Node 0 Matrix Relay Damage

Introduction

Without hot switching, dry reed relays in Reedholm systems have lifetimes of 10^9 operations, with end of life defined by contact resistance increasing to several times initial resistance of 100m∧. Even if operated continuously, which never happens, a relay should last 15 to 20 years. Any failures before that time are due to hot switching.

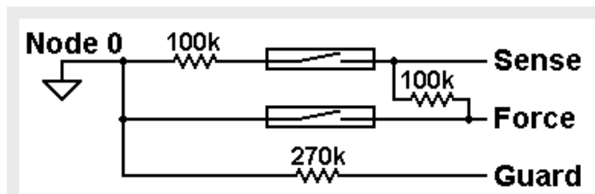
To reduce hot switching during system initialization, the power control logic (PCL) board was modified to prevent turn-on of the ±120V supplies when AC power is applied. Another source of uncontrolled hot switching are sneak paths that charge unassigned pins, only to have those paths discharged to ground between tests when all pins are grounded so that subsequent test structures are not subjected to unknown voltages.

Getting rid of possible sneak paths can be a difficult problem when a system has been doing production testing for any length of time. Hundreds, if not thousands, of test lists can be affected. Stuck relays and scrambling are often highly intermittent, and can bring testing to a halt with different symptoms from wafer to wafer and week to week.

Matrix with Node 0 Protection

Reedholm addressed hot switching damage to node zero relays by with new matrix designs. Migrating to the new PAM-16N and CPM-N will not eliminate scrambling or all hot switching, but will prevent damage to node 0 switches, which bear the brunt of hot switching from sneak paths.

The node 0 triple pole, single throw relays (force, sense, and guard contacts) have been replaced with independent single pole relays for the force and sense lines as shown in figure 1. Connecting guard to ground has no value except for low leakage PAM measurements, so that contact was eliminated. A resistor to ground accomplishes the same thing, and eliminates guard switch welding.



Resistance added to the node 0 sense path prevents welding of the sense relay, but provides a discharge path if there is voltage present. The force relay is not allowed to close until voltage is <|1V|, which is below the arcing voltage. Thus, even if there is switch bounce, the voltage is too low to transfer material, which leads to welding, or sticking, of contacts.

During the PAM-16 redesign, the Test Station Cable (TSC) attached to the PAM was eliminated because the twin-axial connectors have become obsolete. Instead, a very low leakage card edge connector connects the prober analog cable directly to the PAM. This means that removal and replacement of a PAM-N and CPM-N are as simple as replacing other modules.

Node 0 Sense Relay Investigation

On rare occasions, problems are seen with node 0 sense relays, which require replacement. When this happens, it is generally accompanied by unusual diagnostic failures, due to one of the diagnostic tests leaving matrix pins connected to node 1 when they should not have been. There was no doubt that a shorted node 0 sense relay would have produced the failure symptoms even though Reedholm was unable to duplicate the failure after several days of continually exercising the PAM.

How can this be if the PAM-16N (or CPM-N) design is supposed to reduce, if not eliminate node 0 failures? The caveat on node 0 relay damage concerned the force relay, not the sense relay. The 100kΩ series resistor should have prevented any possible damage to the sense relay, yet did not. Any force relay damage is mitigated by the hardware comparator and software, but can still happen with sneak path hot switching.

The culprit in this instance was a defective sense relay since there is a 100kΩ limiting resistor in series with a maximum of |100V|, so <|1mA| can flow, which is much less than the 10mA switching current for relay lifetime of 10^8 operations.

Validation of Performance

Reedholm has not had reason to doubt reliability projects from its relay vendors. To help ensure that there was not a performance issue with the new designs, Reedholm consulted with the reed relay vendors and ran several experiments.

A) Communications with Vendor

The first paragraph in italics was sent to the primary vendor for the single pole node 0 relay. The second paragraph is the response. Reedholm's second relay source uses the same OKI reed switch type, so the claims of 10^8 operations at 10mA are consistant.

> *We use this relay in a switch matrix that might do switching under current to +/-100V with a 100kohm resistor in series. The side of the contact that might be charged to, or held at, |100V| could be dc, or might have a capacitance of 400pF. The trace to the 100k limiting resistor is only an inch long, and is on a 1/16" pcb without a ground shield. It is hard to believe that capacitance is >5pF. Anyway, peak current should be |1mA|, and the switch is supposed to be good for 10^8 operations at 10mA, so how could the switch weld? Our support note and data sheet are attached for further explanation. Any feedback would be appreciated.*
>
> Please have a look in our applications info page 65. Figure 4 shows the bouncing time. During the first reed paddle contact the capacitor will be discharged. Tau = 0.2Ohm x <5pF = <1ps. The discharge has faded away within picoseconds. Our 9001-05-01 contains the RI-27 switch. This switch has a strong paddle spring restoring force. So a sticking of the contacts is not possible with such a small capacitance.

B) Voltage vs Time Sweep

Reedholm set up a simple experiment using a function generator driving the relay coil at 1kHz and running a voltage vs. time sweep. The DMM was used to monitor contact voltage with a 100kΩ series resistor to 100V. This worked okay at low voltages, with DMM readings every 50usec, so a square wave was digitized with 10 readings for each half-cycle. Above 20V, scrambling aborts happened because tying the DMM directly to the switch contact meant that the 350pF node capacitance was being charged/ discharged at each opening and closing of the switch. While not a lot of care was taken with shielding, it was interesting how low the voltage can be to be disruptive. Reedholm does everything possible to eliminate hot switching, so does not have much data of what can be tolerated, and reed switch vendors warn about damage at 50pF charging to 10V!

C) Current vs. Time Experiment

Reedholm then ran a Current vs. Time test so that the contact in series with the 100k resistor had very low capacitance, that of a few inches of non-shielded wire. This required an input 0 delay to get measurements to 100∝sec or so. The relays lasted 100k+ cycles.

Also examined were a pair of relays previously shorted at one time, but this did not limit their reliability at 1mA and 100V. Each one lasted >100k seconds (100M relay operations) without shorting, which takes a total of 27.78 hours.

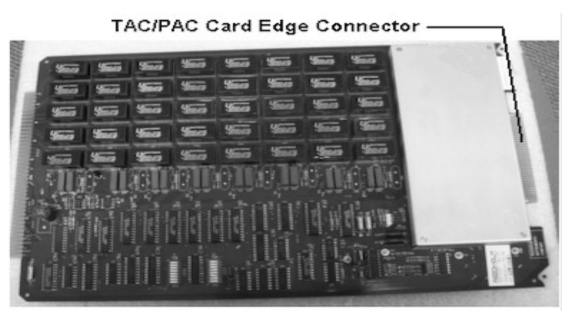
D) Experiment Conclusion

There is no reason to suspect reliability projections at 10mA not being conservative for operation at 1mA and 100V as long as current is really limited and not allowed to get quite high from external storage capacitance. At least one of the relays was identified as defective, although it took 100k cycles to induce the short. The conclusion is that the new design is less susceptible to stuck node 0 relays.

Implementation of Node 0 Matrix

Upgrading to the improved node 0 matrix cards is possible in the field with pre-planning:

- CPM modules can be replaced one at a time. Most of the time, a one time purchase of a longer PAC will then allow replacement of matrix cards one at a time as the budget allows.



- PAM module replacement is more complicated because the twin-axial connectors in the TAC are obsolete, so the prober analog cable needs to be modified or replaced. To help ensure that the integrity of the low leakage measurements are maintained, replacement of all of the matrix cards is recommended.
- To use the new matrix cards, systems must be at RDS DOS 8.14 and 1.32 for Intranet customers.