A Study on Using Solid State Relay (SSR) in Automatic Test Equipment

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Reed relay is widely used in Automatic Test Equipment (ATE) for its high speed, low cost and wide availabilities. However, being mechanical relays, they have their share of limitations and this paper will try to address these challenges and explore alternatives such as solid state relays as replacement.

Keywords: ATE, Reed Relay, Solid State Relay, Arcing, In-circuit Test, Relay switching matrix

Introduction

In Automatic Test Equipment (ATE), a switching device is required to connect to the Device under Test (DUT) for all sorts of testing, like shorts, pins, analog unpowered and powered tests.

The switching needs to be constantly turned on and off with hundreds of millions of operations over the course of its life and endure high "turn-on" current. So far, reed relays fit this bill very well, compared to other mechanical relays, and have been commonly used in this industry for decades. (Figure 1 shows a reed relay and a PCBA.)

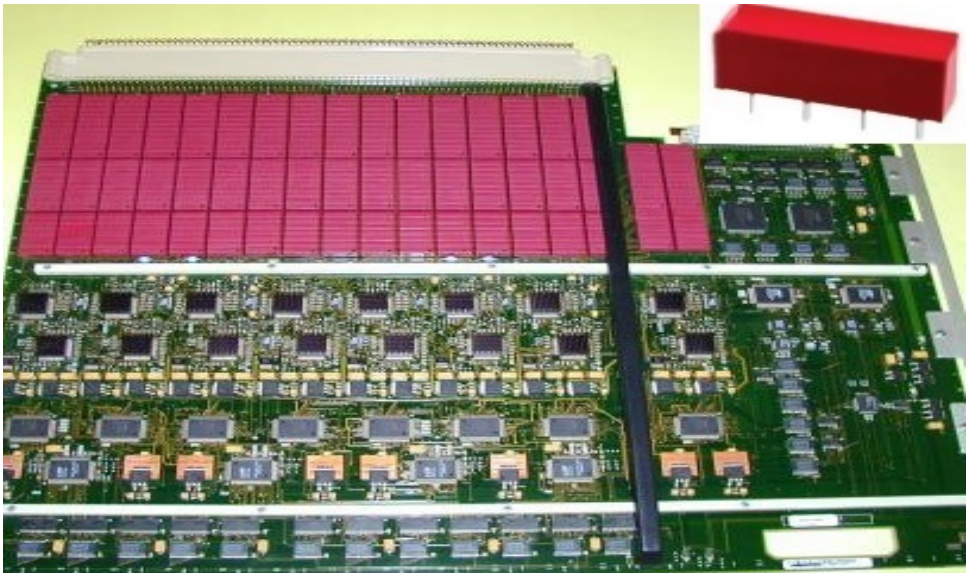

Figure 1: Reed relays used in ATE equipment.

However, reed relay gets its share of issues, the top ones are:

1. Contact Bounce and Arcing caused damage
2. Reliability and limited life expediency
3. Bulky and heavy.

We will take a close look at the arcing issue.

Bouncing and Arcing problems with Reed relays

Armature and reed relay contacts "bounce" when they close. When closing, the contacts touch momentarily, making and breaking continuity, until finally remaining in the closed position. Figures 3 and 4 demonstrate relay bounce.

Every switching system will have some inductance. When a relay opens a circuit with inductance, an arc occurs across the relay contacts, sometimes causing significant damage. The small mass of the reed switch makes it easier to damage during arcing.

During the bounce phase, the first momentary closure starts current flow through the relay. As the contacts open, an arc forms that can melt part of the contact surface.

If the molten contacts solidify in the closed position, a micro-weld may form, sticking the relay closed. The spring force of the reeds may not be sufficient to break this weld when the current stops flowing through the coil. Figure 2 shows a damaged relay.

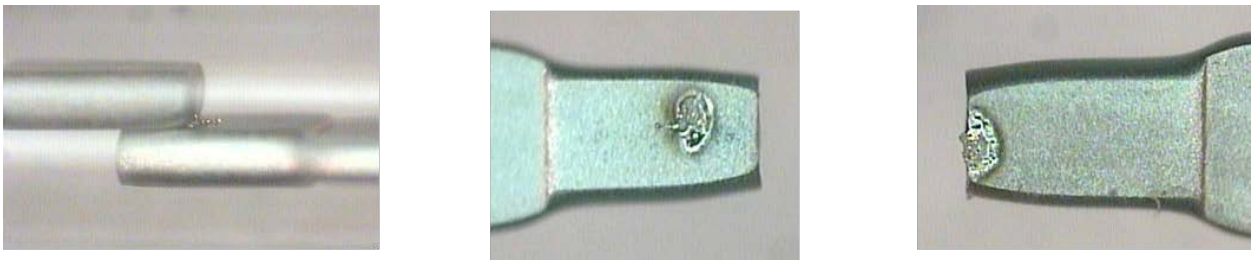

Figure 2: A damaged relay under a microscope.

The Pros and Cons of Solid Sate Relays

The industry is aware of the limitation in reed relays and has been exploring the solid-state relays (SSR) as the alternative to be used in ATE.

The SSR holds a lot of advantages over reed relays as follows:

1. No contact bounce or arcing
2. Super long life expediency. (SSR reliability is determined by time-in operation, not number of switching cycles. When SSRs are used within the published specifications, MTBF can exceed 19 million hours.)
3. Lower Power consumption as there is no need to energize the coil.
4. Smaller in size and lower in weight.
5. Simpler circuit design as lower input drive voltage/current is needed.

However, in terms of low contact resistance, larger current load, better linearity, wide bandwidth, and isolation, the SSR still cannot beat the reed relays. As a result, the adoption rate for SSR in ATE is still pretty low.

Recently, with the rapid development of semi-conductor industry, the performance of Solid State Relay (SSR) has improved dramatically, and their specification and cost from some manufactures are getting close to the reed relays.

Special considerations in In-Circuit Test (ICT) system

For the current product , the ICT (In-circuit Test Equipment) system, the test resources connect to DUT (Device under Test) via a relay switching matrix, to measure the Resistance and capacitance etc. as shown in Figure 3:

There are some key specifications to consider for this kind of application, which are:

Low capacitance improves switching times and isolation characteristics for high frequency load signals.

Low on-resistance (Ron) reduces power dissipation when switching high currents and increases switching speeds to improve the precision of measurement, it can also minimize the effects of temperature drift.

Linearity This is to ensure the measurement of small analog signals without distortion,

Low Off-state Leakage Current helps to cut off the connection to avoid influence to other circuitry.

There has been a search for SSR with comparable specifications to the reed relays. However, due to the inverse relationship between Cout and Ron in a MOSFET switch, there is a trade-off between the signals that is allowed through the switch when it is ON. And the leakage signal when the switch is OFF.

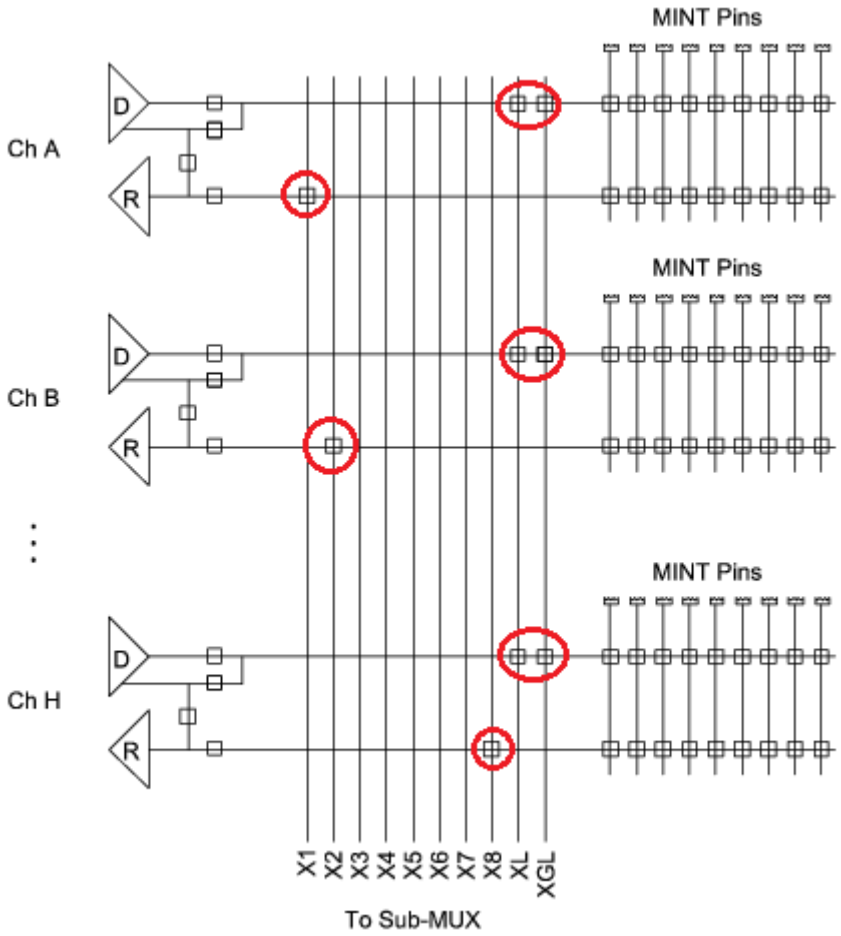

Figure 3: A switching relay matrix used in ICT system.

Basically, a SSR candidate can not be found with the desirable specification in all the aspects. Below is a spreadsheet on a few SSRs:

Table 1: Comparison of a few SSRs

Item	Symbol	Product A	Product B	Product C
on-resistance	Ron (Ohm)	0.033Ohm	0.5Ohm	0.1Ohm
Off state leakage current	Lleak	10uA	0.2uA(typical)	10nA
I/O capacitance	Cout	0.8pF	3pF	230pF

So, none of them can fully qualify to replace the whole reed relays in the system and we have to change our approach to come up with a hybrid relay switching matrix.

Referring back to Figure 3; we have kept those relays in the backbone (Those with red circles) with reed relay, while replacing all the other relays with Product B relays.

By doing, there has been avoided or minimized the situation that the relay resistance adds up in serial relays chains and capacitance/leakage current building up in a parallel situation.

As a result, around 90 percent of relays can be replaced with SSR and the PCB size and weight can be reduced, together with the reduced occurrence of relay welding.

In the meantime, we will continure to looking out for any progress and innovation in SSR development and eventually, look to replace the whole system with SSR.

Conclusions

The performance of SSR has improved tremendously in recent years thanks to the innovation of the industry which has started to challenge the Reed Relay in the ATE. This hybrid SSR/Reed relay switching matrix used in circuit test system shows good potential to achieve 100 percent replacement in the near future.

References

1. Reed relay protection www.ni.com
2. Aimen Kiwan On-resistance vs Output Capacitance for PhotoMOS Relays Panasonic Techinsight

Using Solid State Relay (SSR) in Automatic Test Equipment

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Agenda

- Introduction
- The issue with Reed Relays
- The advantage of Solid State Relays
- Special consideration for in-circuit test equipment
- Hybrid relay switching matrix implementation.

Introduction

Switches serve as the central nerve system in automated test. They interface between the DUT and the test instruments routing signals to and from the DUT.

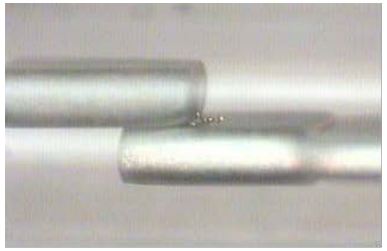
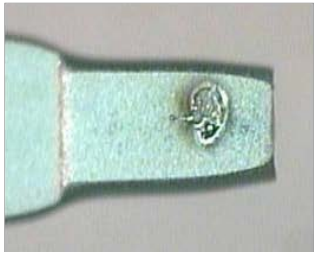
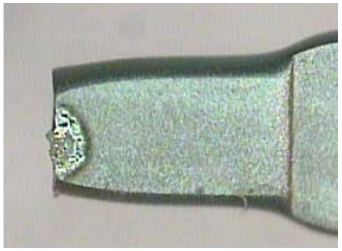
One ATE PCBA loaded with reed relays

Advantage of Reed relays

Compared to armature relays, reed relays switch much faster, have very low contact resistance and offer the added benefit of being hermetically sealed.

That is the reason that they are widely used in ATE.

Major problem of Reed relay: Bounce and Arcing

Other issues with Reed relay

- Reliability and limited life expediency
- Bulky and heavy
- Current/Voltage limit
- Speed compared to SSR

The benefits of Solid State Relays

- No moving parts so no bouncing and arcing problems, no “wear” and “tear”
- Infinite life time if used within the spec.
- High switching speed
- Small and light
- High current/Voltage limit
- Easy for SMT
- Simpler coil control circuits and lower power consumption

The Challenge with Solid State Relays

- Generally high “on” resistance
- Bad “off” isolation
- “Crosstalk” issue

Critical Specification for SSR to be used in ATE

- **Low on-resistance (Ron)** reduces power dissipation and improves the precision of measurement, it can also minimize the effects of temperature drift as well.
- **Low capacitance** improves switching times and isolation characteristics for high frequency load signals.
- **Linearity** This is to ensure the measurement of small analog signals without distortion
- **Low Off-state Leakage Current** helps to cut off the connection to avoid influence to other circuitry.

Challenge to find the best fit

Due to the inverse relationship between “Cout” and “Ron” in a MOSFET switch, there is a trade-off between the signals that is allowed through the switch when it is ON and the leakage signal when the switch is OFF.

Item	Symbol	Product A	Product B	Product C
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Hybrid relay solution

So, none of the candidates can fully qualify to replace all the reed relays in the system and we have to change our approach to come up with a hybrid relay switching matrix.

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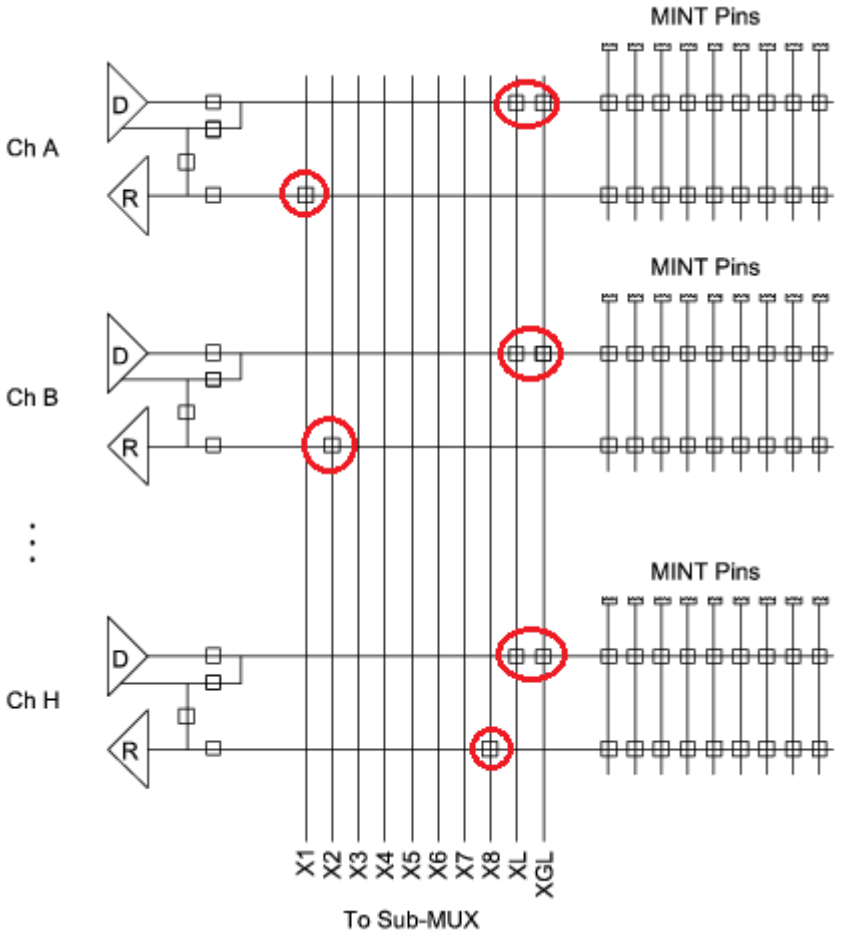
Hybrid relay solution



Hybrid relay solution

As the number of the reed relays have dramatically reduced, now we can afford to do some redundancy design to have spare relay in parallel.

Conclusions

By this Reed relay/SSR hybrid switching matrix approach, we have achieved the following goals:

- Increase the life expectation of relays/products
- Improved the reliability
- Reduced the PCBA foot print

In the mean time, we are looking forward to more innovation from the semiconductor industry so that we can eventually replace all the relays with SSR in our product.

Thank you!

Any Questions?