Switching Low Offset Voltages

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Introduction

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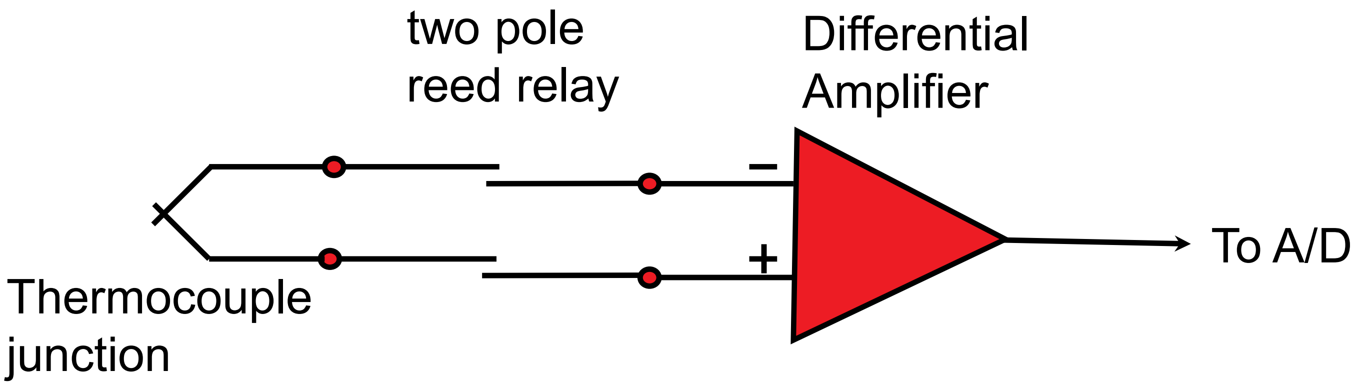

Overview

- Single pole (1 form A) reed relays are used typically on the front end of a voltmeter. In this case the voltage standoff (breakdown voltage) becomes important allowing users to measure very low voltages as well as high voltages in excess of 1000 Volts.

Designing Low Offset Voltage Reed Relays

- Designing a 2 pole vs a 1 pole low offset voltage relays are quite different.
- Generally coil resistance must be as high a value as possible.
- The higher the coil resistance the lower the power generated across the coil.
- The lower the coil power the lower the heat it produces.
- This means we must carefully manage the copper leads to nickel/iron leads of the reed switch inside the relay.

Designing Low Offset Voltage Reed Relays

- In both the designs careful management of the thermocouples internal to the relay is critical.
- It is also important that copper lead wires are used in both cases because they typically will be soldered to the copper lands of a PCB.
- The customer must also manage thermal gradients on his PCB.
- Any two metals when joined together will create a thermocouple.
- This means a voltage will be generated at the metal to metal junction.
- This is even true for the same metals.

Designing Low Offset Voltage Reed Relays

- So our copper leads exiting the relay and connecting up on the copper lands on the PCB are thermocouples and will generate a voltage. Fortunately the voltage is relatively low.
- However, if there is a big enough thermal gradient from one end of the relay to the other, there could be enough offset voltage to affect the signal.

Designing Low Offset Voltage Reed Relays

- Unfortunately, our nickel/iron lead connected to the copper lead forms an excellent thermocouple producing up to 1 millivolt at 20ºC.
- For customers trying to discern signals at the one microvolt level will be lost going through our relay.
- So great care must be taken to prevent this from happening.
- To make matters worse a change of 1ºC at this junction will produce an additional 60µV or a change of 0.1ºC will produce 10µV.

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Designing Low Offset Voltage Reed Relays

- These readings are summarized in the following table:

Copper to nickel/iron thermocouple	Voltage produced at 20ºC	Voltage generated for each 1.0ºC change in temperature	Voltage generated for each 0.1ºC change in temperature
Voltage produced	1 millivolt	60 microvolts	10 microvolts

Designing Low Offset Voltage Reed Relays

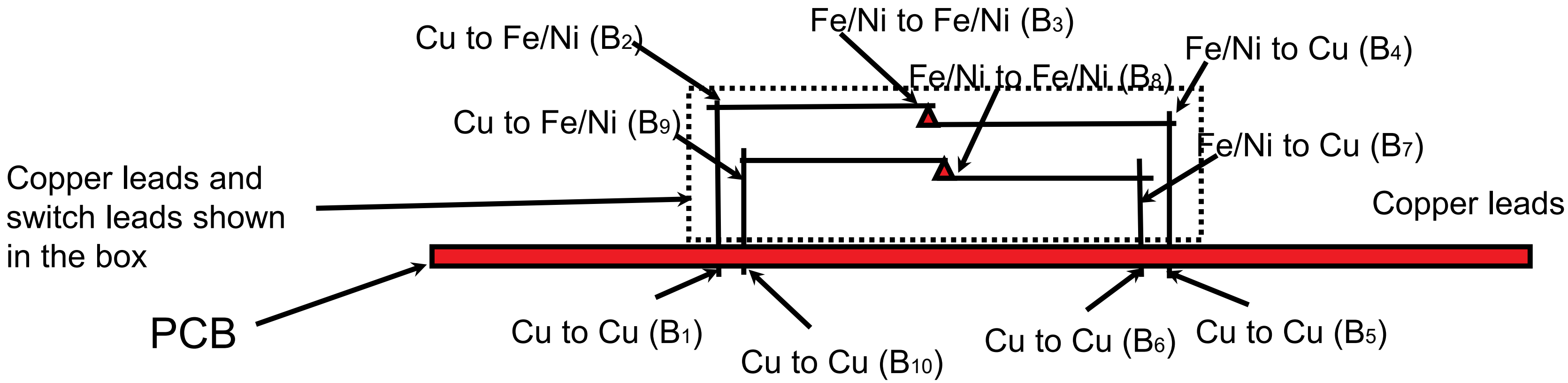
- The third important design element is the symmetry of the coil in relation to the reed switch/es. The more uniform it is will tend to keep the isothermal lines symmetrical on both sides of the relay making it more predictable for the internal thermocouples to be equal and opposite each other.

Design Requirements - Summary

Material	Relay Attribute
Overall design	The layout should be symmetrical
Bobbin	Bobbin and coil should be symmetrical to the switches
Coil	The coil resistance should be as high as possible
Lead material	Copper leads should always be used
For offsets below 5µV	Isothermal alumina metalized chips should be used
Shield	Even if not specified it is a good idea to use an e/s shield between the coil and the reeds for better thermal control
Thermal gradients	Avoid thermal gradients outside the relay
Cover	A metal cover is also recommended to better distribute the heat generated by the coil more uniformly

Designing a Two Pole Low Offset Voltage Relay

› Below shows the potential generation of thermal couples



Here we want the total voltages generated above to equal 0

$$\text{So } B_{Total} = B_1 + B_2 + B_3 + B_4 + B_5 + B_6 + B_7 + B_8 + B_9 + B_{10} = 0$$

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Designing a Two Pole Low Offset Voltage Relay

- If the temperatures are equal at the junction of the PCB then that means.
- B1 and B10 are then equal and they are opposite in polarity, so cancel each other. The same is also true for B5 and B6.
- We can further assume that B3 and B8, the reed switch contacts are equal in temperature and will likewise cancel each other.
- Therefore our equation is reduced to: BTotal = B2 + B4 + B7 + B9.
- Where B2 and B9 are on one side of the relay B4 + B7 are on the other side of the relay.

Designing a Two Pole Low Offset Voltage Relay

- Where B2 and B9 are also opposite in polarity as are B4 + B7.
- So if we can equalize the temperature between the pairs we may be able to come close to our goal of have BTotal equal to zero.
- We have been able to do this by placing a thermal chip soldered to both junctions.
- The thermal chips have plating on their sides and are made of alumina or beryllia, both of which, are excellent thermal conductors (see table).

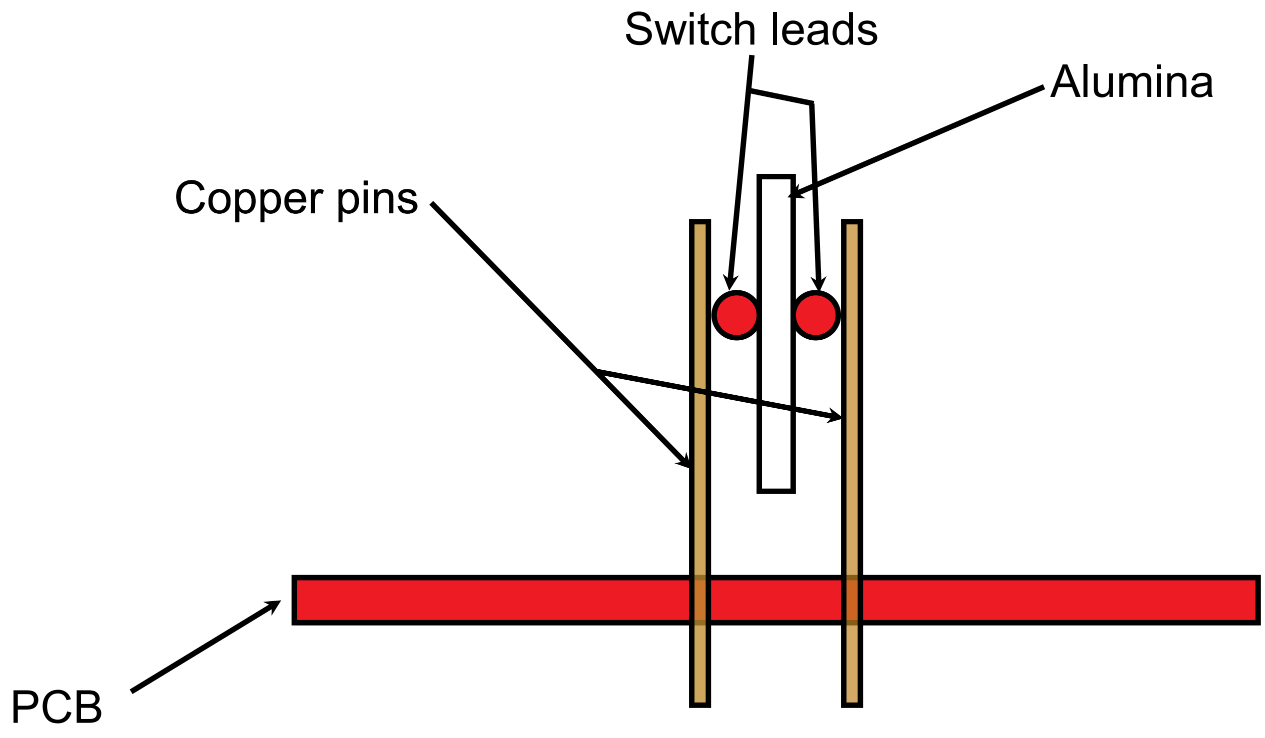
Designing Low Offset Voltage Reed Relays

- Table of thermal conductivities (Kcal/hr m ºC)

Material	Thermal conductivity
Silver	158
Copper	149
Lead	13
Nickel	35
Iron	28
Tin	26
Aluminum	79
Beryllia	84
Alumina	52

Designing a Two Pole Low Offset Voltage Relay

- Below shows an end view of the solder connection to the thermal chip

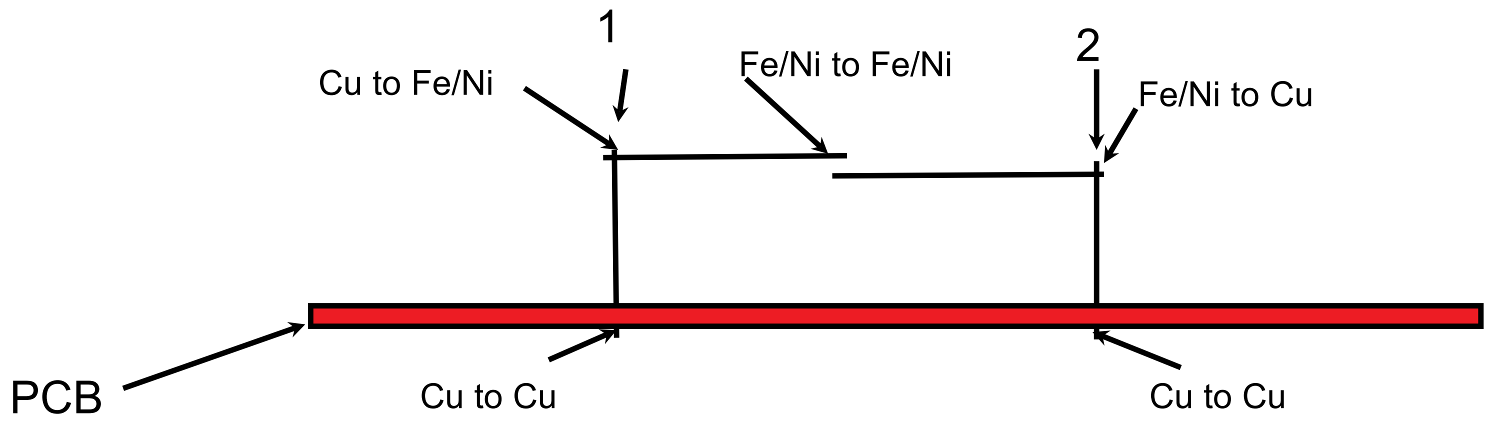


Designing a Two Pole Low Offset Voltage Relay

› So having a isothermal chip on each end of the relay effectively neutralizes copper to nickel/iron thermocouples.
› This approach works only if they are going into a differential circuit.
› This approach does not eliminate any offset voltage across each switch individually

Designing a Single Pole Low Offset Voltage Relay

- Designing a single pole low offset voltage relay can be a very difficult problem because now the thermal junctions we want to neutralize are on opposite sides of the relay. See points 1 and 2 below.
- This makes it very difficult to use an isothermal chip.

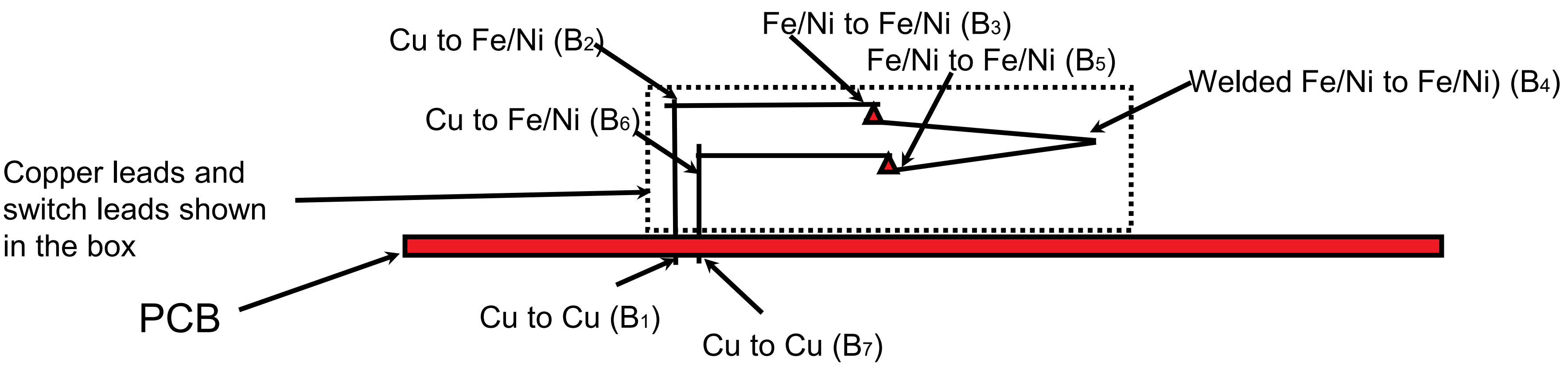


Designing a Single Pole Low Offset Voltage Relay

- The best way to do this is to use two reed switches in series welded at their common end.
- In this manner, the ends of the switch now lie next to each other allowing the use a thermal chip.

Designing a Single Pole Low Offset Voltage Relay

- Below shows the potential generation of thermal couples:



Here again we want the total voltages generated above to equal 0

So $B_{Total} = B_1 + B_2 + B_3 + B_4 + B_5 + B_6 + B_7 = 0$

Designing a single Pole Low Offset Voltage Relay

- Making the same assumptions about the junctions at the PCB at each end are equal, puts B1 and B7 equal to 0. Similarly B3 and B5. We also assume that B4 is small.
- Therefore our equation is reduced to: BTotal = B2 + B6
- Here these thermocouples are on the same side of the relay.
- So we again insert the chip between these to two thermocouples to null their temperature difference.

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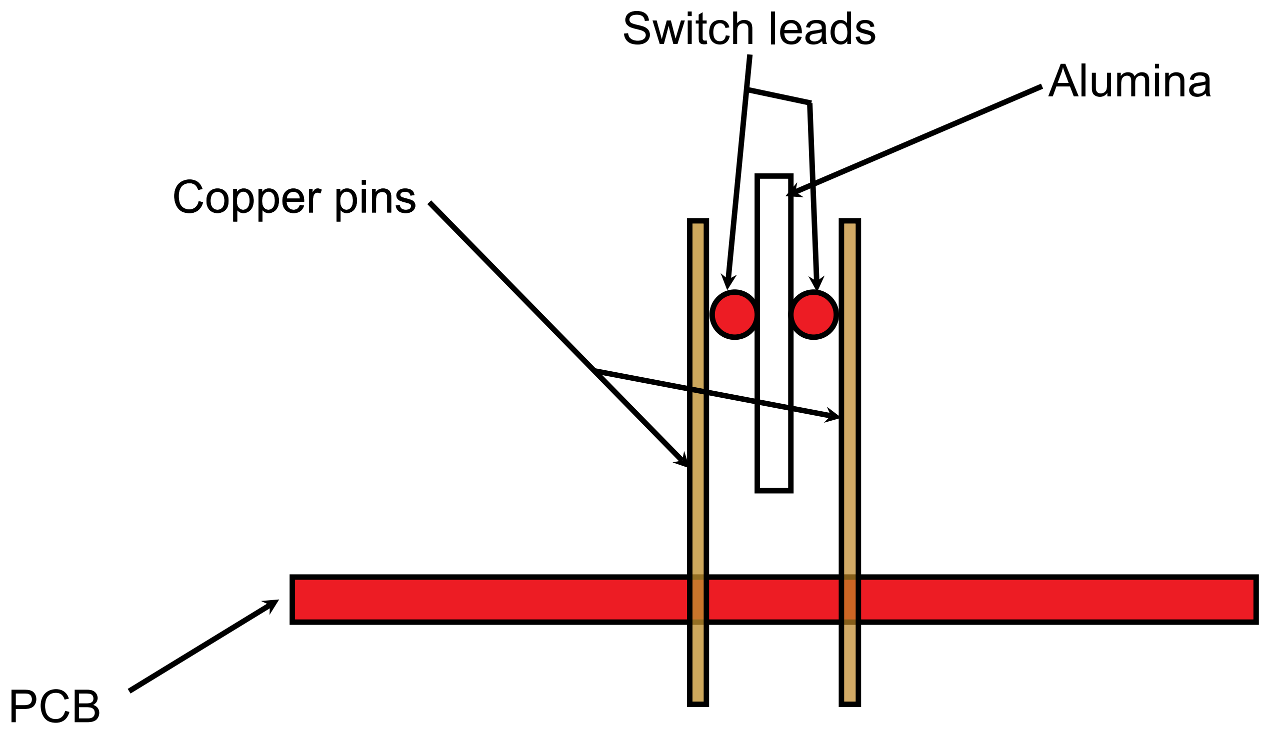
Designing a Single Pole Low Offset Voltage Relay

› Below shows an end view of the solder connection to the thermal chip:

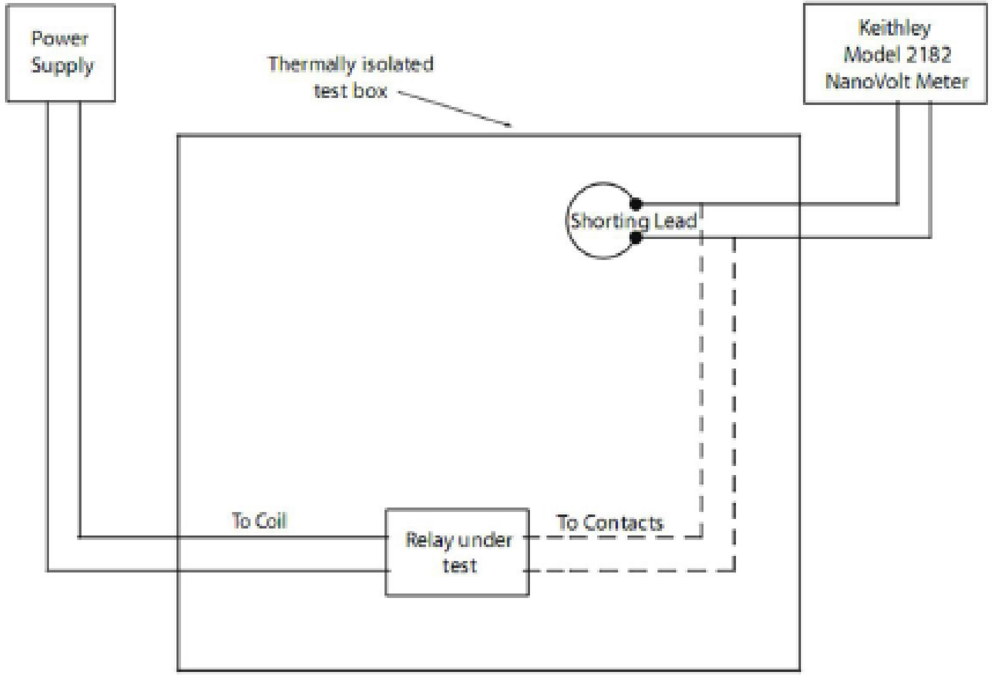


Designing a Single Pole Low Offset Voltage Relay

- So having one isothermal chip on only one end, we are able to achieve < 1µV offset voltage over a 24 hour period with the coil at 100% duty cycle.
- We have also recommended to our customers to achieve even lower offset voltages, turn on the coil with the nominal voltage and then drop the voltage back to 3.5V to 4.0V reducing the power and thermal effect at the square rate of the voltage. This takes advantage of the natural hysteresis of the reed switch.

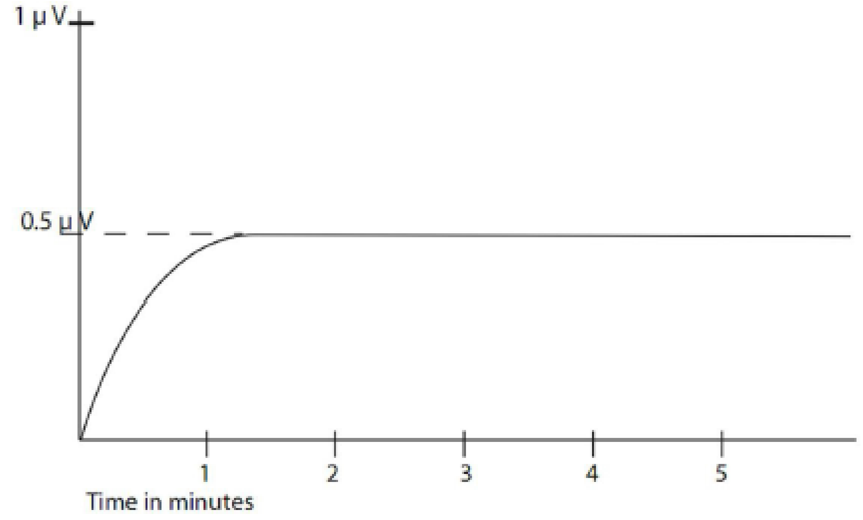
Testing Low Offset Voltages on a Reed Relay

- Testing the single pole relay for low offset voltage we use the below circuit diagram



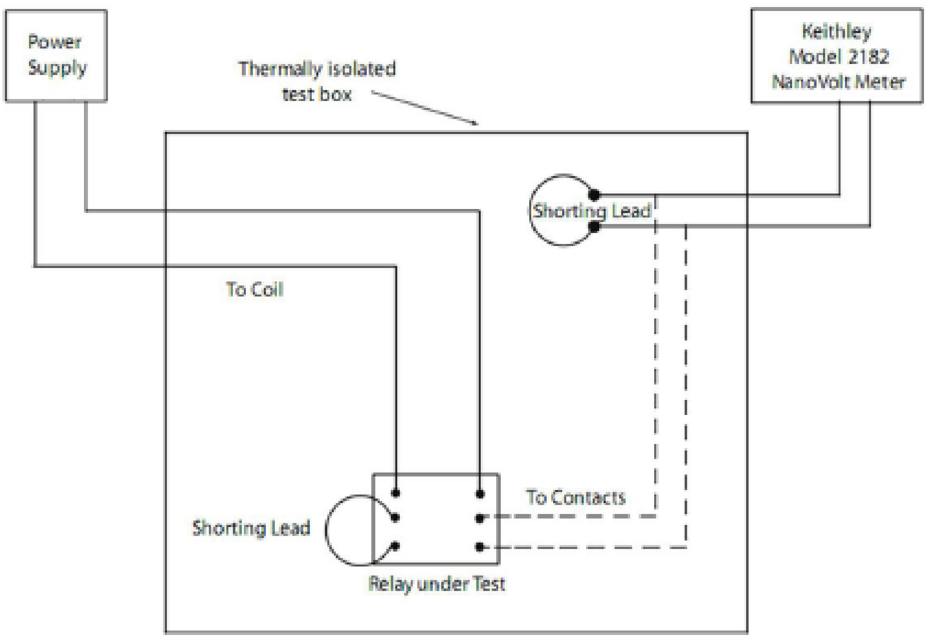
Testing Low Offset Voltages on a Reed Relay

- Typical offset voltage curve seen when measuring the contacts of a reed relay:



Testing Low Offset Voltages on a Reed Relay

- Testing the 2 pole relay for low offset voltage we use the below circuit diagram:



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Two Pole Test Procedure

- The only difference in measuring a two pole vs. a one pole relay is the use of a low mass piece of copper on one end of the relay serving as the differential input.
- Allow the test equipment a suitable amount of time to warm up. The Keithley tester should then be connected to a low mass piece of copper for 10 minutes and zeroed.
- Immediately connect the Keithley leads to the relay under test
- Allow 5 minutes for the Keithley leads to come to equilibrium with the relay leads, and then apply the nominal coil voltage.
- The offset voltage should read near zero once the contacts are closed and rise from there reaching its asymptote usually within 5 minutes as well.

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