

Measuring Reed Switch Sensitivity and Contact Resistance

The purpose of this application note is to document the preferred method of reading the sensitivity and contact resistance of Hamlin reed switches.

Terminology:

- Contact resistance or CR is the resistance of the reed switch when the contacts are closed. It is measured in the units of Ohm (Ω) or mOhm ($m\Omega$) where $0.1 \text{ Ohm} = 100 \text{ mOhm}$.
- Pull-In or PI is the magnetization level at which the SPST (Form A) reed switch closes. Other terms sometimes used are Pick-Up (PU) or Operate Point. Pull-In is measured in the units of AT (Ampere*turn). This is also sometimes written as At or NI, the latter representing number of turns (N) and current (I).
- Drop-Out or DO is the magnetization level at which the SPST (Form A) reed switch opens. It is sometimes referred to as the Release Point. Like Pull-In, this is measured in units of AT.

Standards related to reed switches:

- ANSI/EIA/NARM RS-421 Standard for Dry Reed Switches
- IEC 62246 Reed Contact Units
- MIL-S-55433 Military Specification - General Specification for Switch Capsules, Dry Reed Type

Test Coils

Reed switches are activated by magnetic fields. The magnetic field can be produced by a magnet or a coil. For reasons of history, accuracy and practicality, reed switches are tested by placing the reed switch inside a standard test coil. Hamlin specifies the test coil used in each reed switch data sheet. If a different coil is used, the readings may be different. The more the coil length or coil diameter differs, the more the readings are likely to differ. It is common practice to correlate one coil with another by measuring a set of reed switches with a range of sensitivities in both coils.

Hamlin standard test coils have the following dimensions for the winding:

Test Coil	Winding Length	Winding Inside Diameter
L4991	10.39 mm (0.409 inch)	3.96 mm (0.156 inch)
L4989	18.54 mm (0.730 inch)	5.08 mm (0.200 inch)
L4988	49.53 mm (1.950 inch)	6.99 mm (0.275 inch)

Note that the specified winding inside diameter equals the bobbin outside diameter, and that the winding length equals the bobbin length minus twice the flange width.

Sources of Error

There are several sources of variation or error that are important to consider in obtaining accurate, stable Pull-In and Drop-Out readings.

1. Since the reed switch responds to a magnetic field and a coil's magnetic field is directly proportional to the current through it, the coil's current needs to be carefully controlled or measured. Measuring the coil's voltage does not work well because of temperature effects. Copper has a temperature coefficient of resistivity of $0.393\%/^{\circ}\text{C}$, so ambient temperature or coil self-heating can easily affect measurements made using the coil's voltage.
2. The position of the reed switch inside the coil should be controlled. It is standard practice to center the reed switch contact gap in the center of the coil. If the center of the contact

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Application Note AN103C

cannot be determined visually or by measurement, the reed switch can be centered by measuring and repositioning until the lowest Pull-In is achieved.

3. External magnetic fields need to be considered. The earth's magnetic field can cause reading errors of up to about 1 AT. Static magnetic fields can be compensated for using techniques described below. Dynamic magnetic fields can be produced by nearby fans, motors, or moving magnets and should be avoided.
4. Ferrous material near a test coil can cause errors by altering the magnetic field. Possible ferrous items include screws, brackets, connectors, and tabletops if they are near enough.
5. Large stresses on the reed switch glass or leads can affect the sensitivity readings of the switch by slightly changing the reed switch contact gap.
6. There is a small (0.5-2 AT) amount of magnetic memory associated with the wire in the reed switch. The previous magnetic memory of the wire can be erased by degaussing or by saturating. Saturating is the standard method because it is much simpler.
7. When measuring CR, use of a 4-wire (Kelvin) connection is greatly preferred in order to minimize the effects of the test connections to the reed switch. The Hamlin standard for contact spacing is 25.4 mm (1.0 inch). The nickel-iron reed switch wire has a significant resistance. Depending on the wire diameter, reed switch lead wires have a resistance of about 1.2-3.0 mOhm/mm (30-75 mOhm/inch). Therefore a test contact spacing error of 2 mm (0.1inch) can effect contact resistance by several mOhm.

Compensation for External Fields

There are several techniques to compensate for external unchanging magnetic fields such as that generated by the earth. To determine if an external magnetic field is influencing the readings, simply reverse the polarity of the coil by swapping its connections. If the readings do not significantly change, then there is not significant external field influence. If there is a significant change, there are several techniques to compensate for the external field.

1. Rotate the coil's axis and retest until there is no longer a significant change in readings between normal and reversed coil polarities. This places the coil and reed switch axis perpendicular to the external magnetic field, thereby preventing interference.
2. Add an offset current to the coil to compensate for the external field.
3. Add or subtract an appropriate amount to the measured readings.
4. Always perform the test with both coil polarities and average the results.

Test Procedure

The following test sequence is listed in chronological order and applies to SPST (Form A) reed switches. A chart of the test sequence showing coil drive versus time follows.

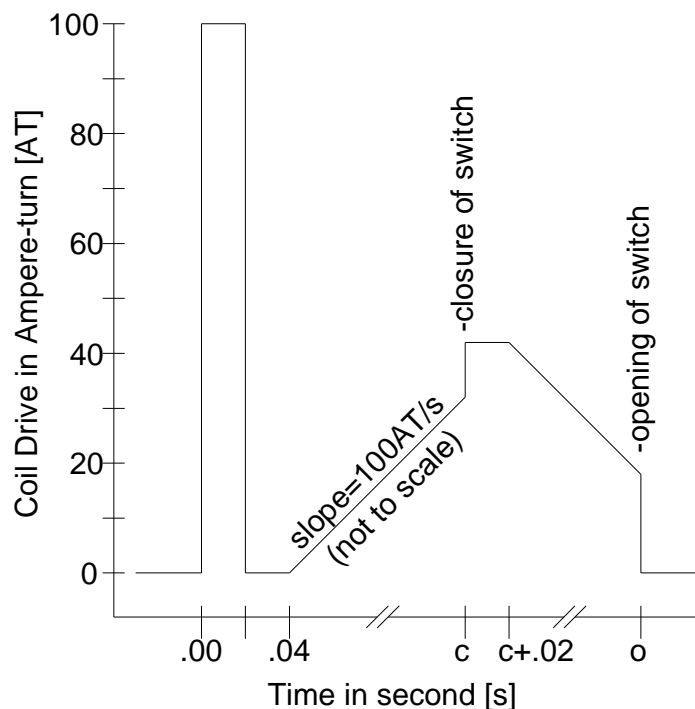
1. Apply a relatively large pulse to the coil to saturate the reed switch wire and remove any magnetic memory in it. An appropriate level for most reed switches is 100 AT. The pulse width must be wide enough to allow the rise time of the current to reach this level. The rise time will be limited by the inductance of the coil with the reed switch acting as a ferrous core. A saturation pulse width of 10 ms is suitable for standard small coils.
2. After applying the current pulse, wait a small time for the current to fall to zero and the reed switch to open. For standard small coils, 10 ms is adequate.
3. Linearly increase (ramp) the coil current until the reed switch closes. When the reed switch closes, measure the current through the coil and multiply by the coil's number of turns to calculate the Pull-In of the switch in Ampere-turns (AT). The ramp rate must be slow

enough that the reed switch has time to react. Also, coil inductance can cause the current to lag behind the applied voltage and result in offset errors. Hamlin's standard for ramp rate is 100 AT/s although slower or somewhat faster will also work. A manual ramp of a power supply, preferably in current drive mode, can be done, but accuracy will be limited by the precision at which an operator reacts to the contact closure.

4. Apply an additional drive level to the coil to measure the contact resistance. Hamlin's standard value to add is 10 AT. Allow the coil drive and switch to settle for a small amount of time, such as 10 ms, after applying this additional coil drive. Then measure the contact resistance using a 4-wire Kelvin connection. Hamlin uses contact spacing of 25.4 mm (1 inch) as a standard.
5. Linearly decrease (ramp) the coil current as in step 3 until the reed switch opens. As in step 3, measure the coil current and multiply by the number of turns to determine the Drop-Out of the switch. Then set the coil supply to zero.

Test Procedure Chart

Recommended Test Sequence (Coil Drive Waveform)



Test Sequence Control

One of the difficulties in accurately measuring Pull-In and Drop-Out is determining the coil current at the time that the reed switch closes and opens. There are several methods that may be employed to do this. In all cases, Pull-In and Drop-Out are found by multiplying the current at closure or opening by the number of turns in the test coil. Also, in all cases, Drop-Out is determined by reversing the direction of coil ramp (decreasing vs. increasing) and monitoring for the reversed switch state (opening vs. closure).

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Application Note AN103C

1. Manual Ramp, Manual Read Method. For this method, the coil voltage or current is slowly increased by hand using an adjustable power supply or other control circuit. When a meter, beeper, or light indicates that the switch closes, the ramping of the coil is stopped and the coil current is measured using a current meter installed in series with the coil. The response time of the person performing the test is a significant factor in limiting the accuracy of this manual method. Using a slower DMM to monitor the switch closure can also be a factor.
2. Manual Ramp, Sample & Hold Method. As above, the coil is manually ramped. However, when the switch closes, it triggers a circuit or instrument that quickly records the coil current. A common circuit for accomplishing this is called a Sample & Hold circuit. Such a circuit would sample the coil current while ramping, perhaps by measuring the voltage across a resistor in series with the coil. When the switch closes, the circuit would hold the sampled value on a low leakage capacitor for example. This method has the advantage of removing the variation resulting from a person responding to the switch closure, but this method still involves manual coil ramping.
3. Automatic Ramp, Manual Read Method. In this method, ramping of the coil current is done using a circuit such as a digital circuit controlling a DAC (Digital-to-Analog Converter) or an analog circuit based on charging a capacitor. When the switch closes, circuitry can stop the ramp circuit very quickly. Then, the coil current can be measured in a leisurely fashion. Like the previous method, the variation of a person's response time is removed, but also the ramp rate is controlled.
4. Automatic Ramp, Automatic Read Method. As in the previous method, the coil is ramped using a circuit, preferably digitally controlled. In addition, a microprocessor or other control circuit controls the measurement of the coil current so that the entire test sequence waveform shown above is automatically carried out in a repeatable manner. This has the advantages of decreasing the test time and improving measurement repeatability and accuracy.