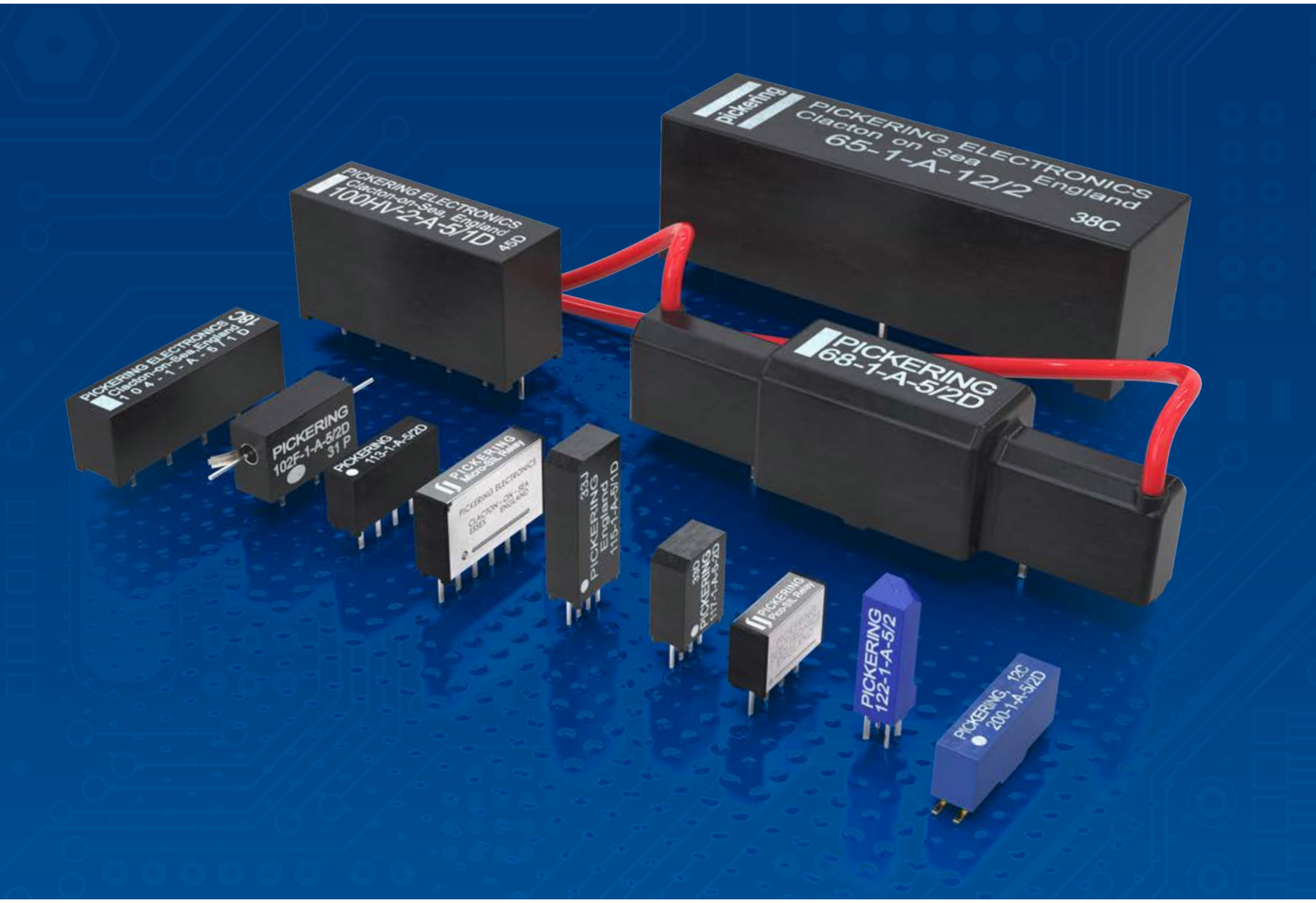
Reed RelayMate

A practical guide to **Reed Relays** for Engineers



Second Edition

Reed RelayMate

This book provides an overview of how reed relays work, how they are constructed, and how to interpret their specifications and make best use of them in your applications. We will also discuss guidelines for PCB construction when Reed Relays are to be used. This includes some surface mount reed relay practices.

It is intended to be a practical book about reed relays aimed at engineers. It requires little or no theoretical knowledge about the materials they are constructed from. All the technical and applications issues are dealt with in a practical manner. The takeaway is that the reader will have a better understanding of where reed relays are superior in test and measurement applications and how best to implement them.

With the information supplied in this book we hope users will better understand the efforts that go into designing what in principle is a simple component but which in practice is a complicated product full of engineering compromises and best value judgements. If you have questions about what you will learn in this book, feel free to contact us.

This is a living document that Pickering Electronics will continue to develop in support of reed relays and their future evolution. We welcome any feedback from users on subjects they would like to be included in future issues.

About Pickering Electronics

Pickering Electronics was formed in January 1968 to design and manufacture high quality reed relays, intended principally for use in instrumentation and automatic test equipment.

Pickering Electronics offer an extensive range of high quality instrumentation grade reed relays designed for applications requiring the highest levels of performance and reliability at an affordable price. Through the experience of supporting the most demanding manufacturers of large ATE systems with high relay counts the company has refined its assembly and quality control methods to optimize its manufacturing methods.

As part of the Pickering group (www.pickering-group.com), we work closely with our sister company, Pickering Interfaces, to provide the most accurate and repeatable switching for electronics test. Pickering Electronics has developed innovative reed relay solutions designed to provide high coil efficiency, minimum external dimensions and low PCB footprint solutions to meet the demands of modern equipment manufacturers.

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1 REED RELAY BASICS

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Reed relays are deceptively simple devices in principle. They contain a reed switch, a coil for creating a magnetic field, an optional diode for handling back EMF from the coil, a package and a method of connecting the reed switch and the coil to the outside of the package. The reed switch itself is simple in operation and relatively low cost to manufacture thanks to modern manufacturing technology.

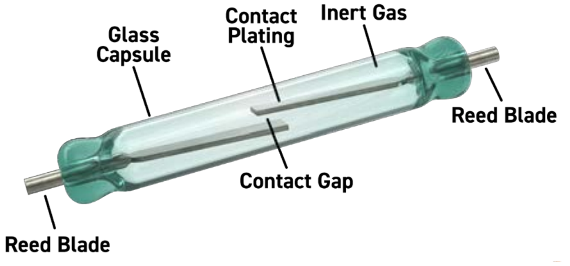


Fig. 1.1 - *Reed Switch*

Reed Switch

The reed switch has two shaped metal blades made of a ferromagnetic material (roughly 50:50 nickel/iron) and a glass envelope that serves to both hold the metal blades in place and to provide a hermetic seal that prevents any contaminants entering the critical contact areas inside the glass envelope. Most (but not all) reed switches have open contacts in their normal state.

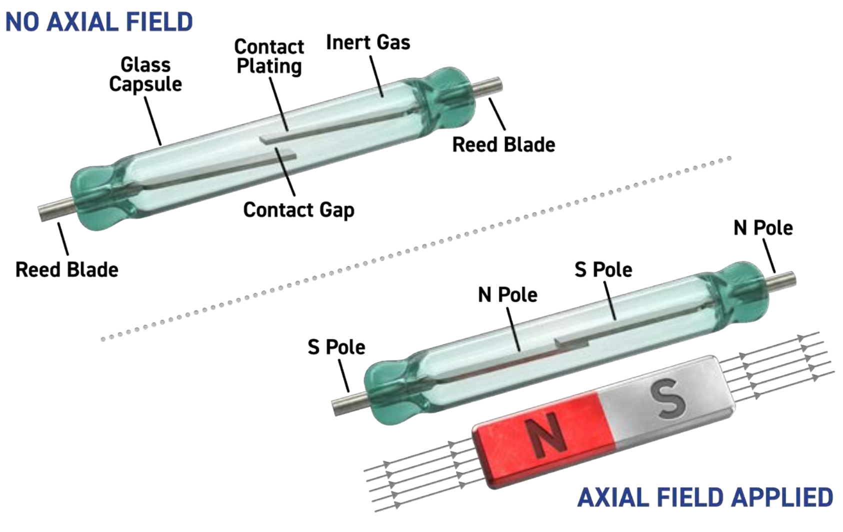


Fig. 1.2 - *Reed Switch Generating the Magnetic Field*

If a magnetic field is applied along the axis of the reed blades the field is intensified in the reed blades because of their ferromagnetic nature, the open contacts of the reed blades are attracted to each other, and the blades deflect to close the gap. With enough applied field the blades make contact and electrical connection is made.

The only movement in the reed switch is the deflection of the blades, there are no pivot points or materials trying to slide past each other. The reed switch is considered to have no moving parts, and that means there are no parts that mechanically wear. The contact area is enclosed in a hermetically sealed envelope filled with inert gasses, or in the case of high voltage reed switches a vacuum, so the switch area is sealed against external contamination. This gives the reed switch an exceptionally long mechanical life.

Inevitably in practice the issues are a little more complicated. The ferromagnetic material is not a good conductor and in particular the material does not make a good switch contact. So, the reed blades need to have a precious metal coating in the contact area. However, the precious metal may not stick to the blade material very well so an additional underlying metal barrier may also be required to ensure good adherence. Some types of reed relay use mercury wetted contacts, consequently reed relays that use plated contacts are often referred to as “dry” reed relays. The metals can be added by selective plating or by sputtering processes. Where the reed blade passes through the glass envelope, any plating (in many cases there may be none) requires controlling to avoid adversely affecting the glass to metal hermetic seal. Outside the glass seal the reed blades have to be suitably finished to allow them to be soldered or welded into the reed relay package, usually requiring a different plating finish to that used inside the glass envelope.

The materials used for the precious metal contact areas inside the glass envelope have a significant impact on the reed switch (and therefore the relay) characteristics. Some materials have excellent contact resistance stability; others resist the mechanical erosion that occurs during hot switch events. Commonly used materials are ruthenium, rhodium and iridium - all of which are in the relatively rare platinum precious metal group. Tungsten is often used for high power or high voltage reed switches due to its high melting point. The material for the contact is chosen to best suit the target performance - bearing in mind the material chosen can also have a significant impact on manufacturing cost.

Another design variable of the reed switch is its size. Longer switches do not have to deflect the blades as far (measured by angle of deflection) as short switches to close a given gap size between the blades. Short reeds are often made of thinner materials, so they deflect more easily but this clearly has an impact on their rating and contact area. Smaller reed switches allow smaller relays to be constructed - an important consideration where space is critical. The larger switches may be more mechanically robust and have greater contact area, improving their signal carrying capability.

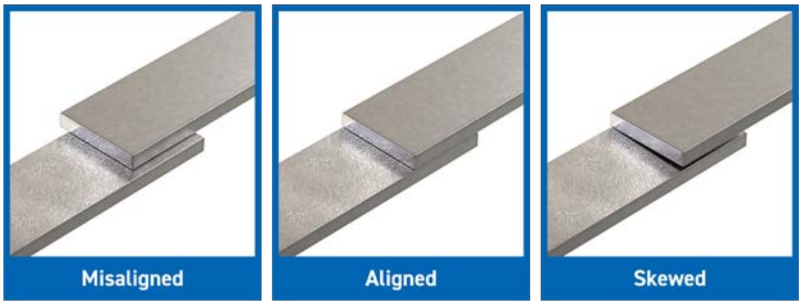


Fig. 1.3 - *Blade Alignment*

It is important to note that Pickering only uses Instrumentation Grade reed switches. The critical difference is the alignment of the reed blades within the glass tube. The alignment of the blades is important, they need to line up and be parallel to each other to ensure when operated, the maximum contact area comes together giving the lowest contact resistance and best contact resistance stability. With misaligned or skewed blades, not all of the contact surface area will come together resulting in higher contact resistances, less area to dissipate heat when hot switching, and reduced life expectancy. High-end reed relay manufacturers using instrumentation grade reed switches will test the contact resistance stability to ensure correct alignment.

It is these compromises in reed switch design that gives rise to the sometimes-bewildering range of reed relays that are available with both subtle and not so subtle differences in performance.

To learn more about the importance of reed switch blade alignment when using reed relays watch this short video here: **pickeringrelay.com/reed-switch-blade-alignment-explained**

Generating the Magnetic Field

To operate a reed relay a magnetic field needs to be created that is capable of closing the reed switch contacts. Reed switches can be used with permanent magnets (for example to detect doors closing) but for the reed relays described in this book the field is generated by a coil which can have a current passed through in response to a control signal. The coil surrounds the reed switch and generates the axial magnetic field needed to close the reed contacts.

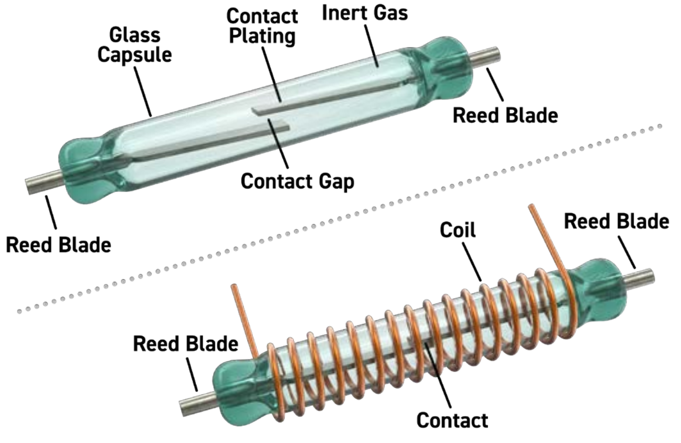


Fig. 1.4 - *Generating a Magnetic Field*

Different reed switches require different levels of magnetic field to close the contact, and this is usually quoted in terms of the ampere turns (AT) - simply the product of the current flowing in the coil multiplied by the number of turns. Stiffer reed switches for higher power levels or high voltage switches with larger contact gaps usually require higher AT numbers to operate, so the coils require more power.

Use of different wire gauges for the coil and number of turns creates relays with different drive voltage requirements and different coil powers. Larger coils can be used to reduce power consumption, but that increases the size of the relay.

A significant factor in some designs is the ability to drive reed relays with standard CMOS logic, requiring that the coil is operated from 5 V or 3.3 V and that the current (power) requirements in the coil are minimized.

Protection against Magnetic Fields

The fact that reed relays are magnetically operated causes a potential problem for users when they are assembled in dense patterns on PCBs.

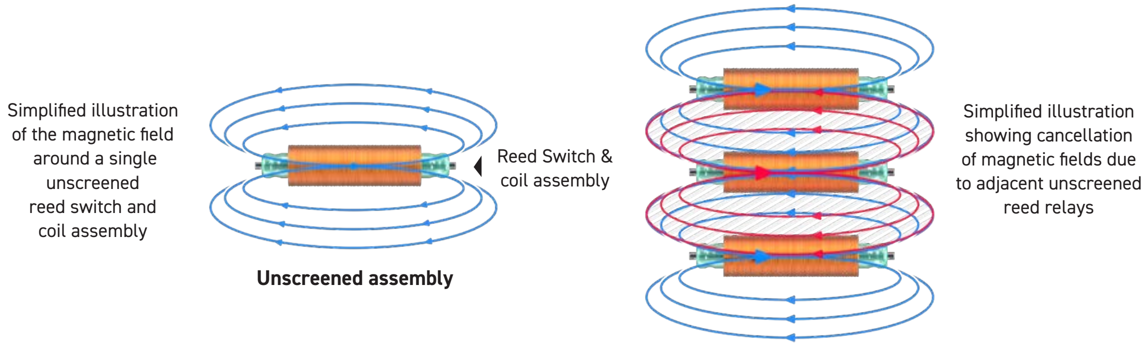


Fig. 1.5 - *Magnetic Interaction*

The magnetic field required to close the reed blades flows through the nickel/iron reed blades and returns by field lines which are outside the reed relay body. If several relays are placed close together, the external field lines of one relay can interact with the neighboring relays' reed blades and either reinforce or partially cancel the field in these reeds, changing the current needed to close or open the contacts. This can in some circumstances cause enough effect that the relay may either fail to close or open depending on the magnetic polarity. Some manufacturers suggest arranging the relays in different polarity patterns to mitigate the worst effect of the interaction, but this can become a complex compromise in dense arrays of relays where there are many near neighbors.

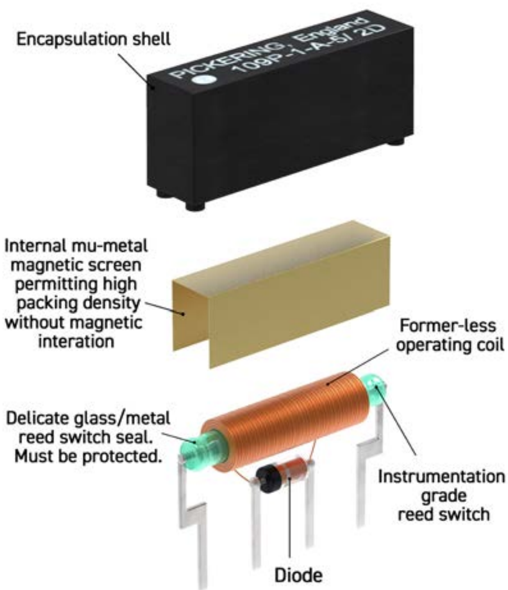


Fig. 1.6 - *Reed Relay with Screen*

A much more sensible approach is to include a magnetic shield (also called a Screen) in the reed relay package, an approach used by Pickering Electronics for many years. (The term screen is a Pickering description of the Mu-metal added to the reed relay assembly. Is it completely interchangeable with the term "shield" used by other manufacturers). The user is then free to use a layout pattern that best suits the application. The approach has the added benefit of improving the coil efficiency since it concentrates the magnetic field lines closer to the reed switch body, shortening the magnetic field length outside the reed blades and creating a larger field for a given number of ampere-turns in the coil. Lower coil operating currents make coil driving simpler and improve other parameters such as thermal EMF generation.

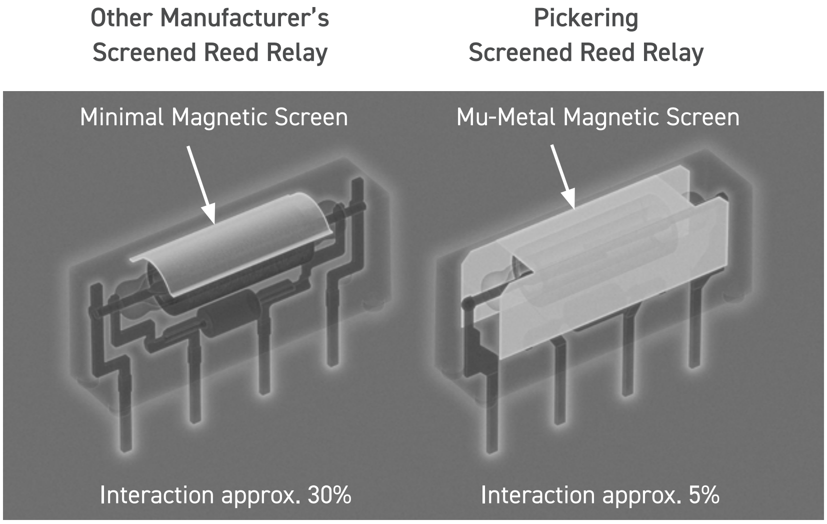


Fig. 1.7 - *Rendered x-ray images of a fully screened Pickering reed relay and another reputable manufacturer's screened relay*

When selecting a shielded relay manufacturer, make sure that the entire relay is shielded. As you can see in this X-ray photo, some reed relay manufacturers only shield the top of the reed switch. While this saves money on the cost of the relay itself, the magnetic interaction of adjacent relays is 6 times greater than a fully shielded relay. Depending on the circuit board layout and the number of relays fitted, greater drive current may be necessary.

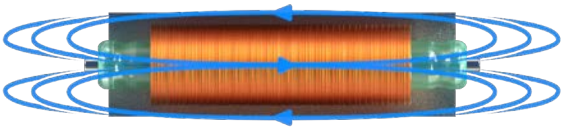


Fig. 1.8 - *Screened Reed Switch*

To learn more about magnetic interaction see here: **pickeringrelay.com/magnetic-interaction**

Mercury Reed Relays

There is a class of reed relays that has been historically very popular where the reed contacts include mercury that provides the electrical contact between the blades. The mercury is contained in a small reservoir and blade actuation pumps the liquid up a grooved surface on the reed blade to the contact area using mercury's high surface tension to retain the material.

Selective chrome plating is often used in the construction since mercury and chrome do not stick together, and this is used to help control the mercury flow.

The glass envelope of mercury relays is also highly pressurized (typically 12 to 14 bar) which helps to manage the switch materials and operation and improves electrical parameters.

These relays are strongly preferred in some industries because they have a long contact life and bounce free contact closure - a feature that is particularly helpful under hot switch conditions. Stability of low contact resistance during their operational life is also considered to be better than that of dry reed relays.

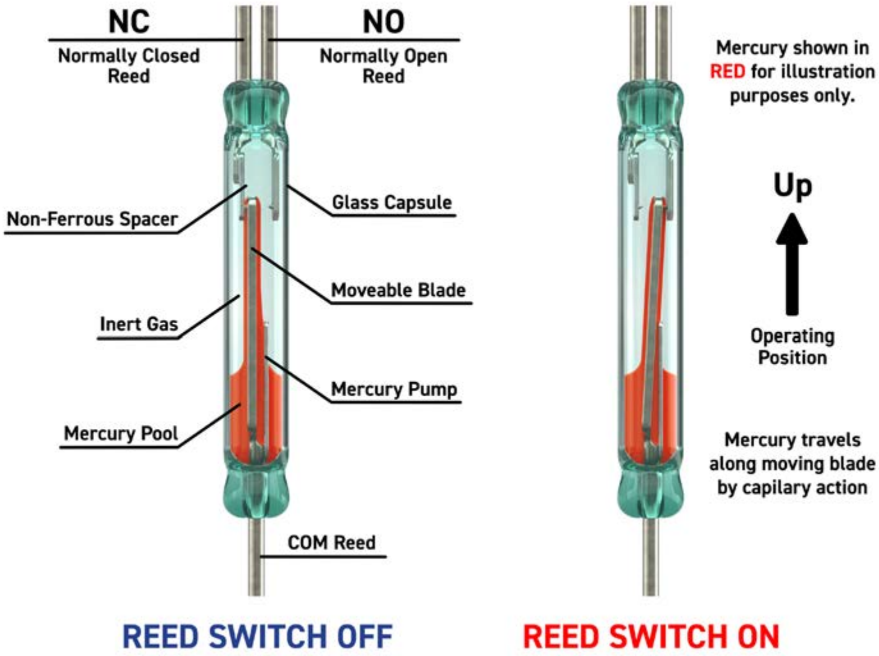


Fig. 1.9 - *Miniature Mercury-Wetted Reed Switch (SPDT)*

Most types of mercury reed relays are position sensitive - they can only be used in a vertical orientation. Some non-position sensitive versions are also available which can be used in any orientation. Mercury wetted relays however are not RoHS compliant and national regulations may limit their use to certain critical applications where exceptions on RoHS have been granted.

High Voltage Reed Relays

High voltage reed relays need to have large clearances between component parts (including the distance between the contacts in the reed switch) to minimize the chance of arcing, and must also have a carefully matched operating environment and specific contact materials to resist the contact erosion that occurs when switching the signals. High voltage reed switches commonly use tungsten, rhodium or ruthenium contacts.

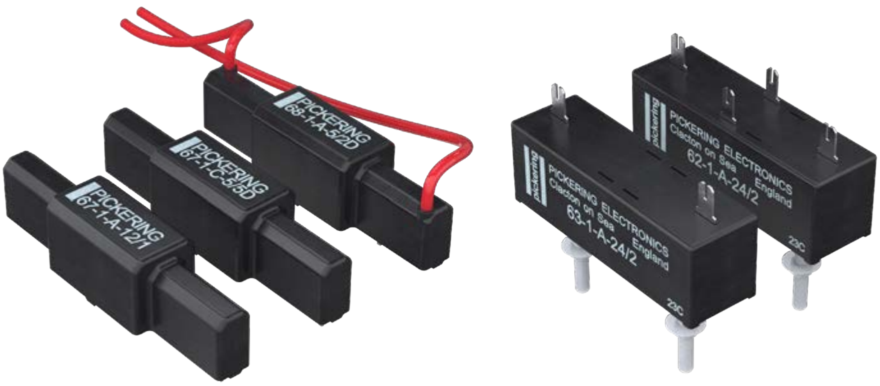


Fig. 1.10 - *High Voltage Relays*

The glass envelope used for high voltage reed switches normally contains a very hard vacuum to maximize the voltage rating for a given blade separation and to manage arc duration as the contacts open or close. Any loss of seal will rapidly degrade the switch operation, so reed switches must be carefully managed as they are packaged into reed relays.

There are typically three contact options for high voltage reed switches. Rhodium and ruthenium offer superior low contact resistance, which enables exceptional current carry performance. Rhodium and ruthenium contacts are preferred for high voltage applications, where low contact resistance and good current carry performance are required, provided the switching voltage is below 1000 V DC or AC peak.

Tungsten contacts are used for switching voltages up to 12.5 kV DC or AC peak (15 kV Standoff) at very low current. Tungsten is a good general purpose switching contact material, but with a higher contact resistance than rhodium or ruthenium.

To see Pickering's comprehensive range of reed relays for high voltage applications see here:
pickeringrelay.com/reed-relays/high-voltage

Normally Closed Reeds

Most of the information in this book relates to normally open reed relays - by far the most common configuration of reed relay. However, normally closed relays can also be supplied where the blade is biased so it is normally closed and the application of a magnetic field opens the relay contacts.

The contact bias is created by adding an internal permanent magnet to hold the reed switch in a normally closed state. When the relay coil is energized, it cancels out the magnetic field bias and the contacts open. If the coil voltage is increased substantially beyond its nominal voltage (typically greater than 1.5 times nominal) there is a risk that the contact will reclose.

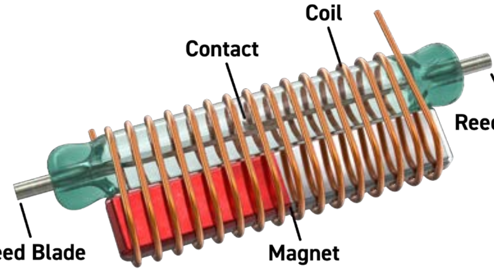


Fig. 1.11 - *Normally Closed Reed*

Not surprisingly normally closed relays are more difficult to manufacture and have higher magnetic interaction due to the bias magnet.

Changeover Reeds

Reed relays can be supplied with changeover switches - the reed switch has a normally closed contact (when no magnetic field is applied) and a normally open contact (which closes when the field is applied). The reed switch normally closed contact uses its blade as a spring bias with a nonferrous spacer to avoid completing a magnetic circuit. The coil field moves this blade to the normally open contact blade which does not have this spacer. As the reed relay switch blades transition between the two states for a brief period neither contact is closed - an important consideration in some applications.

The normally closed position relies on contact pressure being created by the spring bias of the blade. As well as being much harder to manufacture than normally open reed relays the two contacts, normally closed and normally open, can have quite different characteristics. Experience is generally that they have a slightly less stable contact resistance than their simpler normally open counterparts. Even so, they perform a useful function for many applications because unlike the use of two normally open reed relays used to create a changeover function they only need one coil drive and it is mechanically not possible to have both contacts closed at the same time.

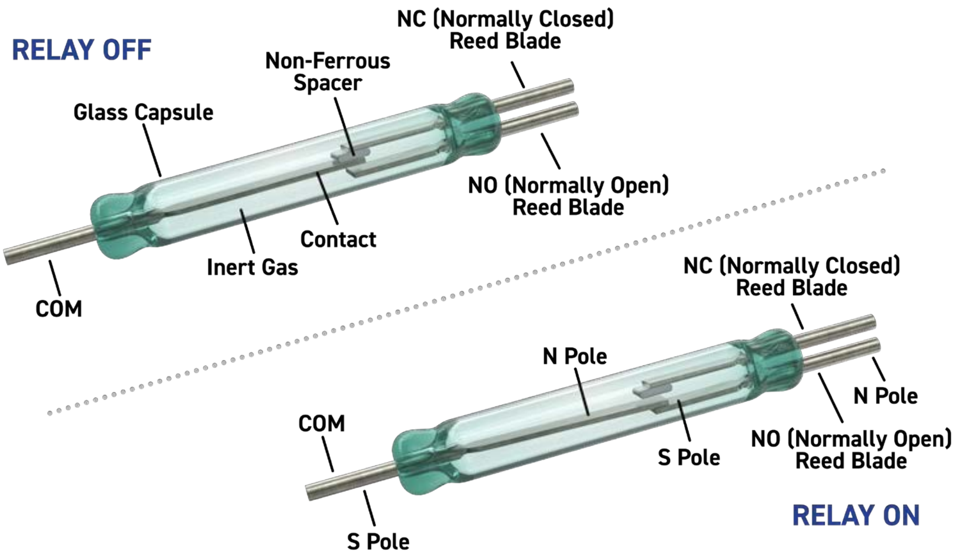


Fig. 1.12 - *Changeover Reed*

Two Pole Relays

Reed relays can also be supplied as 2 pole relays where two reed switches are contained in the same package and operated by a common coil drive.

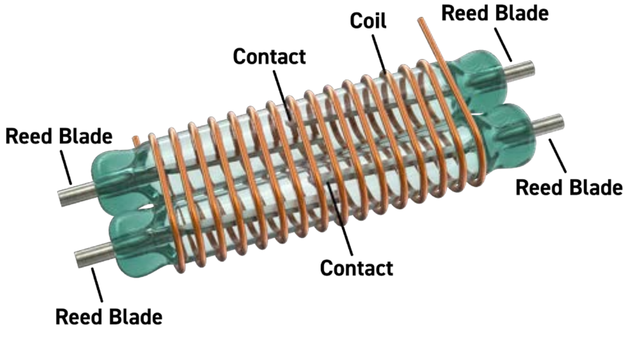


Fig. 1.13 - *Two Pole Relay*

It is important to remember that these relays do not have an interlock mechanism between the two reed switches, so it can't be assumed that the two poles operate at exactly the same time. There could be an operate time difference of between 50 - 250 μs between them. Failure in one (say a contact weld) will not stop the other contact from moving.

2 COMPARING REED RELAYS WITH OTHER RELAY TECHNOLOGIES

Electromechanical Relays (EMRs) 2.2

Solid State Relays 2.3

MEMs (Micro Electro-Mechanical Machines) 2.4

PIN Diode 2.5

Opto MOSFETS 2.6

Comparing Reed Relays with Other Relay Technologies

There are other relay technologies available to users with different characteristics to reed relays, some applications are best served by these alternatives and others are best served by reed relays. This section is intended to give some objective comparison information on the differences.

Electro-Mechanical Relays (EMRs)

Electro-Mechanical Relays are widely used in industry for switching functions and can often be the lowest cost relay solution available to users.

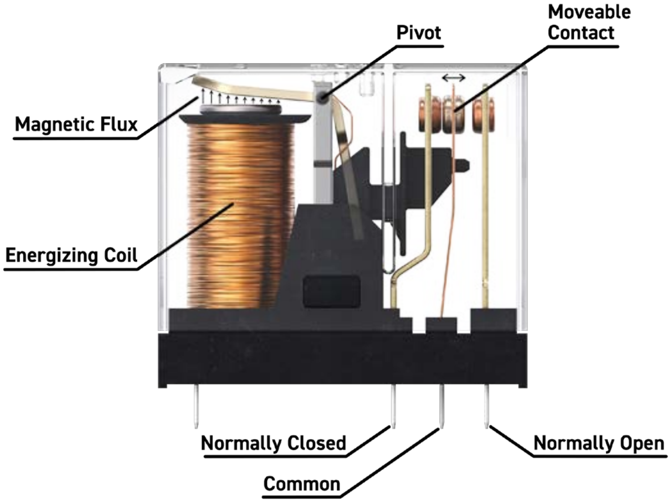


Fig. 2.1 - *Electro-Mechanical Relay*

There are some notable differences between reed relays and EMRs which users should be aware of:

- Reed relays generally exhibit much faster operation (typically between a factor of 5 and 10) than EMRs. The speed difference arises because the reed relay's moving parts are simpler, and reed contacts are lighter and travel less distance than those of an EMR
- Reed relays have hermetically sealed contacts which lead to more consistent switching characteristics at low signal levels and higher insulation values in the open condition. EMRs are often enclosed in plastic packages which give a certain amount of protection, but the contacts over time are exposed to external pollutants, emissions from the plastic body, and oxygen and sulfur ingress. Also, when switching in an environment where flammable vapors could be present (say an airport flight line), the use of EMRs could cause an explosion when hot switching
- Reed relays have longer mechanical life (under light load conditions) than EMRs, typically a factor of 10 to 100. The difference arises because of the lack of moving parts and the encapsulated contacts in reed relays compared to EMRs
- Reed relays require less power to operate the contacts than EMRs
- EMRs are designed to have a wiping action when the contacts close which helps to break small welds and self-clean their contacts. This does help lead to higher contact ratings but may also increase wear on the contact plating

- EMRs can have much higher current ratings than reed relays because they use larger contacts - reed relays are usually limited to carry currents of up to 3 A. Because of their larger contacts EMRs can also often better sustain current surges
- EMRs typically have a lower contact resistance than reed relays because they use larger contacts and can normally use materials of a lower resistivity than the nickel iron used in a reed switch capsule

Reed relays and EMRs both behave as excellent switches. The use of high-volume manufacturing methods often makes EMRs lower cost than reed relays but within achievable ratings, the reed relay has much better performance and longer life.

Solid-State Relays

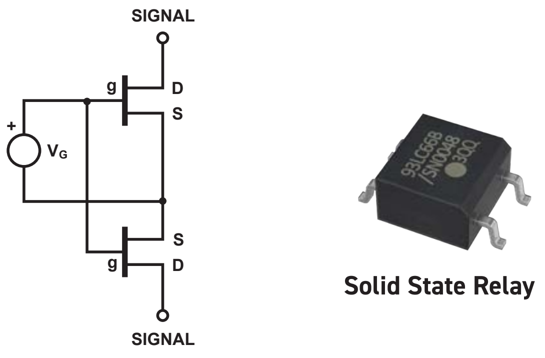


Fig. 2.2 - *Solid State Relay using Two N Channel MOSFETs with an Isolated Gate Drive*

The term solid-state relay refers to a class of switches based on semiconductor devices. There is a large variety of these switches available. Some, such as PIN diodes, are designed for RF applications but the most commonly found devices that compete with reed relays are based on FET switches. A solid-state FET switch uses two MOSFETs in series and an isolated gate driver to turn the relay on or off. There are some key differences compared to a reed relay:

- All solid-state relays have a leakage current associated with their semiconductor heritage, consequently they do not have as high an insulation resistance. The leakage current is also nonlinear. The on resistance can also be non-linear, varying with load current
- There is a compromise between capacitance and path resistance. Solid-state relays with low path resistance have a large capacitive load (sometimes measured in nF for high-capacity switches) which restricts bandwidth. As the capacitive load is decreased, the FET size must decrease, and the path resistance increases. The capacitance of a solid-state FET switch is considerably higher than a reed relay
- Reed relays are naturally isolated by the coil from the signal path, solid state relays are not. So, an isolated drive has to be incorporated into the relay
- Solid state relays can operate faster and more frequently than reed relays

- In theory, solid-state relays have unlimited life, provided that are operated within their specifications
- Solid state relays can have much higher power ratings

In general reed relays behave much more like perfect switches than solid state relays since they use mechanical contacts. In testing a DUT in a HALT (Highly Accelerated Life Testing) or HASS (Highly Accelerated Stress Screening) environment, solid-state relays are ideal as such tests are repeated over weeks and even months.

MEMS (Micro-Electro-Mechanical Systems)

MEMS switches are fabricated on silicon substrates where a three-dimensional structure is micro-machined (using semiconductor processing techniques) to create a relay switch contact. The contact can then be deflected either using a magnetic field or an electrostatic field. They have been used extensively in optical switching for decades, where the switch contact is a mirror that is deflected to route the laser signal down the appropriate path.

The first RF-MEMS devices were presented about 30 years ago and widely developed during the early 1990's. Owing to their superior performance in terms of RF performance, power consumption and cost in comparison with existent technologies (CMOS, PIN...), RF-MEMS was a very promising technology. Reliability issues started to become a serious burden in the early 2000's and this was initially a roadblock toward commercialization. That has changed in recent years with much interest in MEMS switching for 5G Telephony as well as Defense. The Microwaves & RF website noted in 2022 that with extensive research and advances in metal alloys, the promise of RF MEMS switching is now good regarding performance and reliability. The latest generation of RF MEMS switches are mostly capacitive-based devices.

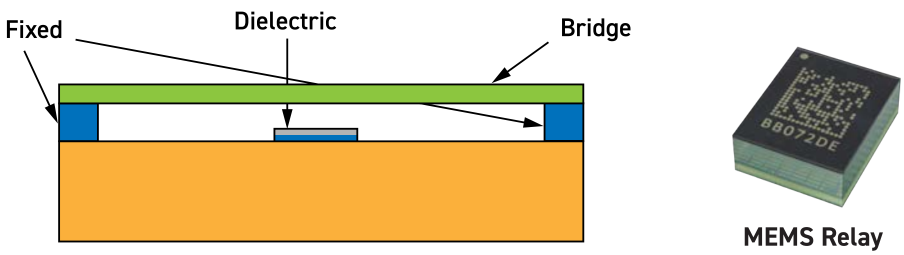


Fig. 2.3 - *"Bridge" Type Capacitive Switches*

Capacitive switches work using capacitive coupling and are well-suited to high-frequency RF applications. During operation, a force is applied to a beam suspended like a bridge across a substrate. When the beam is pulled down by a force (such as an electrostatic force), the beam contacts a dielectric on the substrate and the signal is terminated. A cross-section of a "bridge" type capacitive switch is shown. Prices are still higher than either Reed or EMR relays, but they will get lower in cost as volumes rise.

One of the biggest changes over the years is that the MEMs devices now have specs much better suited to Test & Measurement and are a competitive product to EMR and solid-state based solutions.

On average, MEMS based RF switches have much better performance, lifetime and operation time when compared to an EMR solution:

- 50 μs operate speed (compared to 3 ms)
- Greater than 3x10E9 or 3 billion lifetime operations (compared to 10 million operations), ie 300X more
- 25 W power cold switching (compared to 10 W)
- Up to 26 GHz bandwidth

The downsides of MEMs include low hot switching power - <5 mW (7 dBm) – Actually, it is recommended not to use MEMS RF switches in a hot switching application because of their very small contacts. In comparison to Reed Relays, the isolation spec is similar. In one test, our Engineering department saw 30 dB of isolation at 4 GHz.

Like reed relays, MEMS can be fabricated so the switch part is hermetically sealed (either in a ceramic or glass package or at a silicon level) which generally leads to consistent switching characteristics at low signal levels. However, MEMS switches have small contact areas and low operating forces which frequently lead to partial weld problems and very limited hot switch capacity.

The biggest advantage for MEMS relays is their small size, high-frequency capability, low operating power, long operational life, and fast response.

PIN Diode

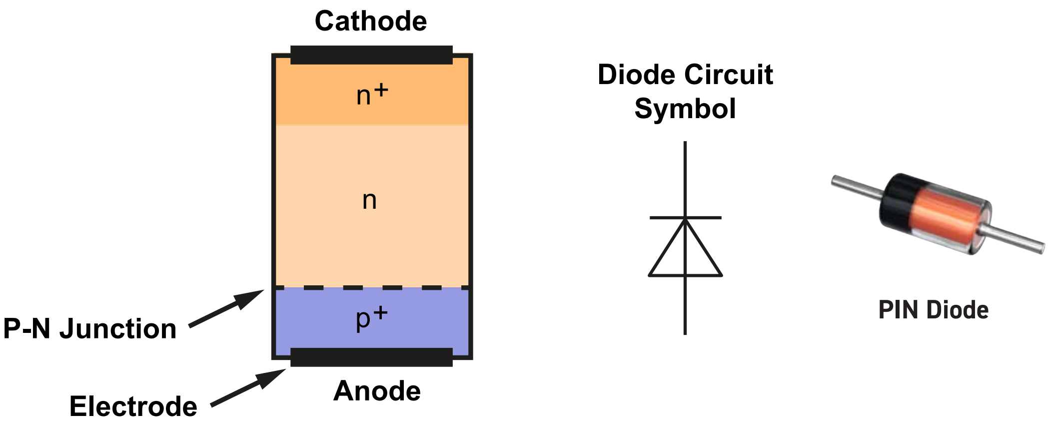


Fig. 2.4 - *PIN Diode Structure*

A PIN diode is a special type of diode made with P type, Intrinsic type and N type semiconductor material. The structure results in diodes with a relatively long carrier lifetime. If PIN diodes are forward biased and used at frequencies well above their specifications, they behave as resistors, the resistance being dependent on the forward current. This allows them to be used as switches for some RF and microwave applications, but at lower frequencies they become non-linear and behave as conventional diodes.

Opto MOSFETS

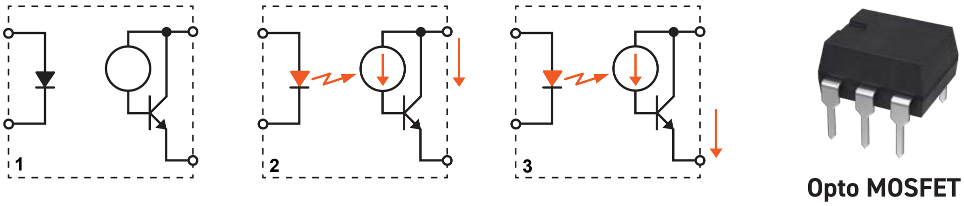


Fig. 2.5 - *Photocoupler Operation Sequence*

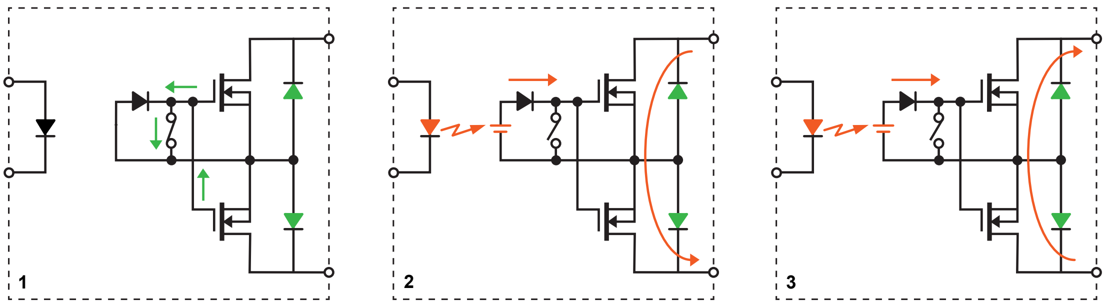


Fig. 2.6 - *Opto-coupled MOSFET Operation Sequence (Make-type Contact)*

Another type of Solid-State Relay is the Opto MOSFET (Optically Coupled MOSFET). In certain applications, they are popular replacements for reed relays. These devices are relatively slow in operation, but they feature very good voltage isolation because of the optical coupling. While the Opto MOSFET operation may seem similar to Photocouplers (also known as an optocoupler or opto-isolator), it is important to note that Photocouplers only conduct DC in the output, while the Opto MOSFET conducts AC and DC signals. Generally, the operating speed of photocouplers is rated in microseconds, while that of Opto MOSFETs is rated in milliseconds.

In the diagram here, you see the difference between a standard Photocoupler and an Opto MOSFET. On the Photocoupler, when the LED is lit, the photodiode (or phototransistor) reacts and a current flows from the collector to the base, forward biasing the transistor which then passes current from the Collector through the Emitter. In the case of the Opto MOSFET, when the LED is lit, the photovoltaic cells charge the gate capacitance to increase the gate-source voltage, turning on the MOSFETs in the case of a make-type contact.

3 PACKAGING REED RELAYS

Reed Relay Assembly 3.2

Packaging Reed Relays

This section talks about the assembly process of a reed relay and the important steps to ensure reliability. The reed switch and coil assembly must be assembled into a package so that users can conveniently handle and mount them onto printed circuits boards.

The package itself must be robust, but also has to allow the components to expand and contract without damage over long periods of time with constant operation of the coil causing temperature changes in the relay assembly. This can happen thousands of times per day.

Different manufacturers have different ways of approaching the packaging problem that they have developed and refined over many years of experience of constructing and testing the relays.

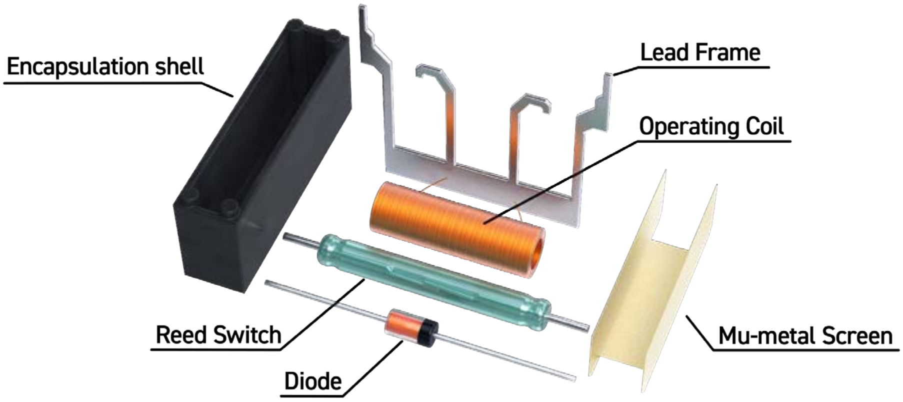


Fig. 3.1 - *Relay Components*

The most common construction methods are based on the use of plastic moldings to protect the reed relay assembly, and this is the method used in Pickering Electronics.

The relay components are first assembled onto a lead frame made from stamped or chemically etched metals. The lead frame has some similarities to the lead frames used in semiconductor manufacture. The lead frame is held together by a metal frame that is removed when the reed relay is finally assembled. The reed switch, coil and coil diode (if fitted) are securely attached to the lead frame by soldering or welding. Pickering Electronics use a welded construction to improve reliability of the reed relay assembly when soldering onto a PCB.

Great care has to be taken at this lead frame stage of assembly to guarantee the continued reliability of the components, in particular ensuring the reed switch blades attached to the lead frame are cropped without damaging the reed to glass seal and without moving the blades within their glass envelope.

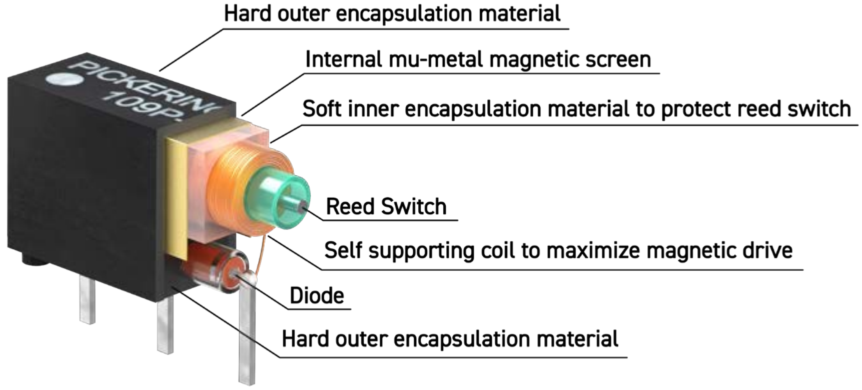
The lead frame and its components are then inserted into a hollow plastic molding which is then filled with appropriate encapsulation materials.

Pickering Electronics have refined the process of packaging to include several unique features that improve the reed relay performance:

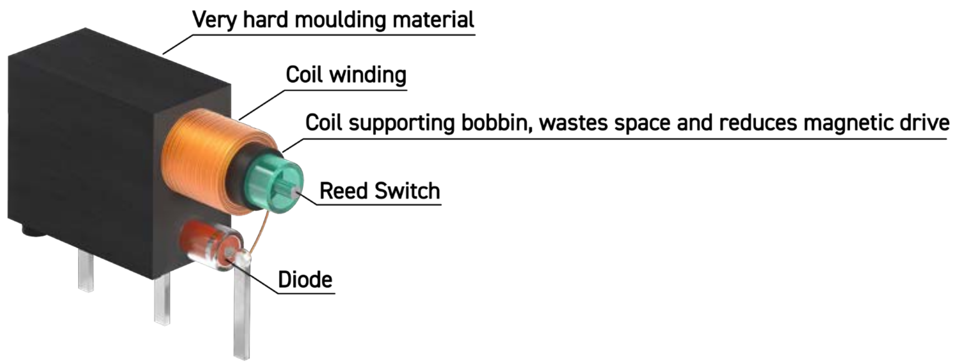
- The coil is wound without a former to reduce the number of parts and improve the efficiency of the coil. The use of a former to wind the coil on takes up space and reduces the magnetic field in the reed switch when the coil is energized

- The lead frame assembly methods have been refined to improve the reed relay reliability
- Inclusion of an internal mu-metal magnetic screen to prevent relay interaction when densely mounted on a PCB
- The use of ***SoftCenter***™ construction with a soft inner encapsulation material allowing for the movement of components under temperature cycling conditions without fear of coil or glass breakage

Unique Pickering *SoftCenter*™ Construction



Conventional Bobbin Construction



Pickering Former-less Coil Construction

Dispensing with the supporting bobbin increases the coil winding room by up to 50%, greatly improving magnetic efficiency.

Fig. 3.2 - *Former-less Coil and* ***SoftCenter*** *Construction*

This ***SoftCenter*** construction method lends itself well to packages for thru-hole plated relay reed relays and is uniquely also used by Pickering for surface mount relays.

To learn more about how reed relays are constructed watch this short video here:
pickeringrelay.com/how-are-reed-relays-constructed-video

4 MANUFACTURING TEST OF REED RELAYS

Pickering Relay Test Methods 4.2

The manufacturing tests performed on reed relays are critical to determine the quality and the life of the end product. A manufacturer of high-quality reed relays will test several key parameters to try to discover reed switches which have performance issues and to establish that the packaging of the switches into a relay with its actuation coil has not introduced any issues. Experience of reed relay manufacturers is that it is hard to achieve the high reliability levels that demanding users require without performing an extensive set of tests. Reed relay manufacture and reed switch quality vary sufficiently to demand that high quality needs 100% test of many parameters and quality control tests on other parameters.

The tests are designed to find issues that might impact reliability, not just tests that find faulty devices on a go/no go basis. Some typical issues that are tested for include:

- **Reed blade misalignment**, either from faulty switches or from disturbance to the switch during the manufacturing process
- Failed glass seals on reed switch
- Coil breakages
- Coil operating voltage failures
- Contact contamination

Different vendors have different methods for finding these faults based on their experience in manufacturing reed relays and from the failure returns and analysis they have historically gathered as part of a continuous process improvement.

Pickering Relays Test Methods

All the primary characteristics are tested on every relay prior to shipment as detailed in the following pages. For long and reliable life however, the most critical test performed is on contact resistance stability and variation. One specialist test, developed by Pickering, involves driving the relay with varying coil drive levels and measuring the changes in contact resistances that are seen as a consequence. This test will find minor contact misalignments or contamination allowing rejection of marginal parts that might otherwise become early life failures.

In addition to the contact stability test a full set of tests is also conducted on an ATE for every Pickering relay, the example below is for a simple single pole Form A type:

- **Adaptor continuity** - All ATE tests are performed using a Kelvin (four terminal) connection technique
- **Coil resistance**
- **Diode (if fitted)** - This is tested by measuring the voltage drop of the forward biased diode
- **Operate time** - Time taken from the application of the coil drive to when the contact is closed
- **Contact bounce period and numbers of bounces**
- **Release time** - Time taken from the removal of the coil drive to when the contact opens

- **Operate voltage** - The actual voltage that is required on the coil to operate the contact. This is determined by applying an increasing ramp voltage to the coil until the switch operates. For catalog items, the specification is less than 75% of the nominal coil voltage. This can be specified with other figures for special parts
- **Release voltage** - The actual voltage that the coil drive needs to fall to for the contact to open. This is determined by applying a decreasing ramp voltage to the coil until the switch opens. For catalog items, the specification is greater than 10% of the nominal coil voltage. This can be specified with other figures for special parts
- **Contact resistance** - This is the resistance of the complete switch path
- **Delta-Contact resistance** - This is the measure of small changes in contact resistance versus small changes in coil drive volts. Measurements are taken at increments just above the operate voltage point and the release voltage point. This test will detect problems with contact alignment, contamination or other factors that are often not found with a simple static contact resistance test
- **Insulation resistance** - This is measured between the switch and the coil connections and between open switch contacts. This is usually in excess of 10^{12} Ω
- **Isolation voltage** - The stand-off voltage between the switch terminals and the coil and between open switch contacts

Fig. 4.1 - *A Pickering ATE System for Testing Reed Relays*

5 UNDERSTANDING SPECIFICATIONS

Capacitance 5.2

Coil Voltage & Resistance 5.3

Contact Resistance 5.3

Insulation Resistance 5.3

Cold Switching 5.3

Hot Switching 5.3

Lifetime 5.4

Minimum Switch Capacity 5.4

Maximum Carry Current 5.4

Maximum Switch Current 5.5

Maximum Standoff Voltage 5.5

Maximum Switching Voltage 5.5

Maximum Switching Power 5.5

Operating Speed 5.6

Thermoelectric, or Thermal EMF 5.6

Many of the specifications mentioned in this chapter may be familiar to our readers, but here we will explain their impact on the operation of a reed relay. When implementing a reed relay in your designs, keep in mind the specifications of your PCB. There are many different reed relays on the market. Once you understand these definitions and their implications, you are ready to choose the correct reed relay for your application.

Capacitance

A Reed Switch has only a very small gap between the two metal contacts. Hence it is possible to form a significant capacitance across this contact gap. Usually, the capacitance in the range of pico farads is found between the two metals.

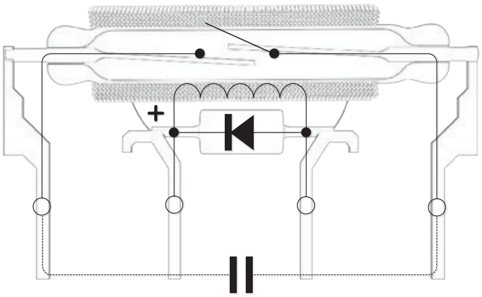


Fig. 5.1 - *Stray Capacitance in a Reed Switch*

The capacitance across an open switch introduces problems in high frequency circuits. At high frequency, a capacitor appears to be short circuited. Hence the stray capacitance makes the Reed Switch appear to be closed at high frequencies even if it is open. For high frequency designs, one should select a Reed Switch with minimum open switch capacitance.

A Reed switch in its closed state introduces not only series resistance to the circuit, but also capacitance to the relay coil. This capacitance can be around 2.5 pF and can introduce certain problems in both high frequency and low frequency circuits. Hence one should select a Reed Switch with minimum contact capacitance.

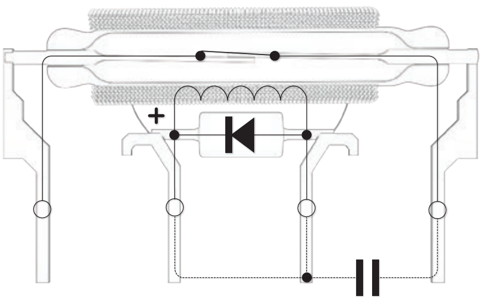


Fig. 5.2 - *Equivalent Capacitance*

Both capacitance specs can be found in the data sheet for your selected relay as seen here.

Device Type	Type Number	Coil (V)	Coil resistance	Max. contact resistance (initial)	Insulation resistance (minimum at 25 °C) (see Note4)		Capacitance (typical) (see Note2)	
					Switch to coil	Across switch	Closed switch to coil	Across open switch
1 Form A Switch No. 1 Package Type 1	98-1-A-5/1D	5	1600 Ω	0.15 Ω	10^{12} Ω	10^{12} Ω	2.5 pF	0.1 pF
	98-1-A-12/1D	12	6000 Ω					
	98-1-A-24/1D	24	6000 Ω					

Fig. 5.3 - *Capacitances Quoted in Data Sheet*

Coil Voltage & Resistance

All the coils for a given reed switch must have a certain number of Ampere Turns, as previously noted in Section I, to develop adequate magnetic field to close the relay contacts. Pickering sells catalog relays that can be driven at 3.0, 5.0, 12.0 and 24.0 V (custom voltage levels can also be quoted). Higher voltages usually mean thinner coil wire to balance the number of ampere turns needed and the amount of current that standard relay driver circuits can supply. More information on this subject is in Section 6.

Contact Resistance

The Contact Resistance is a measurement of the resistance through the closed reed switch (and the lead frame). This is usually defined in datasheets as "Maximum Contact Resistance (Initial)". This is the manufacturer's specification when you initially use the relay in your application. As reed relays are mechanical, they will eventually degrade through mechanical wear - the resistance is dependent upon the number of times the relay is exercised as well as the signals being switched and whether they are hot or cold switched. With the exception of a catastrophic failure, the highest acceptable contact resistance will depend on your applications and how much resistance they can bear.

Insulation Resistance

This specification describes the resistance between the reed contacts in the open position. Ideally switches should have infinite insulation resistance, but the Reed Switch usually has a finite but very high Insulation resistance of the order of 10^{10} Ω for changeover switches to 10^{13} or 10^{14} Ω for other switches.

Cold Switching

Cold switching occurs whenever a relay contact is opened or closed with no signal (current and voltage) present. This method prevents arcing as the contacts move apart or close as and extends the life of the switch. In many cases, a reed switch has a higher cold switch capacity compared to hot switching.

Hot Switching

Hot switching occurs whenever a relay contact is opened or closed with a signal (current and voltage) present. As the contacts move apart or close an arc can be created which transfers material from one contact to another, or simply redistributes the material. As the contact plating is damaged the resistance will eventually start to rise until the relay is no longer fit for the intended application.

For reed relays, hot switching tests are always conducted into resistive loads. The hot switch capacity of a reed relay is typically quoted at a current/voltage that results in the number of operations that the relay will support, typically around 10 million operations. The data sheet specifies a maximum hot switch current (the limiting factor at low voltages), a maximum hot switch voltage (limiting factor at low current) and a maximum power (from the product of the open contact voltage and the closed contact current).

To learn more about hot and cold switching watch this short video here:
pickeringrelay.com/relay-switching-methods-video

Lifetime

The lifetime of reed relays is critically dependent on the load conditions the reed switch encounters. For reed relays which are instrument grade the mechanical lifetime is much greater than 1 billion operations - they are mechanically simple devices that rely purely on the deflection of a blade to operate and there are consequently few wear out mechanisms.

The blade contact area does still wear as the blades are opened and closed. If the signal load when the blade closes or opens is low then the degradation is very slow, but as the load increases and hot switching (interruption or closure of a live signal carrying significant current or voltage) occurs, higher temperatures are generated at the contact interface, and this makes the materials more prone to wear. DC signals can also result in the migration of metal from one contact to another and without regular polarity reversal eventually the underlying contact materials are exposed, resulting in poorer conduction characteristics. Hot switching can also create a temporary plasma in the contact area with high local temperatures, and rapid operation of a relay under load can start to raise the contacts' temperature to an extent where premature wear out can occur.

The life of an instrument grade reed relay can vary by three orders of magnitude according to the load conditions, perhaps 5 billion operations under no or light load to 5 million operations at a heavy load.

Minimum Switch Capacity

Some types of relay have a minimum switch capacity - if the relay is closed on a very low-level signal (current or voltage) oxide or debris on the relay contacts can remain at the interface and cause a higher than expected resistance, or even an open circuit. This tends not to be the case with reed relays because the precious metal contacts are sealed in a hermetic glass envelope containing an inert gas. Minimum switch capacity tends to be a characteristic of higher power mechanical (EMR) relays.

Maximum Carry Current

This is the maximum current that the reed relay can support through its closed contacts without long term damage. The life of the relay should not be impacted when operating within this specification, although some reed relays may also have a higher pulse current rating which can be applied to the relay without damage.

The carry current is determined primarily by the contact resistance of the relay and the heat sinking to the environment. As the current increases the temperature of the reed blades increases until it reaches a temperature where the material is no longer ferromagnetic (Curie Temperature). Once that temperature is reached the relay contacts may open since the blades no longer respond to the magnetic field. The blade temperature is clearly dependent upon the current and relay path resistance - the normal assumption is that this is a square law (with current) relationship. In reality the temperature rise is significantly more than a square law since the metallic resistance also increases with temperature, the magnetic field drops with temperature because of coil resistance rise and the mechanical properties of the blade can change. Consequently, like all relays, exceeding the rating can result in a type of thermal runaway.

The packaging of the reed switch has a significant impact on the temperature rise as a lead frame tends to conduct heat to the outside world while the plastic encapsulation materials insulate it. The packaged reed relay will ALWAYS have a lower current rating than that of the reed switch because manufacturers quote the rating of the reed switch in isolation (no coil, no plastic packaging). The coil power will also add to the heating effect. Consequently Pickering Electronics always de-rates their reed relay specifications to ensure that the relay switch remains within its design limits.

There is also another subtle effect that occurs as the carry current increases - the signal creates its own magnetic field that twists the blades and therefore can modulate the contact resistance. The blade twisting may start to cause a contact resistance rise as the blade contact area reduces or changes.

Care must be taken not to exceed the relay carry current ratings and pulse ratings should take account of the square law relationship between current and temperature.

It becomes difficult to manufacture reed relays with a continuous carry current of greater than 3 A because the contact area has to be increased and that tends to make the blades stiffer and require a higher magnetic field strength to operate them.

Maximum Switch Current

This specification defines the maximum hot-switch current that a reed relay can safely be exposed to. Keep in mind that this current is bound by the voltage level; and especially the maximum power specification. Also, continual hot switching at maximum rated current will significantly reduce the life of the relay. See the Power definition for more details.

Maximum Standoff Voltage

The Standoff voltage is also defined as the dielectric strength or breakdown voltage. No arcing-over will occur at this voltage that is across the relay contacts. This has nothing to do with the voltage that can be safely switched. See Maximum Switching Voltage.

Maximum Switching Voltage

This voltage is the maximum that a specific reed relay can safely switch with no damage to the component. This is also dependent on the maximum current to be switched. See the Power definition for more details.

Maximum Switching Power

The Maximum Power specification is the amount of energy that a reed switch can withstand without subsequent damage. In the case of a reed relay, one must look closely at the maximum voltage and current specs of your applications to determine the signal that can be safely handled. Both specifications are exclusive of each other. If you have a reed relay that has a max voltage of 150 V and a max current of 1 A, but has a power rating of 20 W, it means that you can switch a signal of 150 V at a current flow such that you are switching 20 W of power – in this case, approximately 130 mA. So, you can switch any signal that has a voltage and current with a product equal to 20 W.

Operating Speed

The Operate Time is the time from when the relay coil is energized or de-energized to when the contact reaches a stable position. For a normally open contact, when the coil is energized the current, and therefore the magnetic field, in the coil rises and the blades start to move closer together until they make contact. The contacts may impact each other sufficiently rapidly that there is bounce, where for a short duration the contacts are intermittently opened and closed. The operate time should be the time from when the relay coil was energized until the contacts are stably closed.

If the coil is driven from a higher than specified coil voltage the closing speed of the relay will be faster, however once the contacts make, there may be more contact bounce as they meet with greater force. Overdriving the coil can also increase the release time since the magnetic field takes longer to collapse to the point where the contacts start to open.

For a normally open Form A (SPST) contact the release time is the time from when the coil is de-energized to when the contact is open. This operate time can be dependent on how the reed relay is driven and the presence of a protection diode on the coil that will increase the release time. Typically, the release time is around one half the operate time.

Thermoelectric, or Thermal EMF

The cause of thermoelectric voltages is often misunderstood by users, and often misrepresented in articles and on the internet. The effect of thermoelectric EMF's is to generate a small voltage (measured in microvolts) across the relay terminals when the relay is closed.

Fig. 5.4 - *Thermal EMF Across a Conductor*

A thermal EMF is a naturally occurring phenomenon that affects all conducting materials. When a conductor has a thermal gradient across it, there will be more free electrons at the cooler end than the hotter end of the conductor. The number of free electrons is dependent on the material type and creates a voltage across the conductor, formally known as the Seebeck Effect. This voltage is dependent on the temperature difference and the materials that make up the conductor. Although these voltages are in the micro-Volt range, in applications where very low signal levels are present, or very accurate voltage measurements are critical, they can add in unacceptable errors and minimizing these effects can be important.

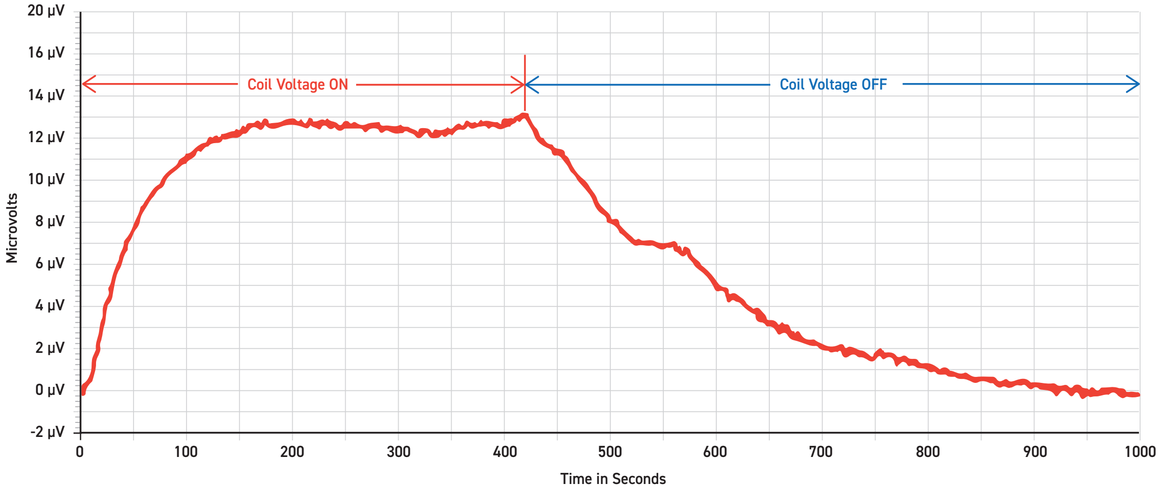


Fig. 5.5 - *An Example of the Seebeck Effect*

An example of the Seebeck effect can be seen in Fig. 5.5. With voltage applied to the coil, the reed switch begins to heat up creating a thermal EMF of 13 µV. It should be noted that this thermal EMF takes several minutes to reach its peak, so short duty cycles on a relay will exhibit less thermal EMF.

Thermal EMF is not just a result from coil voltage. Temperature gradients can occur across a PCB or throughout a piece of equipment. Some components generate heat to dissipate power and cooling fans can create relatively large thermal difference in small areas, generating thermal EMFs across PCB tracks and other components.

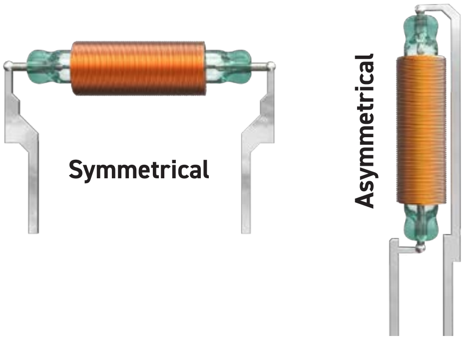


Fig. 5.6 - *Reed Switch Alignment*

For a reed switch, there are many factors that can effect thermal EMF. These include the material used in the reed switch and lead frame materials, symmetry of the pin construction and the heating effects of the drive coil. When the relay is mounted vertically (Asymmetrical), the thermal EMF is higher than horizontal mounting (Symmetrical). Also, reed relays with higher coil resistances will heat the reed switch less than lower resistance coils and therefore exhibit improved thermal EMF characteristics.

Thermal EMF can also be greatly reduced by connecting the two switches of a two-pole relay in a differential configuration as shown in the diagram. The thermal EMF in one switch is the opposite polarity to that generated in the other switch and the two tend to cancel out, resulting in a very low overall thermal EMF.

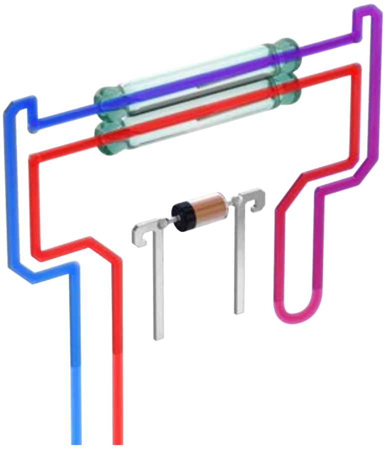


Fig. 5.7 - *Differential Configuration of a Two-pole Relay*

Users can also degrade the performance by how they use the relay. When mounted on a PCB, if there is a temperature profile across it then that will generate an additional thermal EMF. Relay manufacturers usually assume that the thermal EMF is zero when the relay is first closed since up to that point no heat source exists inside the relay body. However, a temperature profile across the PCB (caused by the presence of other heat sources or forced air cooling) will create a thermal EMF.

Reed relays that have good Thermal EMF performance are typically designed to be as symmetric in design as possible and to use highly efficient coils to avoid heating the reed switch. Typically though, this results in a physically larger relay.

Two pole relay designs often quote the Differential Thermal EMF, this is the voltage generated between the two switches (usually) in a single package. Assuming the relay design is reasonably symmetrical, to a first order the voltage in one switch is the same as the other, so the differential voltage can be much smaller for the relay. Differential and single ended Thermoelectric EMF numbers should not be directly compared or confused with each other.

To further understand thermal EMFs in reed relays watch this short video here:
pickeringrelay.com/understanding-thermal-emfs-in-reed-relays

6 CHOOSING A REED RELAY

Signal Voltage, Current and Power Specification 6.2

SMD or Thru-Hole Mounting 6.2

Diode or No Diode 6.3

Limiting the Back EMF on Release Time 6.3

Coil Voltage 6.5

Magnetic Screen 6.6

Electrostatically Screened Relays 6.6

RF Relays 6.6

Signal Voltage, Current and Power Specification

All reed relays have specified maximum operating voltage and current ratings that need to be adhered to if the reed relay is to have a long service life. It important to ascertain whether the relay application will result in any hot switching events (see "Avoiding Failure Modes" section), as this can have a substantial impact on the cost and size of the relay used. Care must be taken when evaluating the operating characteristics of the relay as very often hot switching events can occur inadvertently due to capacitive or inductive discharge of connected circuit components when the relay is operated.

If hot switching is likely to occur the most common mistake is to ignore the maximum power rating of the reed relay - the fact a particular relay may be capable of 100 V and 1 A does not mean it can hot switch a signal with these extremes of value. A 10 W reed relay for example will only hot switch a 100 V, 100 mA signal reliably.

If hot switching is not expected then the user can select a relay based purely on the maximum carry current rating and the maximum rated voltage across the contacts.

SMD or Thru-Hole Mounting

Users often have a choice of using thru-hole components or surface mount packages for reed relays.

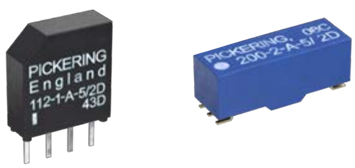


Fig. 6.1 - *Mounting Options*

With other component types the choice may be driven in part by the density that can be achieved on a PCB. However this is not always the case with reed relays as they are not particularly small devices by modern standards due to the size and complexity of their internal components.

Manufacturing processes may dictate the preferential use of SMD components, in which case there are solutions which are available for most applications. However, the choice is more difficult when the relay is considered to be a potential replaceable service item. The relay could be considered to be a service item if it is frequently exposed to hot switching events which might wear out the contact materials or where (as is the case in ATE systems) connection to faulty devices or even programming errors can result in the relay being damaged.

Removing surface mounted components is an intrusive procedure - even when using specialist de-soldering tools, components adjacent to the faulty relay are also subject to heating, solder reflow and stress. In these circumstances thru-hole components are much easier to manage and require no specialist de-soldering tools or high operator skills. It is more likely the item can be serviced locally, and it is less likely to cause damage elsewhere in the assembly. Of course, the relay choice is normally driven by user manufacturing preferences and the component choices such as footprint area, relay ratings and relay height. However, serviceability should also be a consideration.

Diode or No Diode

Reed relays often have an option to include an internal protection diode (in comparison, this is never the case with EMRs).

This diode is usually connected across the relay coil and can be either mounted externally or more commonly integrated within the relay casing. Some relay driver ICs may also include an internal diode so another will not be necessary.

A reed relay operating coil usually comprises many hundreds or even thousands of turns of wire wound around a reed switch (effectively a ferro-magnetic core). This operating coil effectively forms an inductor. When a current flows through this coil, a magnetic field is generated which operates the reed switch. The problem arises when the current through this inductive coil is switched off. This will usually be performed by a semiconductor switch of some sort. The collapsing magnetic field will produce a substantial voltage transient in its effort to disperse the stored energy in the inductor and oppose the sudden change of current flow. This voltage transient can sometimes be equal to many hundreds of volts and is commonly referred to as a Back EMF. If not suppressed, this will be equal to –L * di/dt where L is the inductance of the coil in Henrys and di/dt is the rate of change of current. If the current is reduced quickly, di/dt will be a high figure, resulting in a high level of Back EMF. If the current is reduced slowly, di/dt will be smaller resulting in a lower Back EMF figure, but this method can create a longer relay release delay time which may not be desirable.

The diagram below shows a common method of driving a relay coil using an open collector NPN driver transistor.

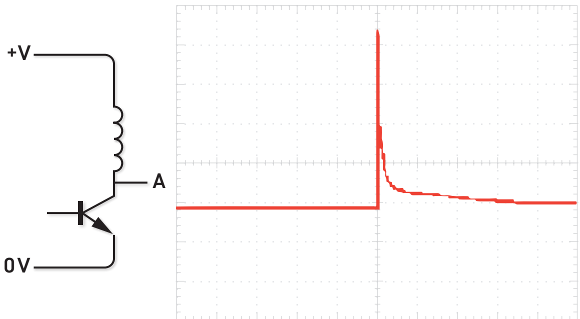


Fig. 6.2 - *Driving a Relay Coil using an Open Collector NPN Transistor*

When the transistor is turned on, it will pull Point A to near 0 V turning on the relay. When the transistor is turned off, the stored energy in the inductor will generate a Back EMF pulse. This pulse will be of the opposite voltage polarity to that which was used to energize the coil. You will see from the oscilloscope display that there is a very large voltage spike which can be hundreds of volts more positive than the supply rail.

If not limited, this voltage spike can quite easily damage the semiconductor driver and interfere with the controlling electronics due to the electrical noise generated.

Limiting the Back EMF and the Effect on Release Time

The most usual method of limiting this Back EMF voltage to protect the driver is by using a diode connected across the coil as shown in this circuit. When the driver output at A rises above the coil supply voltage, the diode conducts and clamps the Back EMF voltage to the Forward Voltage figure of the diode (Vf = 0.7 V for a typical silicon diode) so the driver will only be subjected to the supply line voltage plus 0.7 V. Ideally, this diode should be fitted inside the relay or very close to the coil terminals to avoid the risk of RFI as this current is carried along printed circuit tracks.

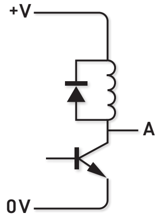


Fig. 6.3 - *Limiting Back EMF*

A consequence of using a simple diode in this way is to increase the opening or release time of the relay as the magnetic field will be retained until the energy is dissipated, as limited by the coil resistance. The release time of a reed relay is quite fast, so this is rarely an issue. But in some instances, a faster release time is desired.

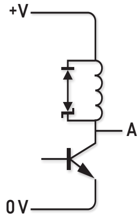


Fig. 6.4 - *Adding a Zener Diode*

Using the circuit shown with a Zener diode in series with a normal diode will achieve this by clamping the Back EMF to the Zener voltage plus 0.7 V. As an example, a small reed relay might have a typical release time of around 120 µs with a simple diode clamp and this could fall to perhaps 50 µs if a 6.2 V Zener is added in this way.

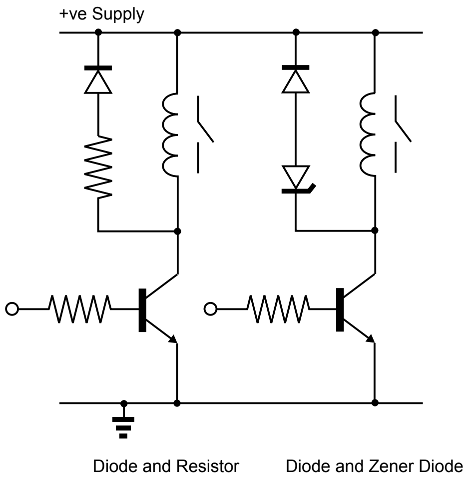


Fig. 6.5 - *Clamping*

It is also possible to modify the clamp arrangement to speed up the release time of the relay. The faster the coil field is discharged the sooner the relay contacts will start to move. In some applications (for example protection of a device from an externally detected surge, a specific example being reverse power protection on signal generators) the time to open a contact is crucially important to protect devices. In this case a modified protection that either clamps using a resistor in series with the diode or clamps to a voltage higher than the supply can considerably speed up the device opening time.

The impact on release times will vary between reed switches, but releases in the region of 40 µs are achievable on some types of reed relay.

Coil Voltage

Reed relays are supplied with a wide variety of coil voltage options. For logic driving, 3.3 V and 5 V coil drives are the preferred choice since these voltages are directly compatible with common logic families. However, all the coils for a given reed switch must have a certain number of Ampere Turns as previously noted, so as coil voltage is dropped the coil current required is increased. For some applications high coil currents are undesirable - they might lead to power loss in power supplies (low voltage supplies are commonly less efficient than higher voltage supplies), losses on PCB traces (also called tracks) and the creation of larger EMC transients. This is especially evident in applications where many relays need to be controlled simultaneously.

LED drivers can directly support either 5 V or 12 V coils, open collector drivers can support even higher voltages. However, as coil voltage increases the wire used to create the relay coil becomes finer and harder to wind without breakages. Ultimately this limits the highest voltage coils that can be offered.

For many applications 5 V coils are considered a good compromise.

One factor often ignored by designers is the impact of temperature on coil current. Data sheets for relays will commonly show a pickup voltage and release voltage and this is usually at a significantly lower voltage than the nominal coil voltage required. There are four principal reasons for this margin:

- As temperature rises the coil resistance rises (by 0.39% per °C), the voltages are measured at more typical temperatures (25 °C), so by the time the maximum rated temperature of the relay is reached the coil current can have dropped very significantly
- The coil drivers will have an output resistance which may be significant
- Actual power supply voltage can vary both from product to product and across a PCB used to distribute it
- External magnetic fields might alter the coil current needed to achieve the required field strength

Consequently, reed relays should have a reasonable operating margin to ensure reliable operation in all conditions. The lowest voltage relay coils are the most vulnerable to this type of problem.

Magnetic Screen

A magnetic screen is usually added to a reed relay to serve three purposes:

- Reduce the effect of **magnetic interaction** between closely packed reed relays. The lack of a magnetic screen is of relatively little consequence from this perspective if the relay is used on its own with no other close relays or other magnetic field sources that might affect the operation of the relay contacts. But if relays are to be closely packed together then it is essential that a relay should be chosen with an integrated magnetic shield
- Reduce injection of noise into the signal path by external magnetic fields
- Increase the magnetic efficiency resulting in a reduction of the coil power needed

Refer to **Section 1** (Protection against Magnetic Fields) for more information on magnetic screens and their advantages.

Electrostatically Screened Relays

A reed switch is enclosed by a coil but is otherwise open to stray signal pick up from adjacent circuits. With a screened relay a foil layer is added between the coil and the glass body of the reed switch and a contact to the foil is brought out to the outside of the package. If this screen is grounded it can reduce the level of interference that is picked up on the relay signal lines from either the coil itself or from other external sources. Coil pick up can be minimized by other measures, such as making sure that the coil is well decoupled to ground.

Fig. 6.6 - *Electrostatically Screened Relay*

It should also be remembered that an electrostatic screen does not provide protection against an external magnetic field inducing signals into the signal path like the magnetic screen described earlier.

RF Relays

RF relays are designed to operate in defined transmission line impedance, usually 50 or 75 Ω. In some ways reed relays seem almost perfect for such applications since the glass tube can be wrapped in a conductive tube and the two ends provided as a connection to ground - the net effect looks rather like a length of coaxial cable. Provided the glass and blade dimensions are correct they form a coaxial transmission line.

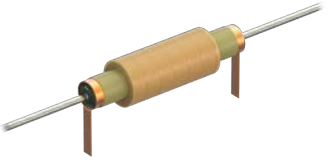


Fig. 6.7 - *RF Relay*

In practice there are potentially problems as reed changeover switches tend to have very poor isolation between the contacts because of their small size (EMR solutions can use a much bigger contact separation and intermediate ground planes to reduce interaction) and the better performing SPST (Form A) relays cannot be used to assemble switching networks without leaving un-terminated transmission line stubs which will limit the bandwidth of the system to be considerably less than the bandwidth of the switch.

RF relay applications must be designed with care since the issues are primarily about the overall system performance and not just the relay performance. If an application simply requires the disconnection of the signal path and not provide alternative routing (for example for a protection system) then reed relays can be a very good choice because of their fast response.

7 PLACING AND DRIVING A RELAY COIL

Magnetic Field Interaction 7.2

Transistor Driving 7.2

LED Driving 7.2

Logic Driving 7.3

Magnetic Field Interaction

Reed switches are operated by magnetic fields provided by coils and occasionally also bias magnets within the reed relay assembly.

Refer to **Section 1** (Protection against Magnetic Fields) for more information on magnetic screens and their advantages.

Transistor Driving

A common method of driving reed relays is to use either a bipolar transistor or an FET to directly drive the coil using an open collector/source. The coil can have one end connected directly to ground or to a power supply – the most common configuration is to connect to a power supply so that a grounded transistor or FET can be used to activate the relay.

When driving with a transistor, a diode has to be fitted to limit the Back EMF voltage spikes generated when the coil drive voltage goes open circuit, as detailed in **Section 6**.

LED Driving

One consequence of the use of LEDs in modern systems has been the development of a large number of different LED drivers which can make excellent alternatives for driving reed relays. LED drivers are available from a number of companies including Macrobloc and Texas Instruments.

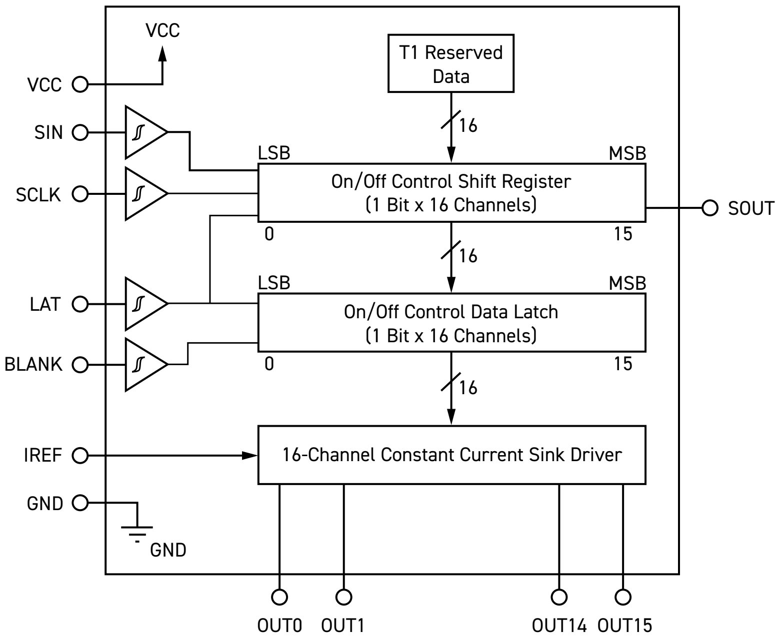


Fig. 7.1 - *LED Driver Example*
(Credit: Macroblock)

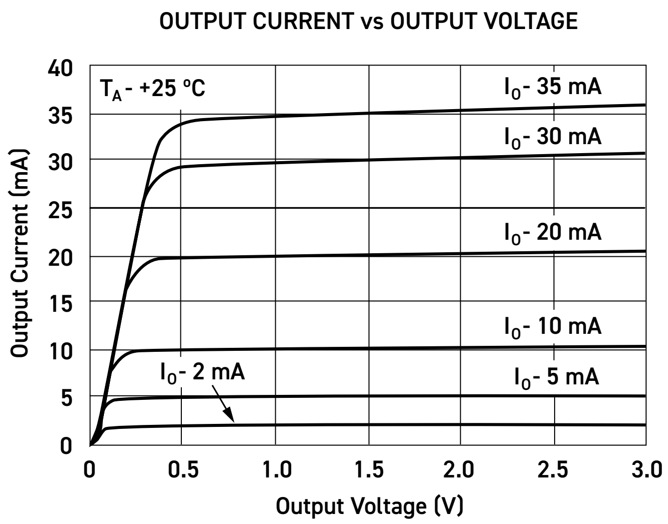


Fig. 7.2 - *LED Driver Example*
(Credit: Texas Instruments)

LED drivers are typically serial input devices with 16 outputs each of which is a current source limited by (typically) a single resistor. Using these outputs to drive reed relays is simply a matter of setting the current limit to (say) 50% more than that required by the reed relay and connecting one end of the reed coil to the voltage supply and the other to the LED driver output. LED drivers are typically rated to 17 V on their outputs so they can interface with most coil options. A back EMF protection diode should be used as described in the previous section.

A useful feature of LED drivers is that in the event of the relay coil or its connections becoming shorted, the resultant current flowing is limited. Many LED drivers also include diagnostic modes where open circuit loads (in this case relay coils) can be detected and reported via the serial control interface.

Logic Driving

Standard logic families can be used to drive 5 V or 3.3 V reed relays directly. The output of these logic families (excluding open collector or drain types) uses CMOS drivers which ensure that there is a path either to ground or logic supply at all times. When they are used to drive relay coils the reed relay does not need a built-in diode since no back EMF spike is generated. Because the drive is connected to either ground or supply in turn with no back EMF, the release time for the relay may be longer than when driven by an LED driver or an open collector drive.

Pickering Electronics reed relays designed for 3.3 V operation are designed with a 3 V operating criteria since the voltage drop in the driver can be a significant issue. Designing the relays around 3 V ensures good operation even when driven by 3.3 V logic with a significant voltage drop in the drive circuit or the power supply.

8 AVOIDING FAILURE MODES

Hot Switching 8.2
Soft and Hard Weld Failures 8.2
Resistive Loads 8.3
Capacitive Loads 8.3
Inductive Loads 8.4

Avoiding Failure Modes

Now that you have analyzed the test specifications and made your choice of relays, you still must be cautious concerning your test system configuration for possible issues with DUT design and even test fixturing and cabling. Here are the issues to keep in mind in your test strategy.

Hot Switching

As discussed in Section 5, Hot switching occurs whenever a relay contact is opened or closed with a signal (current and voltage) present. As the contacts move apart or close an arc can be created which transfers material from one contact to another, or simply redistributes the material. As the contact plating is damaged the resistance will eventually start to rise until the relay is no longer fit for the intended application.

Fig. 8.1 - *Hot Switching Damage*

For reed relays, hot switching tests are always conducted into resistive loads. The hot switch capacity of a reed relay is typically quoted at a current/voltage that results in the number of operations that the relay will support, typically around 10 million operations. The data sheet specifies a hot switch current (the limiting factor at low voltages), a hot switch voltage (limiting factor at low current) and a power (from the product of the open contact voltage and the closed contact current).

To learn more about hot and cold switching watch this short video here:
pickeringrelay.com/relay-switching-methods-video

Soft and Hard Weld Failures

Operation of reed relays (or EMRs) under high load conditions causes one of the most common failure mechanisms for relays – a failure where the contacts are welded together. By convention these welds are classified as being either soft or hard failures. In the event of hard failures, the contacts tend to be welded together and nothing will separate them. This is an easy fault to identify. Soft failures occur where the contacts stick but eventually come apart without any additional assistance. The failure is caused by small areas on the contacts welding together, but the weld area is sufficiently small that the reed blades will separate depending on how hard the weld is.

In either case, the impact on the user is that the switching function of the relay is impaired, and this is likely to have an adverse impact on the user application. So, in either case the relay will require replacing since the defect is unlikely to improve with time. The cause of the weld will also need to be investigated and corrected.

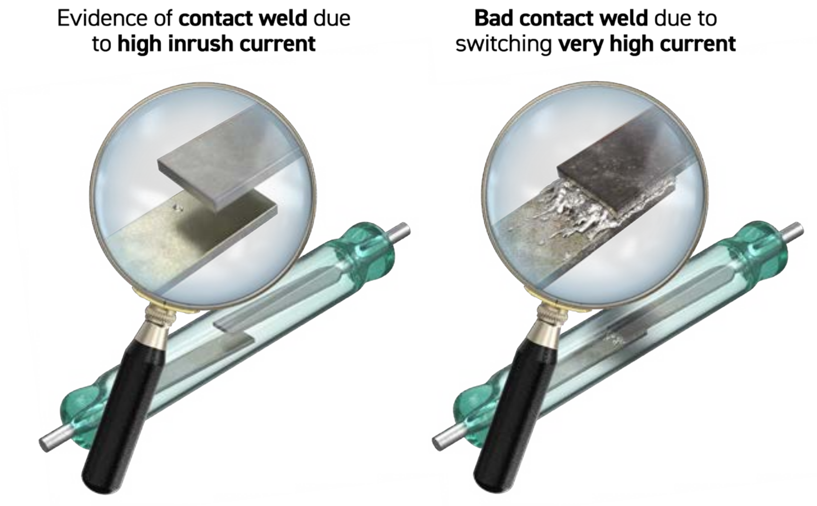


Fig. 8.2 - *Contact Welds*

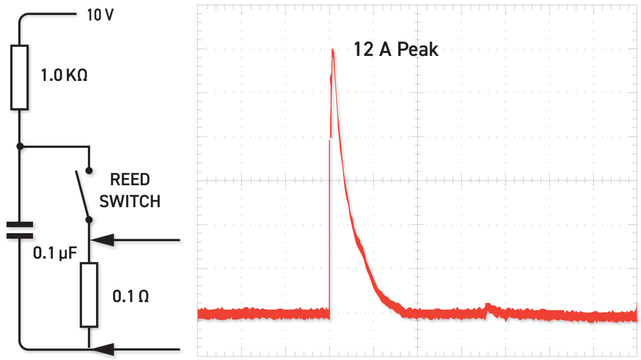
Resistive Loads

Reed relays switching purely resistive loads are very reliable as long as the maximum switch specifications are not exceeded. As detailed in **Section 5**, cold switching is always preferable to prolong relay life, but if hot switching is necessary the relay life will inevitably be reduced from, for example, 10^9 operations down to 10^6 in the case of continuously switching the maximum rated current.

Where high voltages (>100 V) are required to be switched, a current limiting resistor in series with the switch may be required in order to avoid damage to the relay contacts in the event that the device under test develops a short circuit. The value of the limiting resistor should be selected so that the short circuit current does not exceed the maximum current specification of the relay, and its voltage rating must be at least equal to the applied voltage.

Capacitive Loads

Capacitive loads can be extremely destructive to all types of relays if the relay is closed with voltage applied to one terminal and a capacitive load connected to the other terminal. When the contact closes the voltage appears across the capacitive load and a high current surge is created which may exceed the current rating of the switch and damage or even weld the contacts. The value and duration of the surge is limited by resistances, inductance in connections and the value of the capacitive load.



Typical current inrush when discharging a 0.1 μF capacitor at 10 V through a Reed Switch and 0.1 Ω resistor.

Fig. 8.3 - *Current Inrush*

Capacitive loads are created not just by loads with capacitors attached but also by very long cable runs. Cabling of a few meters in length is unlikely to create an issue, but cabling measured in many 10's of meters in a system can be an issue. Cable forms might typically have a capacitance of the order of 100 pF per meter.

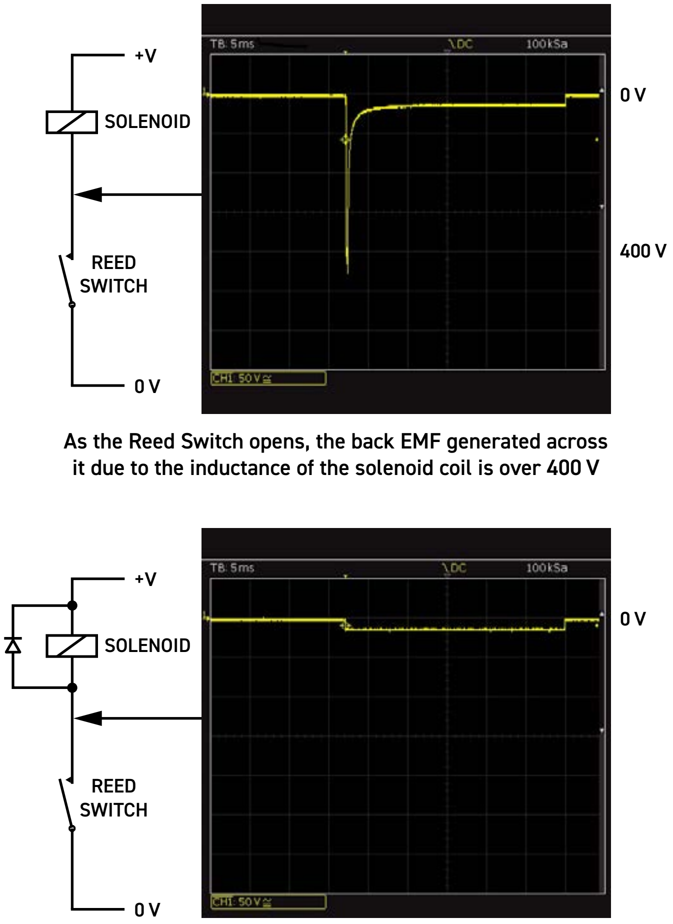
Cable runs are also a cause of another reliability issue on relays as they are commonly capacitive and if a voltage is applied to a cable, when disconnected the cable can retain a residual voltage. The next time a connection is made, the event can be classed as hot switching as the voltage is discharged on relay contact closure. It is always good practice to discharge long cable runs after connection to a voltage source.

The impact of hot switching capacitive loads is to reduce the contact life of the relay as though it was connected to a larger load than the user believes is present. Hot switching of capacitive loads is something that should always be avoided unless cold switching is impractical, and then the resulting current surges should be limited, usually by the inclusion of suitable series resistors placed as close to the relay as possible.

Inductive Loads

In the same way that capacitive loads can impact relay life on contact closure with a voltage source present, then inductive loads can shorten relay life if the relay contacts are opened when current is flowing. The consequences of opening the contacts are similar for those described when driving a reed relay coil, the magnetic field in the inductor has to be collapsed and interruption of the current causes a large voltage spike (back EMF) to appear. This can erode the materials on the relay contact and again shorten the life of the relay.

Applications that involve switching inductive loads include testing solenoids, motors, and transformers. There are ways of managing the inductive load issues, but these are usually very specific to the load being switched. When a reed relay is used to operate a DC solenoid for example, a diode can be included across the solenoid coil to suppress the voltage spike.



As the Reed Switch opens, the back EMF generated across it due to the inductance of the solenoid coil is over 400 V

The back EMF from the inductive load is considerably reduced when a diode is fitted across the solenoid

Fig. 8.4 - *Switching a Typical Inductive Load*

9 MANUFACTURING PCBs WITH REED RELAYS

Recommendations for Hand Soldering Through Hole Relays 9.2

Wave Solder, SMT Reflow and Vapor Phase Profiles.................................... 9.3

Socketed Through Hole Relays.. 9.6

Cleaning PCBs with Reed Relays... 9.7

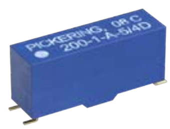
Manufacturing PCBs with Reed Relays

So far, we have discussed how reed relays are assembled, their advantages in test, selecting the right relay based on the application and the pitfalls to avoid. Hopefully you have now made your reed relay selection and are about to assemble your product's PCBs. Now, let's review some guidelines on how to properly solder Reeds Relays in order to avoid any damage to these components.

In this section we will use guidelines for working with Pickering Reed Relays. The recommendations should also apply to any other Reed Relay vendor. If you are not sure, contact the manufacturer.

NOTES:

- Temperatures are based on using a lead-free (SAC) alloy
- Solder wetting is affected by many factors such as storage conditions, handling, choice of alloy, equipment, ventilation, the board thermal mass and AQL (ref IPC-A-610 class 1, 2 or 3)
- We recommend the PCB manufacturer performs appropriate tests to verify the suitability of their processes as far as the Reed Relays are concerned

Soldering Method	Manual	PTH Wave Solder	SMT Reflow	SMT Vapor Phase
Package/ Footprint	SILs		SMDs	
				
Recommended Peak Temperature	340 °C/ 3 s	265 °C/ 10 s	250 °C/ 30 s	240 °C/ 30 s
Typical Profile	–	See Fig 9.1	See Fig 9.2	See Fig 9.3

Recommendations for Hand Soldering Through Hole Relays

The tip should be set to the minimum temperature required to produce a consistent solder joint. It should first be accurately measured using calibrated equipment (traceable to National and International standards) to determine whether there is an offset. We recommend any offset is adjusted out by recalibrating the solder iron because offset may not be linear across the temperature range.

It may be possible to solder at a lower temperature than indicated and this should always be the aim of an assembler soldering any type of component. Lower temperatures reduce heat stresses and the possibility of flux within the solder wire being burnt off too quickly which can create dry joints. Lower temperatures will also help to maximize the tip life.

The solder alloy and tip size will also have an influence. We always recommend using as large a tip size as possible because this improves the contact. It will also have a better heat mass which means its temperature is less likely to reduce as contact is made with the component lead and printed circuit board (PCB).

The PCB will also act as a thermal mass. Single layer boards can generally be soldered at a lower temperature than multi-layer boards or those with extensive grounding.

We recognize there may be other components on a PCB that require a higher temperature and/or different tip etc. It may seem possible to find a set up that works for all components, but this can lead to stresses on the most sensitive components. A common mistake is to set an iron at its maximum temperature.

In summary, incorrect calibration, tip degradation, insufficient tip contact time/position and thermal mass can mistakenly be overcome by increasing the temperature. Too hot can be as bad as too cold! Optimizing the tip size to take into the above variables will usually mean it's possible to use much lower tip temperature.

Wave Solder, SMT Reflow and Vapor Phase Profiles

Recommended soldering profiles may vary according to the process, machine and solder manufacturer's advice and the item being soldered. However, a typical soldering profile is shown below:

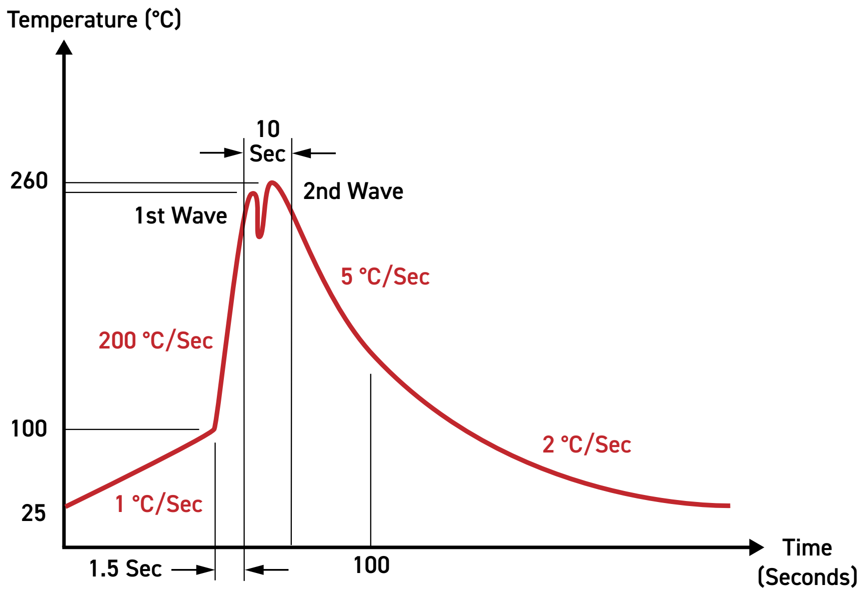
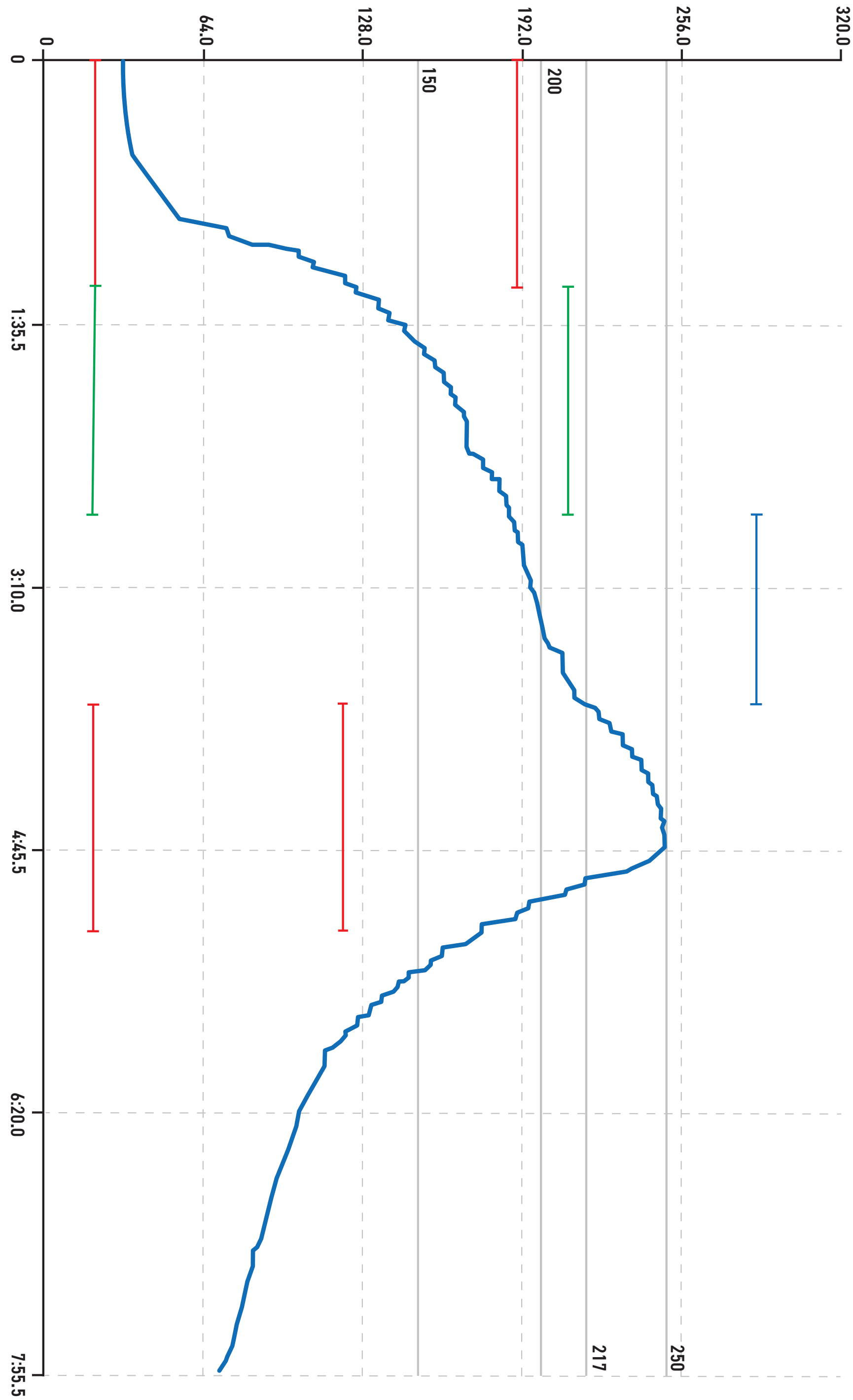


Fig. 9.1 - *Typical (lead free) Wave-Solder Profile*



Process Data							Zone Slopes					
Channel	Peak	1-150	1-200	150-200	t=217	t>217	t>250	Z1	Z2	Z3	Z4	Max+	Max-
Channel 3	249.1	103.5	205.5	102.0	233.5	64.5	0.0	1.9	0.9	0.3	-1.7	1.9	-1.7

Fig. 9.2 - *Typical (lead free) SMT Reflow Profile*

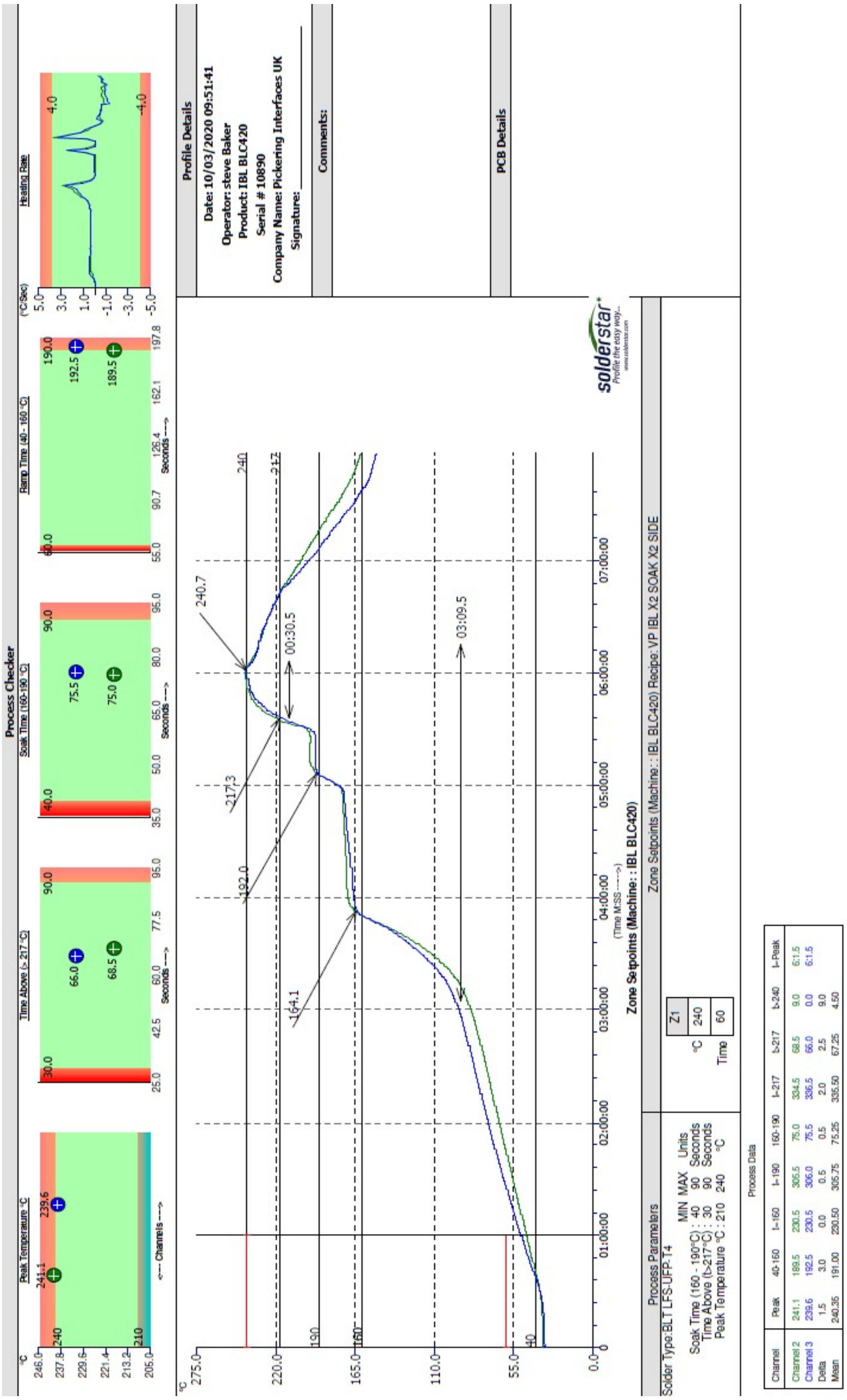


Fig. 9.3 - *Typical (lead free) Vapor Phase Profile*

Socketed Through-Hole Relays

Pickering is aware some customers may choose to use sockets for serviceability. However, it should be noted inserting relays into sockets does bring risks. Due to the tolerances of relays' pins and the sockets there is a possibility of a mismatch with respect to the pitch. In addition, if a relay is not inserted extremely carefully, this can lead to excess forces being induced into the switch.

The package stand-off is designed to ensure there is a gap between the underside of the relay package and the PCB. This aids the formation of solder fillets around pins on the component/top side of a PCB. The package stand-off also ensures excess pressure is not applied from the top of the package as it is inserted into a PCB (if a SIL) or when placed onto a PCB (if an SMD).

The switch blades of a reed relay are encapsulated in a fragile sealed glass capsule to maximize its performance and long-term reliability. Any excess pressure being induced into the switch via the package or pins could compromise the integrity of the glass seal and thus affect the working life of a relay.

Pickering relays have only been designed for soldering. If a customer wishes to use a socket, Pickering may be able to offer a non-standard clip length to accommodate the depth of the socket. See the diagrams below for an explanation.

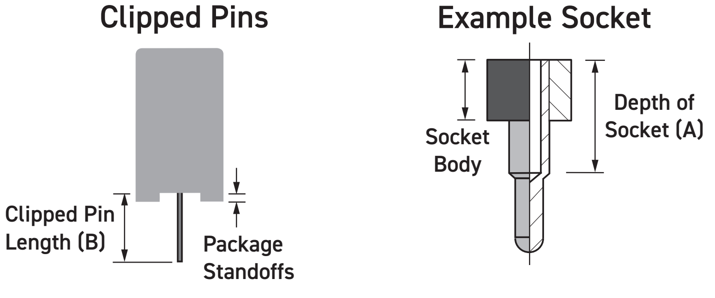


Fig. 9.4 - *Clipped Pins and Sockets*

If sockets are used the package standoffs may not perform as intended. The standoffs may not make contact with any surface. Refer to the Socket Awareness and Improved Socket Application sections for more detail.

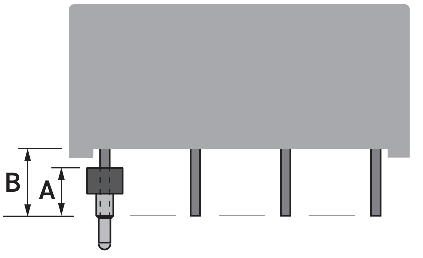


Fig. 9.5 - *Socket Depth Awareness*
(Legs Bottoming Out in Socket)

If the depth of socket (A) is smaller than the clipped pin length (B) then the socket depth is insufficient. This will allow the relay pins to 'bottom out'. This means the pins will make contact with the bottom of the holes within the socket. If any further force is applied this will lead to stress being induced into the switch.

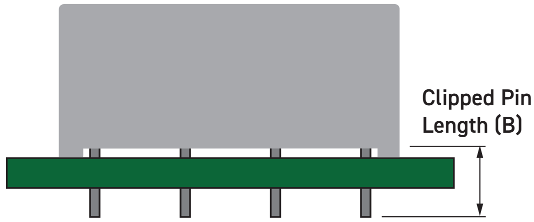


Fig. 9.6 - *Recommended PCB Application*
(Clipped Pin Length (B) is Not Critical)

Relay pins are inserted into the PCB through holes and the standoffs make contact with the PCB. No further force (downward pressure) is applied to the pins.

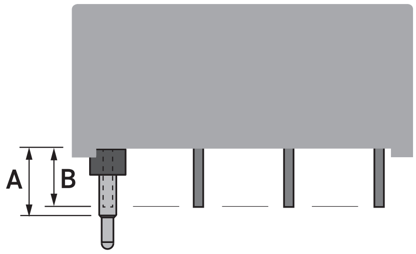


Fig. 9.7 - *Improved Socket Application*
(The Relay Pin does not Bottom Out and the Socket Body Contacts the Relay Body)

Note. Depth of Socket (A) must be greater than the clipped pin length (B). This reduces the stress applied to the switch. The pins do not make contact with the bottom of the holes within the socket as the standoffs are utilized.

Cleaning PCBs with Reed Relays

Pickering reed relays are compatible with a comprehensive range of cleaning systems. Many of our customers use cleaning systems without reporting any quality problems. However, cleaning systems involve many variables, such as pressure, mechanical forces, number of cycles, vibration, temperature, and cleaning solvents. Cleaning solvents can sometimes include anti-foaming agents, neutralizers, surfactants, saponifiers, and dispersants. Extra care should be taken with ultrasonic cleaning as strong vibratory forces can affect the reed switch performance characteristics.

Due to the large number of factors in cleaning processes, it is not practical for Pickering to carry out tests using many different cleaning systems and tactics. Thus, Pickering does not test or make recommendations regarding cleaning systems.

We do, however, suggest that all washing should incorporate a drying process at an elevated temperature (typically 80 °C for at least 1 hour).

Pickering always recommends the customer should take the appropriate steps to verify the suitability of our relays for washing.

10 GLOSSARY

Relay Terminology 10.2

Form A 10.2

Form B 10.2

Form C (Change-over - break-before-make) 10.2

Form D (Change-over - make-before-break) 10.3

Latching Relay 10.3

Safety Relay 10.3

Relay Terminology

The relay industry has evolved with a set of its own nomenclature that describes the products that are available, not all of these terms are familiar to users. The following section seeks to describe some of these relay terms.

For a full glossary of terms relating to reed relays see here: pickeringrelay.com/glossary

Form A

This reference describes a relay whose contact is a simple switch which is open or closed and the de-energized position is the open condition. For a single relay this would also be described as a single pole, single throw (SPST) relay with a normally open (NO) contact.

If the relay has multiple contacts in the same package it would be described as having (for example) 2 Form A contacts (DPST).

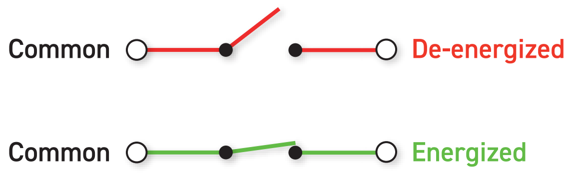


Fig. 10.1 - *Form A Relays*

Form B

This reference describes a relay whose contact is a simple switch which is open or closed and the de-energized position is closed.

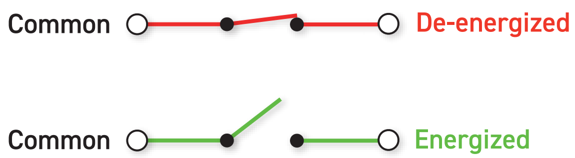


Fig. 10.2 - *Form B Relays*

Form C (Change-over - break-before-make)

This reference describes a relay with two contact positions, the normally closed contact and the contact which becomes closed when the relay is energized. For a single relay this would also be known as a changeover switch or a single pole double throw (SPDT). If the relay has two contacts sets it would be described as 2 Form C contacts, or double pole double throw (DPDT).

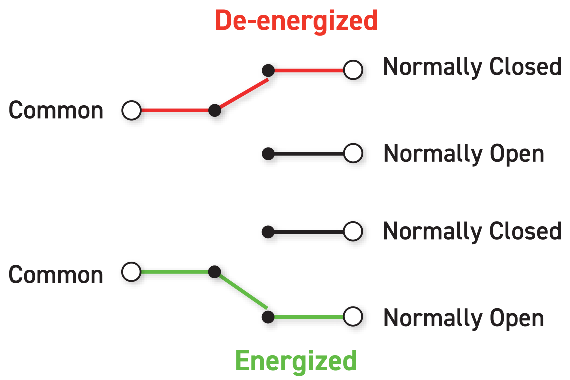


Fig. 10.3 - *Form C Relays*

Form D (Changeover - make-before-break)

This reference is to a changeover relay that is designed to make contact with the second contact before releasing from the first contact. These relays are very rarely constructed from reed switches because of implementations issues.

Latching Relay

Latching relays have two or more stable positions for the contacts when power is not applied. To change the state of a relay, a coil has a voltage transiently applied to it with a defined duration. Latching relays can be used for applications where minimisation of control power (coil current) is critical or where a power failure requires the switch to be left in the state it was set to until power is restored. The latter case needs careful design to avoid transient change instructions as the power fails. The latching mechanism usually relies on a magnet to provide the latching function.

Latching relays are generally not liked in modern software controlled systems because the software may not have direct knowledge of the relay state, particularly at power on. Some latching relays can have extra contacts to provide a direct indication of the contact position. This type of relay is not commonly available in reed relay form.

Safety Relay

Also known as a force guided contact relay this type of relay is designed with two or more contact sets (poles) and the mechanical design is such that if one contact one pole fails to change position because of a weld the other contact on another pole cannot close the corresponding contact. The mechanical design usually relies on forces being applied to close to the contacts. There are no commercial solutions for a safety relay using reed switches.

11 Product Gallery

Pickering Reed Relay Products.......... 11.2

Ultra High Density 4mm^2™ Reed Relays.......... 11.2

High Density Vertical SIL Reed Relays.......... 11.2

Surface Mount Reed Relays.......... 11.3

General Instrumentation SIL Reed Relays.......... 11.3

High Voltage/High Power Reed Relays.......... 11.4

Low Power/Low Thermal EMF Reed Relays.......... 11.5

RF/High Speed Digital Reed Relays.......... 11.5

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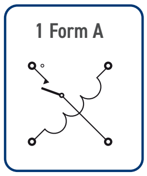
Ultra High Density *4mm²* ™ Reed Relays

- Highest packing density currently possible
  - requires a board area of only 4 mm x 4 mm
- Plastic package with internal mu-metal magnetic screen
- Very fast operate and release times - ideal for high speed test systems



Series 120

3.9 mm (0.15 in) 3.9 mm (0.15 in)
15.5 mm (0.6 in)

- Switching up to 1 A, 20 W
- 3, 5 or 12 V coils

Series 122

3.9 mm (0.15 in) 3.9 mm (0.15 in)
12.5 mm (0.492 in)

- Switching up to 0.5 A, 10 W
- 3 or 5 V coils

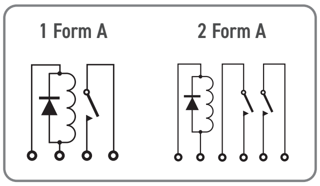
Series 124

3.9 mm (0.15 in) 3.9 mm (0.15 in)
9.5 mm (0.375 in)

- Switching up to 0.5 A, 10 W
- 3 or 5 V coils

High Density Vertical SIL Reed Relays

- Ideal for Very High and High Density ATE/Instrumentation applications
- Plastic package with internal mu-metal magnetic screen
- 3 V, 5 V, or 12 V coils. Diodes are Optional
- Dry Instrument Grade switches
- *SoftCenter*™ Technology

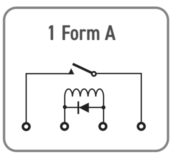


Series 110

10.0 mm (0.39 in) 3.7 mm (0.145 in)
15.2 mm (0.6 in)

Series 112

10.0 mm (0.39 in) 3.7 mm (0.145 in)
11.0 mm (0.43 in)



Series 115

6.6 mm (0.26 in) 3.7 mm (0.145 in)
15.5 mm (0.61 in)

- Pin compatible with Series 116 and 117 but using same switches as the Series 109 & 109P

Series 116

6.6 mm (0.26 in) 3.7 mm (0.145 in)
12.45 mm (0.49 in)

- 10 Watts, 0.5 Amp switching, requires a board area of only 0.15 x 0.27 inches

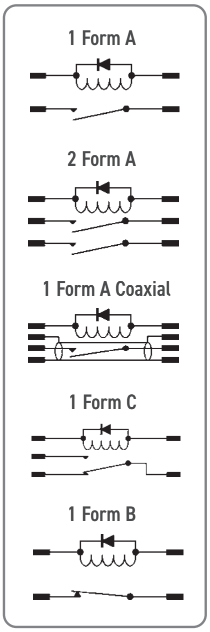
Series 117

6.6 mm (0.26 in) 3.7 mm (0.145 in)
9.5 mm (0.375 in)

- 10 Watts, 0.5 Amp switching in 1 Form A & 2 Form A

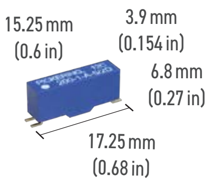
Surface Mount Reed Relays

- Ideal for High Density ATE/Instrumentation applications
- High temperature plastic package with internal mu-metal magnetic screen
- Wide range of switching configurations
- Coaxial version for high speed digital or R.F. to 5 GHz.
- 3, 5 or 12 V coils with optional diode
- Dry Instrument Grade or Mercury Wetted switches
- *SoftCenter*™ Technology

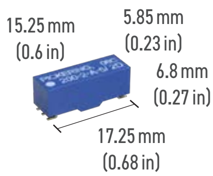


Series 200

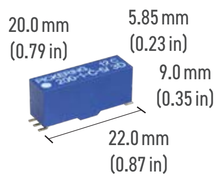
1 Form A, 1 Form A Coaxial



1 Form B, 2 Form A

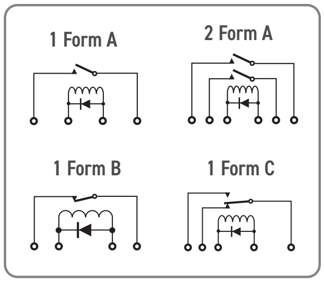


1 Form A - HV, Dry or Mercury
1 Form C

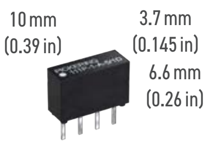


General Instrumentation SIL Reed Relays

- Ideal for General Purpose and High Density ATE/ Instrumentation applications
- Plastic package with internal mu-metal magnetic screen
- 3 V, 5 V, 12 V or 24 V coils. Diodes are Optional
- Using the highest-grade reed switches ensures low & stable contact resistance, fast operating times & long life



Series 111P

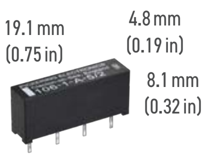


- 1 Form A only

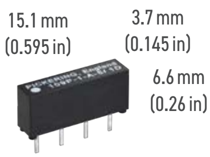
Series 105

- Dry or mercury wetted switches

Series 106

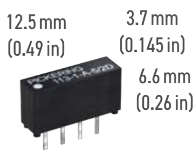


Series 109P



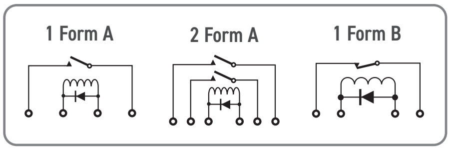
- 1 Form A only

Series 113



High Voltage/High Power Reed Relays

- Ideal for high power/voltage applications
- Plastic package with internal mu-metal magnetic screen
- 3 V, 5 V, 12 V or 24 V coils. Diodes are Optional
- Dry Instrument Grade switches
- *SoftCenter*™ Technology



Series 114

24.1 mm (0.95 in)
6.3 mm (0.245 in)
8.2 mm (0.32 in)

- High Power up to 40 W
- Will replace mercury wetted relays in many applications

Series 100HC

24.1 mm (0.95 in)
10.2 mm (0.40 in)
12.7 mm (0.50 in)

- 1 Amp switching up to 40 W
- Carry up to 3 A continuous
- Pulsed Carry > 3 A
- 1 Form A, 1 Form B

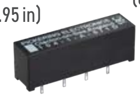
Series 100HV

24.1 mm (0.95 in)
10.2 mm (0.40 in)
12.7 mm (0.50 in)

- High Voltage up to 3000 V
- High Coil Resistance (Up to 6800 Ω) for Low Power Consumption

Series 104

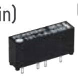
24.1 mm (0.95 in)
6.3 mm (0.245 in)
8.2 mm (0.32 in)



- High Voltage up to 4000 V
- Single Pole Relays now up to 4 kV Standoff
- Double Pole Relays up to 2 kV Standoff
- Electrostatically Screened version 104ES
- 104HT - high temperature (up to 150 °C) option

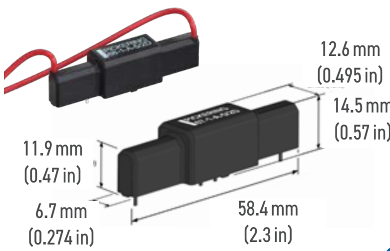
Series 131

12.5 mm (0.49 in)
3.7 mm (0.145 in)
6.6 mm (0.26 in)

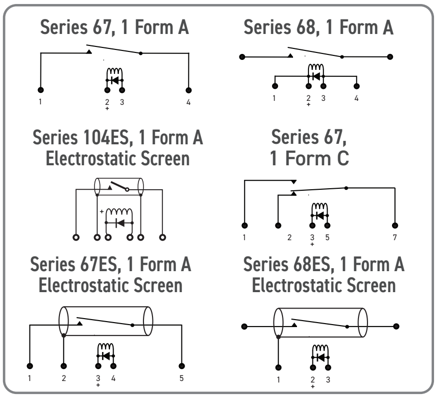


- 1 Form A only
- Minimum 1.5 kV Standoff

Series 67/68

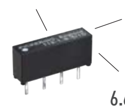


- Up to 10 kV standoff at 50 W, 8 kV standoff at 200 W NEW
- Robust 50 or 200 W Tungsten contacts
- Series 67 has pcb pins for all connections. Series 68 has flying leads from the top face for the high voltage connections
- 1 Form A. Standing off 5 kV, switching up to 3.5 kV
  1 Form A. Standing off 8 kV, switching up to 6 kV
  1 Form A. Standing off 10 kV, switching up to 7.5 kV
  1 Form C. Standing off 5 kV, switching up to 2.5 kV
- Electrostatically Screened Versions 67ES and 68ES NEW

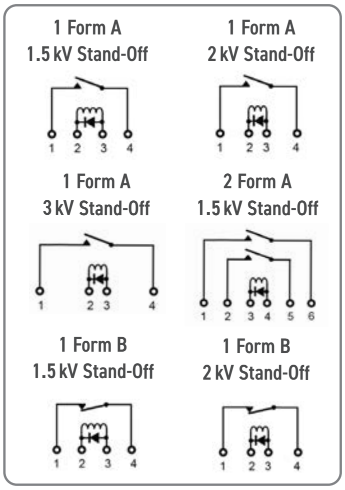


Series 119

1 Form A, 1 Form B
1 kV, 2 kV 15.1 mm (0.595 in)
1 Form A 3 kV, **2 Form A**
20.1 mm (0.79 in)
3.7 mm (0.145 in)
1 Form A
6.6 mm (0.26 in)
2 Form A, 1 Form B
8.9 mm (0.35 in)

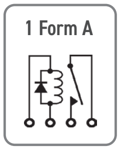


- High Voltage up to 3000 V
- Single Pole Relays up to 3 kV Standoff
- Double Pole Relays up to 1.5 kV Standoff



Low Power/Low Thermal EMF Reed Relays

- Ideal for Data Aquisition or Thermo-couple switching
- Plastic package with internal mu-metal magnetic screen
- 3 V, 5 V, 12 V or 24 V coils. Diodes are Optional
- Dry Instrument Grade or Mercury Wetted switches
- Internal thermal EMF levels as low as 1 microvolt



Series 118

8.4 mm (0.33 in)
4.8 mm (0.19 in)
15.24 mm (0.6 in)

- 1 Form A only
- High Coil Resistance for Portable Instrumentation

Series 100

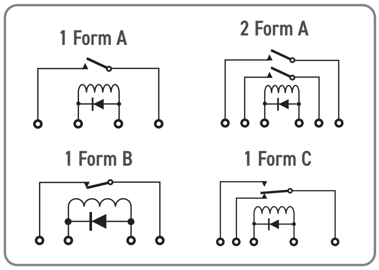
24.1 mm (0.95 in)
10.2 mm (0.40 in)
12.7 mm (0.5 in)

- Direct Drive from CMOS

Series 101

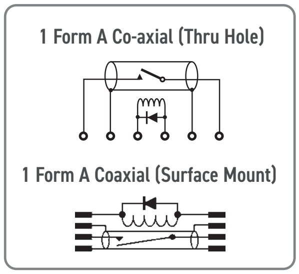
20.1 mm (0.79 in)
7.4 mm (0.29 in)
9.4 mm (0.37 in)

- Direct Drive from HC or HCT CMOS



RF/High Speed Digital Reed Relays

- Ideal for High Density ATE/Instrumentation applications
- Mu-metal or Plastic package with internal mu-metal magnetic screen
- 3 V, 5 V, or 12 V coils. Diodes are Optional
- Dry Instrument Grade switches
- *SoftCenter*™ Technology



Series 102M

19.1 mm (0.75 in)
4.8 mm (0.19 in)
7.6 mm (0.3 in)

- Up to 1.5 GHz

Series 103G

19.1 mm (0.75 in)
4.8 mm (0.19 in)
8.1 mm (0.32 in)

- Up to 2 GHz

Series 109RF

15.1 mm (0.595 in)
3.7 mm (0.145 in)
6.6 mm (0.26 in)

- Up to 2 GHz

Series 111RF

10 mm (0.39 in)
3.7 mm (0.145 in)
6.6 mm (0.26 in)

- Up to 2.5 GHz

NEW

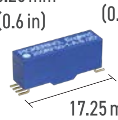
Series 113RF

12.5 mm (0.49 in)
3.7 mm (0.145 in)
6.6 mm (0.26 in)

- Up to 3 GHz

Series 200RF

15.25 mm (0.6 in)
3.9 mm (0.154 in)
6.8 mm (0.27 in)

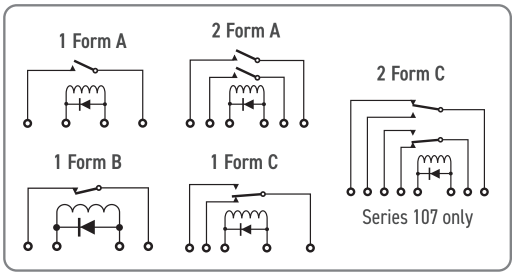


17.25 mm (0.68 in)

- Up to 5 GHz (Surface Mount)

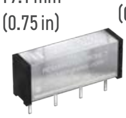
Mu-Metal Package SIL Reed Relays

- Ideal for General Purpose and High Density ATE/Instrumentation applications
- Mu-metal package eliminating the risk of magnetic interaction
- 3 V, 5 V, 12 V or 24 V coils. Diodes are Optional
- Dry Instrument Grade switches
- *SoftCenter*™ Technology



Series 107

19.1 mm (0.75 in)
4.8 mm (0.19 in)
7.6 mm (0.3 in)



- Dry or mercury wetted switches

Series 108

20.1 mm (0.79 in)
3.7 mm (0.145 in)
6.6 mm (0.26 in)

Series 109

15.1 mm (0.595 in)
3.7 mm (0.145 in)
6.6 mm (0.26 in)

Series 111

10 mm (0.39 in)
3.7 mm (0.145 in)
6.6 mm (0.26 in)

- 1 Form A only

12 ABOUT PICKERING

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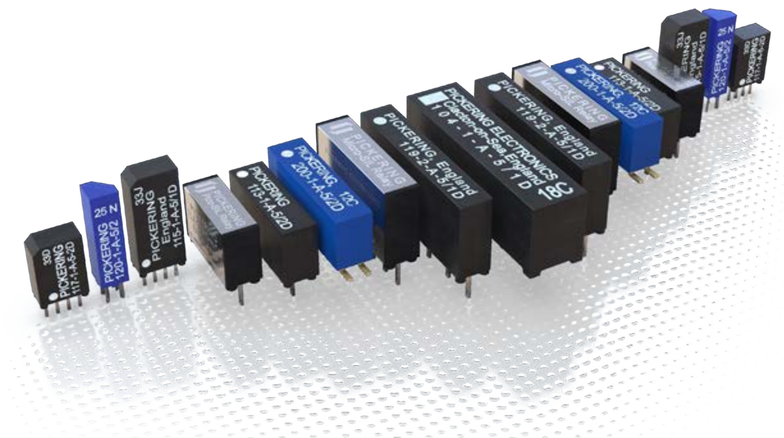
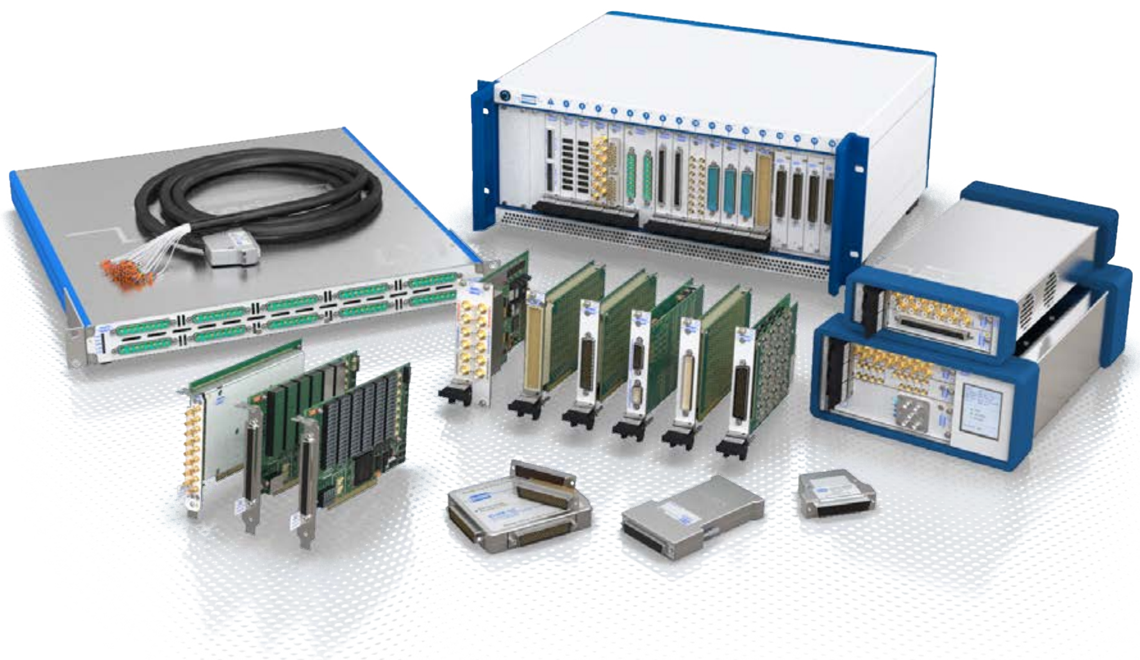
Modular Switching & Simulation 12.5

Cables and Connectors 12.8



Reed Relays from **Pickering Electronics**



Modular Switching, Simulation and **Connectivity**
from **Pickering Interfaces** and **Pickering Connect**

Introduction - Pickering Group

The Pickering Group of companies is comprised of: Pickering Electronics–our relay division; Pickering Interfaces–our switching and simulation division and Pickering Connect–our connection division. Together, we deliver high-quality switching and simulation products and a full range of standard and custom cable and connector solutions.

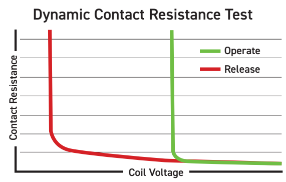
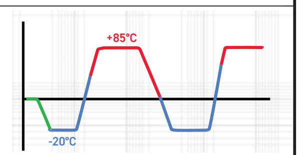
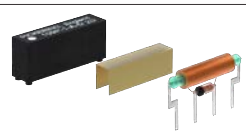
Pickering Electronics was established in 1968 to manufacture high-quality Reed Relays predominantly for use in Instrumentation and Test equipment. Pickering Relays are available in Surface Mount, Single-in-Line (SIL/SIP) and Dual-in-Line (DIL/DIP), with the option of dry or mercury wetted switches. These small relays are sold in high volumes to large ATE and instrumentation companies worldwide.

Pickering Interfaces was formed in 1988 to design and manufacture modular signal switching and simulation for use in electronic test and verification and now offers the most extensive range of switching and simulation products in the industry for PXI, LXI, USB and PCI applications. Our products are specified in test systems installed worldwide and have a reputation for providing excellent reliability and value. We serve many electronics industries, including automotive, aerospace & defense, energy, industrial, communications, medical and semiconductor.

Pickering Connect offers a comprehensive range of standard and custom connectivity solutions, specializing in custom cable and connectivity and can manufacture in quantities of one to many thousands. Established in 2004 our high-quality products are used throughout the world in many applications, including aerospace, automotive, medical and military.

Learn more at **pickering-group.com.**

10 Key Benefits of Reed Relays from Pickering Electronics

Key Benefit	Pickering Reed Relays	Typical Industry Reed Relays	
1 Instrumentation Grade Reed Switches	Instrumentation Grade Reed Switches with vacuum sputtered Ruthenium plating to ensure stable, long life up to 5x10E9 operations.	Often low grade Reed Switches with electroplated Rhodium plating resulting in higher, less stable contact resistance.	
2 Formerless Coil Construction	Formerless coil construction increases the coil winding volume, maximizing magnetic efficiency, allowing the use of less sensitive reed switches resulting in optimal switching action and extended lifetime at operational extremes.	Use of bobbins decreases the coil winding volume, resulting in having less magnetic drive and a need to use more sensitive reed switches which are inherently less stable with greatly reduced restoring forces.	 Pickering former-less coil  Typical industry coil wound on bobbin
3 Magnetic Screening	Mu-metal magnetic screening (either external or internal), enables ultra-high PCB side-by-side packing densities with minimal magnetic interaction, saving significant cost and space. **Pickering Mu-Metal magnetic screen - interaction approx. 5%**	Lower cost reed relays have minimal or no magnetic screening, resulting in magnetic interaction issues causing changes in operating and release voltages, timing and contact resistance, causing switches to not operate at their nominal voltages. **Typical industry screen - interaction approx. 30%**	 X-Ray of Pickering mu-metal magnetic screen  X-Ray of typical industry magnetic screen
4 ***SoftCenter***™ Technology	***SoftCenter***™ technology, provides maximum cushioned protection of the reed switch, minimising internal lifetime stresses and extending the working life and contact stability.	Transfer moulded reed relays (produced using high temperature/pressure), result in significant stresses to the glass reed switch, which can cause the switch blades to deflect or misalign leading to changes in the operating characteristics, contact resistance stability and operating lifetime.	 Pickering soft center protection of the reed switch  Typical industry thermo-setting hard moulded protection of the reed switch
5 100% Dynamic Testing	100% testing for all operating parameters including dynamic contact wave-shape analysis with full data scrutiny to maintain consistency.	Simple dc testing or just batch testing which may result in non-operational devices being supplied.	
6 100% Inspection at Every Stage of Manufacturing	Inspection at every stage of manufacturing maintaining high levels of quality.	Often limited batch inspection.	
7 100% Thermal Cycling	Stress testing of the manufacturing processes, from -20 °C to +85 °C to -20 °C, repeated 3 times.	Rarely included resulting in field failures.	
8 Flexible Manufacturing Process	Flexible manufacturing processes allow quick-turn manufacturing of small batches.	Mass production: Usually large batch sizes and with no quick-turn manufacturing.	FAST
9 Custom Reed Relays	Our reed relays can be customized easily, e.g. special pin configurations, enhanced specifications, non-standard coil or resistance figures, special life testing, low capacitance, and more.	Limited ability to customize.	
10 Product Longevity	Pickering are committed to product longevity; our reed relays are manufactured and supported for more than 25 years from introduction, typically much longer.	Most other manufacturers discontinue parts when they reach a low sales threshold; costing purchasing and R&D a great deal of unnecessary time and money to redesign and maintain supply.	Product 25+Years Longevity

Modular Switching & Simulation from Pickering Interfaces - pickeringtest.com

We introduced our first modular switching system in 1988 and are now a leading manufacturer of PXI, PCI, LXI & USB switching & simulation products. With our deep portfolio of products, we assure you that we can optimize your test system switching and simulation to exactly fit your needs.

PXI Switching

We first entered the PXI market in 1998 and are now offering over 1,000 PXI & PXIe switching modules. These modules range from the ***BRIC***™ highest density switching matrices, RF/microwave up to 110 GHz and optical switching to fault insertion modules.

PXI Simulation Solutions

Does your test strategy require simulating environmental sensors, including temperature, pressure, altitude, movement, PLC/instrument communications and strain gauges? We offer an extensive range of PXI & PXIe solutions for sensor simulation, including programmable resistors, strain gauge simulators, thermocouple simulators, LVDT, RVDT and resolver simulators, analog output/current loop simulators, battery simulators and Digital I/O.

LXI Switching Solutions

We were early adopters of the LXI standard to provide a standardized interface for Ethernet (LAN) controlled instruments. We now offer a large range of LXI switching solutions, including low-frequency matrices, multiplexers, RF & microwave up to 110 GHz, optical systems, and turnkey microwave & optical switch and signal routing solutions.

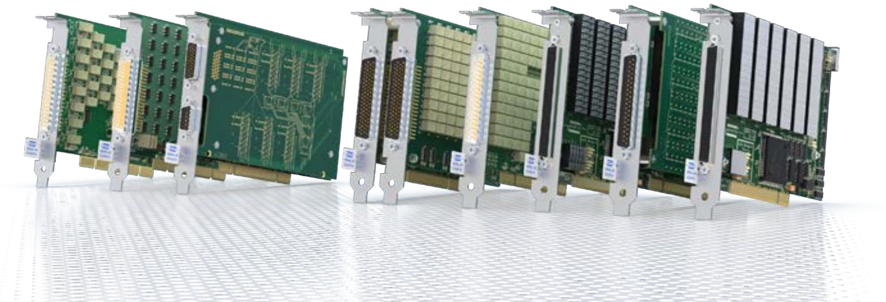
PXI & LXI/USB Modular Chassis

Our PXI modules plug into any PXI compliant chassis or a Hybrid slot in a PXIe chassis, and our PXIe module into any compliant PXIe slot or Hybrid slot in a PXIe chassis. We offer both PXI & PXIe modular chassis, including 8, 14, 18 & 19-slot versions.

We also offer LXI/USB modular chassis—these chassis allow any of our extensive range of 3U PXI modules to be controlled in an LXI environment, enabling remote control over a gigabit Ethernet connection, or via a USB3 connection. These include 2, 4, 6, 7 & 18 slot versions.

PCI Switching & Simulation

Our PCI switch & simulation cards are built using the same basic technology as our acclaimed PXI range utilizing the same software drivers, soft front panels and control electronics. The range includes matrices, multiplexers, fault insertion switching, programmable resistors and Digital I/O.



Comprehensive Software Solutions

Our commitment to delivering you high-quality products does not just extend to our switching and simulation products. Our in-house software team has created all of our application software packages and software drivers to help you simplify and expedite the development and deployment of your automated test systems. Our Switch Path Manager signal routing software simplifies signal routing through switching systems and speeds up the development of switching system software. Our Simulation tools allow test program development to begin before actual hardware is received.

Diagnostic Test Tools

Verification and diagnosis of complex switching operations in a test system have always been an issue. Our BIRST and eBIRST diagnostic test tools provide you with a quick and straightforward way of finding relay failures within our PXI, PCI, LXI and USB switch systems.

Long-term Support

Many of you expect your test systems to last at least as long as the products being tested. We understand this need and pride ourselves that the design and manufacture of all our switching, simulation, software and connectivity products are done in-house. These capabilities enable us to provide guaranteed long-term support, typically 15 to 20 years, and very low obsolescence.

Cables & Connectors from Pickering Connect - pickeringconnect.com

We offer a comprehensive range of standard and custom connectivity solutions. We specialize in cables and connectivity and can manufacture in quantities of one to many thousands. Our cable engineering expertise, in-house PCB, 3D mechanical design, CNC and PCB component placement capabilities enable us to provide quick turn around on customized solutions to match all of your requirements.

Since 2004 we have nurtured a reputation for excellence, reliability and value. Our high-quality products are used throughout the world in many types of applications, including aerospace, automotive, medical and military.

We can also manufacture cable assemblies to your specific requirements. Try our unique, free Cable Design Tool to create custom cable assemblies. With this online tool, you can graphically design your cable assemblies using our built-in library of standard cable sets or create them from scratch.

To learn more or to try the tool, go to **pickeringtest.com/cdt.**

Contact Us

info@pickeringrelay.com

+44 1255 428141

Pickering Electronics Ltd, Stephenson Rd, Clacton-on-Sea CO15 4NL

For a full list of agents and representatives visit: pickeringrelay.com/agents

Scan here to find your local representative

Pickering Electronics maintains a commitment to continuous product development, consequently we reserve the right to vary from the descriptions given in this document.

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pickeringrelay.com