Application Guide

The Role of Reed Relays in High-Performance EV Motorsport Vehicle Development

Discover the many benefits of reed relays in this application guide

In this application guide:

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Pickering 55 Years 1968 - 2023

An Introduction to Electric Motorsport

Attracting increasingly larger audiences and contributing significantly to technologies that are likely to make their way into commercial electric vehicles (EVs), electric motorsport is all about the development and racing of electric-powered vehicles.

The ABB Federation Internationale de l'Automobile (FIA) Formula E World Championship, 'Formula E' for short, is perhaps the most well-known electric motorsport event. It is an incarnation of Formula 1, in which the vehicles are all electric.

Since the introduction of Formula E, its rules and regulations have evolved. For example, up until season 4, first generation (Gen1) cars were used and pitstops could be made to swap cars as the batteries could not manage a whole race. When Gen2 cars were introduced, for season 5, the race was set to 45 minutes plus one lap, so no pitstops needed to be made other than for repair work. Season 5 also saw the introduction of Attack Mode, in which the cars would make available an additional 25kW of power when driven through a designated area of the track off the racing line.

With the introduction of Gen3 cars, the traditional racing lap format was adopted and pitstops were back in. Most recently, the so-called Attack Charge has been introduced in some races and require that drivers make a 30 second pitstop to recharge the cars' batteries. This requirement is of course making teams develop rapid charging technologies to make best use of that half-minute stop, plus calling into the pits unlocks certain enhanced attack modes to boost the vehicle's performance.

On the subject of performance, it is improving all the time and, at the time of producing this application guide, the new Gen3 Evo race car is the quickest accelerating FIA single-seater race car and is capable of 0 to 60mph in 1.82 seconds (0-100kph in 1.86s), some 30% faster than a current F1 car.

However, electric motorsport is not all about acceleration and speed. In some events, distance and endurance are more important. For example, the Eco Grand Prix - EcoGP, for short – is a European 24-hour race for electric cars. Launched in 2013 and taking inspiration from Le Mans 24, it is won by the car that travels the longest distance in 24 hours.

Measuring & Monitoring

The development of an electric motorsport car, or any EV for that matter, is not without its challenges, a major one of which is that batteries, power inverters, motors, and cabling all need to be optimised for size, weight and power (SWaP). All store or carry high and potentially lethal voltages, that need to be monitored.

Also, contactors used to switch electrical power must often accommodate high inrush currents. These occur when switching a high voltage into a capacitive load (or one in which the impedance is predominantly capacitive). Pre-charge circuits (See Figure 1) are essential for applications with capacitive loads as current spikes of thousands of Amperes can easily damage system components and cause contactors to weld closed.

Inductive loads, such as motors, present another type of problem in that it is the act of removing the high voltage (i.e., opening the contactor) that produces a high current, increasing the duration and energy of the arc the contactor must break.

Insulation testing is also an important aspect of vehicle development. The HV system of an EV is electrically floating in that it is unearthed/ungrounded (also known as isolé-terré, isolated terra, or simply IT) and the isolation resistance between any component (such as a motor winding) or cable core that is part of the HV circuit and the vehicle chassis should be high.

The test can be performed by injecting a high voltage into a component that is not live at the time of the test. A current sensing circuit that is electrically in parallel with the insulation measures current flow. If the current through the measurement circuit is lower than expected, this means some current is making its way to ground via an alternative route.

On another note, insulation monitoring devices (IMDs) are used in EVs and charging stations to constantly monitor for faults (both symmetrical or asymmetrical) that might develop and lead to fire or present an electric shock hazard. Many IMDs work by superimposing a measuring voltage (usually a low-level AC waveform) onto live conductors. In the event of a fault being detected an IMD will send a signal to the vehicle's battery monitoring system (BMS) which, depending on the severity of the fault, can disconnect the power.

High-voltage reed relays are ideal for both high voltage measurement and insulation resistance tests because they have high stand-off voltages. Also, compared to solid-state relays (which are a semiconductor device), reed relays have much lower leakage currents.

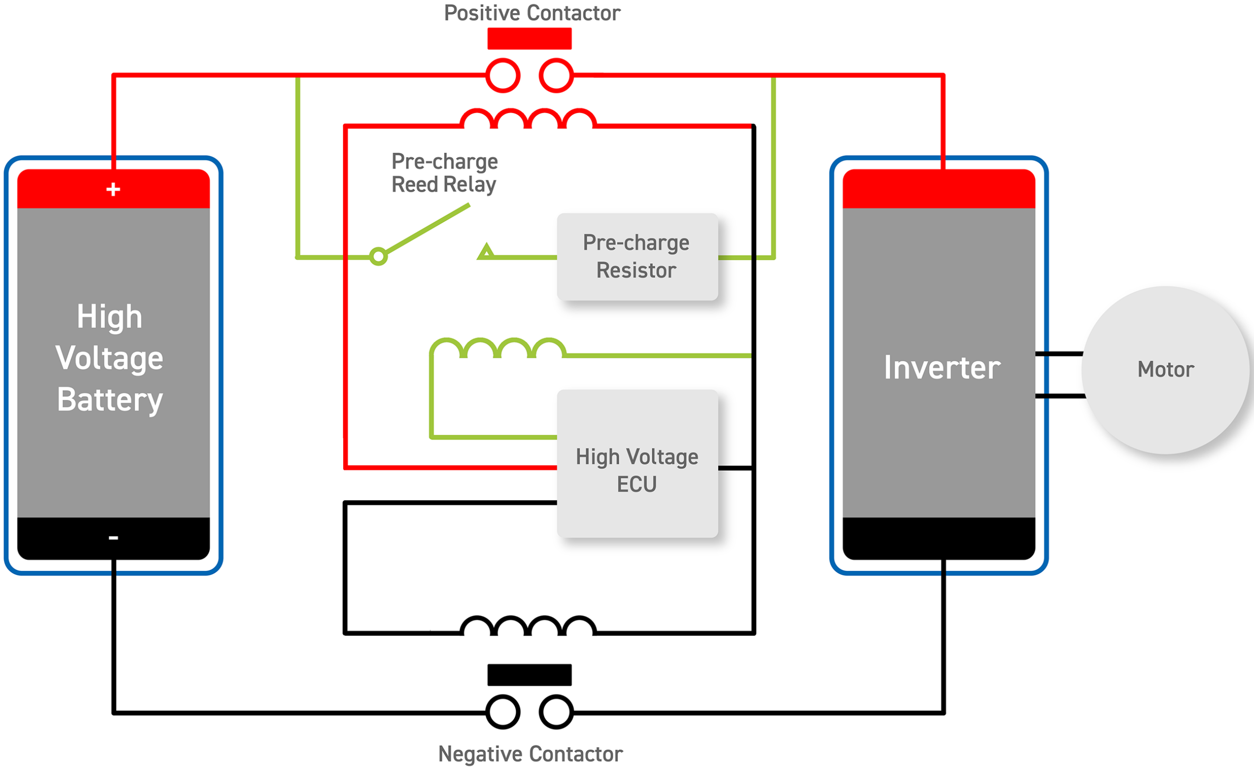


Figure 1 - An example of a precharge circuit diagram

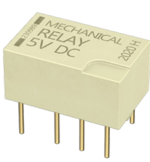
In Use

As mentioned, Formula-E is becoming increasingly popular. Moreover, many universities are getting involved and students not only get to develop life-long skills but also get to participate in the many aspects of the sport. One such student body – operating under the banner Gopher Motorsports – is the University of Minnesota Student Chapter of the Society of Automotive Engineers. Pickering is an official sponsor and Gopher Motorsport is using a high voltage Form C (changeover) reed relay from our Series 67. This single relay solution is effectively part of both the pre-charge and tractive system discharge circuits and provides significant space saving compared to using an electromechanical relay or contactor.

Pickering has also supplied reed relays to more than 20 other teams including Nevada Electric Racing in the USA, University of Alberta in Canada, Race Up Team and Dynamics PRC in Italy, UMD Racing and KA-Racing in Germany, Align Racing UiA in Norway, ERM in Hungary, Green Team Twente and Formula Student Team Delft in the Netherlands, Prom Racing Team and Democritus Racing Team in Greece, and University of Nottingham in the UK. Devices supplied include reed relays from Pickering's Series 62, Series 63, Series 67, Series 100HV, Series 104, and Series 131.

Why Reed Relays

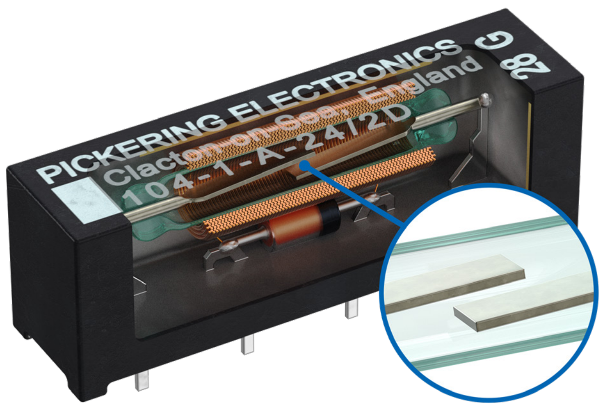
There are essentially three ways to electronically switch at high voltages

Electromechanical Relays (EMRs)	Solid State Relays (SSRs)	Reed Relays
		
Used in many general purpose switching applications. However, with contacts exposed to the atmosphere, surface oxidization can significantly impact their low level switching performance along with relatively slow operating speeds.	There are no physical contacts but there can be relatively high ON resistances. SSRs may have high leakage current and capacitance which can also impact low level signals.	With instrumentation grade reed switches sealed in an inert gas or a vacuum, reed relays can switch varied signals with little degradation over billions of operations. Much faster than EMRs and providing better isolation and signal path than SSRs, they are often the best solution for a wide range of data aquisition applications.

These are the most important things you need to consider when switching a high voltage and if there is no need to handle more than a few Amperes:

- **Maximum Switching Voltage.** The highest DC or AC (peak) voltage that can be switched.
- **Minimum Standoff Voltage. T**he devices will cope with a higher voltage as, in the case of Pickering Electronics' high voltage relays, they are tested at 500V above the declared standoff. For your design purposes we recommend you do not exceed the standoff voltage given on the datasheet.
- **Maximum Switching Current.** Most high voltage reed relays are rated at up to 1A, but you are unlikely to need to switch this much current when measuring a high voltage; a few mA will suffice. And an insulation resistance test would require switching just a few µA.
- **Insulation Resistance.** This is the resistance between any of the device pins. This needs to be very high (ideally greater than 1TΩ (Tera Ohms, so 1 x 1012 Ohms) if the reed relay is to be used in circuitry intended to measure insulation resistance. Or, to put it another way, if you are trying to measure a current leak (indicative of failing insulation), the last thing you want is for your switching circuit to introduce a current leak, which is why solid-state relays are considered unsuitable.
- **External Shield Clearance.** Some devices (typically low cost) have an external metal shield to protect against EM interference from neighbouring relays. If the screen extends to the relay base, or is too close to the base, this can cause problems when placed on a PCB carrying high voltages. However, the clearance might not even be stated on the datasheet. You may need to refer to technical drawings or measure the clearance on a sample device. Note: the relays we recommend below have internal shielding - mu-metal screens around their coils.

For high-voltage reed relays, the contact is sealed in a vacuum, greatly increasing the minimum standoff and maximum switching voltages. Insulation resistance is high thanks to pin spacing and the relay's base material. As for external shield clearance, this is not an issue when the EM shielding is on the inside of the device.

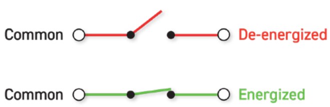
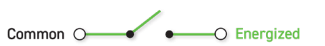
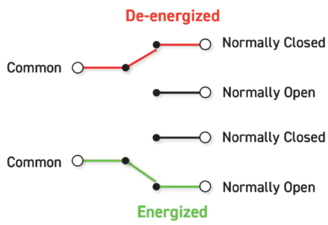


Other information you will need to consider, when designing your circuitry:

- **Coil Voltage.** The DC voltage needed to energise the coil and close the normally open contacts in the reed.
- **Coil Resistance.** If energising the coil using a transistor, you need to know the coil resistance to calculate the current the transistor must handle.
- **Operating Temperature.** This tends to be about -20 to 85˚C for most relays. However, for more demanding applications, specialized devices (that use non-standard materials) are available that can work down at -40˚C and up at 155˚C. Also, it is important to understand how temperature affects reed relay performance; most notably the times to make and break the contact.

By considering all the above factors you will be able to make a well-informed decision when selecting the appropriate reed relay for your application. Other information you will need to consider when designing your medical equipment includes contact configuration and service life.

Contact Configuration (Forms)

Form A	Form B	Form C
		
With the coil de-energized the switch is normally open (NO). If just one switch is present, the form is 1A, meaning single pole single throw normally open (SPST-NO). If two switches are present, the form is 2A, meaning double pole single throw normally open (DPST-NO). With three switches it is 3A (3PST-NO).	With the coil de-energized the switch is normally closed (NC). If just one switch is present, the form is 1B, meaning single pole single throw normally closed (SPST-NC). If two switches are present, the form is 2B, meaning double pole single throw normally closed (DPST-NC). With three switches it is 3B (3PST-NC).	These are changeover devices that break their NC contact (and close the NO one) when the coil is energized. If just one switch is present, the form is 1C, meaning single pole, double throw (SPDT). If two switches are present, the form is 2C DPDT. With three switches it is 3C.

What's the Service Life?

This is the one figure on any datasheet, from any manufacturer, that is open to interpretation. We state 1×10^9 operations for most applications, but the fact of the matter is the figure could be higher or lower depending on the exact application. Considerations are: How close to voltage and current limits are you operating? What is the switching duty cycle? Are you likely to see inrush currents?

Also, at what point do you consider the device to be failing? When contact resistance increases by 10%? 20%? More?

Rest Assured, We're Here to Help

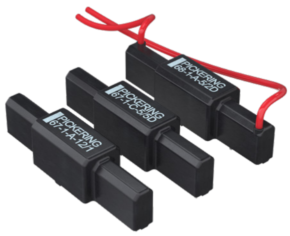
Tell us about your application and we'll not only recommend the most suitable device, but we'll also give you an indication of the device's realistic service life.

email: techsales@pickeringrelay.com

RECOMMENDED PRODUCTS

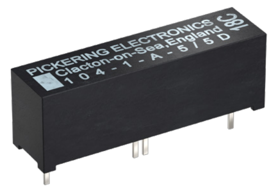
Pickering Electronics has an extensive range of high-performance, high voltage isolation reed relays that are ideally suited to high voltage measurement applications. Furthermore, with device footprints starting at just 46mm2, many relays can be accommodated on a single PCB. We particularly recommend the following series.

Series 67 & 68



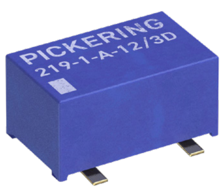
This range has switching voltages up to **7.5 kV** and minimum standoff voltages up to **10 kV**. Maximum switch current is **3 A** (at up to **50 W**) and maximum carry current is up to **5 A**. High power **200 W** switch available. **5**, **12** or **24 V** coils. Optional electrostatic shield available.

Series 104



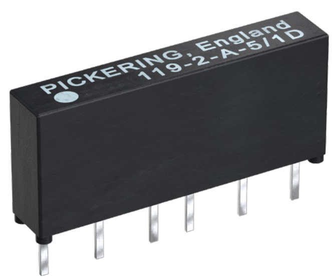
This range has switching voltages up to **1 kV** and minimum standoff voltages up to **5s kV**. Maximum switch current is **1 A** (at up to **25 W**) and maximum carry current is **1.5 A**. High Temperature option available that can withstandup to 125°C (& up to 150°C as a standard build option) Optional electrostatic shield.

Series 219



This Surface Mount range has switching voltages up to **1kV**. Minimum standoff voltage is up to **3kV** (Switch-Switch) and up to **5kV** (Switch - Coil). Maximum switch current is **0.7A** (at up to 10W) and maximum carry current is **1.25A**. Body dimensions from (W x H x D): **17.2 x 8.5 x 10.5mm**.
Available forms: **1 Form A**, **2 Form A**, and **1 Form B** contact configurations.

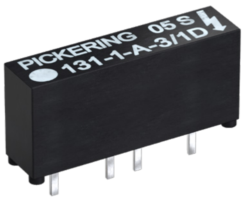
Series 119



This range has switching voltages up to **1kV** and minimum standoff voltages up to **3kV**. Maximum switch current is **0.7A** (at up to **10W**) and maximum carry current is **1.25A**. Body dimensions from (W x H x D): **15.1 x 6.6 x 3.7mm**.
Available forms: **1 Form A**, **2 Form A** and **1 Form B** contact configurations.

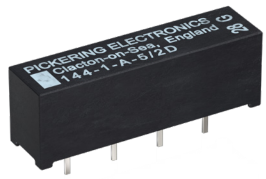
RECOMMENDED PRODUCTS

Series 131



This range has switching voltages up to **1kV** and minimum standoff voltages up to **1.5kV**. Maximum switch current is **0.7A** (at up to **10W**) and maximum carry current is **1.25A**.
Body dimensions from (W x H x D): **12.5 x 6.6 x 3.7mm**.
Available forms: **1 Form A** contact configuration.

Series 144



This range has switching voltages up to **1kV** and minimum standoff voltages up to **3kV**. Maximum switch current is **2.0A** (at up to **60W**) or **1.0A** (at up to **80W**) and the maximum carry current is **3.0A**.
Body dimensions from (W x H x D): **24.1 x 8.2 x 6.3mm**.
Available forms: **1 Form A**, **2 Form A** and **1 Form B** contact configurations.

Series 60 & 65

This range has switching voltages up to **12.5 kV** and minimum standoff voltages up to **15 kV**. Maximum switch current is **3 A** (at up to **50 W**) and maximum carry current is up to **3.5 A**.

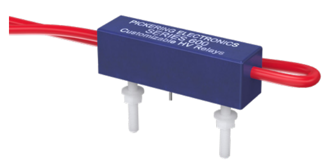
Series 62 & 63

This range has switching voltages up to **12.5 kV** and minimum standoff voltages up to **20 kV**. Maximum switch current is **3 A** (at up to **50 W**) and maximum carry current is **3.5 A**.

Series 100HV

This range has **5, 12 or 24 V coils.** HV + high coil resistance reed relays in **Form A** and **Form B. 3000 V stand-off, 1000 V switching.** Up to **6800 Ohms coil resistance.**

Series 600



This range is fully **customizable**. Up to **20kV** standoff, **12.5kV** switching, and **200W** power handling. Available with **5V**, **12V**, or **24V** coils and optional EMF suppression. Offers NO, NC, and changeover contacts. Features vacuum-sealed reed switches, **$>10^{13}\Omega$ insulation**, magnetic/electrostatic shielding, and modular design.

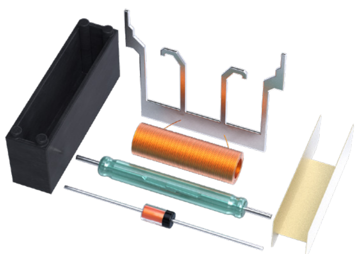
email: techsales@pickeringrelay.com

Why Pickering Electronics for Reed Relays?

- ✓ We've been making reed relays since 1968. It's our core business and has laid the foundation for the switching and simulation division of Pickering Group, **Pickering Interfaces**.
- ✓ The relays recommended in this guide are all instrumentation grade and the reed contacts will be plated with either Rhodium (electro-plated) or Ruthenium (vacuum sputtered) to ensure a long life – typically up to $5x10^9$ operations.
- ✓ They are of a **formerless coil construction**, which increases the coil winding volume, maximizes the magnetic efficiency, and allows for the use of less sensitive reed switches, resulting in optimal switching action and **extended lifetime** at operational extremes.
- ✓ Mu-metal magnetic screening enables **ultra-high PCB side-by-side packing densities** with minimal magnetic interaction, **saving significant cost and space**. Our magnetic screen reduces EM interaction to approximately 5%. Low quality relays typically exhibit an EM interaction of 30%.
- ✓ **SoftCenter™** technology provides maximum cushioned protection of the reed switch, minimizing internal lifetime stresses and **extending the working life and contact stability**.
- ✓ Inspection at every stage of manufacturing **maintaining high levels of quality**. Also, **100% testing** for all operating parameters including dynamic contact wave-shape analysis with full data scrutiny to maintain consistency. Stress testing of the manufacturing processes, from -20°C to +85°C to -20°C, repeated 3 times.

Customization

While we've recommended several series of reed relays as being ideal for use in test equipment and instrumentation for performing high voltage and insulation resistance tests on electric vehicles and charging stations/equipment, we have over a thousand catalogue parts; so, there's plenty to choose from.



However, if you cannot find a product that meets your exact requirements, we offer a full customization service.

We have a well-proven development lifecycle of: Agree requirements, design, manufacture, test, approve, and deliver. And if your custom design is based on one of our existing products (which is likely to be the case) you can expect to receive samples in as few as two weeks.

For further information, contact our technical sales team at:
techsales@pickeringrelay.com

About Pickering Electronics

Pickering Electronics was established over 50 years ago to design and manufacture high quality reed relays, intended principally for use in instrumentation and test equipment. Today, Pickering's Single-in-Line package (SIL/SIP) range is by far the most developed in the relay industry, with devices 25% the size of our competitors' electrically equivalent devices. These small SIL/SIP reed relays are sold in high volumes to large ATE and semiconductor companies throughout the world.

The privately-owned Pickering Group comprises three electronics manufacturers: reed relay company Pickering Electronics; Pickering Interfaces, designers and manufacturers of modular signal switching and simulation products, and Pickering Connect, which designs and manufactures cables and connectors. The group employs over 500 people primarily in the UK and Czech Republic with additional employees in sales offices in the US, China, Germany, Sweden, and France.

Technical Help

Please go to: **pickeringrelay.com/help**.
If your questions are not answered here, please e-mail: **techsales@pickeringrelay.com**.
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