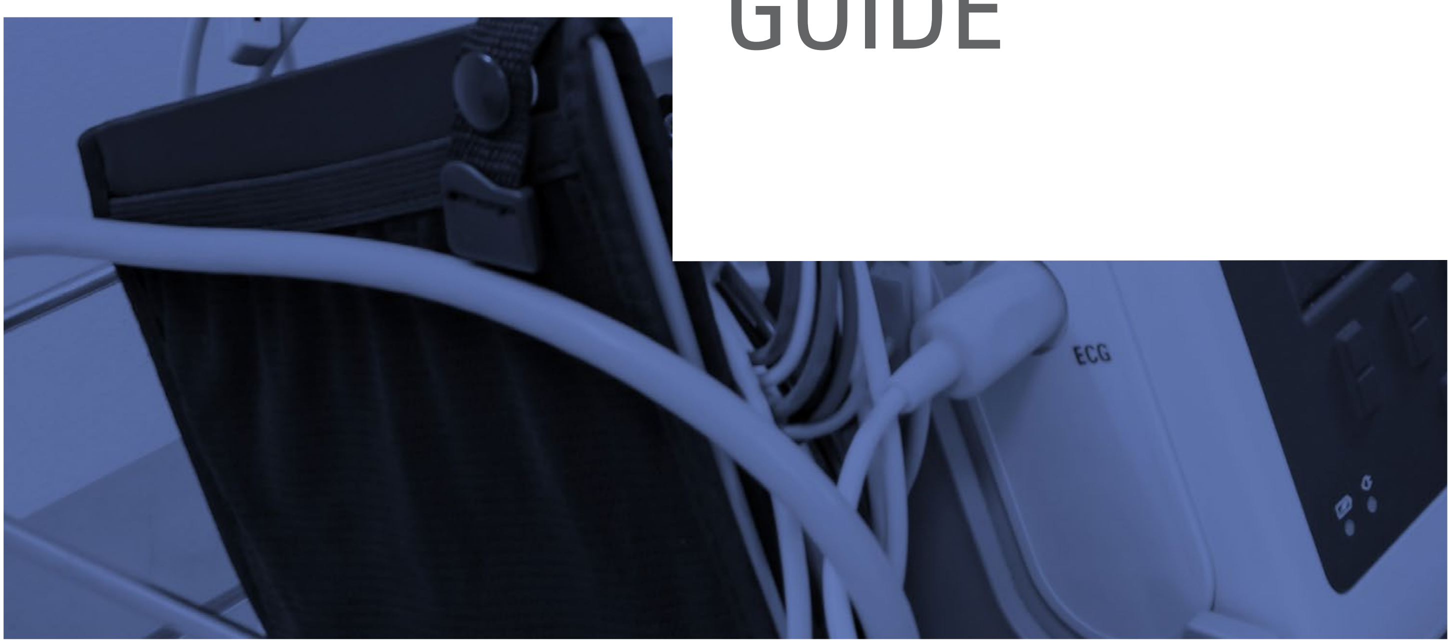
Sensata Technologies

HIGH VOLTAGE RELAY APPLICATION AND DESIGN GUIDE



We take pride in knowing that our technologies improve safety, efficiency and comfort for millions of people every day

For more than 100 years, we have provided a wide range of customized, sensor-rich solutions that address complex engineering requirements to help customers solve difficult challenges in many industries.

Our solutions help make products safer, cleaner, and more efficient and connected.

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Sensata's High Voltage Relays deliver the switching solutions needed in the medical, semiconductor, and insulation testing industries – among others. Our HV relays are sealed, providing rugged, small, and efficient high voltage designs for most demanding applications.

Within this document, we share documentation, diagrams, and application design expertise around our Gigavac High Voltage Relays to help deliver the best end product possible for your customers.

SENSATA | GIGAVAC HIGH VOLTAGE RELAY DESIGN NOTES

In this section, we will review several features of Sensata | GIGAVAC High Voltage Relay designs.

SENSATA | GIGAVAC HIGH VOLTAGE RELAY DESIGNS

Sensata | GIGAVAC high voltage relays typically follow three general design structures – an internal armature style, a diaphragm style, and our specialized G81 package design.

Internal Armature Style

Figure 1 is a typical Sensata | GIGAVAC design used in many of our high current, high voltage relays. The armature is inside the vacuum or gas filled sealed ceramic envelope, and the coil is outside the sealed switching chamber. This is a single pole double throw relay. Depending on the switching application, various contact materials are used inside the sealed chamber. Tungsten / molybdenum is used for "Making or Breaking" loads in our G8, G15, G18, G50, G60 and G61 relays. Copper contacts have less contact resistance and are used for higher current "carry only" applications such as for RF in our G2 and G52 relays.

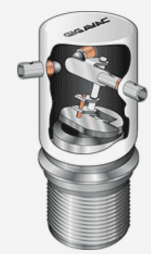


Fig. 1, GIGAVAC Internal Armature style, Double Throw relay design

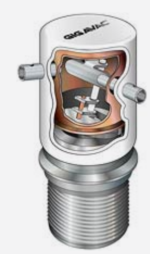


Fig. 2 , GIGAVAC G18 relay. Same as Fig 1, but with built-in shield for power switching

Figure 2 shows the same design but with a built-in internal shield that extends the relay life. When power switching a load using a vacuum relay, even hard contacts vaporize, and the material becomes deposited and plate-out the internal walls of the ceramic envelope. Over time, these deposits reduce the isolation voltage, which causes the relay's end of useful life. We have approached the plate-out condition by adding an internal shield as shown. The deposits hit the shield (G18 relay) rather than the ceramic wall, resulting in a relay life many times longer than relays without the shield.

When power is applied to the coil of these relays, a magnetic filed is transferred through a pole the runs through the center of the coil to the armature, that is located inside the sealed switching chamber. The armature moves the common contact to the normally open contacts. A spring inside the sealed chamber returns the moving contact to the normally closed contact when coil voltage is removed.

Diaphragm Style

Figure 3 & 4 show the Sensata | GIGAVAC diaphragm style relays. The contacts are sealed in a chamber at the top of the relay. The chamber is sealed with a braze joint at the top, and with a diaphragm below. The external high voltage connections are integral to the braze seal. The relay armature is below the sealed chamber and is not shown. When power is applied to the coil, the armature moves, and a ceramic insulating rod that is attached to the diaphragm moves the common contact to the normally open contact (a small rod) inside the sealed chamber. Figure 3 is a single throw, normally open configuration. The top contact (A3) is open and the moving contact (A2) is below.

Figure 4 is a double throw relay. The normally open contact is at the top, the normally closed contact is in the center, and the moving contact is at the bottom. For this relay, the sealed chamber extends from the top of the relay down to the diaphragm that is the moving contact. Both the normally open and normally closed contacts are in the same sealed chamber.

G81 Package Design

Figure 5 is the Sensata | GIGAVAC G81 style relay. For this relay, the G41 relay (Fig. 3 or 4) is packaged inside a cup that provides more mounting and high voltage terminal options. Because contacts of the G41 are in a vacuum, the contacts can withstand more high voltage than the distance between the external terminals. By potting the G41 relay inside the G81 cup, the high voltage capabilities are greatly improved.

Our team packages many relays for this same reason, such as the G60 relay (figure 1 style) to make the G61 relay.

Fig. 3 , GIGAVAC Diaphragm Style, Single Throw relay design

Fig. 4 , GIGAVAC G18 relay. Same as Fig 1, but with built-in shield for power switching

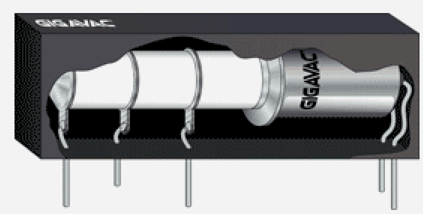


Fig. 5 , GIGAVAC G81 package, using GIGAVAC Diaphragm Style, Double Throw relay design.

SENSATA | GIGAVAC RELAY SCHEMATICS & FORMS

The following are industry accepted relay schematics and forms that GIGAVAC uses for most of its relays.

Shown are:

- Single Pole Single Throw – Normally Open (SPST-NO) Form A
- Single Pole Single Throw – Normally Closed (SPST- NC) Form B
- Single Pole Double Throw (SPDT) Form C
- Double Pole Double Throw (DPST-NO) 2 Form C
- 4 Pole Double Throw (DPDT) 4 Form C
- Single Pole Single Throw (SPST) Latching Form P
- Single Pole Double Throw (SPDT) Latching Form R
- Single Pole Single Throw – Normally Open (SPST-NO) Double Make Form X
- Single Pole Single Throw – Normally Closed (SPST-NC) Double Break Form Y

High Voltage and Power Terminal designations are:

- Terminal 1 is Normally Open (NO)
- Terminal 2 is the moving contact (sometimes called Common)
- Terminal 3 is Normally Closed (NC)

Coil terminals designations are as follows (Coils of GIGAVAC relays are not polarity sensitive unless otherwise noted):

- X for non-latching relays
- X and Y for Latching relays

For specific terminal locations on diaphragm style relays, refer to Figure 7 below

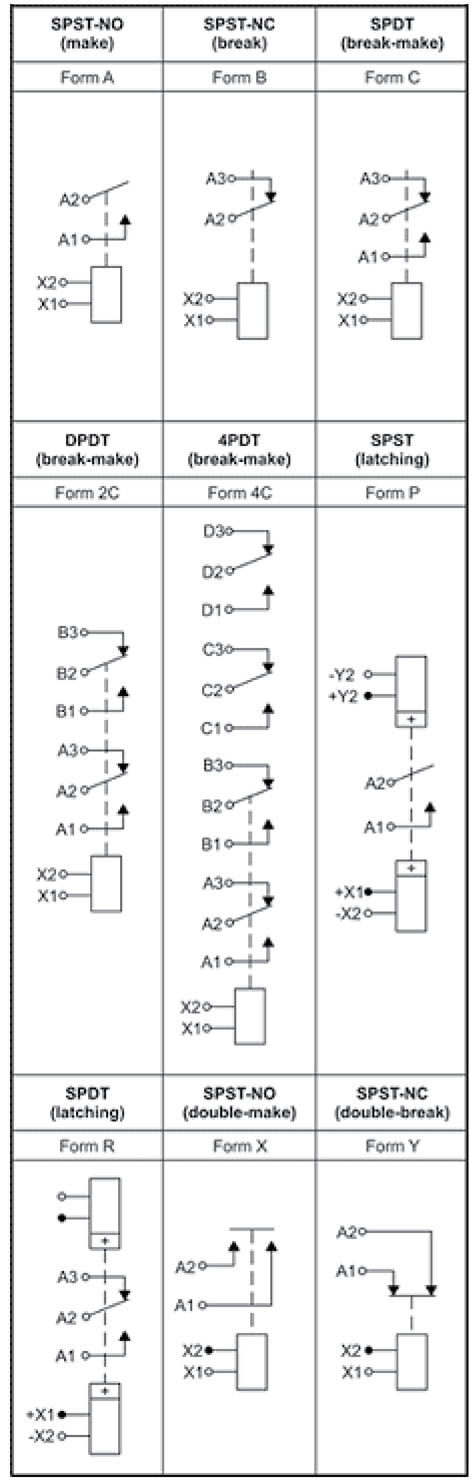
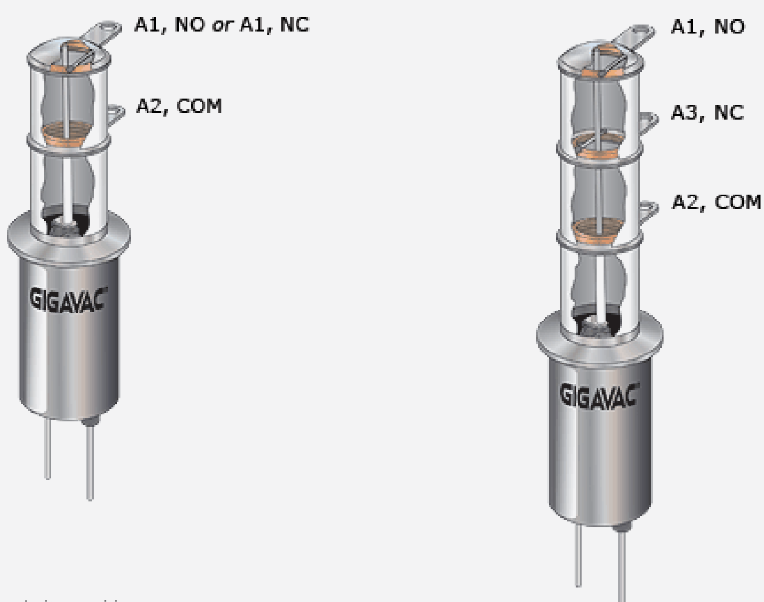


Fig. 7



Coil is not polarity sensitive

HIGH VOLTAGE RELAY AND CONTACTOR DIELECTRIC MATERIALS

Sensata | GIGAVAC is the established leader in the design and manufacture of sealed relays and contactors. Sealing is critical in preventing contamination from polluting the internal parts of any component.

We have developed and use several sealing technologies to accomplish this task for our products. More important is that these sealing technologies allow us to precisely control the internal switch environment by providing a variety of dielectric medium. This has led to several innovations including special liquid filled relays.

The choice of dielectric is based on product design and the intended primary function of the product. For instance, High Voltage Relays are designed to isolate voltage in the smallest space possible and switch small current levels under load. These products generally use vacuum as the dielectric. While there have been many design modifications that allow High Voltage Relays to switch larger loads, including the use of various gases as the dielectric, their load switching capability remains limited. Sensata | GIGAVAC Contactors, and many of our other Power Products, are designed to switch loads at various voltage and higher current combinations.

The two dielectric materials used throughout our high-voltage product offering today are vacuum and gas.

Vacuum as a dielectric

The styles of High Voltage Relays manufactured by Sensata | GIGAVAC were initially intended for use in high power RF circuits. The relays were to be as small as possible, have low RF losses, have good dielectric isolation at the rated RF voltage, and be able to operate at various altitudes and in harsh environments.

The dielectric strength of vacuum is about 8 times greater than air. And because there is no oxidation in a vacuum, low resistance copper contacts can be used, allowing the relay to carry significantly more current than traditional open-air relays.

These small vacuum relays quickly gained acceptance and new applications. Many of these applications required additional load switching capability. In order to accommodate the larger loads, relay designs were changed to include versions with harder contact materials such as molybdenum and tungsten.

Gas as a dielectric

As High Voltage Relays became more popular, other applications developed which took advantage of the hard contact materials. These applications include high in-rush capacitive make and capacitive discharge such as those found in ESD test equipment, cable test equipment, heart defibrillators, and for applications where no high voltage is applied for long periods of time where low and or stable leakage current is needed. In High Voltage Relays a mixture of sulfur hexafluoride, SF6, and nitrogen is used, primarily because of the way the gas performs during switching. SF6 is an excellent insulator but once the switch is closed if the relay bounces the SF6 becomes easily ionized and carries the arc current. This makes the relay electronically 'bounceless' and dramatically reduces contact wear.

Contactors are by definition designed to switch larger amounts of power versus relays. As with relays there are several aspects of contactor design and application requirements that facilitate the use of a particular gas. Sensata | GIGAVAC EPIC® sealed contactors use a ceramic to metal seal which allows the use of virtually any gas as a dielectric. Standard GX EPIC® contactors use hydrogen as a dielectric. While providing an excellent medium for the power switching requirements of the GX contactors, hydrogen allows higher voltage ratings versus other gases. Standard MX EPIC® contactors use nitrogen as a dielectric. While nitrogen does not allow for the higher voltage ratings it does allow for higher inrush and overload currents at the lower voltages.

Sensata | GIGAVAC also provides custom gas mixes for special applications.

SENSATA | GIGAVAC CHANGEABLE RELAY COILS

Sensata | GIGAVAC has designed many of our relays to make coils easy to change, even if the relay is installed.

Customers can change the coils on the Sensata | GIGAVAC GH, G2, G8, G15, G60 & G70 relays by following the instructions below using a replacement coil package available through our local sales offices.

(Contact Sensata | GIGAVAC for part numbers)

- **1 coil**
- **1 coil retaining plate marked with coil resistance and voltage.**
- **1 circular spring washer.**
- **1 coil retaining screw (GH relay) or 1 coil knurled retaining nut or all others**

Instructions – Removing the Coil

Hold the relay firmly with one hand. You may want to use gloves or a clean cloth as the oil from your skin can contribute to a high voltage breakdown. If you need to clean the relay, use 99% isopropyl alcohol or acetone.

For GH Relays - Use a flat blade screwdriver to remove the retaining screw located between the coil terminals. Take care not to bend or damage the coil terminals.

For all others - Using a small pliers remove the knurled retaining nut located between the coil terminals. Take care not to damage the tubulation in the center of the knurled nut. Also take care not to bend or damage the coil terminals.

Grab one of the coil terminals with your fingers and pull out the coil.

Turn the relay over to remove the circular spring washer. It will fall out of the coil cavity.

Instructions – Replacing the Coil

Place the new circular spring washer in the coil cavity with the bends in the washer facing towards the coil. Taking care that the circular spring washer does not fall out while placing the new coil into the cavity with terminals facing outward from the relay.

Slide the coil retaining plate over the coil terminals. The coil terminals are not polarity sensitive so orientation of the plate is not important.

For the GH Relays - Holding the assembly in one hand insert and tighten the coil retaining screw. Take care not to bend or damage the coil terminals. Tighten the retaining nut to 0.3 Nm (3 in-lb) maximum.

For all others - Holding the assembly in one hand insert and tighten the knurled retaining nut. Take care not to damage the tubulation or coil terminals. Tighten the retaining nut to 0.3 Nm (3 in-lb) maximum.

APPLICATION AND SYSTEM DESIGN FOR SENSATA | GIGAVAC HIGH VOLTAGE RELAYS

In this section, we will review several application design concepts and how to best incorporate Sensata | GIGAVAC High Voltage Relays into your designs.

REED RELAY SPACING

Most Sensata | GIGAVAC high voltage relays are not affected when they are placed in close proximity to another relay. However, because Reed Relays operate with such low coil power, they are more sensitive to proximity issues than other relays and board layout considerations are necessary.

Our "rule of thumb" spacing between Reed Relays is at least 5 mm on all sides and "test & try" between a Reed Relay and any other Sensata | GIGAVAC relay. Normally closed and latching Reed Relays have a greater effect on adjacent Reed Relays because they have a permanent magnet.

When laying out your board, it is always best to alternate the Reed Relays end-to-end.

COIL SUPPRESSION

The specifications for all Sensata | GIGAVAC relays, unless otherwise specified, are without the use of coil suppression. If you need to suppress the back EMF of the relay coil, we recommend the use of a zener-zener or diode-zener combination with the zener voltage at 2x, or more, of the coil source voltage.

Other coil suppression techniques - such as single diode, resistor capacitor combination, resistor, or varistor - noticeably slow down the release time of the relay and can affect the life of the relay or the use of the relay in the application.

In carry only applications, the release time may not be important, so these less expensive coil suppression techniques can be used. However, if the release/reset time is important, or if the contacts are to interrupt a load, do not use these techniques and use the recommended zener-zener or diode-zener combination.

HIGH VOLTAGE PROCESSING OF VACUUM RELAYS

Vacuum is an excellent dielectric. However, sometimes a vacuum relay may show reduced dielectric strength over a period of time. This is generally caused by a trace amount of free ions out-gassing from the metal or ceramic materials inside the relay.

Normally, this is not noticeable because when the rated high voltage is applied, the free ions become charged and deposit themselves on the inside walls of the relays much like what occurs in a vacuum deposition process. Sometimes when the high voltage is first applied the relay may "burp" as the particles become charged. On other occasions, some relays may not clean themselves and may require external processing.

The following procedure explains how to process these types of relays. (This is not applicable to gas filled relays.)

1. Connect a high voltage AC or DC variable power supply in series with a 10 megohm resister, a microampere meter, and the relay. The relay should be on the ground side of the power supply.
   a. SPST, Normally Open - Apply rated "test voltage" voltage between open contacts.
   b. SPST, Normally Closed - Apply coil voltage and apply rated "test voltage" voltage between open contacts. The base should be grounded.
   c. SPDT - With the coil energized and de-energized, apply rated "test voltage" voltage between open contacts. Ground the base and connect the normally open contacts to the base.
   d. DPDT - Process the same as a SPDT relay for each pole.
2. Immerse the relay in a dielectric fluid. Transformer oil or Florinert (FC-77 made by 3M) can be used. The florinert evaporates from the relay surface quickly and is a much cleaner operation.
3. Slowly raise the voltage to the rated "test voltage". At the maximum voltage, if leakage current is less than 5 micro amps and no glow is visible in a darkened room, then the vacuum is good and no further processing is necessary.
4. If a glow occurs at a voltage lower than maximum, hold the voltage just above the glow initiation level until the glow disappears. This can take a couple of minutes. Then drop the voltage and raise it again to the onset of glow, or until the maximum specified test voltage is reached. If a DC supply is used, reverse the polarity and repeat the process.
5. If needed, processing at levels up to 20% above the maximum "test voltage" may be used.

* Please note the use of the word "pollution" and "pollutants" is used only as an illustration relative to the vacuum inside the relay. The pollutants could be pure oxygen, air, or anything.

WARNING: Above 15 kV for vacuum relays, X-rays are produced during high voltage processing. Refer to the following section regarding X-ray emission in vacuum relays.

X-RAY EMISSIONS IN VACUUM RELAYS

Above 15 kV, all products that operate in a vacuum, including vacuum relays, can produce X-rays that can be considered hazardous. This is one reasons we recommend using Sensata | GIGAVAC's SF6 gas filled relays because the electrons collide with the gas molecules and are unable to accumulate sufficient energy to make significant radiation.

When vacuum relays are used over 15kV, the equipment should be shielded with lead that is at least 16 mm thick.

If shielding is not possible, then appropriate X-ray warnings should be posted and a radiation X-ray monitoring program should be implemented. Contact your local regulatory agency regarding your specific situation.

SENSATA | GIGAVAC HIGH VOLTAGE RELAY GROUNDING REQUIREMENTS

It is normal practice to ground the base of all high voltage relays for safety.

For Sensata | GIGAVAC diaphragm style relays (G41, G43, G47, G81, etc), grounding is not necessary. This is because there is no ground plane inside the sealed switching chamber that an arc can go to during hot switching, and because the external distance to ground, combined with the added insulation of the coil, is greater than the breakdown voltage between contacts. These relays can be used in hot switching applications on either side of the load (see Fig. 8).

For our internal armature style relays (GH1, G8, G61, G50 etc.), the relay base must always be grounded (see Fig. 9) unless the voltage across the contacts is less than the specified dielectric voltage breakdown between the coil and case.

When hot switching voltages above the coil to case dielectric voltage rating, the relay MUST be on the ground side of the load (see Fig. 9) and the case MUST be grounded. For hot switching voltages lower than the coil to case dielectric voltage rating, the relay can be on either side of the load (see Fig. 9 & 10) and the case does not have to be grounded but is recommended to be grounded for safety.

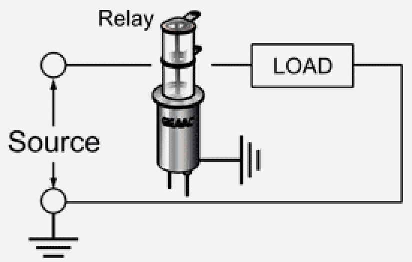


Fig. 8 , for GIGAVAC diaphragm style relays, relay can be on either side of load. Grounding of case is not necessary but is recommended for safety.

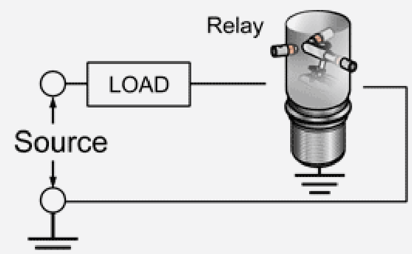


Fig. 9 , for GIGAVAC internal armature relays, relay should be ONLY on ground side of load unless voltage is lower than the coil to case dielectric rating.

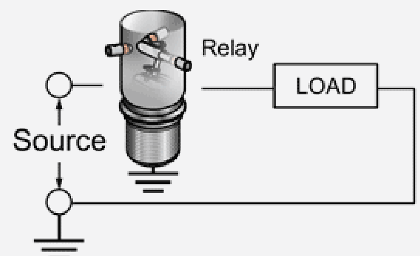


Fig. 10 , for GIGAVAC internal armature relays, relay can be on either side of load if voltage is less than the coil to case dielectric rating. Grounding of case is not necessary but is recommended for safety

SOLDERING WIRES TO SENSATA | GIGAVAC HIGH VOLTAGE RELAYS

Soldering wires to Sensata | GIGAVAC high voltage relays is straighforward. The ceramic on GIGAVAC HV relays is brazed at over 800°C in a hydrogen atmosphere so no damage should occur.

However, good soldering techniques should be used and heat, flux and solder should be kept to a minimum (See Fig. 11).

When soldering a wire to solder pots on models such as GH1, GH3, GH5, G2, G8, G15, G18 and G60 series relays, first pre-tin the wire (See Fig. 12).

The solder pot is already tinned, therefore it does not require a large amount of solder to make a good connection. Insert the wire into the solder pot, but not all the way.

The hole in the top of the solder pot is not to be used to connect a wire, but to allow heat to escape when soldering. Apply heat, but use minimal amount of solder (See Fig. 13).

NEVER fill the solder pot entirely with solder. If too much solder is used, it can cause a crack in the ceramic to metal seal due to different coefficients of expansion between the solder and the ceramic body.

Outside atmosphere will enter and the relay will lose dielectric and high voltage isolation between contacts. This can occur immediately or over time when a load is applied to the relay.

Please wipe off all flux after soldering. Flux left on the outside of the relay can lead to loss of high voltage isolation on the outside of the relay. Do not use flux that contains any acid, as this can damage the ceramic surface of the relay.

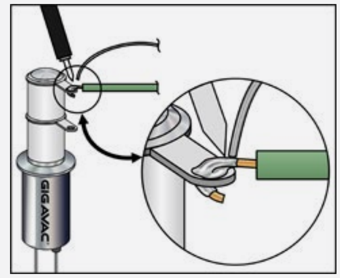


Fig. 11, Soldering to diaphragm style relays

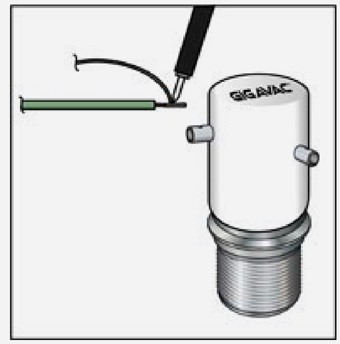


Fig. 12, Pre-tin the wire for solder pot type relays

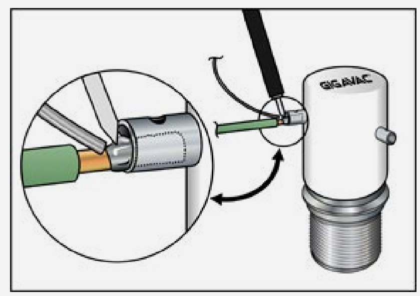


Fig 13, Soldering to solder pot style relays

The Sensata team has decades of experience in the engineering, manufacturing, testing, and application of high voltage relays. With a variety of voltages from 2- 100kV, we will spend the time to guide you through all of the possible selections and tradeoffs to help you make an informed decision.

Contact our sales and applications team for more details about your next high voltage relay application.

ABOUT US

Sensata Technologies is one of the world's leading suppliers of sensing, electrical protection, control and power management solutions with operations and business centers in twelve countries. Sensata's products improve safety, efficiency and comfort for millions of people every day in automotive, appliance, aircraft, industrial, military, heavy vehicle, heating, air-conditioning and ventilation, data, telecommunications, recreational vehicles and marine applications. For more information, please visit the Sensata website.

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