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Proximity Sensor Application Notes

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Proximity Sensor Basics

Proximity sensors are reed switches that are over-molded or assembled in housings to protect the switch and provide easy installation. Proximity sensors come in various housing sizes, shapes, and materials, and can be customized at HSI Sensing with a variety of wires, cables and connectors to suit your specific application.

Basic Function

Proximity sensors are manufactured in one of several configurations described below. The contacts will either complete or interrupt a circuit when the actuator comes within proximity of the sensor.

Basic Configurations

Form A
SPST (Single pole, single throw) contains a normally open contact that closes when an actuator comes within the specified operate distance. When the actuator withdraws beyond the specified release distance, the proximity sensor returns to its original open state.

Form B
SPST (Single pole, single throw) contains a normally closed contact that opens when an actuator comes within the specified operate distance. When the actuator withdraws beyond the specified release distance, the proximity sensor returns to its original closed state.

Form C
SPDT (Single pole, double throw) contains two contacts. When an actuator comes within the specified operate distance, the normally closed contact opens, and then the normally open contact closes. When the actuator withdraws beyond the specified release distance, the proximity sensor returns to its original state.

Latch Proximity Sensor
The proximity sensor contact(s) lock into either position until a reset by the reversal of the magnetic field from the actuator. Available in both SPST and SPDT.

Steel Proximity Sensor
The proximity sensor can be configured with internal magnets, so that the activating device can be any type of steel including a frame component, control panel door, or any other component containing ferrous material. HSI Sensing patented this technology (5,293,523 and 5,233,322).

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Actuators

An actuator is a magnetic or ferrous material component that activates a proximity sensor.

Magnetic Actuator
A magnetic actuator features a magnet placed in a housing and is often paired with the proximity sensor for a matching sensor package. The actuator housings provide a convenient way to mount the magnet onto a surface.

Ferrous Material
Steel-sensing proximity sensors contain internal magnets, which enables them to be activated by ferrous material. HSI Sensing tests all of our steel sensing proximity sensors with a standard steel target composed of 1018 cold rolled steel that is 3″ x 1″ x 0.062″ thick.

Proximity Sensor Operation

A proximity sensor is activated by a magnetic field or ferrous material component. There are numerous possibilities for sensor orientation within a given magnetic field. The following information outlines several key factors to consider when determining proximity sensor operation.

Operate and Release

Operate distance (D) is the dimension between the proximity sensor and the actuator where the sensor must operate. Release distance is the dimension between the proximity sensor and the actuator where the sensor must release. See Figure 1 for illustrations of proper proximity sensor and actuator alignment.

Magnetic Overdrive

Magnetic overdrive is a critical parameter in the operation of proximity sensors providing low and stable contact resistance as well as outstanding performance. This is achieved by employing the sensor at the recommended must-operate distance or closer.

Milli-Tesla and Gauss

Surface-mounted sensors and small proximity sensors can be conveniently tested for magnetic sensitivity using a Helmholtz Coil. This device is a relatively large assembly consisting of two sets of windings. The windings are arranged to produce a "zone" or volume of space with uniform magnetic field strength. The field strength in the "zone" is directly related to the current in the windings. The field strength is measured in milli-Tesla (mT) or Gauss (G).

$$1mT = 10G$$

Placing a proximity sensor in the test "zone" of a Helmholtz Coil is an excellent way to test magnetic sensitivity. The sensor under test can be subjected to various predetermined fields to verify response or non-response to each field. The test system can also determine the exact field strength required to operate the sensor. This scheme of testing complies with international standards for implantable medical devices, which requires that the devices not respond to certain ambient stray fields.

Contact Resistance

The electrical resistance of the proximity sensor—measured in Ohms—is the combined resistance of the entire assembly, including the reed switch contacts and wire or cable. Contact resistance is measured the following ways in these proximity sensor types:

- Form A contact resistance is measured when an actuator is located at the must-operate distance
- Form B is measured when an actuator is not present
- Form C contact resistance is measured in the following ways:
    - normally open contact resistance is measured when the actuator is located at the must-operate distance
    - normally closed contact resistance is measured when the actuator is located at the must-release distance or greater

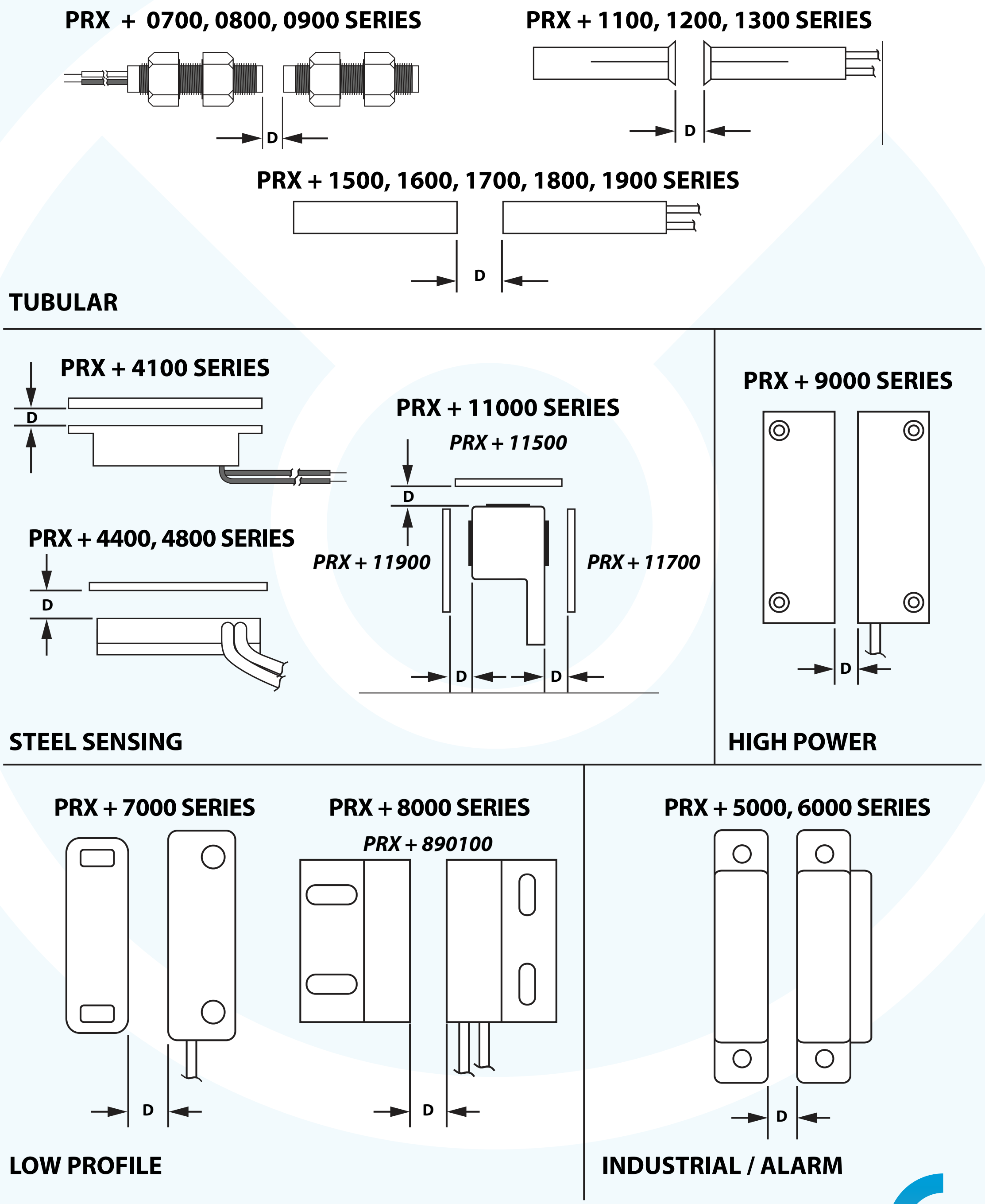

Figure 1

Proximity Sensor Signal/Electrical Requirements

Proximity sensors contain an internal reed switch. A reed switch, though mechanical in nature, ultimately transfers current and voltage when it completes a circuit. HSI Sensing uses several basic definitions and formulas when determining the electrical and signal requirements for each application.

Maximum Switching Current

The maximum electrical current that will pass or is passing through the internal contact(s) at the time of operate or at the time of release. More arcing will occur at the opening and closing of internal contacts when the current is at the maximum specified limit. Arcing between the internal contact(s) will shorten the life expectancy of the proximity sensor. Maximum switching current is measured in amperes DC or amperes peak AC.

Maximum Switching Voltage

The maximum circuit voltage allowed across the open internal contact(s). Proximity sensors are designed for millions of cycles. One factor that may shorten the life of the internal contacts is contact arcing. The higher the voltage, the greater the possibility of arcing. Arcing can cause metal transfer or damage the internal contact(s). To minimize contact arcing, it is imperative to select a proximity sensor with the appropriate features, including the proper reed switch. In general, for applications switching above 250 volts, HSI Sensing recommends a reed switch with an internal vacuum or pressurized gas and/or tungsten contacts. Maximum switching voltage is less than the breakdown voltage.

When selecting a wire or cable, care must be taken to ensure that the voltage rating meets or exceeds the application requirements.

Maximum Switching Power

The maximum recommended switching power—measured in Watts or VA—that the internal contacts can withstand. Switching power is calculated by multiplying the open-circuit voltage by the closed-circuit current that will flow through the internal contacts.

Example: 24 volts x .100 amps = 2.4 watts

Although maximum recommended current and maximum recommended voltage are both given, the maximum power restriction usually requires limiting the actual values. HSI Sensing specification sheet power ratings are for resistive-type loads.

AC and DC loads
Proximity sensors can operate on AC or DC loads, with the exception of sensors with a triac installed. In general, the AC maximum voltage is approximately 70% of the DC maximum voltage rating. Power and current ratings are equal.

Minimum Switching Power

The minimum recommended power level the contacts need for signal transfer.

Contact Material versus Performance

HSI Sensing manufacturers proximity sensors with different internal contact materials intended to provide optimal performance over a wide variety of applications. A universal contact to cover the broad range of current, voltage and power levels does not exist. Durel, Rhodium and Tungsten are contact materials that offer benefits to enhance specific applications. See our Application Notes: Proximity Sensor Internal Contact Performance for additional information.

Load versus Life

The life expectancy of a proximity sensor ranges from one hundred-thousand to millions of switching cycles at maximum power. Operation of the internal contacts above the maximum electrical ratings can damage the contacts and reduce the life of the proximity sensor. Life expectancy can be prolonged further with internal contact protection measures. Selection of the proper contact material (Rhodium, Durel, or Tungsten) is imperative for contact performance.

The internal contact material, internal atmosphere, applied magnetic field, electrical load, and circuit protection (if any) all have an effect on the life of a proximity sensor. For more information on choosing the appropriate proximity sensor for the best performance in your application, contact HSI Sensing.

Types of Electrical Loads
The electrical ratings on HSI Sensing specification sheets are for resistive-type loads. Lamps, capacitive, and inductive loads tend to be more destructive and may require some form of transient or arc suppression. HSI Sensing has several recommendations to prolong the life of the internal contacts and keep the load within the voltage or current ratings specified. This information is for reference only. Actual internal contact performance improvement and/or compatibility in the application should be verified.

Resistive Loads
An electrical load not having any significant inrush current; an electrical load in which voltages are consistent. When a resistive load is energized, the current rises instantly to its steady-state value, without first rising to a higher value.

Inductive Loads
An electrical load which interrupts a large amount of current when de-energized. Inductive circuits tend to create a voltage spike when the circuit energy is dissipated.

When using a proximity sensor for inductive loads, such as motors, relay coils, solenoids, or long signal wires and cables, the internal contacts will be subjected to high induced voltages during opening of the internal contacts. Such high induced voltages may cause damage to the typical proximity sensor with Rhodium or Durel contacts, or may significantly reduce its life. To withstand these inductive loads HSI Sensing recommends Tungsten contacts. These are available in Form A, Form B and Form C proximity sensor types.

Depending on the value of the inductance, HSI Sensing recommends contact protection circuits such as RC, resistors, or clamping diodes.

Capacitive Loads
An electrical load which operates on a large amount of voltage when first energized.

When using proximity sensors for capacitive loads such as capacitors or long cable runs, the contacts can be subjected to high surge (inrush) current. Therefore, protective circuits such as surge suppressors or current limiting resistors are recommended.

Basic Electrical Science Formulas

Power = Volts x Amps ($P = VA_1$) or Power = Amps squared x Resistance = I^2R
Volts = Amps x Resistance ($V = IR$)

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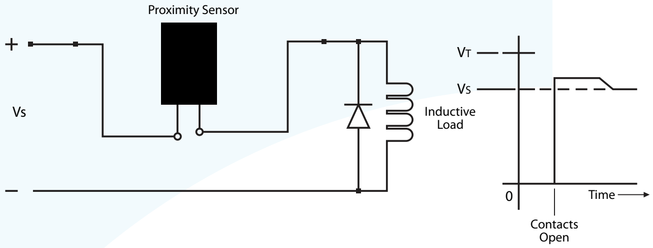
Contact Protection

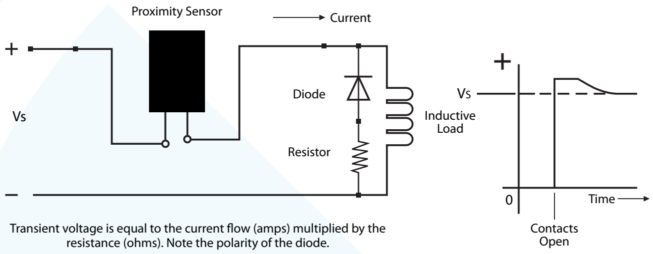
DC Load, Inductive Load, Diode Protection



Vs = Voltage Source

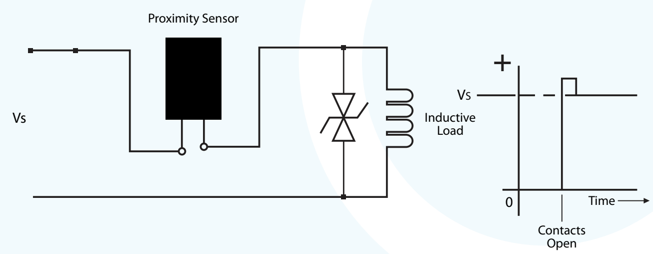
V_T = Transient voltage is equal to the forward voltage drop of the diode. Note polarity of the diode.

Inductive Load, Diode-Resistor Protection



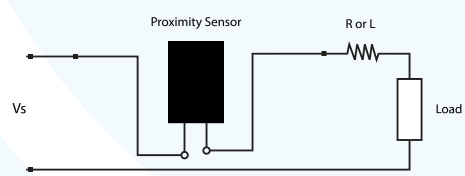
Transient voltage is equal to the current flow (amps) multiplied by the resistance (ohms). Note the polarity of the diode.

Inductive Load, Zener Diode Protection, Featuring Back to Back Zener Diode

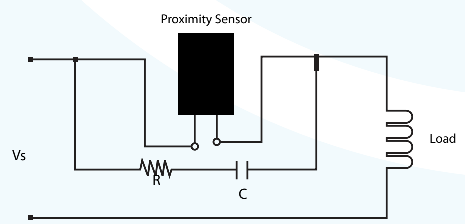


AC or DC Loads

1) Series Resistor or Inductor for capacitive lamp or long cable (or wire) loads



2) Resistor Capacitor Protection for inductive or resistive loads



Capacitor and/or Resistor Value Calculation:

<u>Capacitance</u>

$C = \frac{I^2}{10}$ Value in Micro-farads just prior to contacts opening [I = Amperes of current flowing.]

Voltage = Voltage of source immediately prior to closing to closing contacts.

Proximity Sensor Environmental Considerations

Several environmental factors should be taken into consideration when choosing or working with a proximity sensor. These various environments can have an impact on how the proximity sensor performs.

Shock and Vibration

Risk factors to consider in high shock and vibration applications include:

- epoxy type
- strain on the wires
- wire size and type
- housing material
- mounting surface
- mounting methods

For assistance in choosing the appropriate materials for optimal performance in your application, please contact HSI Sensing.

Severe shock or vibration can change the magnetic sensitivity of a proximity sensor or render it non-functional. In severe cases, a crack in the glass capsule of the internal reed switch may occur. Dropping a proximity sensor may cause shock damage to the internal reed switch.

See Reed Switch Handling Instructions for additional information.

Thermal

Proximity sensors are manufactured using various housing, wire/cable, potting, and insulating materials. All of these materials have their own performance capabilities in relation to thermal requirements.

Caution must be taken for each application to avoid thermal shock when transitioning from extreme heat to extreme cold. If operating near or above the recommended maximum temperature, power and current ratings should be evaluated. Review proximity sensor specification sheets for recommended storage and operating temperatures.

Magnetic Interference

Proximity sensors are designed to react to a specific magnetic signal, typically from a corresponding actuator. When the presence of another magnetic field enters within the operational range, the response of the proximity sensor can change, causing false operation, false release, or no function. Consideration should be given to the proximity sensor application and surrounding environment to avoid interference by other magnetic sources. Examples of these sources include but not limited to other magnets, coils, motors, weld joints, capacitors, resistors, batteries, and relays.

Ferrous Components

Components containing ferrous materials in the immediate area of the proximity sensor can increase or decrease the magnetic flux required to operate the proximity sensor. These components can interfere with proximity sensor function. Careful consideration should be given to the location of the proximity sensor to avoid interference by other ferrous sources. Examples of these sources include but not limited to resistors, capacitors, inductors, screws, bolts, nuts, brackets, mounting surfaces and housings.

Chemical

Proximity sensors are manufactured using various housing, wire/cable, potting, and insulating materials. All of these materials have their own performance strengths and weaknesses for chemical resistance.

Consideration should be given when choosing appropriate materials for a chemical environment.

Proximity Sensor Handling

Proper handling, mounting, and storage of a proximity sensor is critical to effective operation. A proximity sensor can be damaged by improper mounting, dropping or other impact. HSI Sensing has years of experience handling proximity sensors and has developed several best practices.

Handling, Drop, Shock, Vibration Warnings

Excessive physical shock can alter the sensitivity of the proximity sensor. It can also damage the glass capsule of the reed switch inside the proximity sensor, causing a loss of the hermetic seal and thus decreasing the useful life of the proximity sensor. Excessive vibration can also cause glass damage or changes to the magnetic sensitivity.

After a proximity sensor has been dropped or has been subject to excessive physical shock or vibration, always test the sensor. Make sure all characteristics are within the acceptable limits.

Many sensors feature dual potting compounds. One is silicone-based to improve shock and vibration performance, and the other is designed for strength and sealing out the environment. Consult HSI Sensing if your application requires extreme performance.

Printed Circuit Board Mounting

HSI Sensing pioneered the methodology for mounting reed switch assemblies to printed circuit boards (patent number 5,796,254).

When mounting on a printed circuit board, attention should be given to flexing and thermal expansion characteristics. Using epoxy to secure a proximity sensor to a printed circuit board may cause stress on the sensor. This stress can be transferred to the proximity sensor, causing the internal reed switch to break, chip, crack, or change magnetic sensitivity. In typical applications it is better for the mounted proximity sensor to rely on its own strength.

HSI Sensing has multiple options for mounting proximity sensors to a printed circuit board. These options include overmold, housing, trilobular bars, multiple diameter round bars, through-hole, and J-bend.

Storage

When storing proximity sensors, avoid areas that experience a rapid thermal change. Also avoid storing near magnetic fields. An oscillating field, such as a transformer, could activate the proximity sensor and wear it out prematurely. A large, fixed magnetic field holding normally-open durel contacts of a proximity sensor closed for extended periods of time may prevent the internal contacts from releasing properly. See HSI Sensing specification sheets for proper storage temperature recommendations.

Proximity Sensor Internal Contact Performance

HSI Sensing takes great care when selecting the internal reed switch plating material of a proximity sensor to ensure that it functions properly in the final application. Each material has its own unique set of benefits that affect the way a proximity sensor performs.

HSI Sensing offers proximity sensors with these internal contact options:

R – Rhodium

- A noble metal contact material intended for low to midrange power level circuits (.01 watts to 25 watts)
- High durability and wear resistance
- Mechanically capable of up to billions of cycles under normal operating conditions
- Rhodium has a higher power rating than Ruthenium
- HSI recommends Rhodium contacts for applications that remain closed for long periods of time

D – Durel

- Diffused copper plating paired with a treated 52 alloy that HSI Sensing designates as Durel
- Intended for very low power level circuits (less than 1 watt)
- Can go into the millions of cycles
- HSI recommends Durel contacts for applications that are in the normally open state

W – Tungsten

- Solid Tungsten contacts
    - Highest power level contact material available (3 watts to 200 watts)
    - High voltage rating
    - Rated for switching inductive and capacitive loads
- Coated Tungsten contacts
    - High power level coating (1 watts to 50 watts)
    - Highest voltage rating
- High durability and wear resistance
- Intended for midrange to high power level circuits
- Tungsten contacts within a vacuum atmosphere can switch up to 200 Watts, 10,000 Volts DC, or 3 Amps
- Can go into the millions of cycles
- Tungsten contacts within a pressurized gas atmosphere can switch up to 100 Watts, 500 Volts, or 3 Amps
- HSI recommends Tungsten contacts for applications that remain closed for long periods of time

To ensure that you are getting the best plating or coating for your application, please consult individual product specification sheets and then HSI Sensing staff. Actual contact performance may vary depending on the switching power load. By selecting the appropriate switch, wire, and housing, HSI Sensing can custom engineer proximity sensors that achieve higher voltage ratings to match your desired voltage specifications.

Proximity Sensor Testing

For standard testing methods, see Application Notes: Proximity Sensor Operation. These methods include operate, release, actuator alignment, magnetic overdrive, milli-Tesla, and contact resistance.

The following tests can be performed by HSI Sensing and are outside of our standard testing methods.

Voltage Breakdown

This test measures the voltage level a switch can withstand across its open contacts without excessive leakage current. This test can be done in AC and/or DC voltage.

Insulation Resistance

This test measures the DC resistance across the open contacts, measured in Ohms with an ohm-meter and the switch in a de-energized state. The test voltage is typically 100 Volts.

Grounding

HSI Sensing can check a proximity sensor that contains a wire connected to the metal housing for proper grounding. Electrical isolation to all other internal proximity sensor components is also validated.

Customer-Specific Testing

HSI Sensing can replicate testing a sensor in the end-use application for 100% compliance.

HSI Sensing engineering staff can also assist in or design custom test equipment.

Proximity Sensor Components

HSI Sensing uses many standard components in the manufacturing of proximity sensors. HSI Sensing provides engineering services to design custom components tailored to your specific application needs, or we can build based upon your existing component designs.

Housings

Proximity sensors can come in a wide variety of shapes and sizes.

Shapes

- Rectangle
- Tubular
- Square
- Threaded
- Flanges
- Overmolded to custom fit specific application needs

Materials

HSI Sensing uses various materials for external housings. These include but are not limited to:

- Plastic – ABS, Valox, HySol, Peek, Plaskon 7, Xydar, Lexan, Ryton, Fortron, Delrin, Propionate, Epoxy Glass (Phenolic),
- Steel – Sintered, 300 Series Stainless
- Aluminum
- Brass

Accelerated Design

HSI Sensing has the ability to rapidly prototype and machine housings on a limited-run basis to help accelerate the design process.

Wire/Cable

HSI Sensing uses many different types, lengths, gauges, and colors of wire and cables. We utilize both industry standard and specialty wire types and materials. Contact HSI Sensing custom engineering staff for more information regarding available options.

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Depending on application requirements, the following types of wire can be utilized: Stranded Insulated Wire, Non Insulated Solid Wire, or Multi Conductor Cable. Gauges of wire range from 16 AWG – 30 AWG.

Pins and Connectors

HSI Sensing can install various types of pins, connectors and terminal blocks. Contact HSI Sensing custom engineering staff for more information regarding available options.

Potting

HSI Sensing can use a variety of epoxy materials depending on your application.

Materials

- **Silicone** – a soft potting material to protect the internal components from shock, vibration, thermal expansion, and moisture.
    - Dow Corning
    - GE Silicones
- **Hard Epoxy Resin** – a hard potting material for security and bonding strength to secure wire to housing and seal out the environment
    - Dymax
    - Emerson and Cuming
    - Royal Adhesives
    - Armstrong
    - Aremico
    - 3M
- **Adhesive** – holds components in place and is used to seal out the environment
    - Loctite
    - Permabond
    - 3M
    - Dymax UV Adhesives

Solder

HSI Sensing meets J-Standard solder requirements on requested applications.

HSI Sensing utilizes RoHS compliant Pb (lead) free solder (Sn 96.5, Ag 3.0, Cu 0.5). We also use other types of solder when requested, such as the following: 60/40 Sn/Pb, 90/10 Sn/Pb, Sn 95, Sn 96

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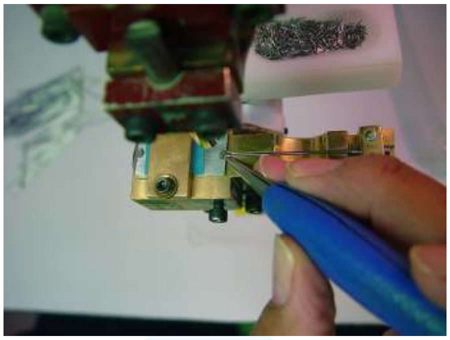
Heat Shrink, Tubing

HSI Sensing works with more than 20 kinds of heat shrink and tubing materials for insulation or cable/wire markers. Contact HSI Sensing custom engineering staff for more information regarding available options.

Welding



For high-temperature applications, HSI Sensing recommends using a welding sleeve to bond the wire and switch together.

HSI Sensing uses ultrasonic welding to press housings and lids together on requested applications. and has the capability to weld surface mount bars and tabs to proximity sensors.

Packaging

HSI Sensing uses the best possible packaging to ensure that orders arrive in pristine condition. Some of our packaging options for proximity sensors are:

- Tape and Reel
- Foam Blocks
- Zip Lock Bags
- Boxes

Printing and Engraving

HSI Sensing can print or engrave anything that will fit on the application housing including, numbers, letters, and symbols. Examples of our capabilities include:

- Ink Jet Printing
    - Blue
    - White
- Laser Engraving
- Mechanical Engraving

Lead Free

HSI Sensing will utilize lead free RoHS compliant components whenever possible. See our specification sheets for details.

UL, CSA, ATEX, Outside Labs

HSI Sensing can utilize outside labs to certify our products. We have customers with multiple certifications and can accommodate external audits from the certifying entity. Contact HSI Sensing custom engineering staff for more information regarding certification and outside lab testing.

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