Welcome to the Basic Training for Inductive Sensors and Connectivity from Pepperl+Fuchs.
In this training we will cover what an inductive sensor is, why you would use an inductive sensor, and where inductive sensors are used in application.

While doing so, we’ll talk about the features and benefits, just the basic technology as a whole, the terminology, mechanical styles, and output types of Pepperl+Fuchs’ inductive sensors, and then a little bit about nomenclature so you can become familiar with our models.

Finally, we will touch on cordsets that are used with these sensors.
An inductive sensor is a sensing device that detects metal objects that come within a defined distance of the sensing face.

Inductive sensors are commonly referred to as inductive switches or proximity sensors.

The term “switch” is used interchangeably with “sensor” because these devices often replace other types of mechanical switching devices.
Inductive sensors are used to improve the performance and reliability of automated machine operation. These sensors provide speedy and accurate feedback about target detection, so that the control system can properly coordinate machine operation sequences.

Inductive sensors—because of their reliability, repeatability, and detection speeds, are the preferred choice in factory automation equipment.
Prior to the implementation of inductive proximity sensors in factory automation, many machines used mechanical switching devices to monitor machine sequencing. These mechanical switches were the workhorses for many factory machines, but had some disadvantages because of their mechanical nature.

Since object detection was based on physical contact with the target, object damage could occur as well as switching level damage. Moving parts including the mechanical levers or push rods as well as the internal switching element were prone to wear, and the contacts and housings were prone to contamination.
So, what can we identify as some of the key benefits of the inductive sensor when compared to a mechanical switch?

First, we know that it functions without contacting the target object.

Second, we see that it has no moving parts to fail or wear out.

Third, it offers a completely sealed design to protect the electronics from moisture or vibration.

Finally, because of its solid-state output technology, it provides fast switching frequencies for more advanced machinery.
As shown here, the electronic circuit functions of an inductive sensor include the inductive coil system, oscillator circuit, trigger or threshold detector circuit, and output circuit.
The heart of the inductive sensor is the electromagnetic coil system and oscillator circuit that define the performance of the object detection characteristics of the device.

The oscillator circuit provides the high-frequency electrical energy to the coil system. This energy is then transformed into electromagnetic field energy by the coil system, producing a high-frequency radiated field that is directed out from the face of the sensor coil.
The back end of the inductive sensor circuit contains the threshold detection circuit. The threshold detection circuit monitors the oscillator amplitude, which is affected by the presence of metal in the electromagnetic field area. When metal enters the radiated field, the amplitude of the oscillator is reduced.

If the oscillator amplitude falls below the level of the internally defined threshold, the output switching device will change state as an indication of target presence.
When speaking of an inductive sensor’s sensing distance, several standard definition terms are often referred to.

First is the nominal sensing (Sn) range, which is a sensing distance for a defined target size, temperature, and applied voltage. This nominal sensing distance does not completely specify the sensing range for a given application.

Second is the assured sensing distance (Sa), which is the distance tested and assured over the complete temperature and voltage range with the standard target size. This assured sensing distance is a more reliable distance to use when designing a sensor for a specific function.

Third is the hysteresis of the sensors, which defines the difference in distance between the on distance and the off distance.
Here we see an illustration of the definition of hysteresis.

Note that the on distance is the position when the sensors output will change to the active state. When the target is moved away from the sensing face, there will be a position where the sensor will change to the inactive or off state.

The difference between these two distances is defined as the hysteresis and is designed into the sensor so that output chatter or instability can be minimized when the target is at the activation distance.
Here we see an example of how the sensing definitions are applied to a basic inductive sensor. The NBB10-30GM50-E2 is a standard Pepperl+Fuchs inductive sensor with a defined sensing range of 10 mm. In this case, the standard sensing distance is 10 mm, the assured sensing distance is 8 mm, and the hysteresis at 5% is 0.5 mm.

Since the assured distance is defined based on multiple factors including supply voltage and temperature, it is common to have a sensor that triggers at a distance less than the assured distance. The assured distance only defines the position where a sensor is guaranteed to activate if the sensor is operated over the complete temperature range.
When thinking about sensor activation, we should also consider how the target approaches the sensor activation area.

There are two main ways that the target can approach. The first way is shown in this slide and is the basis for all prior discussions about sensing distance.
When thinking about the radial approach and the mechanism in which the inductive sensor detects the metal target, we can see that the radial activation point will be affected by the axial distance that the target is from the sensor face.

Looking at target position (1) relative to target position (2), the sensor will activate sooner for target position (2) as it moves in a radial path. This is because when the target is closer to the sensor face, it will trigger the detection threshold with less metal coverage over the sensor face.
The next topic we will address deals with things that can affect the real application sensing distance of an inductive sensor. In this slide, we see that two target-related issues can affect the detection distance.

First is the target size and shape. As we have mentioned in prior slides, there is a defined standard target, and if the real target size is very different than the standard target, we will see an effect on the detection distance.

Second is the target material. Standard sensors are designed and trimmed to detect mild steel ferrous target materials. This is part of the standard target definition. If the real target material is something other than mild steel, such as stainless steel or aluminum, the detection distance will be reduced based on the amount of nonferrous metal content.
As we mentioned previously, the sensor’s detection distance is defined based on a standard target size and material. This standard target is defined as a mild steel (FE 360), 1 mm thick square target with sides equal to the diameter of the sensor or 3 times the nominal sensing distance.

As you can see from the diagram, a larger target will cut or cross more electromagnetic field lines as it approaches the sensor face compared to a smaller target.

This action increases the damping and reduction of the oscillator amplitude, which causes the output to trigger at a greater distance. The smaller target will need to get closer to the sensor face to achieve the same damping effect on the coil and oscillator circuit.
Here in this diagram, we show that the detection distance of the target is also a function of the target metal type. For a given sensor, the mild steel target will have the greatest sensing distance, followed by stainless steel. The copper target will have the shortest. These sensing distances are shown relative to each other by the numbers in the Reduction Factor table. Here we can see that with a standard sensor, an aluminum target will be detected at 40% of the distance of detecting a standard ferrous mild steel target.

At this point, we would like to mention that there are inductive sensor technologies that are not affected by the type of the target metal. If a sensor is required that can detect both mild steel and aluminum at the same distance, in effect a reduction factor = 1 for aluminum, we can offer our Reduction Factor 1 inductive sensors.
Just some general statements about the sensing distance of inductive sensors. The sensing range is directly related to the diameter of the coil system and therefore the outside diameter of the sensor. Therefore, the larger the sensor the greater the sensing distance.

Another factor that relates to sensing distance is whether or not the sensor is a shielded or unshielded design type. Unshielded sensors (nonembeddable) offer longer detection distances than shielded (embeddable) sensors. This we will discuss more in coming slides.
Since inductive sensors are designed to activate when metal enters into the electromagnetic field, it only makes sense that the sensor mounting could play a role in the performance of any application. To provide flexibility in applications and optimization of sensing distance vs. sensor diameter for various applications, sensors are designed with different mechanical structures. These different structures accommodate the trade-offs when specifying inductive proximity sensors. Some common terms that you may see when discussing inductive sensors are shown on this slide.

As we can see:

Flush, shielded, and embeddable all refer to one type of mounting condition where the sensing surface can be flush with surrounding metal. Non-flush, unshielded, and non-embeddable all refer to one type of mounting condition where the sensing surface must have a metal-free zone surrounding the sensing area. Quasi-embeddable mounting refers to a type of mounting condition where the sensing surface must extend out beyond any metal mounting surface.

We will see this demonstrated pictorially on the next slide.
Here we can see the mounting condition pictorials, which also show the features and benefits of each sensor style.

Embeddable sensors have shorter sensing distances relative to the same size nonembeddable or quasi-embeddable sensors, but provide a flush mount in metal that offers protection from side impact in the application.

Nonembeddable sensors have the longest sensing distances relative to the same diameter embeddable or quasi-embeddable sensors, but require a metal free-area around the sensor face, making them susceptible to side impact in the application.

The quasi-embeddable is a third construction that brings the advantages of a longer sensing distance to a semi-flush mounting arrangement.
The inductive sensor comes in several general application output types. These output types fit all of our customers application needs, whether it be retrofitting an old machine or designing a new process.

Most common for new machinery and equipment are the DC types and most typically these are the 3-wire DC PNP models.

For older machinery, replacement parts, and stand-alone equipment with only an AC power source, customers will select AC or AC/DC output types.
Up to this point, we have discussed the basics about inductive sensor technology, construction, mounting, and outputs. Now we will briefly explain the Pepperl+Fuchs inductive sensor basic nomenclature.

For a basic cylindrical inductive sensor NBB5-18GM50-E2-V1, we see the nomenclature is defined as shown here. We see that the first four characters define the sensor type, series, shielding and the sensing range.
The next four characters define the mechanical characteristics of the sensor. Here we see that the sensor diameter is 18 mm, the housing type is threaded, the material is nickel-plated brass, and the thread length on the housing is 50 mm.

Just as a note, this nomenclature is for cylindrical sensor types. Other rectangular sensor types have slight variance to the nomenclature structure.

Most notably, character 5 defines the housing style for standard Pepperl+Fuchs’ housing types.
The last two characters in the sensor nomenclature define the output type and electrical connection. Here it is E2 for PNP, normally open, and the output connection type V1 for an M12 connector.
Up to this point, we have discussed the basics about inductive sensor technology, construction, mounting, and nomenclature. Now we will briefly show the variety of the Pepperl+Fuchs inductive sensor product line.

Inductive sensors come in a variety of shapes and sizes. We will not try to explain all of the models in detail, but only show you the differences between some of the family housing styles. These are four of the main housing types, although there are many more depending on specific applications.

The most common is the cylindrical-style housing, an industry standard, while the second most common are the variety of rectangular styles.

Then there are special housing styles for specific applications. These housing styles include the ring and slot sensor types.
The inductive sensor is very often selected based on the housing style. The housing style is important because the machine or application is limited as to where you can mount the sensor.

The most common housing style by far is the cylindrical shape. Available in many different diameters and housing lengths, these sensors provide the widest assortment of products and solutions for your customers’ needs. As we can see from the image, the sensors come with cables, connectors, and in various sizes.
When a cylindrical housing style does not meet the application mounting requirements, the next common style are the rectangular or cubical shapes. We might see rectangular or square shapes in various sizes to accommodate the application sensing range and mounting conditions. These sensor are available in sizes as small as 8 mm wide up to 120 mm wide.
For special applications, we have the ring style sensors, used primarily for float detection or for part ejection counting operations.
And finally, we have the slot sensor housing style for detection of narrow metal targets as they enter between the “U” shape of the sensor body.
When customers purchase an inductive sensor with a quick disconnect, they will also need a cordset to connect the sensor to the application. Pepperl+Fuchs offers a complete line of cordsets designed for use with our sensor products. The cordsets themselves are very adaptable, with unique models that can fit any application need.

Some key benefits of our cordsets are:

- Different jacket types allow us to meet any application need
- Primary types are PVC & PUR
- Cordsets come in single- and dual-ended models, with straight or right-angled connections available
- Field-attachable connectors offer the capability for cordsets to be custom made to fit even the most unique applications
- Standard lengths of 2, 5, and 10 m are commonly stocked and available, but we can manufacture any cordset from .1 to 100 meters in length

We also offer a full line of junction blocks, IO modules, and AS-Interface components to meet all of your connection needs.
The image shown is a diagram of all of the different connection types that we offer in our cordsets. The “V#” designations on the screen are the appropriate nomenclature that corresponds to that specific connection type. This nomenclature is consistent throughout all of our products.
To finish cordsets we have an example part number of the specific cordset shown in the image. In general, the nomenclature for a cordset can be broken into the four following groups:

1. Primary Connection Type – This encompasses the first two sections of the part number, indicating the type of connector on the cordset
2. Jacket Color and Cable Length – This is usually the third section of the part number, and designates the jacket and cabling of the cordset.
3. Jacket Type – This is directly after the jacket type and color and specifies what the jacket material is.
4. Secondary Connection Type – This is the last section of the part number, and indicates the other connector type on the cordset. If it is not present then the cordset will just have flying leads coming out of the back.
Now that you have completed the basic training portion on inductive sensors and connectivity, we should be ready for the next step toward building thorough product understanding.