Semester project sensors and data acquisition

1 Sensors 2
2 Data acquisition 3
2.1 Labview software 3
2.2 Labview programming skills 3
2.3 CompactDAQ hardware 4
3 Required reading material: 5
3.1.1 Temperature 5
3.1.2 Strain 7
3.1.3 Vibration 9
3.1.4 Position and Displacement 11
3.1.5 Pressure 14
3.1.6 Fluid and gas flow and speed 15
3.1.7 Force 16
3.2 Selection 18
3.2.1 Type of Sensing 18
3.2.2 Composition of Target 18
3.2.3 Distance to Target 18
3.2.4 Form Factor 18
3.2.5 Control Interface 19
3.2.6 Special Requirements 19
3.2.7 Electrical Connection 19

1 Sensors

There is a separate budget for buying sensors. This is made available to digitize the data acquisition at ASE and thus provide you, the students, with a better and more professional experience.

To make use of this budget follow these 6 points:

1) Determine what you need to measure and what would be nice to measure.
2) Determine the specific sensor you need for your application. You can use the reading material uploaded to campusnet to assist you with this point.
3) Check whether such a sensor is already available in the instrument depot, contact person is Thomas Greve tgr@iha.dk
4) Send a purchase request as well as the quotes from a Danish distributor to Mikkel Bo Nielsen mbn@ase.au.dk . The purchase request form is found on the homepage of the Instrument Depotet (link) under "Ordre- og Indkøbsseddel".
    a. Use the number "937000-82152" in the "Sagsnr.-Sagsopgave" field on the purchase request form.
    b. The quotes should include the price, the discount and the delivery time for the sensor excl. VAT.
        i. All student groups are advised to collect their purchases at as few distributors as possible to get volume discount.
        ii. Students are also advised to haggle for better discounts incl. academia discount.
        iii. Some manufacturers might even be inclined to donate sensors to your projects if you ask nicely.
        iv. If the discount is not large enough, your request might be denied.
    c. The sensors should be made available to later students. Please explain how you will ensure that.
5) Mikkel Bo Nielsen will evaluate your request and confirm or deny depending on the reasoning.
    a. Sensors purchased without Mikkels prior consent will not be covered.
6) If everything is in order, the sensors can be ordered.

Mikkel Bo Nielsen mbn@ase.au.dk can be booked for a meeting in his office 03.026 to assist each group with setting up the requirements for their project measurement and control needs.

2 Data acquisition

We already have a large selection of National Instruments Data acquisition hardware available to you for your projects. Mikkel Bo Nielsen will check the sensor output to see if we have the necessary data acquisition hardware.

You will need 1) Labview software, 2) Labview programming skills and 3) compactDAQ hardware.

2.1 Labview software

Labview 2014 32 bit (not 64 bit!) and NI DAQmx 14.0 can be downloaded and installed from https://software.ase.au.dk/ when logged in on the ASE intranet or using the following external links.

LabVIEW 2014 32 bit: http://www.ni.com/download/labview-development-system-2014/4735/en/

NI DAQmx 14.0: http://www.ni.com/download/ni-daqmx-14.0/4918/en/

An installation Guide is found here: http://www.ni.com/white-paper/13413/en/

You can evaluate labview for 7 days and extend this period with 45 days by registering. If you have decided to use Labview for your project you can acquire a student serial number. A student serial number is provided by Mikkel Bo Nielsen mbn@ase.au.dk by sending the following table with your information filled in. One serial number is available pr. Group.

Student ID	Student Name	Course	Serial number return date

Labview student install option serial numbers terms of use:

- The student is responsible for the serial number is not shared with others.
- The serial number you will receive may only be used on a single computer.
- If you reinstall on the same computer again then the activation code sent by email is used so it does not count as 2 activations.
- The serial number is returned by uninstalling Labview and then sending me an email that you guarantee that Labview is uninstalled. I must confirm reception of this email.
- To uninstall labview it is advantageous to perform the following command to uninstall all parts automatically (if necessary edit the path to the uninstaller if you have not used the default install path): "C:\Program Files (x86)\National Instruments\Shared\NIUninstaller\uninst.exe /qb /x all"

2.2 Labview programming skills

You can acquire the programming skills via video training provided by National Instruments.

Basic Labview training (9 parts): http://www.ni.com/academic/students/learn-labview/

Data acquisition using Labview and compactDAQ hardware (3 parts): http://www.ni.com/academic/students/learn-daq/

2.3 CompactDAQ hardware

The compactDAQ hardware is available in the Instrument Depotet, contact person is Thomas Greve tgr@ase.au.dk.

If you need help selecting the correct modules, contact Mikkel Bo Nielsen mbn@ase.au.dk.

3 Required reading material:

Copied from: *http://www.ni.com/white-paper/13654/en/*

You can choose from many different sensors on the market today to measure all types of natural phenomena. This white paper categorizes and compares the most common sensors for measuring seven of these phenomena to help you choose the best option for your application.

3.1.1 Temperature

The most common sensors for measuring temperature are thermocouples, thermistors, and resistance temperature detectors (RTDs). Fiber-optic sensors, while more specialized, are growing in popularity for temperature measurements.

Temp. Sensor	Signal Conditioning Required	Accuracy	Sensitivity	Comparison
Thermocouple	• Amplification • Filtering • Cold-Junction Compensation	Good	Good	• Self-Powered • Inexpensive • Rugged • Large Temperature Range
RTD	• Amplification • Filtering • Current Excitation	Best	Better	• Very Accurate • Very Stable
Thermistor	• Amplification • Filtering • Voltage Excitation	Better	Best	• High Resistance • Low Thermal Mass
Fiber Optics	•Little or No Amplification • Filtering	Best	Best	• Good for Hazardous Environments • Good for Long Distances • Immune to Electromagnetic Interference (EMI)-Induced Noise • Small, Lightweight

Table 1: Comparison of Common Temperature Sensors.

Thermocouples

Thermocouples, the most popular temperature sensors, are effective in applications that require a large temperature range. They are inexpensive ($1 to $50 USD) and have a response time of fractions of a second. Due to material properties and other factors, temperature accuracy of less than 1 °C can be hard to achieve.

View the how-to guide for temperature measurements with thermocouples

RTDs
RTDs are nearly as popular as thermocouples and can maintain a stable temperature reading for years. In contrast to thermocouples, RTDs have a smaller temperature range (-200 to 500 °C), require current excitation, and have a slower response time (2.5 to 10 s). RTDs are primarily used for accurate temperature measurements (±1.9 percent) in applications that are not time critical. RTDs can cost between $25 and $1,000 USD.

View the how-to guide for temperature measurements with RTDs

Thermistors
Thermistors have a smaller temperature range (-90 to 130 °C) than previously mentioned sensors. They have the best accuracy (±.05 °C), but they are more fragile than thermocouples or RTDs. Thermistors involve excitation like the RTD; however, the thermistor requires voltage excitation rather than current excitation. A thermistor typically ranges between $2 and $10 USD in price.

View the how-to guide for temperature measurements with thermistors

Fiber Optics
Another alternative is the use of fiber optics to measure temperature. Fiber-optic temperature sensors are effective for environments that are hazardous or where there could be regular electromagnetic interference. They are nonconductive, electrically passive, immune to electromagnetic interference (EMI)-induced noise, and able to transmit data over long distances with little or no loss in signal integrity.

3.1.2 Strain

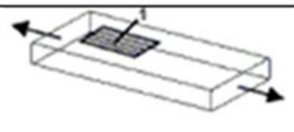
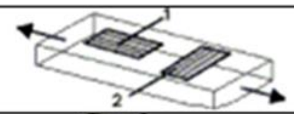
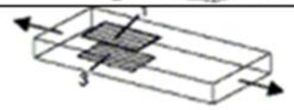
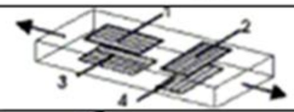
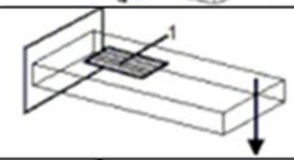
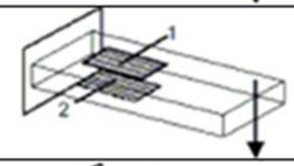
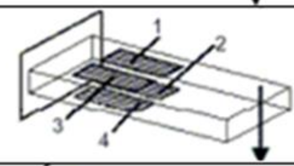
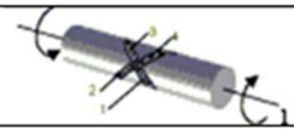
Strain	Gage Setup	Bridge Type	Sensitivity MV/V @100 uE	Details
Axial		¼	0.5	Good: Simplest to implement, but must use a dummy gage if compensating for temperature. Also responds to bending strain.
		½	0.65	Better: Temperature compensated, but it is sensitive to bending strain.
		½	1.0	Better: Rejects bending strain, but not temperature. Must use dummy gages if compensating for temperature.
		Full	1.3	Best: More sensitive and compensates for both temperature and bending strain.
Bending		¼	0.5	Good: Simplest to implement, but must use a dummy gage if compensating for temperature. Responds equally to axial strain.
		½	1.0	Better: Rejects axial strain and is temperature compensated.
		Full	2.0	Best: Rejects axial strain and is temperature compensated. Most sensitive to bending strain.
Torsional and Shear		½	1.0	Good: Gages must be mounted at 45 degrees from centerline.
		Full	2.0	Best: Most sensitive full-bridge version of previous setup. Rejects both axial and bending strains.

Table 2: Comparison of Common Strain Gage Configurations.

Strain is typically measured by a resistive strain gage. These flat resistors are usually attached to a surface that is expected to flex or bend. One use case for resistive strain gages is structural testing of airplane wings. Strain gages can measure very small twists, bends, and pulls on surfaces. When more than one resistive strain gage is wired together, a bridge is created.

A more sensitive measurement is available with the purchase of more strain gages. You can use up to four active strain gages to build a Wheatstone bridge circuit; this is called a full-bridge configuration. There are also half-bridge (two active strain gages) and quarter-bridge (one active strain gage) configurations. The more active strain gages you use, the more accurate your readings will be.

Strain gages require current or voltage excitation and are susceptible to temperature drift, bending strain, and axial strain, which can give false readings without the use of additional resistive strain gages.

- Axial bridges measure stretching or the pulling apart of a material.
- Bending bridges measure a stretch on one side of a material and a contraction on its opposing side.
- Torsional and shear bridges measure the twist of a material.

Strain is measured with a dimensionless unit (e or ε), which is equivalent to a small change in length divided by the full length of an object under measure.

Similar to temperature systems, fiber-optic sensors can be used to measure strain in hazardous environments, where a regular electrical measurement could be altered by electromagnetic interference. Fiber-optic strain sensors are nonconductive, electrically passive, immune to EMI-induced noise, and able to transmit data over long distances with little or no loss in signal integrity.

View the how-to guide for measuring strain with strain gages

3.1.3 Vibration

Vibration Sensors	Natural Frequency	Number of Axes	Damping Coefficient	Scale Factor	Comparison
Ceramic Piezoelectric (accelerometer)	>5 kHz	Up to 3	Small	Requires High Output	• Used in vibration and shock measurements
Linear Variable Differential Transformer (LVDT)	<80 Hz	Up to 3	Medium	Varies	• Limited to steady-state acceleration or low-frequency vibration measurement
Proximity Probe	<30 Hz	Up to 3	Medium	Varies	• Limited to steady-state acceleration or low-frequency vibration measurement • Spring mass attached to wiper of potentiometer
Variable Reluctance	<100 Hz	Up to 3	Medium	Varies	• Output exists only when mass is in motion • Used in shock studies and oil exploration

Table 3: Comparison of Common Vibration Sensors.

Ceramic Piezoelectric Sensor or Accelerometer
Vibration or acceleration is most commonly measured using a ceramic piezoelectric sensor or accelerometer.

Three major factors differentiate vibration sensors: the natural frequency, the damping coefficient, and a scale factor. The scale factor relates the output to an acceleration input and is linked to sensitivity. Together, the natural frequency and damping coefficient determine the accuracy level of a vibration sensor. In a system consisting of a spring and attached mass, if you were to pull the mass back away from equilibrium and release the mass, the mass would vibrate forward (past the equilibrium) and backward until it came to rest. The friction that brings the mass to rest is defined by the damping coefficient, and the rate at which the mass vibrates forward and backward is its natural frequency.

Ceramic piezoelectric vibration sensors are the most commonly used sensors because they are the most versatile sensors. These vibration sensors can be used in shock measurements (explosions and failure tests), high-frequency measurements, and slower low-frequency vibration measurements. This is shown by their higher than average natural frequency.

However, this sensor typically has outputs in the millivolt range and requires a high-input-impedance, low-noise detector to interpret voltages from its piezoelectric crystal.

Proximity Probes and Linear Variable Differential Transformers (LVDTs)

Proximity probes and LVDTs are similar. Both are limited to steady-state acceleration or low-frequency vibration measurement; however, the LVDT vibration sensor has a slightly higher natural frequency, meaning that it can handle/detect more vibration. The proximity probe is simply a spring mass attached to the wiper of a potentiometer.

Variable Reluctance Vibration Sensor

A variable reluctance vibration sensor uses permanent magnets and movement through coils to measure motion and vibration. This is a special vibration sensor because it registers output only when the mass it is measuring is in motion. This makes it particularly useful in earthquake shock studies and oil exploration to pick up vibrations reflected from underground rock strata.

View the Sound and Vibration Measurements: How-To Guide.

3.1.4 Position and Displacement

Position Sensor	Price	Environment	Accuracy	Sensitivity	Comparison
Hall Effect Sensor	Low	Standard	On or off	On or off	• Only certain that target is nearby when depressing sensor
Optical Encoders – Linear and Rotary	Varies	Standard	Varies	High	• Accuracy determined by number of counts per revolution
Potentiometers	Low	Standard	High	High	• Required to be physically attached to moving target
Linear and Rotary Variable Differential Transformers (LVDT) or (RVDT)	High	Known for tolerance of dirty industrial environments and precision	High	High	• Handles a high degree of power • Requires signal conditioning • RVDTs typically operate over any angular range of ±30 to 70 °C
Eddy-Current Proximity Probe	Medium	• Noncontacting • Tolerance of dirty environments • Not sensitive to material between sensor and target	Medium	Varies	• Not good where high resolution is required • Not good for use when a large gap exists between sensor and target (optical and laser sensors are better) • Good when mounted on a reasonably stationary mechanical structure to measure nearby moving machinery
Reflective Light Proximity Sensor	Varies	Standard	Varies	High	• Line of sight to target required for measurement • Good for use when large gap exists between sensor and target • Accuracy determined by quality of sensor

Table 4: Comparison of Common Position Sensors.

You can choose from many different types of position sensors. The driving factors in selecting a position sensor are excitation, filtering, environment, and whether line of sight or a direct, physical connection is required to measure distance. There is not one universally preferred sensor type as with pressure or force. Position has been measured with sensors for a long time, so both preference and application play a role in making this decision.

Hall Effect Sensors
The output of a Hall effect sensor varies based on the presence of a magnetic field. Commonly they are provided in a digital configuration where an "on" is output when an object is present and an "off" otherwise. This sensor provides no scale for how far away an object is from the sensor, but it is effective for applications that do not require highly detailed position information.

Potentiometers
Potentiometers are sensors that use a sliding contact to create an adjustable voltage divider. This adjustable voltage measures position. Potentiometers provide a slight drag to the system that they are physically connected to. While this is required for their use, potentiometers are cheap compared to other position sensors and can offer great accuracy.

Optical Encoders
Another position sensor commonly used is the optical encoder, which can be either linear or rotary. These devices can determine speed, direction, and position with fast, high accuracy. As the name suggests, optical encoders use light to determine position. A series of striped bars divide up the distance to be measured by counts. The more counts, the higher the accuracy. Some rotary optical encoders can have up to 30,000 counts to offer tremendous accuracy. Also, because of their fast response time, they are ideal for many motion control applications.

Sensors with physical components that attach to a system, like the potentiometer, add a small amount of resistance to the movement of the system's parts. However, encoders hardly produce any friction when they move and are very lightweight, but they must have seals to operate within a harsh or dusty environment, which adds to cost. An additional cost is also typically incurred in high-accuracy applications because optical encoders require their own bearings to avoid misalignment when incorporated into products.

See how to take a measurement with an optical encoder

Linear Variable Differential Transformers (LVDTs)
Linear variable differential transformers (LVDTs) and their rotary counterpart (RVDTs) use magnetic induction to determine position. They are both effective for industrial and aerospace applications because of their robustness. Both require signal conditioning, which can add to cost. Also, these sensors must be accurately aligned inside heavy, expensive packaging and contain wound coils that are expensive to manufacture. In addition to their cost, they are known for their high precision.

Eddy-Current Sensors
Eddy-current sensors use magnetic fields to determine position and are moderately priced. They are used less in applications that require highly detailed positioning information or where large gaps exist between the sensor and the target. These sensors are better used on assembly lines when mounted on a reasonably stationary mechanical structure to measure nearby moving machinery or products. For more precise positioning information, use a light proximity sensor instead.

Reflective Light Proximity Sensors

Reflective light proximity sensors use a beam's travel time to and from a reflective target to determine distance. They have a quick response time and are excellent in applications where large gaps exist between the sensor and target. Line of sight is required when using this sensor, and the accuracy and quality of this sensor is directly related to its price.

3.1.5 Pressure

High or low pressure is all relative – like heat. It can be "hot" in a room, but the temperature in that room is nothing compared to the temperature on the surface of the sun. With pressure, the comparison makes the measurement.

There are five common pressure measurement types: absolute, gauge, vacuum, differential, and sealed. Consider the following example of measuring the pressure within a tire, and note how each major type is relative to a different reference pressure.

Pressure Relative Measurement Types	Tire Example	Comparison
Absolute	Absolute pressure = standard atmospheric pressure + gauge pressure	Relative to 0 Pa, the pressure in a vacuum
Gauge	Reading from tire pressure gauge	Relative to local atmospheric pressure
Vacuum	Typically negative value when relative to local atmospheric pressure. Flat tire = 0 kPa on vacuum gauge	Relative to either absolute vacuum (0 Pa) or local atmospheric pressure
Differential	Differential pressure = pressure difference between two different tires	Relative to another pressurized container
Sealed	Sealed pressure = gauge pressure + difference between local atmospheric pressure and sea level pressure	Relative to sea level pressure

Table 5: Comparison of Relative Pressure Measurement Types.

- An absolute pressure measurement includes the standard pressure from the weight of the atmosphere (101.325 kPa) and the additional pressure within the tire. The typical tire pressure is 34 PSI or about 234 kPa. The absolute pressure is 234 kPa plus 101.325 kPa or 331.325 kPa.
- A gauge pressure measurement is relative to the local atmospheric pressure and is equal to 234 kPa or 34 PSI.
- Vacuum pressure is relative to either an absolute vacuum or local atmospheric pressure. A flat tire could have the same pressure as the local atmosphere or 0 kPa (relative to atmospheric pressure). This same vacuum pressure measurement could equal 234 kPa (relative to an absolute vacuum).
- Differential pressure is just the difference between any two pressure levels. In the tire example, this means the difference in pressure between two tires. It could also mean the difference between atmospheric pressure and the pressure inside a single tire.

- Sealed pressure measurements are differential pressure measurements taken with a known comparison pressure. Typically this pressure is sea level, but it could be any pressure depending on the application.

Each of these measurement types could alter your pressure values, so you need to know which type of measurement your sensors are acquiring.

Bridge-based (strain gages), or piezoresistive sensors, are the most commonly used pressure sensors. This is due to their simple construction and durability. These characteristics allow for lower cost and make them ideal for higher channel systems.

These common pressure sensors can be either conditioned or nonconditioned. Typically conditioned sensors are more expensive because they contain components for filtering and signal amplification, as well as excitation leads and the regular circuitry for measurement. If you are working with nonconditioned pressure bridge-based sensors, your hardware needs signal conditioning. Check the sensor's documentation so that you know whether you need additional components for amplification or filtering.

Review the how-to guide for pressure measurements

3.1.6 Fluid and gas flow and speed

Except for very special requirements you are asked to use existing sensors for these measurements. Thomas Greve (tgr@iha.dk) can help you with an inventory list.

If you have a special requirement for you flow or speed measurement, please contact Mikkel Bo Nielsen mbn@ase.au.dk with the details of your requirement and your proposed flow sensor including distributor and price.

3.1.7 Force

Load Cell Sensors	Price	Weight Range	Accuracy	Sensitivity	Comparison
Beam Style	Low	10 – 5 k lb	High	Medium	• Used with tanks, platform scales • Strain gages are exposed and require protection
S Beam	Low	10 – 5 k lb	High	Medium	• Used with tanks, platform scales • Better sealing and protection than bending beam
Canister	Medium	Up to 500 k lb	Medium	High	• Used for truck, tank, and hopper scales • Handles load movements • No horizontal load protection
Pancake/Low Profile	Low	5 – 500 k lb	Medium	Medium	• All stainless steel • Used with tanks, bins, and scales • No load movement allowed
Button and Washer	Low	Either 0 – 50 k lb or 0 – 200 lb typically	Low	Medium	• Loads must be centered • No load movement allowed

Table 6: Comparison of Common Load Cell Sensors.

At one time, mechanical lever scales were primarily used to measure force. Today, strain gage based load cells are the most common because they do not require the amount of calibration and maintenance that scales need.

Load cells can be either conditioned or nonconditioned. Typically conditioned sensors are more expensive because they contain components for filtering, signal amplification, as well as excitation leads, and the regular circuitry for measurement. If you are working with nonconditioned bridge-based sensors, your hardware needs signal conditioning. Check the sensor's documentation so that you know whether you need additional components for amplification or filtering.

Beam style load cells are useful when a linear force is expected and are typically used in weighing applications of both small and large items (10 lb up to 5k lb). They have an average sensitivity, but are highly accurate. This load cell has simple construction and a low cost.

The S beam load cell is similar to the beam style with the exception of its design. Because of this design difference (the load cell's characteristic S shape), the sensor is effective for high side load rejection and measuring the weight of a load that is not centered. This low-cost load cell's design is also simple.

The canister load cell can handle larger loads than both S and beam style load cells. It can also handle load movement easily and is highly sensitive; however, the sensor requires horizontal load protection.

Pancake or low-profile load cells are designed in such a way that they require absolutely no movement to achieve an accurate reading. If your application has time constraints or requires quick measurements, you may consider using the canister load cell instead.

Button and washer load cells are typically used to measure the weights of smaller objects (up to 200 lb). Like pancake or low-profile load cells, the object being weighed must not be moving to obtain an accurate measurement. The load must also be centered on what is usually a small scale. The benefit to these load cells is that they are inexpensive.

Review the how-to guide for load measurements

3.2 Selection

Copied from: *http://sensortech.wordpress.com/2010/02/24/hello-world/*

Selecting an industrial sensor can be a daunting task. With so many different sensing technologies and the endless variety of products in the market, how is it possible to find that one ideal sensor for any given application?

Turns out, it's not really so much a process of selecting the right sensor…it's really about eliminating all the wrong choices. Selecting a sensor is a process of asking a series of questions to eliminate any technology or product that doesn't fit the application requirements. For example:

3.2.1 Type of Sensing

Am I sensing a process parameter (e.g. temperature, pressure, flow), the presence of an object, the distance to a target, or the position of a mechanism? Let's say I want to detect the presence of an object. That means I am looking for some kind of proximity sensor (sometimes called "presence sensors" or "object detection sensors"). There are several kinds of sensor technologies that can detect the presence (or absence) of an object. Inductive, photoelectric, capacitive, magnetic, and ultrasonic sensors are all possible candidates at this stage of the selection process.

3.2.2 Composition of Target

What is the material composition of the object (metallic, non-metallic, solid, liquid, granular)? Let's say the object is metallic. Inductive, photoelectric, capacitive, and ultrasonic sensors are all capable of detecting metallic objects, so we need to ask some more questions.

3.2.3 Distance to Target

How far away from the object must the sensor be? Well, if I am building a compact piece of automation machinery, I want to keep everything as close together as possible. I expect the sensor to be installed pretty close to the metallic object that I want to detect. In this case, an inductive proximity sensor would be the best choice. Although inductive sensors have rather short sensing distances (typically 1mm up to about 50mm) compared to other sensing technologies, they have some strong advantages: a) they ignore all materials except metal (e.g. water, oil, non-metallic dust) b) they are very robust physically and c) they are relatively inexpensive. Let's say that I have decided the sensor needs to see the metallic target at a distance of 4mm.

3.2.4 Form Factor

What sort of physical form-factor best fits my application? In our example, it's fairly tight space and there isn't much room to mount something with a lot of length to it. That eliminates the most common inductive proximity sensor type: the threaded tubular housing. We're going to be looking at some kind of low-profile, flat sensor, typically called a block style or rectangular type.

3.2.5 Control Interface

What kind of controller interface and switching logic is required? These days, most sensors are 3-wire DC types. There are other types out there, such as 2-wire DC and 2-wire AC/DC, but by far the vast majority of control systems will require a 3-wire DC sensor. In our case, we need a "3-wire PNP N.O. sensor," meaning 3 wires (+24DC, 0VDC, and output), a PNP-type "sourcing" output (current is sourced *from* the sensor *to* the controller), and "normally open" switching logic (means the output is "off" when the sensor does not see the target).

3.2.6 Special Requirements

Are there any special application requirements? Special application requirements might be things like high temperatures (more than 80 degrees C), nearby welding processes, or high-pressure washdown procedures. In our machine, we don't expect anything worse than a little machine tool oil getting splashed around. This is completely normal for inductive sensors to work around, so nothing special is required other than an IP67 liquid ingress protection rating (standard on most good-quality sensors).

3.2.7 Electrical Connection

How do I want to make the electrical connection? Sensors are typically available with three kinds of electrical connections: a) pre-wired cable with flying leads b) integrated quick-disconnect connector c) a pre-wired cable with a molded-on connector (often called a "pigtail" connector). A fourth connection type – terminal chamber – was once common in the days when proximity sensors were used to replace mechanical limit switches, but is becoming less common in today's industrial environment.

Armed with the above information, it's now possible to visit a sensor manufacturer's website or catalog and be able to find an appropriate match for nearly any application. If you're still not sure, sales people and technical support personnel are always ready to help you find the right sensor for your application.