King Fahd University of Petroleum and Minerals

Electrical Engineering Technology
Diploma Program

EXPERIMENT # 2

Study and Identification of Various Sensors

Sensors are components of data acquisition systems that convert changes in a physical parameter into electrical signals. Some sensors are strictly electrical like thermocouples, and have no moving parts. Other sensors are electromechanical and translate motion into an electrical signal. Anemometers (wind speed) and tipping bucket rain gauges are good examples of this type. Electro-chemical sensors monitor changing chemical concentrations and are represented by pH probes and ion specific electrodes.

Strain Gauge:

Selecting the most suitable transducer is the initial step in designing effective instrumentation system. A strain gage is a sensing or detecting element that converts mechanical force, weight or pressure into an electrical signal which provides a readout of t quantity being measured.

The strain gage is a transducer employing electrical resistance variation to sense the strain produced by a force. It is a very versatile detector for measuring weight, pressure, mechanical force, or displacement.

Strain, being a fundamental engineering phenomenon, exists in all matters at all times, due either to external loads or the the weight of the matter itself. These strains vary in magnitude, depending upon the materials and loads involved. Engineers have worked for centuries in an attempt to measure strain accurately, but only in the last decade have we achieved much advancement in the art of strain measurement. The terms linear deformation and strain are synonymous and refer to the change in any linear dimension of a body, usually due to the application of external forces. The strain of a piece of rubber, when loaded, is ordinarily apparent to the eye. However, the strain of a bridge strut as a locomotive passes may not be apparent to the eye. Strain as defined above is often spoken of as "total strain." Average unit strain is the amount of strain per unit length and has somewhat greater significance than does total strain. Strain gages are used to determine unit strain, and consequently when one refers to strain, he is usually referring to unit strain. As defined, strain has units of inches per inch.

Strain gages work on the principle that as a piece of wire is stretched, its resistance changes. A strain gage of either the bonded or the unbonded type is made of fine wire wound back and forth in such a way that with a load applied to the material it is fastened to, the strain gage wire will stretch, increasing its length and decreasing its crosSsectional area. The result will be an increase in its resistance, because the resistance, R, of a metallic conductor varies directly with length, L, and inversely with cross-sectional area, A. Mathematically the relationship is

$$R = \frac{KL}{A}$$

where K is a constant depending upon the type of wire, L is the length of the wire in the same units as K, and A is the cross-sectional area measured in units compatible with K.

Four properties of a strain gage are important to consider when it is used to measure the strain in a material. They are:

1. Gage configuration.
2. Gage sensitivity.
3. Gage backing material.
4. Method of gage attachment.

The sensitivity of a strain gage is a function of the conductive material, size, configuration, nominal resistance, and the way the gage is energized.

Strain-gage conductor materials may be either metal alloys or semiconductor material. Nickel-chrome-iron- alloys tend to yield high gage sensitivities as well as have long gage life. These alloys are quite good when used for dynamic strain measurements, but because of a high temperature coefficient, they are not as satisfactory for static strain measurements.

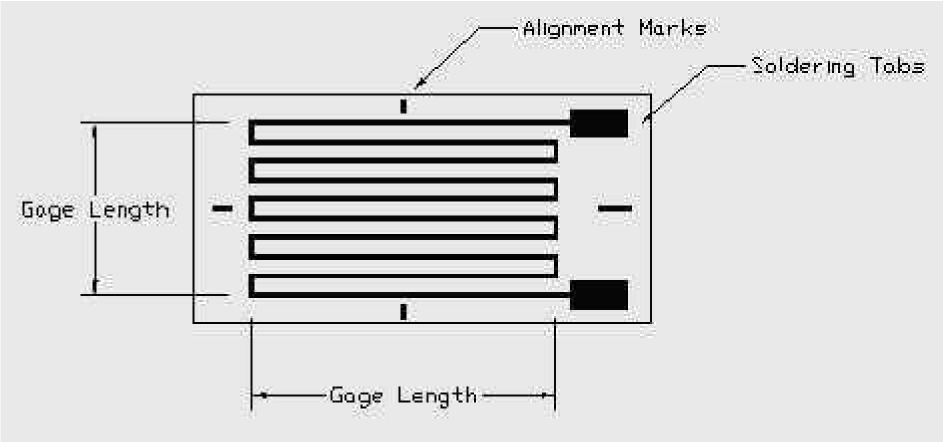
Copper-nickel alloys are generally use when temperatures are below 500 to 600°F. They are less sensitive to temperature changes and provide a less sensitive gage factor than the nickel-chrome-iron alloys. Nickel-chrome alloys are useful in the construction of strain gages for high temperature measurements.

In using electric strain gages, two physical qualities are of particular interest, the change in gage resistance and the change in length (strain). The relationship between these two variables is dimensionless and is called the "gage factor" of the strain gage and can be expressed mathematically as:

$$F = \frac{\Delta R / R}{\Delta L / L}$$

In this relationship R and L represent, respectively, the initial resistance and the initial length of the strain gage wire, while ΔR and ΔL represent the small changes in resistance and length which occur as the gage is strained along with the surface to which it is bonded. The gage factor of a strain gage is a measure of the amount of

resistance change for a given strain and is thus an index of the strain sensitivity of the gage. With all other variables remaining the same, the higher the gage factor, the more sensitive the gage and the greater the electrical output.
The most common type of strain gage used today for stress analysis is the bonded resistance strain gage shown below.



These gages use a grid of fine wire or a constantan metal foil grid encapsulated in a thin resin backing. The gage is glued to the carefully prepared test specimen by a thin layer of epoxy. The epoxy acts as the carrier matrix to transfer the strain in the specimen to the strain gage. As the gage changes in length, the tiny wires either contract or elongate depending upon a tensile or compressive state of stress in the specimen. The cross-sectional area will increase for compression and decrease in tension. Because the wire has an electrical resistance that is proportional to the inverse of the cross-sectional area, $R \alpha \frac{1}{A}$, a measure of the change in resistance will produce the strain in the material.

Thermocouple:

Thermocouples plays very important role in industry. They are used as transducers to produce electromotive force to actuate equipment. They are used directly in such devices as furnace valves, recorders, and temperature-recording instruments.

The simplest electrical temperature-sensitive device is the thermocouple. It consists of a pair of wires of dissimilar metals joined together at one end. The other ends are connected to an appropriate meter or circuit. The joined ends are known as the hot junction and the other ends are the cold ones. When the hot junction is heated, a measurable voltage is generated across the cold ends.

With proper selection of the wires, the voltage varies in relationship to the temperature being measured. Because of this, the thermocouple can be considered a thermoelectric transducer because of its characteristic of converting thermal energy into electrical energy. Figure 1 shows a typical circuit using a thermocouple to record temperature changes in a heat chamber.

When the thermocouple is heated at the hot junction, while the cold junction is at a relatively constant temperature, the difference in temperature of the two junctions causes the meter to indicate a current. The indication of the meter is calibrated to be proportional to temperature.

Photocell:

The photocell is used as a control device because of its diversified characteristics. The application of photocells in industry are numerous and varied.

The photoemission cell gives off electrons from one plate to another when illuminated by a light Source. The plates require an initial voltage applied to them and the electrons emitted are called photoelectrons.

The photoconduction cell acts as a variable resistor. When light falls upon its sensitive material, the resistance of the device goes down, allowing more current to flow in the external circuit. The phototransistor is a good example of the photoconductor.

The photovoltaic cell is primarily a voltage Source. This device produces a potential (emf) when light falls upon its photosensitive material. This device does not require an external Source like the photoemission cell. The photographer's "electric eye" is an example of this device. Several of these cells can be placed in series to make what is known as a solar cell.

The photovoltaic cell can generate enough power to actuate a relay. The relay must be very sensitive and its resistance must be chosen so that the cell delivers approximately maximum power output. These relays are usually slow in action and are normally used where high speed is not essential.

The photovoltaic cell can be used as a source to produce electrical energy. In the space industry they are called solar cells. Through these cells, scientists have been able to put man into space and recharge the batteries on board his space craft every time the craft is sunlit.

Because small voltages and currents are produced from fairly large-sized cells, about 0.6 volts per cell in full daylight, many cells are required to produce appreciable power.

The internal resistance of this device is in the range of 300 to 6000 ohms, and its surface temperature should not exceed 122^{o} F.

Photoelectric cells of one type or another are being used in many places around the home and community. Some examples are the automatic eye which controls outside lights around the home, automatic opening and closing of doors at the supermarket, burglar alarms in various establishments, flame indicators for fire alarms, heat control, and also fluid level controllers.

One application of a photoemissive cell is in the operation of a relay. The relay could further be used to turn street lights on and off, dim the lights of an automobile or send a signal to the police or fire department.

In most applications, we choose the photodevice on the basis of the light source and the degree of variation of the light. The selection specifies the size of supply voltage and the gain of the amplifier needed.

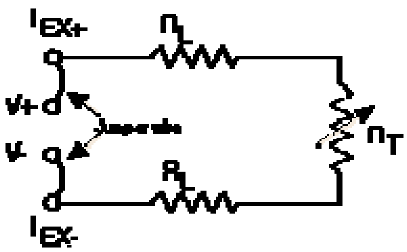
Resistance Temperature Detectors (RTDs):

Resistance temperature detectors, or RTDs, are highly accurate temperature sensors. They are also know for their excellent stability characteristics. They are used to measure temperature from 0°C to 450°C, although some can be used up to 800°C. Due to their low resistance values, you must be careful with the RTD lead resistances.

Resistance temperature detectors (RTDs) are made of coils or films of metals (usually platinum). When heated, the resistance of the metal increases; when cooled, the resistance decreases. Passing current through an RTD generates a voltage across the RTD. By measuring this voltage, you determine its resistance, and thus its temperature.

RTD Basics

- Resistance varies with Temperature
- Platinum 100 Ohm at 0°C
- Very accurate
- Very stable



Resistance temperature detectors, or RTDs, are highly accurate temperature sensors. They are also know for their excellent stability characteristics. They are used to measure temperature from 0°C to 450°C, although some can be used up to 800°C. Due to their low resistance values, you must be careful with the RTD lead resistances.

Summary of RTD Characteristics

Material	Platinum (most common), Gold, Copper, Nickel
Temperature Coefficient	Positive
Resistance	10 Ohm to 1 kOhm
Standards	European and American

Thermistor:

Thermistors are thermally sensitive resistors used in a variety of applications, including temperature measurement. A thermistor is a piece of semiconductor made from metal oxides, pressed into a small bead, disk, wafer, or other shape, sintered at high temperatures, and finally coated with epoxy or glass. The resulting device exhibits an electrical resistance that varies with temperature.

There are two types of thermistors negative temperature coefficient (NTC) thermistors, whose resistance decreases with increasing temperature, and positive temperature coefficient (PTC) thermistors, whose resistance increases with increasing temperature. NTC thermistors are much more commonly used than PTC thermistors, especially for temperature measurement applications.

A main advantage of thermistors for temperature measurement is their extremely high sensitivity. Another advantage of the thermistor is its relatively high resistance. This high resistance diminishes the effect of inherent resistances in the lead wires, which can cause significant errors with low resistance devices such as RTDs. For example, while RTD measurements typically require 3-wire or 4-wire connections to reduce errors caused by lead wire resistances, 2-wire connections to thermistors are usually adequate. The major tradeoff for the high resistance and sensitivity of the thermistor is its highly nonlinear output and relatively limited operating range.

Thermistor Basics

- Thermally sensitive resistor
- Resistance varies with temperature
- Semiconductor made from metal oxides
- 2,252 Ohm to 10 k Ohm at 25 °C
- Up to 300 °C
- Very accurate, stable
- Fast response

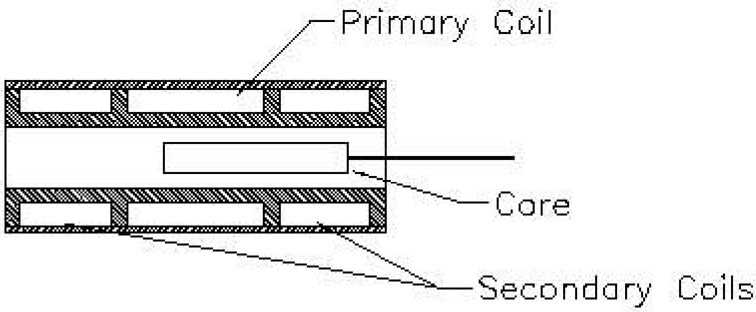
Potentiometer:

The potentiometer is an instrument which can be used to measure the emf of a source (or the potential difference between two points in a circuit), without drawing any current. It is a null device, which essentially balances the unknown potential difference against an adjustable potential difference, which in turn can be calibrated in terms of a standard voltage cell.

The potentiometer is commonly used to measure voltages in situations where the circuit condition would be altered by the flow of current to a meter. One example is the measurement of the emf of a flashlight dry cell; such a cell has an appreciable internal resistance, and its terminal voltage will be lowered when current is drawn from it. Another example is the measurement of the small voltage across a thermocouple, used to determine temperature differences by means of the thermal emf produced at the junctions of dissimilar metals. In this case, the thermal emfs cannot supply sufficient current to be measurable on an ordinary meter.

Linear Variable Differential Transformer:

Another common type of transducer is the Linear Variable Differential Transformer, also known as the LVDT. The LVDT is basically a series of inductors in a hollow cylindrical shaft and a solid cylindrical core. See figure below. The LVDT produces a electrical output proportional to the position of the core. The LVDT may be used in many different types of measuring devices that need to convert changes in physical position to an electrical output. The lack of friction between the hollow shaft and the core prolong the life of the LVDT and enable very good resolution. In addition, the small mass of the core allows for good sensitivity in dynamic tests.



CROSS SECTION OF A LVDT

The LVDT is constructed with two secondary coils placed symmetrically on either side of a primary coil contained within the hollow cylindrical shaft. Movement of the magnetic core causes the mutual inductance of each secondary coil to vary relative to the primary, and thus the relative voltage induced from the primary coil to the secondary coil will vary as well.

These LVDT's may also be calibrated by varying the position of the core and measuring the corresponding output voltages. Then a calibration curve or calibration constant may be determined and applied to arrive at the engineering units of position.

Humidity Sensor:

Controlling the humidity in the greenhouse can yield powerful benefits in disease reduction, improved water and nutrient uptake, and improved plant growth. It is too often under utilized and not well understood. Humidity control is a standard function of nearly all greenhouse control systems. Humidity measurement is expressed as a percentage (i.e., relative humidity). It is the actual amount of moisture in the air, relative to the maximum capacity the air can hold. Accurate humidity sensing can be a challenge, even with the most expensive sensors, which are typically not suitable or practical for the commercial greenhouse industry.

There are three common types of humidity sensors: capacitive, resistive, and wet/dry bulb. Both capacitive and resistive solid-state sensors are fairly common because they offer reasonable accuracy and, in the humidity range typical of most horticultural applications, maintenance is generally limited to cleaning once or twice per year. However, solid-state sensors are susceptible to chemical contamination and high humidity conditions (i.e., over 90%), which may require more frequent recalibration or replacement.

Wet/dry bulb sensors offer the best accuracy if maintained properly, particularly in environments with humidity levels consistently above 90%, such as germination chambers and fog houses. These sensors do require frequent but simple maintenance. Water reservoirs must be refilled and wicks trimmed and replaced regularly. The drier the climate, the more frequent maintenance is required. These sensors are more common in Europe and Canada, due to a number of factors, including tradition, more crops requiring closer humidity control, and climates more appropriate for this type of sensor.

Proximity Switches:

Proximity Switches allow the user to detect the presence of material without having to make physical contact.