A Short Overview of Common Input Transducers

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There are two types of electrical transducers – input and output. Input transducers produce an electrical signal in response to a real-world signal. Output transducers produce a real-world signal in response to an electrical signal. In general, a transducer is a device that converts energy in one form to energy in another form.

All physical quantities are measured by the effect they have on something else – i.e. in a mercury thermometer, temperature is measured by thermal expansion of the mercury. Length can be measured directly by people using a yard stick, etc. Can you name anything else that can be directly measured?

Temperature transducers

Thermocouple: This device works using the Seebeck-effect – an emf is produced across the junction of two dissimilar metals in proportion to temperature. The emf is typically several tens of microvolts per degree Celsius. The transfer cure is typically non-linear although some regions may be fairly linear. Thermocouples are capable of making temperature measurements up to several hundred an in some cases over a thousand degrees Celsius. Note that the measurement is not absolute – but relative to the ambient temperature of the connecting electronics. Ambient temperature compensation is necessary. Thermocouples are used often for high temperature measurements because they are very reliable and their calibration depends mostly on established physical properties of the metals used.

The signal from a thermocouple is very small – typically around 40 microvolts per degree Celsius.

It is not possible to have a single thermocouple in a temperature measurement. There are always at least two or more (whether we want them or not) due to electrical connections to the thermocouple. It is important for all connections to be at the same temperature - isothermal.

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Thermistors: A thermistor is a special resistor whose resistance is a strong negative function of temperature – the resistance decreases as temperature increases. Thermistors are useful up to around 150 degrees Celsius – some can go above 200 C. Because of variations from device to device, thermistors generally need to be calibrated although for a premium price, factory screened thermistors are available that are within a fraction of a percent of a published curve. The transfer function of a thermistor is very non-linear although it is not hard to linearize the characteristic over a reasonable range. A common use for thermistors is in electronic thermostats. Thermistors are specified to have a specific resistance (R_{ref}) at a particular temperature (T_{ref}), typically 25 degrees Celsius and an average temperature coefficient (%TC), typically in the range of -3 to -5 percent per degree Celsius. The temperature coefficient tends to increase in magnitude at lower temperatures. Thermistors also have a bulk resistance (R_{bulk}) that may be around five percent of the resistance at 25 degrees Celsius. The following equation is a good approximation for the resistance of a given thermistor at a given temperature, T.

$$R = R_{ref} * (1 + \%TC/100)^\wedge(T - T_{ref})) + R_{bulk}$$

RTD - resistance-thermometer device: RTDs are special resistors with a positive temperature coefficient. The coefficient is usually only a fraction of a percent per degree Celsius. RTDs are useful at higher temperatures than thermistors. A widely used RTD is Platinum wire which can be used at over 1000 degrees Celsius. A standard RTD is made of Platinum and typically has a resistance of 100.00 Ohms at 0 degrees Celsius and the resistance increases by 0.39 Ohms per degree Celsius.

Semiconductor junction: When forward biased with a constant current a semiconductor junction has a voltage coefficient in the -1 to -2 millivolts per degree Celsius from about -40 degrees to about +200 degrees.

IC temperature sensor: Although only useful from a little less than 0 to about 150 degrees Celsius, there are a number of integrated circuit sensors that put out a linear voltage (typically 10 mV/deg. C) or current as a function of temperature.

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Pressure transducers

Piezo-electric: This type of device produces a voltage proportional to applied force. An everyday example is a crystal microphone which produces a voltage in proportion to the expansions and contractions caused by the force of sound waves. A corollary device is the crystal earphone which expands and contracts in proportion to applied voltage thus producing acoustical pressure waves.

Resistance strain gage: This device is made up of four resistors connected in a bridge configuration. The resistors are built so that stretching changes the effective length, thus changing the resistance. An instrumentation amplifier is connected across the bridge to detect the extremely small voltage change due to an applied force on the strain gage.

Displacement transducers

These types of transducers are used to measure position such as shaft angle and linear displacement. The most common method is the linear variable-displacement transformer (LVDT). This device consists of three windings on a movable iron core. The primary winding is connected to an AC voltage source known as the excitation. The two secondaries are identical and connected in series opposing. As the iron core is moved, the flux coupling from the primary to each of the secondaries changes – the coupling to one secondary increases while the coupling to the other decreases. Thus, the net output voltage and phase is proportional to the location of the iron core.

Accelerometers

An accelerometer is typically a piezo-electric crystal attached to a mass. The product of mass and acceleration produces a force on the crystal which in turn produces a voltage. A common application of accelerometers is measuring vibration in vibration test systems.

Hall-effect device

The Hall-effect is the deflection of electrons in a conductor due to a magnetic field. A voltage is produced across the lateral dimension of the conductor in proportion to the strength of the magnetic field. The voltage is inversely proportional to the velocity of the electrons in the conductor. The polarity of the voltage is related to the magnetic flux direction. A differential amplifier is connected across the conductor to amplify the Hall-effect voltage.

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Photometric transducers

Photo-conductive devices: These devices have a special resistive element that is exposed to light through a window. Light increases the generation of free electrons in the material thus increasing the conductivity. These materials are usually slow to respond to changes in light level, have hysterisis, and also respond to temperature. There prime application is in light-beam detection systems.

Photo-emissive devices: In the photo-multiplier tube (PMT) light (or other wavelength) photons knock electrons loose from a metal cathode inside a vacuum tube. Positive anode voltages accelerate the electrons which then impinge on the anode knocking even more electrons loose which are in turn accelerated towards anodes of even higher voltages. This process continues until the final anode collects all the electrons. The PMT is extremely sensitive and can detect the light of a faint star. The typical output current is from about a nanoamp to several tens of microamps.

Photo-diodes: There is an increase flow of majority carriers through a pn junction due to the application of light photons. Thus, the conductance of a photo-diode increases with light. Photo-diodes are usually only responsive to a narrow band of wavelengths typically in the infrared band – around 900 to 1100 nanometers.

Photo-transistors: These work on the same principle as photo diodes except that the current is into the base of a transistor and is amplified by transistor's beta. Thus, photo-transistors are about a factor of one-hundred more responsive than photo-diodes. The price paid for this is about a factor of one-hundred lower bandwidth. Photo-transistors also only respond to a narrow band of wavelengths typically in the infrared band.