CHAPTER 6

Sensors

Sensors are devices that measure a physical property, such as temperature, humidity, stress, and so on. As this is an electronics book, we are concerned with converting such measurements into electrical signals. We have also stretched the definition of a sensor a little to include things such as global positioning systems (GPSs) that locate your position in space.

Many sensors will provide an output signal that is simply a voltage proportional to the property being measured. Others are digital devices that provide digital data about the property. In both cases, these measurements will often be the input to a microcontroller.

6.1 General Principals

Before we look at some of the vast array of sensors that are available, we will cover some of the general principles that underpin all sensing.

6.1.1 Precision, Accuracy, and Resolution

When looking at a sensor, it is important to understand the difference between precision and accuracy, particularly as precision often gives a misleading impression of the accuracy of the sensor. A classic example of this is digital weighting scales. These may confidently tell you that you weigh 85.7 kilograms when you actually weigh 92.1 kilograms. This is only an error of 10 percent or so, and may not matter if you always use the same scales, but as an absolute measurement, it might be well off the mark.

So precision is a matter of the number of digits reported by the sensor. For an analog sensor, the readings are continuous.

When it comes to digital sensors, there will be a number of bits of resolution. That might be 8 bits (1 in 256), 12 bits (1 in 4096), or higher; that is, the reading is no longer continuous, but has been quantized.

TYPES OF SENSORS — Sensors in bold are covered in this chapter.

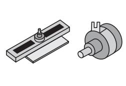
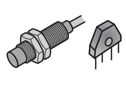
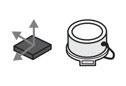
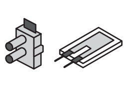
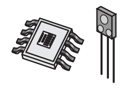
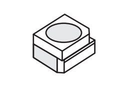
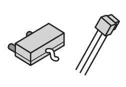
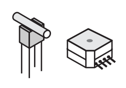
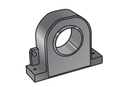
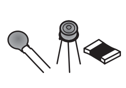
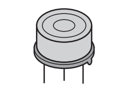
Category of Sensor		What It Does	Example Devices
Position Measuring Devices		Designed to detect and respond to changes in angular position or in linear position of the device.	**Potentiometer** Linear Position Sensor Hall Effect Position Sensor Magnetoresistive Angular **Encoders:** **-Quadrature** -Incremental Rotary **-Absolute Rotary** -Optical
Proximity, Motion Sensors		Designed to detect and respond to movement outside of the component but within the range of the sensor.	**Ultrasonic Proximity** **Optical Reflective** **Optical Slotted** **PIR (Passive Infrared)** **Inductive Proximity** **Capacitive Proximity** Reed Switch Tactile Switch
Inertial Devices		Inertia Devices designed to changes in the physical movement of the sensor.	**Accelerometer** **Potentiometer** Inclinometer Gyroscope Vibration Sensor/Switch **Tilt Sensor** **Piezo Shock Sensor** LVDT/RVDT
Pressure/Force		Pressure Devices designed to detect a force being exerted against it.	**IC Barometer** **Strain Gauge** Pressure potentiometer LVDT Silicon transducer Piezoresistive sensor Capacitive transducer
Optical Devices		Optical Devices designed to detect the presence of light or a change in the amount of light on the sensor.	**LDR** **Photodiodes** **Phototransistors** Photo interrupters **Reflective Sensors** IrDA Transceiver Solar Cells LTV (Light to Voltage) Sensors
Image, Camera Devices		Image, Camera Devices designed to detect and change a viewable image into a digital signal.	CMOS Image Sensor
Magnetic Devices		Magnetic Devices designed to detect and respond to the presence of a magnetic field.	**Hall Effect sensor** Magnetic Switch Linear Compass IC Reed Sensor
Media Devices		Media Devices designed to detect and respond to the presence or the amount of a physical substance on the sensor.	**Gas** **Smoke** **Humidity, Moisture** Dust Float Level Fluid Flow
Current and Voltage Devices		Current Devices designed to detect and respond to changes in the flow of electricity in a wire or circuit.	Hall Effect current sensor DC current sensor AC current sensor Voltage Transducer
Temperature		Temperature Devices designed to detect the amount of heat using different techniques and in different mediums.	**Thermistor NTC** **Thermistor PTC** **Resistance Temp Detectors (RTD)** **Thermocouple** **Thermopile** **Digital IC** **Analog IC** **Infrared Thermometer/Pyrometer**
Specialized		Specialized Devices designed to provide detection, measurement, or response in specialized situations, which also may include multiple functions.	**Audio Microphone** **Geiger-Müller Tube** **Chemical**

FIGURE 6.1 Sensor types.

6.1.2 The Observer Effect

The observer effect states that the act of observing a property changes it. This is the case in a car tire, for example. When you measure the pressure with a conventional tire gauge, you will let a little of the air out, thus changing the pressure that you are measuring. For most sensors, this change will have a negligible effect, but it is something worth keeping at the back of your mind when deciding whether you are getting a true reading.

6.1.3 Calibration

If your invention is a low-cost consumer item that will be mass-produced, then it will be much cheaper and easier to produce if there is no calibration to do. In fact,

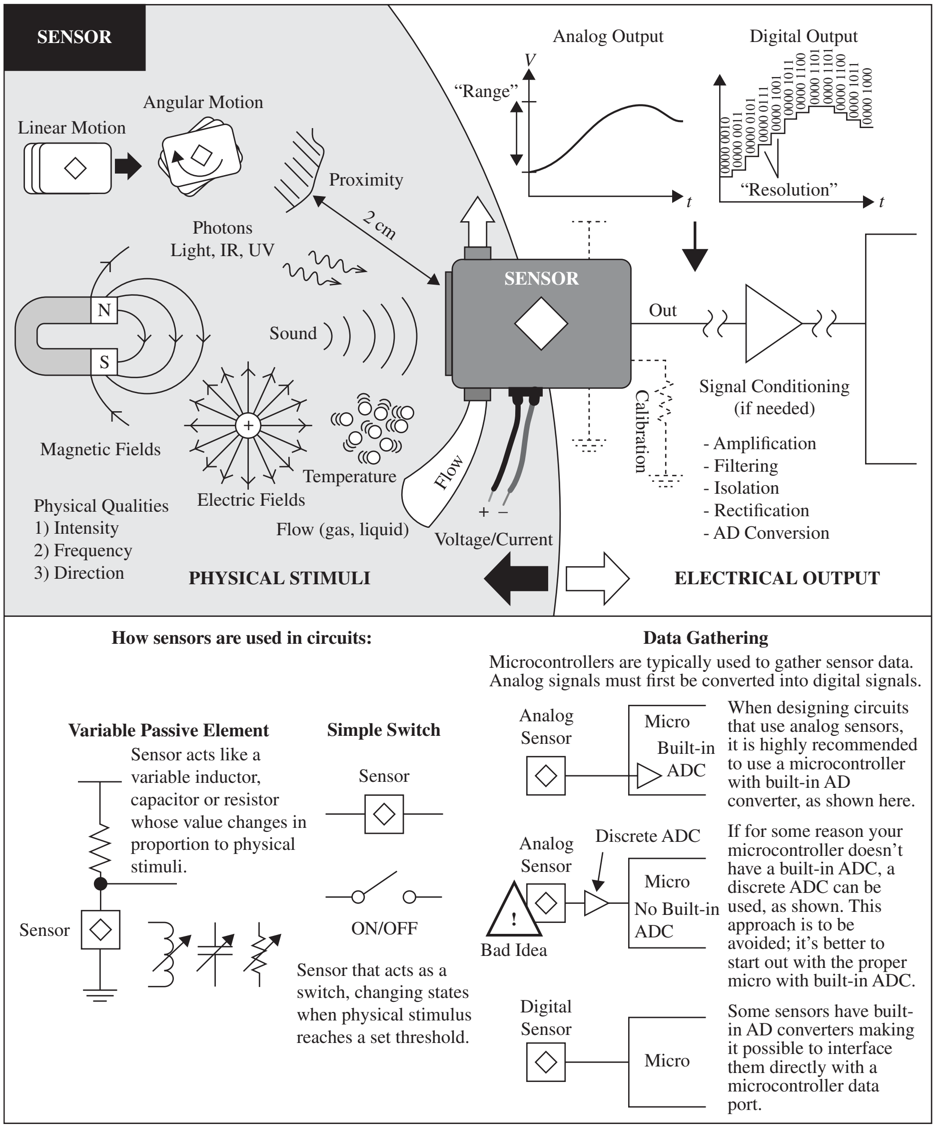


FIGURE 6.2 Sensors.

individual calibration to take differences in individual sensors into account is likely to be prohibitively expensive.

If, on the other hand, your invention is specialized, high-value equipment, then individual calibration of sensors is possible.

The principal of calibration is the same whatever property the sensor measures. The idea is that you take a number of readings from the sensor of unknown accuracy while the sensor is measuring a standard value of known accuracy. So, to calibrate a temperature sensor, your accurate standard might be boiling distilled water at 100°C, or more likely, the temperature in a highly accurate oven constructed for the purpose of calibrating the sensor. This oven will itself need to have been calibrated against an even more accurate standard.

When you have discovered the degree to which your sensor deviates from the standard, then you can compensate for it in some way. Since the sensor will almost certainly be supplying information to a microcontroller, a common way to make the calibration is to change the values in a lookup table. This table contains accurate values against raw values. For example, the raw value straight from a 12-bit analog-to-digital converter is a number between 0 and 1023. These numbers, perhaps in increments of 5, might be the left-hand side of the table, with the right-hand side of the table containing the equivalent temperature as a decimal in degrees Celsius. Interpolation can be used in the gaps between the raw readings by assuming that the small segment of the curve is linear (see Fig. 6.3).

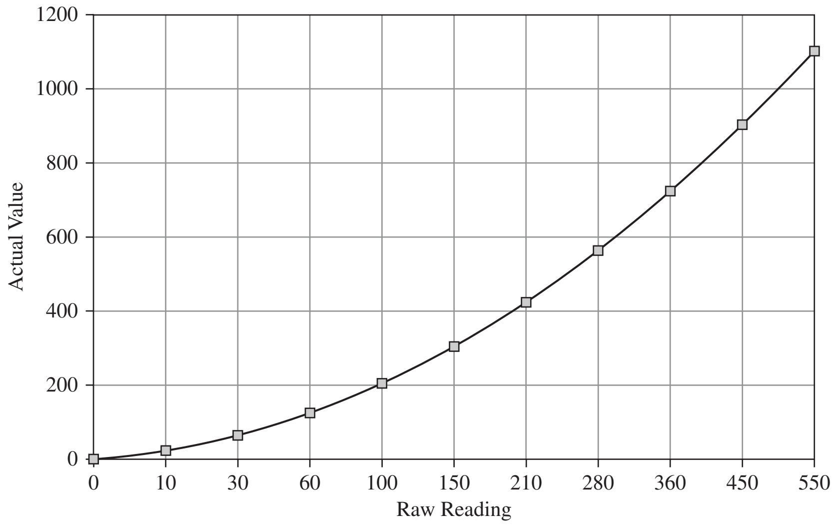


FIGURE 6.3 Actual reading against raw value for a fictional sensor.

Some IC sensors are actually calibrated individually during the manufacturing process, with the values for the lookup table being written into the read-only memory (ROM) of the sensor. This allows accurate sensing at low cost.

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