Chapter 2
Interfacing of Sensors and Signal Conditioning

Introduction

In this chapter, a few signal conditioning methods to interface analog and digital signals to processors, microcontroller, microprocessors etc will be introduced. The readers will get a good idea about different stages required to make an intelligent sensing and measurement system. The process involves passive and/or active devices and use circuits such as filters, current-to-voltage converters or vice-versa and so on. The main purpose of this chapter is to provide some fundamentals of interfacing the signals obtained from different sensors to be available to the digital processor for the necessary computation. The digital signal may be directly connected to a digital input of a processor provided it is within the required voltage range. The analog signals are usually connected to the Analog-to-Digital converters of the processor.

2.1 Change of Bias and Level of Signals

In most applications the sensor signals need some form of change of bias and/or shift of voltage level. For example, the output voltage available from the sensor may vary from 0.2 V to 1.3 V as a change of the input variable over the entire range of measurement. When the output of the sensor is connected to a microcontroller, it may require a voltage level from 0 V to 3.3 V for the same variation of the input variable.

The required signal conditioning is done by changing the output of the sensor from 0.2 V to 0 V with the input variable is 0 V. This may be done simply by subtracting 0.2 V from the output of the sensor. This may be defined as a bias adjustment or zero shift of the output.

Once the bias adjustment is done, the output of the sensor is now varying from 0 V to 1.1 V. In order to utilise the full range of 0 V to 3.3 V of the processor, the signal is multiplied by a gain of 3. This process is known as amplification and the amplifying factor (3 in this case) is known as gain. In many situations, the output to the processor need to be reduced, this is known as attenuation. Both the amplification and attenuation is achieved by the same circuit, known as amplifier. The gain of the amplifier is more than unity for an amplifier and is less than unity for an attenuator.
It is important to take note of the frequency response, input impedance and output impedance while the bias and amplifier circuits are designed.

2.2 Loading Effect on Sensor’s Output

It is useful to understand the loading effect of sensor’s output while designing the signal conditioning circuit. The voltage measured across the output of the sensor is the open-circuit voltage. When the sensor is connected to a circuit, the voltage across the terminals of the sensor drops down to a value and is less than the open-circuit voltage. This is explained with the help of figure 2.1. The output of the sensor is represented by the source voltage $V_s$. The impedance of the sensor (the output resistance) is $R_s$. The sensor is connected to a load of resistance $R_{load}$ which can be the input resistance of any amplifier or any port pin of the processor.

Under open-circuit condition the output of the sensor is $V_s$.

From the figure 2.1, the output $V_{out}$ across the resistance $R_{load}$, can be calculated as

$$V_{out} = \frac{R_{load}}{R_s+R_{load}} V_s$$

(2.1)

$$\frac{V_{out}}{V_s} = \frac{1}{1+\frac{R_s}{R_{load}}}$$

(2.2)

From (2.2), it can be said that the output voltage $V_{out}$ will be equal to $V_s$ only when the load resistance $R_{load}$ is much larger that the source resistance $R_s$. The effect of loading can be illustrated with the help of the following example.

Ex 2.1: A temperature sensor provides an output of 1 mV/°C and has an output resistance of 1 kΩ. The sensor is connected to an amplifier of input resistance of 4 kΩ. If the gain of the amplifier is 100, find the output of the amplifier for a temperature of 50°C.

Sol: The simple solution will be as follows:

The output of the sensor at 50°C, is $50 \times 1 \text{ mV} = 50 \text{ mV}$. 

![Fig. 2.1 The connection of sensor to explain loading effect](image-url)