Real World Signals and Signal Transducers

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The first step performing electronic signal processing on real world signals is to convert them to an electronic signal. In general, a transducer is a device that converts energy in one form to another form. Input transducers convert a real world signal such as light or sound into an electronic signal. Output transducers such as a light bulb or speaker convert an electronic signal into a real world signal.

Examples of Input Transducers

Real World Signal	Transducer	Electrical Effect (sometimes non-linear)
Light	Photo cell	Power proportional to optical power
Light	Photo resistor	Conductivity proportional to optical power
Light	Photo diode	Current proportional to optical power
Light	Photo transistor	Current proportional to optical power
Light	Photo tube	Current proportional to optical power
Sound	Microphone	Alternating voltage proportional to sound
Temperature	Thermocouple	Voltage proportional to temperature
Temperature	Thermistor	Conductivity proportional to temperature
Temperature	Resistor Thermometer Device (RTD)	Resistance proportional to temperature
Temperature	Diode	Voltage drop inversely proportional to temperature
Force	Strain gauge	Change of resistance proportional to force
Force	Piezo sensor	Charge proportional to force
Magnetic field (AC)	Coil	Voltage proportional to magnetic field
Magnetic field (DC or AC)	Hall effect sensor	Voltage proportional to magnetic field

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Examples of Output Transducers

Transducer	Real World Signal	Effect
Light Bulb	Light	Electrical power is converted to optical power
Light Emitting Diode	Light	Current is converted to optical power
Speaker	Sound	AC electrical power is converted to acoustical power
Solenoid	Force	Current is converted to force
Torquer	Force	Current is converted to torque
Heater	Temperature	Electrical power is converted to heat

Signal Processing of Input Transducers (also known as Signal Conditioning)

Frequently, the signal from an input transducer is very small (from femtowatts to nanowatts) and considerable amplification is needed to make the signal usable. With high amplification it is possible for unwanted interference to be picked up and amplified. Some transducers have a DC bias that must be removed. Some transducers may have a non-linear response which must be linearized by the signal processing electronics.

The purpose of signal processing electronics is to first amplify the desired transducer signal while rejecting interfering signals. This is the most critical part of the system and extreme care is needed to prevent an otherwise usable (but extremely weak) signal from being permanently corrupted by much larger interfering signals (Interference tends to be much larger than desired signals). Careful shielding and prevention of ground loops either DC or AC is very important. It often takes considerable time to get everything right.

In many cases it is impossible to prevent interference from being picked up. The strategy is to make the desired signal differential and then make sure that the interference is picked up identically on both signal lines. Since the interference is the same or common to both signal lines, the interference is referred to as a common-mode signal. Then, an instrumentation amplifier can be used to amplify the desired differential-mode signal while rejecting the undesired common-mode signal. Good instrumentation amplifiers can reject the common-mode signal by a factor of 100,000 or more while amplifying the differential signal by a factor of 100 or more.

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There is no point in amplifying signals outside the useful bandwidth of a transducer. It is better to use frequency filters to limit the frequency response of the system to only that which is needed. This permits smaller signals to be detected, thus widening the dynamic range of the system.

Once the signal has been amplified to a usable level, it may be necessary to remove any offset and correct for any non-linear response of the transducer. A piecewise linear transfer function is constructed to create the inverse of the non-linearity of the transducer. The net effect is a linearized signal.

All transducers have an upper limit on the real world signal they can handle before going into saturation (or even being destroyed). Various effects such as hysterisis, deadband, and noise limit how small a signal can be detected. The dynamic range of a transducer is the ratio of the largest to the smallest signal it can convert. No transducer has an infinite dynamic range. Typical transducers have a dynamic range from less than 100 to over 1,000,000. It is important to choose a transducer capable of handling the desired range of signals. The signal processing electronics also has a limited dynamic range. An important design step is to match this range to that of the transducer. It is not hard to obtain a signal processing dynamic range of 1000. With significant effort, the range can be extended to about 10,000. Achieving a signal processing dynamic range of 100,000 or more is very hard to do. One way to achieve wide total dynamic range is to use switched scaling such that the dynamic range on any given scale is 10,000 or less but the total system dynamic range may exceed 1,000,000.

The final function of analog signal processing is to scale the signal appropriately for an analog to digital converter. The dynamic range of the analog to digital converter has to be matched to that of the analog electronics.