1.Sensor Systems

The purpose of a measuring system is to observe and quantify a variable physical quantity (called a measurand) and to process the obtained information.

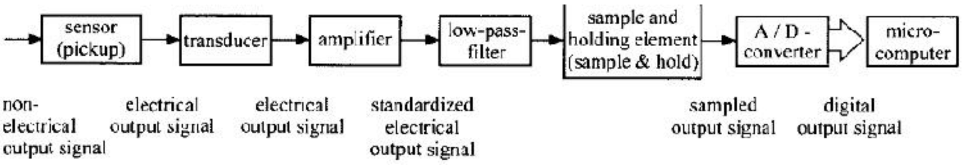

Figure 1. Measuring system components

- The first element of this system is the sensor or sensing element (increasingly used instead of "pickup"). Its primary function is to detect the measurand and transform it into a suitable signal, Mechatronic systems generally rely on sensors with an electrical output signal. The characteristics of the output signal depends on the measurement principle of the sensor.
- Transducers and amplifiers transform the electric sensor output signal into a standardized electrical signal, e.g., 0...20 mA or 4...20 mA or 0...10 V, which is more suitable for further processing.
- If high-frequency disturbances contaminate the usable signal, a low-pass filter is applied in order to decrease the influence.
- A sample and hold device and an analog-to-digital converter are necessary if the sensor signal is to be processed by a microcomputer.

Consumer goods and low-cost appliances do not require high precision measurement and a modular arrangement of the measuring system.

1.2 Signal Types and Measuring Amplifiers

The type of signal supplied by the sensor depends on both the measuring principle and on the associated signal transmission and signal processing devices. Signal types may be subdivided into the following categories:

- amplitude-modulated signals;
- frequency-modulated signals;
- digital signals.

Amplitude-modulated signals are characterized by a proportional relationship between the signal amplitude and the measured quantity.

If the signal frequency is proportional to the measured quantity, the signal is called a frequency-modulated signal. Digital signals encode a measured quantity using serial or parallel binary signals.

properties \ signal type	amplitude-modulated	frequency-modulated	digital
static accuracy	large	large	limited by word length
dynamic behavior	very fast	limited through transducer	limited through sampling
noise sensitivity	medium/large	small	small
galvanic separation	costly	simple (transducer)	simple (optical coupling)
interfacing to a digital computer	analog-digital converter	simple (frequency counter)	simple
computational operation	very limited	limited	simple, if microcomputer

Table 1 Comparison of signal types

2.Interface Electronic Circuits

A system designer is rarely able to connect a sensor directly to processing, monitoring ,or recording instruments, unless a sensor has a built-in electronic circuit with an appropriate output format.

When a sensor generates an electric signal, that signal often is either too weak or too noisy, or it contains undesirable components. In addition, the sensor output may be not compatible with the input requirements of a data acquisition system.
To mate a sensor and a processing device, they either must share a “common value”. In other words, the signal from a sensor usually has to be conditioned before it is fed into a processing device. Such a device usually requires either voltage or current as its input signal. An interface or a signal conditioning circuit has a specific purpose: to bring the signal from the sensor up to the format which is compatible with the load device.

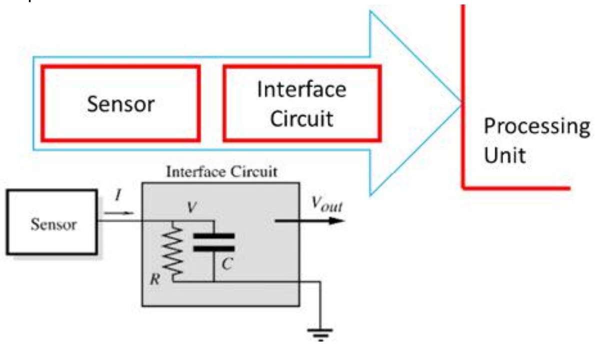

Figure 2. Electronic pathway of Sensor signal

An interface or a signal conditioning circuit has a specific purpose: to bring the signal from the sensor up to the format which is compatible with the processing device. The input part of an interface circuit may be specified through several standard numbers.

- *The input impedance* shows by how much the circuit loads the sensor. Whenever an input impedance of a circuit is considered, the output impedance of the sensor must be taken into account. *For example, if the sensor is of a capacitivenature, to define a frequency response of the input stage, sensor’s capacitance must be connected in parallel with the circuit’s input capacitance.* In any particular case, an equivalent circuit of a sensor should be defined. This helps toanalyze the frequency response of the sensor–interface combination.
- *The voltage e_0 is called the input offset voltage*. If the input terminals of the circuit are shorted together, that voltage would simulate a presence of an input dc signal having a value of e_0. It should be noted that the offset voltage source is connected in series with the input and its resulting error is independent of the output impedance of the sensor.
- The *input bias current i_0* is also internally generated by the circuit. Its value is quite high for many bipolar transistors, much smaller for the JFETs, and even lower for the CMOS circuits. This current may present a serious problem when a circuit or a sensor employs high-impedance components. The bias current passes through the input impedance of the circuit and the output impedance of the sensor, resulting in a spurious voltage drop. This voltage may be of a significant magnitude. In contrast to the offset voltage, the bias current resulting error is proportional to the output impedance of the sensor.

2.1. Amplifiers

Passive sensors produce weak output signals. The magnitudes of these signals may be on the order of microvolts (μV) or picoamperes (pA).
On the other hand, standard electronic data processors, such as A/D converters, frequency modulators, data recorders, and so forth, require input signals of sizable magnitudes—on the order of volts (V) and milliamperes (mA).
Therefore, an amplification of the sensor output signals has to be made with a voltage gain up to 10,000 and a current gain up to 1,000,000. Amplification is part of signal conditioning.
An amplifier is much broader than just increasing the signal magnitude. An amplifier may be also an impedance matching device, an enhancer of a signal-to-noise ratio, a filter, and an isolator between input and output.
Principal building blocks for the amplifiers is the so-called operational amplifier or OPAMP integrated circuits. An analog circuit designer, by arranging discrete passive components around the OPAMP may create custom-made application-specific integrated circuits or ASICs
Gain programing and bandwidth????

2.1.1 Instrumentation Amplifier

An instrumentation amplifier (IA) has two inputs and one output. The main function of the IA is to produce an output signal which is proportional to the difference in voltages between its two inputs It is distinguished from an operational amplifier

- by its finite gain (which is usually no more than 100) and

- the availability of both inputs for connecting to the signal sources.

An instrumentation amplifier can be either built from an OPAMP, in a monolithic or hybrid form. It is important to assure high input resistances for both inputs, so that the amplifier can be used in a true differential form. A good and cost-effective instrumentation amplifier can be built of two identical operational amplifiers and several precision resistors. A differential input of the amplifier is very important for rejection of common-mode interferences having an additive nature. The gain is programmed by a set of resistor.

$$A = \left(1 + \frac{2R}{R_a}\right)\frac{R_3}{R_2}$$

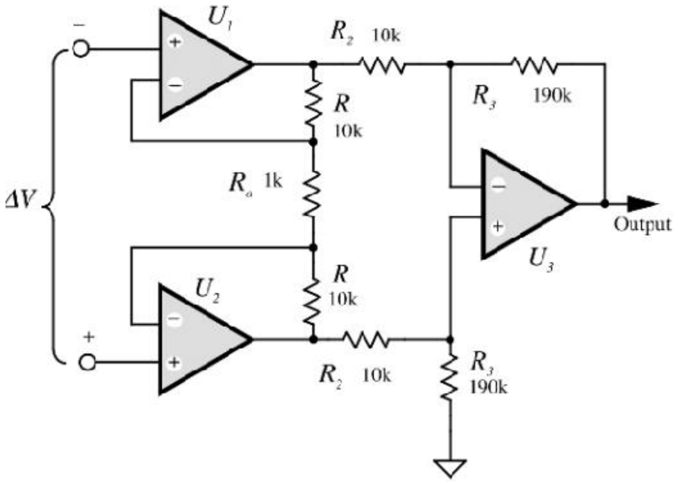

Figure 3. Instrumentation Opamp

2.1.2 Charge Amplifiers

The charge amplifier (CA) is a very special class of circuits which must have extremely low bias currents. These amplifiers are employed to convert to voltage signals from the capacitive sensors, quantum detectors, pyroelectric sensors, and other devices which generate very small charges (on the order of picocoulombs, pC) or currents (on the order of picoamperes) A good film capacitor is usually recommended along with a good quality printed circuit board where the components are coated with conformal coating.

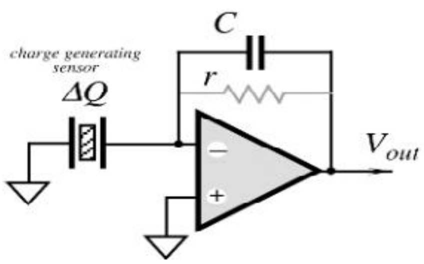

Figure 4. Charge to voltage amplifier and current to voltage converter

Many sensors can be modeled as capacitors. Some capacitive sensors are active; that is, they require an excitation signal. Examples are microphones, capacitive force and pressure transducers, and humidity detectors. Other capacitive sensors are passive; that is, they directly convert a stimulus into an electric charge or current. Examples are the piezoelectric and pyroelectric detectors.

There are also non-capacitive sensors that can be considered as current generators. An example is a photodiode.

2.2 Excitation Circuits

External power is required for the operation of active sensors. Examples are temperature sensors [thermistors and resistive temperature detectors (RTDs)], pressure sensors (piezoresistive and capacitive), and displacement (electromagnetic and optical). The power may be delivered to a sensor in different forms. It can be a constant voltage, constant current, or sinusoidal or pulsing currents.The name for that external power is an excitation signal. In many cases, stability and precision of the excitation signal directly relates to the sensor's accuracy and stability.

2.2.1 Current Sources

A voltage reference is an electronic device which generates constant voltage that is little affected by variations in power supply, temperature, load, aging, and other factors.

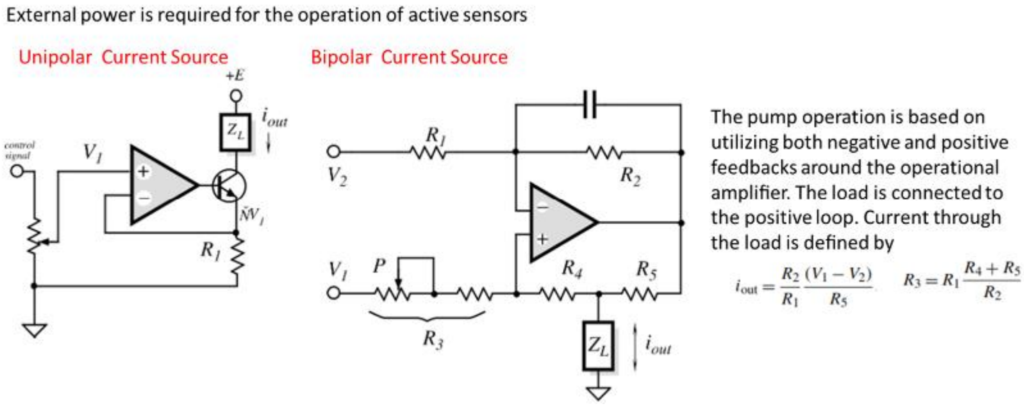

Figure 5. Current Sources

2.2.2 Voltage Sources

A voltage reference is an electronic device which generates constant voltage that is little affected by variations in power supply, temperature, load, aging, and other factors. Each comparator, ADC, DAC, or detection circuit must have a voltage reference in order to do its job (Figure 1). By comparing the signal of interest to a known value, any signal may be quantified accurately.

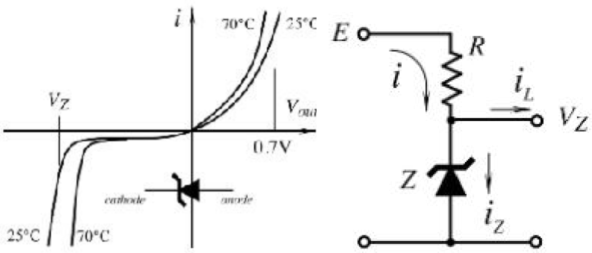

Figure 6. Zener Diode as voltage source

A zener diode has a constant voltage drop in a circuit when provided with a fairly constant current derived from a higher voltage elsewhere within the circuit. The active portion of a zener diode is a reverse-biased semiconductor p-n junction. When the diode is forward biased (the p region is more positive), there is little resistance to current flow.. When the diode is reverse biased (minus is at the anode and plus is at the cathode), very little current flows through it if the applied voltage is less than V_z

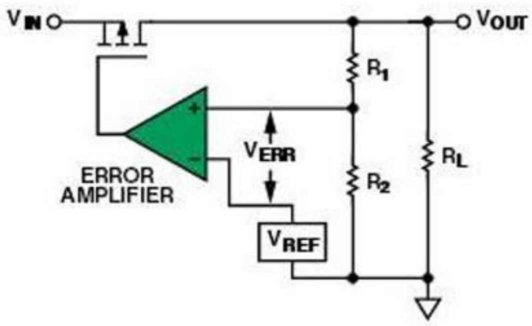

Figure 7. Dc to DC converters

DC to DC converters: In the linear regulator design, an error amplifier (op amp) compares its output voltage to a fixed voltage, usually provided by a specialized reference diode, shown on the left. The closed-loop nature of the design forces the amplifier to maintain the output at the reference voltage, regardless of load

2.3 Bridge Circuits

The Wheatstone bridge circuits are popular and very effective implementations of the ratiometric technique or a division technique on a sensor level. Impedances Z may be either active or reactive; that is, they may be either simple resistances, as in piezoresistive gauges, or capacitors, or inductors.

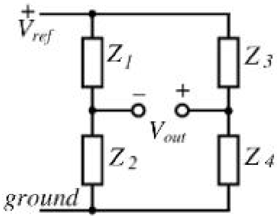

Figure 8. Wheatstone Bridge

Under the balanced condition, the output voltage is zero. When at least one impedance changes, the bridge becomes unbalanced and the output voltage goes either in a positive or negative direction, depending on the direction of the impedance change.

$$V_{out} = V_{ref}\left(\frac{Z_2}{Z_1 + Z_2} - \frac{Z_4}{Z_3 + Z_4}\right)$$

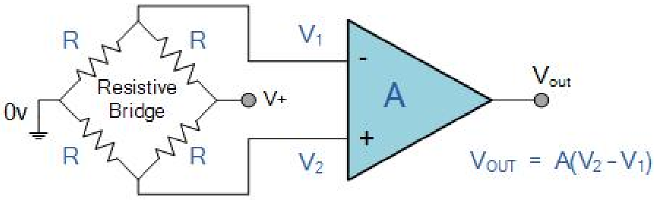

Figure 9. Bridge Amplifier

The standard Differential Amplifier circuit now becomes a differential voltage comparator by “Comparing” one input voltage to the other. For example, by connecting one input to a fixed voltage reference set up on one leg of the resistive bridge network and the other to either a “Thermistor” or a “Light Dependant Resistor” the amplifier circuit can be used to detect either low or high levels of temperature or light