Q5_Measurement Methods and Techniques

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Amplifiers

- An amplifier is an electronic device that increases the amplitude, or strength, of an electrical signal. It is used to boost the power of a weak signal to a level that is sufficient to drive a load, such as a speaker or motor.
- In many cases, the signal being measured may be very small or weak, and an amplifier is needed to boost the signal to a level that can be accurately measured or detected by other equipment.
- amplifiers are often used in instrumentation and control systems to amplify signals from sensors or other sources, and to drive output devices such as actuators or displays.

Types of Amplifiers

- Operational Amplifier (Op-Amp)
- Power Amplifier
- Transistor Amplifier
- Vacuum Tube Amplifier
- Instrumentation Amplifier
- Class-D Amplifier

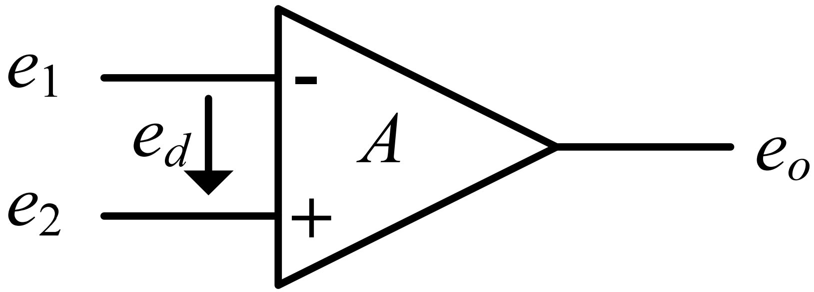
Operational amplifiers

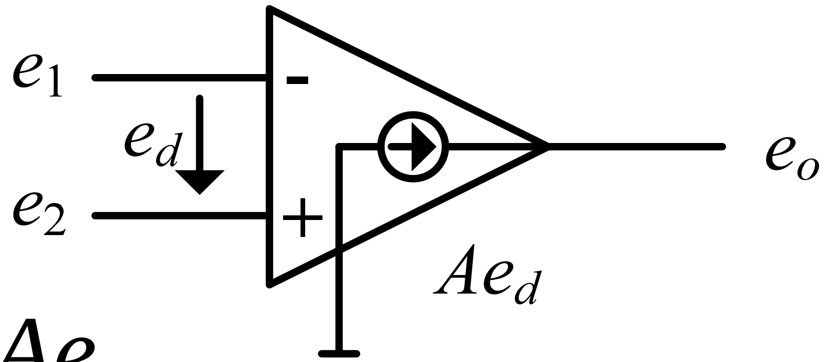
An operational amplifier (op-amp) is a type of electronic amplifier that is widely used in electronic circuits for amplifying and processing signals. It is a high-gain, voltage amplifier with a differential input and a single-ended output, and is characterized by a very large open-loop gain, high input impedance, and low output impedance

Ideal operational amplifier is characterized by parameters:

- Infinite high gain $A \to \infty$,
- Infinite low input offset voltage $V_{os} \to 0$,
- Infinite low input bias currents $I_{B1} = I_{B2} \to 0$,
- Infinite high input impedance
  - Between inputs – differential $Z_d \to \infty$,
  - Between every input and ground – common mode $Z_s \to \infty$,
- Infinite low output impedance $Z_o \to 0$,
- Infinite wide signals band $f \to \infty$,
- Infinite high common mode rejection ratio $\text{CMRR} \to \infty$.

Amplifiers



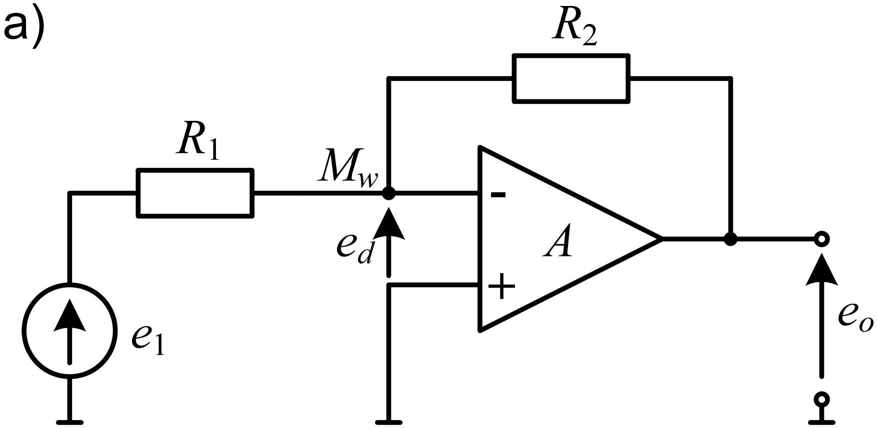


$$e_o = A(e_2 - e_1) = Ae_d$$

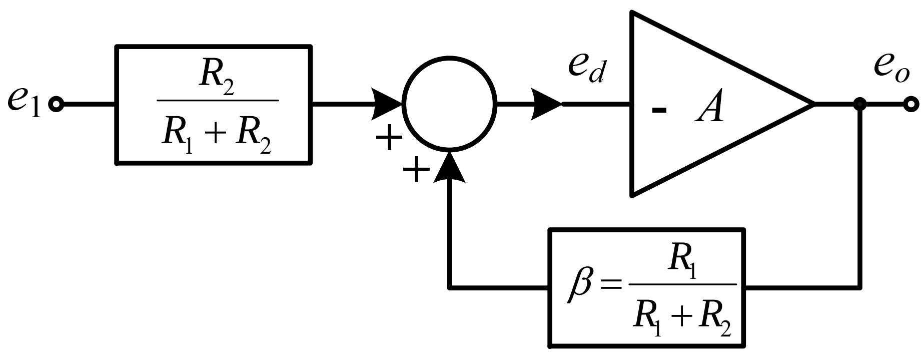
A – amplifier gain,
e_d – differential voltage.

Inverting amplifier

a)



b)



$$\frac{e_1 - e_d}{R_1} = \frac{e_d - e_o}{R_2}$$

$$e_d = \frac{R_2}{R_1 + R_2} e_1 + \frac{R_1}{R_1 + R_2} e_o$$

$$e_d = -\frac{e_o}{A}$$

$$e_o = -\frac{R_2}{R_1} \frac{1}{1 + \frac{1}{A\beta}} e_1 \qquad \beta = \frac{R_1}{R_1 + R_2}$$

Inverting amplifier

Voltage gain

$$A_u = \frac{e_o}{e_1} = \left(1 - \frac{1}{\beta}\right)\frac{1}{1 + \frac{1}{A\beta}}$$

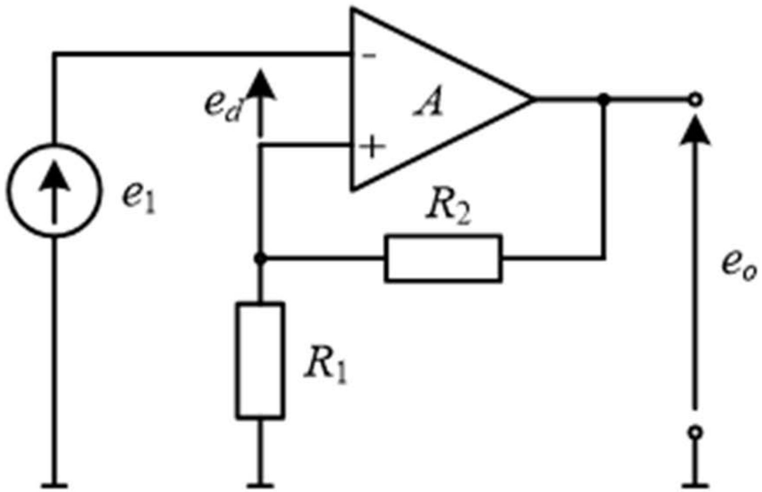
$$A_u = \frac{e_o}{e_1} = \left(1 - \frac{1}{\beta}\right)\left(1 - \frac{1}{A\beta} + \frac{1}{(A\beta)^2} - \ldots\right)$$

Because $A\beta >> 1$

$$A_u \approx \left(1 - \frac{1}{\beta}\right)\left(1 - \frac{1}{A\beta}\right)$$

Non-inverting amplifier

a)



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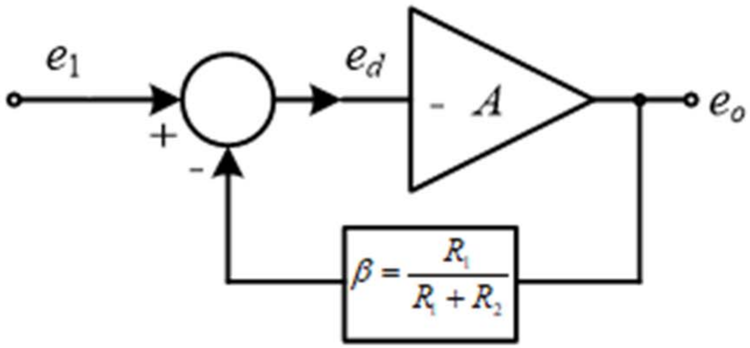


$$e_1 = e_d + \frac{R_1}{R_1 + R_2} e_o$$

$$e_d = e_1 - \frac{R_1}{R_1 + R_2} e_o$$

$$e_o = \frac{1}{\beta} \frac{1}{1 + \frac{1}{A\beta}} e_1$$

$$\beta = \frac{R_1}{R_1 + R_2}$$

Non-inverting amplifier

Voltage gain

$$A_u = \frac{e_o}{e_1} = \frac{1}{\beta} \frac{1}{1 + \frac{1}{1 + A\beta}}$$

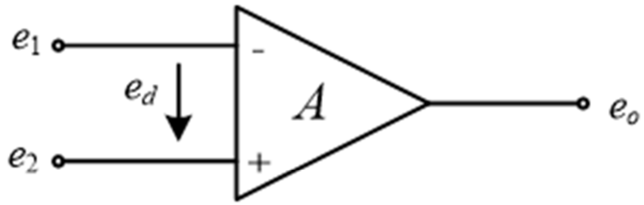
When $A\beta >> 1$

$$A_u \approx \frac{1}{\beta}\left(1 - \frac{1}{A\beta}\right)$$

Common mode rejection ratio (CMRR)

- Common mode rejection ratio (CMRR) is a measure of the ability of an electronic circuit, such as an amplifier or a differential input stage, to reject unwanted signals that are common to both input terminals. These unwanted signals are referred to as common mode signals, and they can be caused by external electromagnetic interference, power supply noise, or other sources.
- The CMRR is defined as the ratio of the differential gain (the gain between the two input terminals) to the common mode gain (the gain of the circuit for common mode signals). A high CMRR indicates that the circuit is able to reject common mode signals effectively, while a low CMRR indicates that the circuit is more susceptible to common mode interference.
- CMRR is expressed in decibels (dB), with higher values indicating better rejection of common mode signals. A typical CMRR for an operational amplifier (op-amp) is in the range of 60 to 120 dB.

Common Mode Rejection Ratio CMRR of operational amplifiers



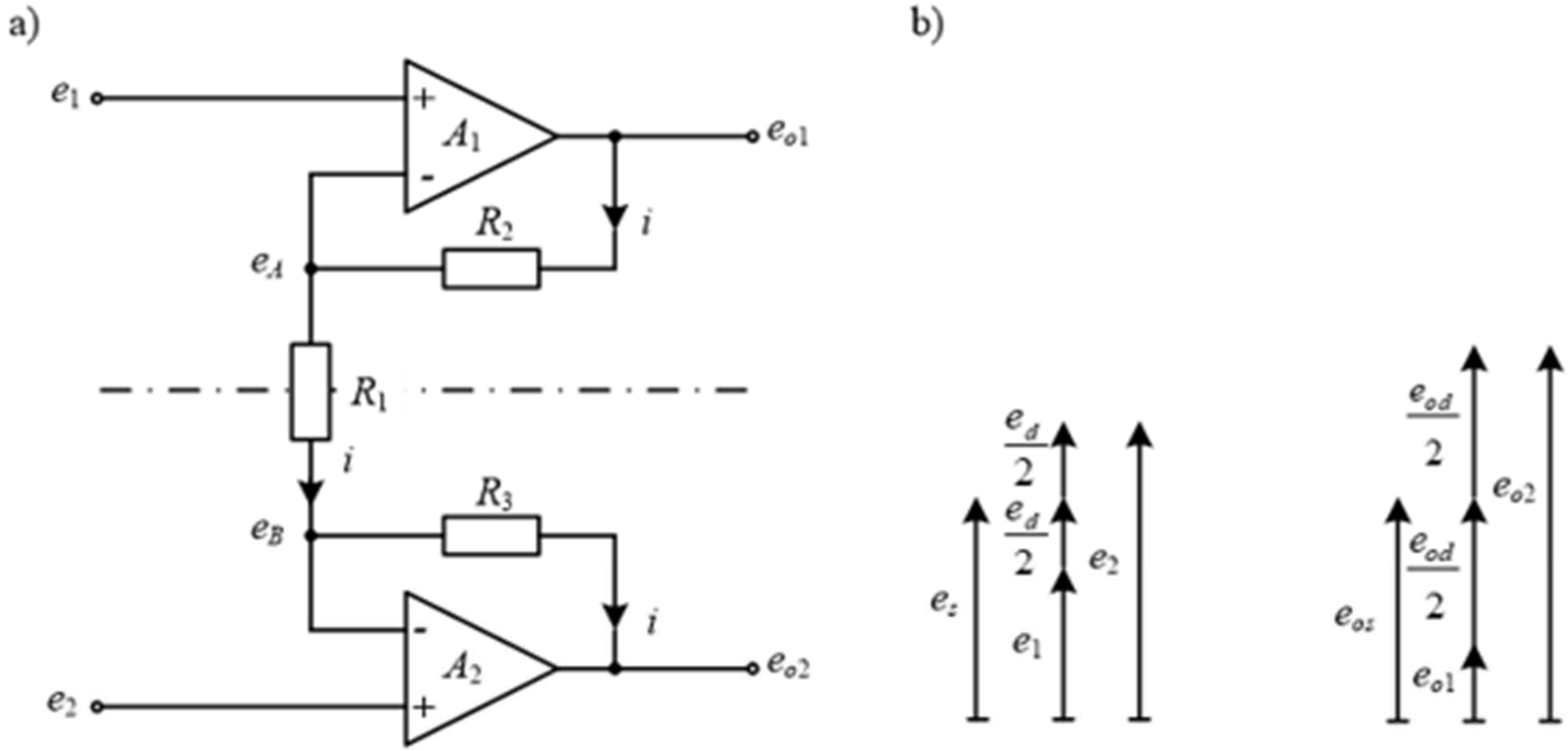
$$e_o = A(e_2 - e_1) = Ae_d$$

$$e_d = e_2 - e_1$$

$$e_s = \frac{e_1 + e_2}{2}$$

Differential input differential output (DIDO)

- Differential input differential output (DIDO) is a type of electronic circuit architecture that is commonly used in analog signal processing and amplification applications. In a DIDO circuit, the input signal is applied to a pair of input terminals, and the output signal is taken from a pair of output terminals.
- The input signal is amplified by a differential amplifier, which is a type of amplifier that amplifies the difference between the voltages at its two input terminals. The output of the differential amplifier is then fed to one or more additional stages of amplification or processing, before being applied to the output terminals.
- The advantage of the DIDO architecture is that it provides good common-mode rejection, meaning that it is able to reject any signal that is common to both input terminals. This is important in many applications where unwanted interference or noise can be present on both input terminals.



a)
b)
e1
A1
eo1
i
R2
eA
R1
i
eB
R3
A2
i
eo2
e2
ed/2
ed/2
ez
e1
e2
eod/2
eod/2
eo2
eoz
eo1

Inductive current transducers and sensors

Sensor is a device that detects or measures a physical quantity and its output is electrical.

Transducer is a device that converts one form of energy into another. Sensors are therefore forms of transducers. The difference between sensors and transducers lies in the efficiency of energy conversion and in linearity of response. For transducers, that convert energy, its efficiency is very important, but for sensors the efficiency is almost immaterial. Linearity of response is important for sensors, but for transducers is less significant.

Smart sensor is a device integrated in a single chip (new constructions) with a processor. So, it is a monolithic integrated sensor that transfers signal information in digital code to digital measurement system with use of a standard communication protocols and a standard interface.

Digital measurements errors

Digital measurement errors are errors that can occur in digital measurement systems. These errors can arise due to a variety of factors, including the design and construction of the measurement system, the characteristics of the signal being measured, and the effects of noise and interference.

1. Quantization Error - This is the error that occurs when an analog signal is converted into a digital signal. Quantization error arises because the resolution of the digital signal is limited by the number of bits used to represent the signal, resulting in rounding errors and loss of information.
2. Sampling Error - This is the error that occurs when a continuous signal is sampled at discrete intervals. Sampling error can result in aliasing, where high-frequency components of the signal are incorrectly represented as lower frequencies.
3. Timing Error - This is the error that occurs due to the delay in the measurement system, such as the time it takes to process the signal or the time it takes for the signal to propagate through the system.

Continued..

4. Noise and Interference - Noise and interference can distort the signal being measured, resulting in measurement errors. This can be caused by external factors such as electromagnetic interference or by internal factors such as thermal noise in the measurement system.

5. Nonlinearity - Nonlinearity can result in measurement errors when the response of the measurement system is not proportional to the input signal. This can occur due to nonlinearities in the components of the measurement system or due to saturation effects.

Methods of measurement noise reduction in DAQ systems.

It is known a lot of techniques for reducing noises in a measurement systems.

For most popular can be accounted: measurement circuits shielding and correct

signal connection to transducers inputs (using correct wires, connections).

This basic methods of reducing measurement noise sometimes are insufficient in measurement circuits with high resolution data acquisition cards (DAQ).

In order to make use of this high resolution the following circuits can be used:

- reject DC common-mode voltage,
- reject AC common-mode voltage,
- break ground loops,
- use 4-20mA current loops,
- use 24V digital logic level.

Reject AC common- mode voltage

Sources of AC noise can be classified by their coupling mechanisms: capacitive, inductive, and radiative.

Capacitive coupling results from time-varying electric fields (e.g., created by nearby relays).

Inductive or magnetically coupled noise results from time-varying magnetic fields (e.g., created by nearby motors).

Radiative coupling results from other noise sources e.g., fluorescent lighting. It is possible when the electromagnetic field source is far from the measurement circuit.

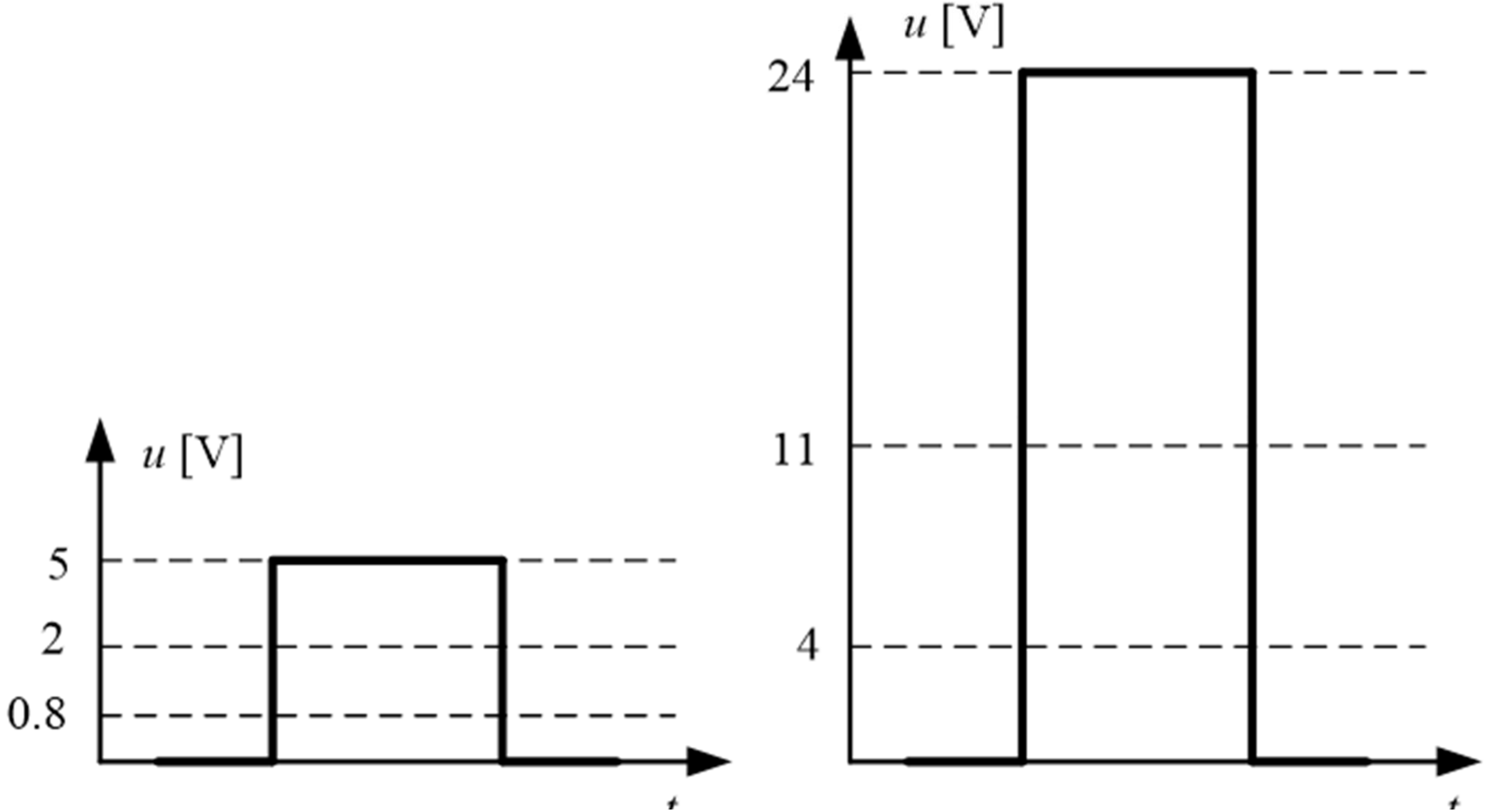
In all cases, a time-varying common-mode voltage is coupled into the measured signal (power-line frequency 50Hz).

4-20mA current loops

Long cable lengths and the presence of noise in industrial applications can make accurate voltage measurements difficult. Industrial transducers that sense flow, pressure, proximity, and often emit current signals instead of voltage.

A 4-20 mA current loop is a popular method of sending measurement information over long distances in many process-monitoring applications, especially when apllication is realized in dangerous conditions.

24V digital logic




The end
Thank you