

COMMON CONTROL SIGNALS AND COMMUNICATIONS PROTOCOLS FOR FIELD MEASUREMENT TECHNICIANS

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A number of control signals have been developed and used as technology has evolved and been applied to the natural gas industry. Control signals are a standardized method of conveying information from one device to another. A control signal is the data sent from one device to another by a specific method.

In industrial process instrumentation, transmitted information is data. Data can be transmitted in many formats and over many different types of media. In addition, the data may be analog or digital in form.

This paper will discuss the most common types of control signals used in the natural gas industry. These signals are:

- Discrete
- Analog
- Pulse
- RTD

Discrete

Discrete control signals are very common in the gas industry. This type of control signal is primarily an on/off or hi/low signal produced by one to two methods.

Mechanical or contact switching is common in large-scale equipment where there is plenty of mechanical or electrical power to activate a mechanical switch. For signaling or control, one leg of a circuit is made or broken interrupting a circuit supplying power to a device.

Testing a mechanical switch is simply a matter of measuring the resistance across the switch during activation with no voltage applied to the circuit. Closed circuits show no or very low resistance while open circuits will show high or infinite resistance.

Testing can also be performed while voltage is applied to the circuit by measuring the voltage across the switch. With a multi-meter set to read the appropriate voltage, place the meter probes on opposite sides of the switch. When the switch is open circuit voltage will be read. When the switch is closed no voltage is shown.

One possible drawback of mechanical contacts is the phenomenon known as switch bounce where the contacts make multiple connections for each opening and/or closing. This may not be a concern when switching loads such as lights or resistance heaters but may be an issue when interpreted by something like an RTU or PLC.

Electronic or transistor switches are very common in today's low power computer controlled equipment. This type of control uses a solid state device to change a circuit resistance high or low thus changing the amount of current within the circuit. This type of switch is generally used for very low current circuits and is not sufficient for directly controlling a large load such as pumps or motors.

Testing of this type of switch usually cannot be performed by measuring resistance as the electronic switch needs voltage applied in order to operate. The circuit can be tested by measuring the voltage across the switching device as discussed above.

Analog

Standard analog signals used in industrial controls can be either a variable voltage or a variable current. An analog signal can be defined as a continuous range of values from a minimum to a maximum that can be related to a specific engineering unit range. Measurement values and signal values can be easily converted between forms because they both represent the same fraction or percent of span.

Variable voltage loops are a method in which the transmitter regulates the voltage in the signal loop. A specified voltage potential is applied to a circuit and the voltage drop across a resistor at the receiver is measured. Analog voltage signals are very convenient but are subject to errors caused by voltage losses in the connecting wires and voltage variations from other sources.

Voltage variations in control circuits can be caused by leakage of AC power from the power supply of the transmitter or receiver or by induction into the signal wire in the presence of nearby AC fields.

Voltage loss along the circuit loop is dependent on the loop resistance. Loop resistance is affected by the impedance of the measuring element, type and length of wire, and type of wire connections within the circuit.

Voltage signals can be used for transmission of information if the distances are short, with low wiring resistance, and with measuring instruments that have high input impedances of more than 1 megohm. Common voltage signals are:

- 1 VDC to 5 VDC
- 0 VDC to 10 VDC
- 0 VDC to 5 VDC

Variable current loops are a method in which the transmitter regulates the current in a transmission loop. Current transmission is not normally effected by distance and associated voltage drop. A current signal is also generally unaffected by noise pickup.

Current loops in the United States have been standardized on the range of 4 mA to 20 mA. Receiving instruments convert the 4 mA to 20 mA signal into a voltage signal in order to be measured. This is done by passing the current through a precision resistor, typically 250 ohms. The resistor may be external or internal to the measuring element. The voltage drop is calculated using Ohm's law as follows:

$$E = I \times R$$

For example, a typical receiver has a 250 ohm resistor. The current is a minimum of 4 mA (0.004 A) and a maximum of 20 mA (0.020 A). The minimum and maximum voltages developed across the 250 ohm resistor can be calculated as follows:

$$E = I \times R$$

$$E = 0.004 \times 250$$

$$E \text{ at } 4 \text{ mA} = 1 \text{ VDC}$$

And

$$E = I \times R$$

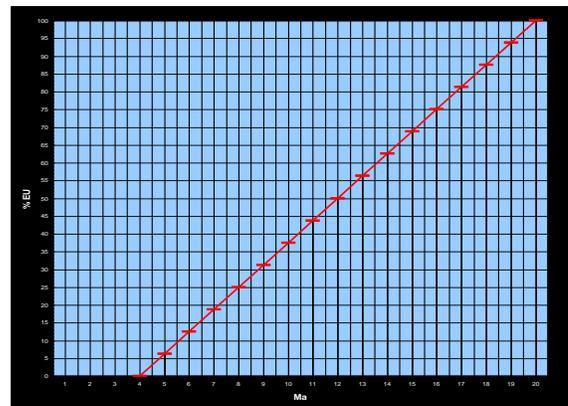
$$E = 0.020 \times 250$$

$$E \text{ at } 20 \text{ mA} = 5 \text{ VDC}$$

This shows that a 1 VDC to 5 VDC signal is developed across a typical resistor due to the 4 mA to 20 mA current

flow. There are voltage drops in the circuit, but the current remains constant in all portions of the loop as stated by Kirchhoff current law.

The "live zero" represented by 4 mA allows the receiving instrument to detect some failures in the loop, and allows transmitter devices to be powered by the same current loop (called two-wire transmitters). Such instruments are used to measure pressure, temperature, flow, pH or other process variables. An output current loop can also be used to control a valve positioner or other output actuator. The relationship between current value and process variable measurement is set by calibration, which assigns different ranges of engineering units to the span between 4 mA and 20 mA. The mapping between engineering units and current can be inverted, so that 4 mA represents the maximum and 20 mA represents the minimum. This relationship can be visualized using the graph below where 4 mA represents 0% EU and 20 mA represents 100% EU.



Analog Conversions

Converting an engineering unit to its equivalent analog value and analog values to engineering units is useful for determining if the transmitter and/or receiving device are functioning properly. The formula is to convert EU's to mA is as follows:

$$mA = \frac{EU - EUL}{EUL - EUL} \times (mAU - mAL) + mAL$$

Where

mA = Milliamp

EU = Measured value

EUL = Engineering unit lower value

EUL = Engineering unit upper value

mAU = Milliamp upper value

mAL = Milliamp lower value

For example, to calculate the mA value with an EU range of 0°F to 150°F and a transmission signal of 4 mA to 20 mA, and a measured temperature of 80°F,

$$mA = \frac{80 - 0}{150 - 0} \times (20 - 4) + 4$$

$$mA = \frac{80}{150} \times 16 + 4$$

$$mA = 0.533 \times 16 + 4$$

$$mA = 8.53 + 4$$

$$mA = 12.53$$

It is also easy to determine an EU value from a mA value. This is useful for checking and calibrating the receiving channel by introducing a signal from a current simulator in place of the transmitter. The formula is as follows:

$$EU = \frac{mA - mA_L}{mA_U - mA_L} \times (EU_U - EU_L) + EU_L$$

For example, to calculate the EU represented by 10.23 mA where the EU range is 50°F to 250°F, and the mA range is 4 mA to 20 mA,

$$EU = \frac{10.23 - 4}{20 - 4} \times (250 - 50) + 50$$

$$EU = \frac{6.23}{16} \times 200 + 50$$

$$EU = 0.389 \times 200 + 50$$

$$EU = 77.8 + 50$$

$$EU = 127.8^\circ F$$

Pulse

Pulse signals consist of a rapidly changing voltage from a low value to a high value. Each pulse can be configured to represent an incremental value such as cf, ccf, or Mcf. The pulse channel can count pulses during a given time period and compute a rate.

Various flowmeters use pulse outputs. Turbine, vortex shedding, coriolis mass, rotary and positive displacement meters can all provide pulse outputs.

RTD

A *resistance temperature detector* (RTD) is an electrical temperature device consisting of a high-precision resistor with resistance that varies with temperature. A voltage source must be applied to the RTD and the voltage drop across the resistance to be measured.

Although RDT's are not technically control signals, they are included here because many RTU's and flow computers utilize direct RTD inputs.

The resistor element of an RTD can be manufactured from platinum, nickel or copper wire wrapped around an insulator. Platinum is the best and most common wire used to manufacture RTD's because it is useful over a wide range of temperatures – from -400°F to 1200°F. Platinum RTD's are manufactured to have a fixed resistance of 100 ohms at 32°F. The resistance increases and decreases in a very predictable manner with an increase or decrease in temperature.

RTD receiving channels measure the voltage drop across the resistor and calculate the resistance using Ohm's law. The calculated resistance then relates directly to a given temperature.

Communications Protocols

Communications Protocols can be informally defined as a set of procedures to be followed when communicating using well-defined formats for exchanging messages. Each message has an exact meaning. These communications protocols are generally open, digital, serial, two-way networks that connect with high-level information devices. These information devices include smart process control valves and transmitters, flowmeters, and other complex field devices that are typically used with control equipment.

Advanced Modbus

Modbus is a serial communications protocol published by Modicon in 1979 for use with its programmable logic controllers. It has become a de facto standard communications protocol in industry and is now the most commonly available means of communicating electronic devices. Modbus is a messaging system with master-slave communications.

The main reasons for the extensive use of Modbus over other communications protocols are that it is openly published and royalty-free. Modbus is a relatively easy network to deploy and Modbus allows for

communications between many devices connected to the same network.

There are five common variants of Modbus. The two most common are Modbus ASCII and Modbus RTU.

Hart

Hart, or Highway Addressable Remote Transducer Protocol is a hybrid protocol because it combines digital and analog communication on the same wire. The digital information is superimposed on a standard 4 – 20 mA current loop

The protocol was developed by Rosemount Inc., built off the Bell 202 early communications protocol standards, in the mid 1980's as a proprietary digital communications protocol for their smart field instruments. Soon it evolved into Hart. In 1986 it was made an open protocol.

Foundation Fieldbus

Foundation Fieldbus is the name of a family of industrial computer network protocols used for real-time distributed control and is now standardized as IEC 61158. Fieldbus is a complex automated industrial system made up of human machine interfaces with programmable logic controllers (PLC's) connected to sensors, actuators, motors, lights, switches, valves, contactors, positioners and other controllers.

The disadvantages of Foundation Fieldbus over standard control systems or HART is that the systems tend to be much more complex. Users need to be more extensively trained with more highly qualified technicians. The price of Fieldbus components is generally much higher. Device manufacturers have to offer different versions of their device due to the different number of Fieldbus standards. One or more Fieldbus standards may predominate in the future and others may become obsolete. This increases the investment risk when implementing Fieldbus systems.