Understanding 4 to 20 Milliamp Loops

An Online Continuing Education Course for Engineers

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Understanding 4 to 20 Milliamp Loops

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1. Introduction

Before current loops, variable pressure systems were used to control many industrial applications. There were many measuring devices, such as temperature and pressure, that gave a 3 to 15 pounds per square inch signal to indicate some process variable. An example would be a temperature measuring device that measured from 0 to 1000 degrees. The temperature transmitter would convert 0 to 1000 degrees to 3 to 15 psi. This pressure signal could be used to control various devices such as switches or gas valves. These systems required a compressed air source to constantly supply clean, cool, dry air. The air was referred to as minus 40-degree air because the dew point was specified to be minus 40 degrees. Incidentally, minus 40 degrees Fahrenheit is equal to -40 degrees Centigrade. The dew point is the point where the moisture in the air would just start to drop out of the air as water. Air with a minus 40-degree dew point has a relative humidity of 100 %. These systems could send information over relatively long distances through small diameter tubing, but they were susceptible to small leaks in the tubing.

In the 1950's electronic systems began to replace the older pneumatic systems and current loops became an alternate technology. 10 to 50 milliamp and 4 to 20 milliamp control systems were developed. Because of safety concerns, the higher current 10 to 50 milliamp systems are not used very much today.

Today, 4 to 20 milliamp current loops are used in many industrial and commercial applications. They are found anywhere some process information needs to be available some distance from where the information was generated. As an example, there can be a thermometer transmitter measuring the temperature of a vat of hot liquid. That temperature needs to be available in a control and measurement station 3 buildings and 600 feet away. One of the most reliable and accurate ways of getting that information to the control station is by means of a current loop.

Following are some of the industries that use current loops:

A. Petroleum refineries
B. Chemical plants
C. Plastics extrusion

D. Water treatment plants
E. Waste water treatment plants
F. Electric power generating plants
G. Cement manufacturing plants
H. Food processing facilities

The above list by no means covers all places where 4 to 20 milliamp current loops are found. Anytime position, pressure, temperature, flow, current, voltage, and other physical parameters need to be measured, displayed, and controlled, 4 to 20 milliamp loops are likely to be found.

2. DC Circuit Theory

To get a real understanding of current loops, we will first have a review of DC circuit theory. The three most important elements of DC circuits are voltages, currents, and resistances. Voltage can be likened to a pressure. The symbols shown in Figure 2.1 are some of the ways that DC voltages are represented.

Something to notice here is that the DC voltage has a polarity. Batteries, typical DC sources, have a positive and negative end, this is true of all DC sources. The positive end can be denoted by the 'plus' sign, sometimes, all that is seen is the arrow pointing to the positive end of the voltage. Anytime a voltage exists, in this course, the voltage arrow will point to the positive end of the voltage. If a voltage arrow is present, it will point to the positive end of the voltage, for both voltage rises and voltage drops.

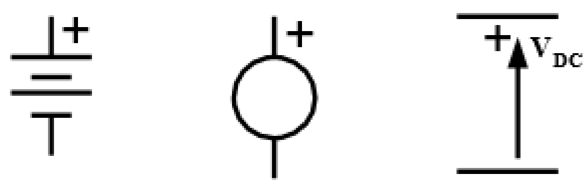


Figure 2.1 Various Ways to Represent a DC Voltage

Now the next thing to consider is the concept of current. The voltage source can supply a current. This course will use conventional current flow, meaning the current will flow out of the positive terminal of the source. Current can be likened to water flow. If a pressure exists, water can flow. If a voltage exists, a current can flow. Current is not seen like water flow, although a spark or arc can be thought of as 'seeing' current flow. In the current loop that we are studying, the current will not be seen, but will flow through wires and resistors. It will also have to flow out of the positive terminal of the source and into the negative terminal of the source. In other words, the current makes a complete loop.

This leads to resistance. Resistance is a property of materials that opposes current flow. All materials that I know of have resistance. There is a class of conductors that have zero resistance at very low temperatures. We will not consider these materials, called superconductors, in this course. Insulators have high resistance, and conductors have low resistance. If we put a voltage across a resistance, current flows. This is shown in Figure 2.2.

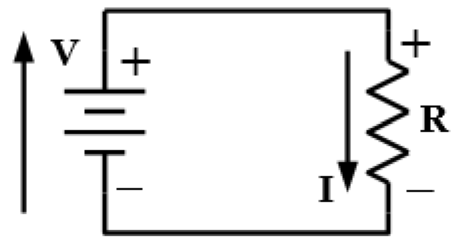


Figure 2.2 Voltage Source Across a Resistance, Showing Current Flow

There are several things to note that will make the understanding of current loops very easy. Figure 2.2 is technically a current loop. First, notice that the voltage arrow points to the positive end of the voltage source or battery. The current arrow shows current flowing out of the positive terminal of the battery and back into the negative terminal. If the current is going to flow out of the source, it must flow back into the source. For practical purposes, the current can't leave the battery and not flow back into the battery. This is one of the reasons that current loops work as well as they do. Something to notice here is that the voltage across the resistor is same as the voltage of the source. This brings up the next idea, Ohm's Law.

3. Ohm' Law

Ohm's Law very simply states that:

V = I * R

If we look at Figure 2.2, we can see that if we know 2 out of the three items in the drawing, we can determine the third. The next idea that is important is something called Kirchoff's Voltage Law.

4. Kirchoff's Voltage Law

Let's look at Figure 4.1 to get a better understanding of Kirchoff's Voltage Law.

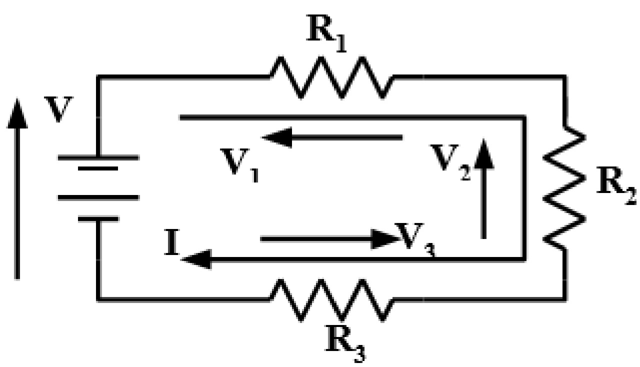


Figure 4.1 ***A Circuit with Three Resistors in Series***

There are several things that need to be understood. First, resistors in series add so that the total resistance of the circuit of figure 4.1 is:

Then, the current, I, is equal to: And:

And:

$$R_T = R_1 + R_2 + R_3 \quad I = V / R_T$$

$$V_1 = I * R_1,\ V_2 = I * R_2, \text{ and } V_3 = I * R_3 \quad V_T = V_1 + V_2 + V_3$$

Let's do an example and let the voltage, V, be 36 volts, R_1 = 6 ohms, R_2 = 12 ohms, and R_3 = 18 ohms. Then the current, I, would be V / R_T = 36 / 36 = 1 amp. Then V_1 = 1 * 6 = 6 volts, V_2 = 1 * 12 = 12 volts, and V_3 = 1 * 18 = 18 volts. Notice that $V_1 + V_2 + V_3$ = 36 volts, which is equal to the original power supply voltage. This is an example of **Kirchoff's Voltage Law** which says that '**The sum of the voltage rises in any closed loop is equal to the sum of the voltage drops**.'

One very important thing to reemphasize is that the current through each of the resistors in this three-element circuit is the same. When working with current loops, the current through the entire circuit is always the same.

5. Current Sources

Ideal current sources don't exist in the electronic world, however, a practical current source can be made. The main property of a current source, is that it gives a constant current, independent of the load. If we look at Figure 5.1, we can see that the voltage across the resistor depends upon the resistance of the resistor. If the resistor is very large, the voltage will be very large, even if the current is small. Remember that V = I * R. As an example, let the current, I, be 10 ma or .01 amp. This is a reasonable value for a 4 to 20 ma current loop. If the resistor is 100,000 ohms, the voltage across the resistor would be 1000 volts. That is much too high for practical transistorized electronic circuits. The value of the resistor in most current loops is either 100 ohms or 250 ohms. The maximum voltage across the 250-ohm resistor for a 4 to 20 ma current loop would then be 5 volts. Go ahead and prove this for yourself. If the current source is made to change with some physical quantity (temperature, pressure, flow, etc.) the voltage across the resistor, R, will change with the current, and can be used to tell what the value of the physical quantity is.

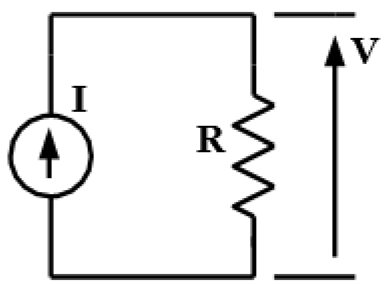
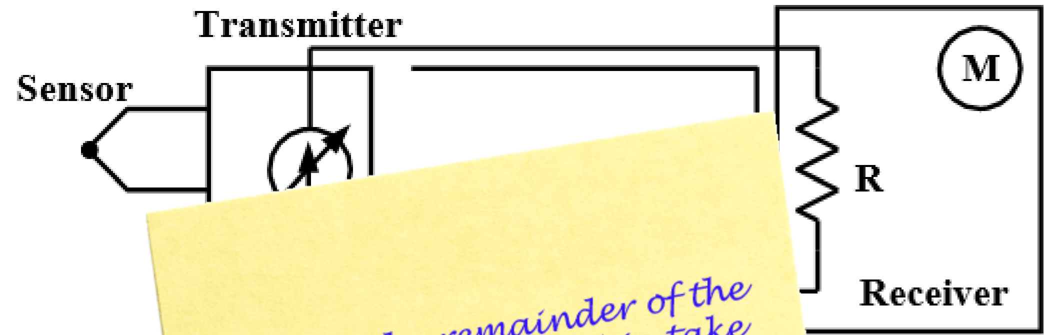


Figure 5.1 Example of a Current Source

6. A Model of a Typical Current Loop

A typical current loop has at least 3 parts. One is a device for controlling the loop current, **The Transmitter**. The function of the transmitter is to control the current in the loop and make it follow the value of some physical variable. For instance, a temperature transmitter can control the current in a loop from 4 to 20 ma as the temperature changes from 0 to 100 degrees. We could know what the temperature was at any time just by measuring the current. In the example given, if the current were 12 ma, and the system were linear, the temperature would be 50 degrees. The next part of the current loop is a **Power Supply**, commonly 24 Volts DC. It can be placed anywhere in the loop. The third part of the current loop is the **Receiver**. The current in the current loop flows through a resistor in the receiver and is converted to a voltage, which the receiver translates into a physical quantity. The value of the resistor, R, is usually 100 ohms or 250 ohms, with 250 ohms being the more common value. The power supply can be a separate component, but is quite often built into the transmitter or the receiver. Let’s look at Figure 6.1 to see the setup of a typical 4-20 ma current loop.



Notice that Figure 6.[illegible] loop. Let’s review how this works. The s[illegible] mperature. The **transmitter** uses that [illegible] ce, this means that the current is depend[illegible] voltage, usually 24 to 32 volts, and is usually [illegible] be regulated. The **receiver** has a resistor [illegible] outside. 250 ohms is the most common valu[illegible] esistors. The resistor has the loop current flo[illegible] across the resistor is translated by the electronics inside t[illegible] give a readout on the meter, M, the readout can be analog or digital.

If the loop current varies from 4 to 20 ma, and the resistor is 250 ohms, the voltage across the resistor varies from 1 to 5 volts. Using Ohm’s Law, V = I * R, prove this for yourself.

Note that the current in the loop never goes below 4 ma. This is because the transmitter needs some way to get power to run its electronic circuits, this power is supplied by the loop current. In figure 6.1, if the loop current is 4 ma, the voltage drop across the transmitter is 23 volts, therefore, some power is supplied to the transmitter. That power is equal to V * I or 0.092 watts. That small amount of power is what runs the electronics of the transmitter. What is happening is that the current that is being controlled by the transmitter is being used to power the transmitter. The only requirements are that the current be kept above 4 ma and the voltage across the transmitter not get too small.