Bridges And Differential Amplifiers - Just A Voltage Divider In Disguise

by Roger Secura

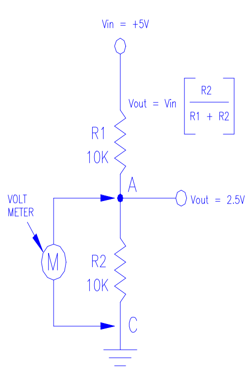
The voltage divider is perhaps one of the most fundamental and ubiquitous circuits used in electronics. Its function, utility, and simplicity in circuits are occasionally overlooked by the student/ hobbyist. This article will reveal how the voltage divider became the foundation of all bridge and differential amplifier circuits. – For those readers who have a fear of formulas, there is only one in this article

The bridge and differential amplifier are two of the most versatile circuits used in the electronics industry. You'll find bridge and differential amplifier circuits employed extensively in a variety of medical, industrial, and scientific instrumentation. Considering how important and ubiquitous both circuits have become, it behooves the student/electronics enthusiast to familiarize him/herself with their operation.

What follows is an attempt to show the student or hobbyist how both the bridge and differential amplifier are nothing more than a voltage divider circuit in disguise.

Voltage Divider

Look at Fig. 1 and you'll see a simple voltage divider circuit.



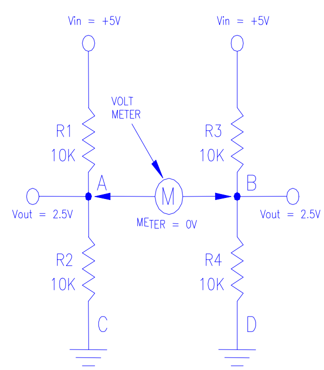
BASIC VOLTAGE DIVIDER

Fig.1

The output voltage (Vout) of this circuit is measured across R2 (A to C) and can be calculated by using the voltage divider formula shown in Fig. 1. In this example the output voltage (Vout) is 2.5V.

If you are a newcomer to the world of electronics, don't be misled by the simplicity of the circuit in Fig. 1. Voltage dividers are used extensively in electronics to bias transistors, set upper and lower trip points for comparators and, as you will see, they form the basic building blocks of bridges and differential amplifier circuits.

Now take a look at Fig. 2.



If each voltage divider is measured (A TO C and B to D), and the voltage level between point A and B are EQUAL, the volt meter will show zero volts (assuming "perfect" resistors).

Fig.2

Here we have two voltage dividers of equal proportions. Except for the placement of the voltmeter (A to B), each of the two dividers in Fig. 2 function exactly like the voltage divider in Fig. 1. Once again, if you measure the voltage level across R2 (A to C) and then across R4 (B to D) you'd get a voltage reading of 2.5 volts at point A and 2.5V at point B. Now what voltage should register on the meter if it is placed between points A and B, as depicted in Fig. 2? That's an easy question to answer if you remember that voltage is defined as a *difference* in potential between two points. Since there is no difference in the voltage level between point A and point B (A=2.5V, B=2.5V) the voltmeter will read zero volts (This, of course, assumes that we are using "perfect" 10K resistors).

It should be apparent by now, that the voltage level between points A and B is dependant on the voltage output of each voltage divider (A to C and B to D). The important point to remember here is: *The only time we have a voltage reading on the meter is when there is a 'difference' in voltage potential between points A and B.*

The Bridge

Try (mentally) tying together the top leg of R1 in Fig. 2 to the top leg of R3 and, in turn, connect the bottom leg of R2 to bottom leg of R4. Now look at the bridge circuit in Fig. 3.

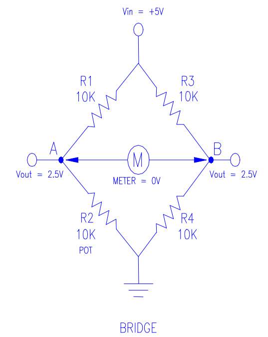


Fig.3

That's right, a bridge circuit is just two voltage dividers connected together. Don't let the configuration of the bridge circuit fool you; it functions exactly like the two voltage dividers in Fig. 2.

Let's take a look at a bridge circuit at work in a "real world" application. For example, suppose we replace R4 in Fig. 3 with a thermistor (T). Thermistors have a large negative temperature coefficient (NTC). That is, the internal resistance of the thermistor decreases as temperature increases.

Now with the thermistor in place (Fig. 4), we adjust the potentiometer (R2) to balance the bridge so that zero volts registers on the meter (M).

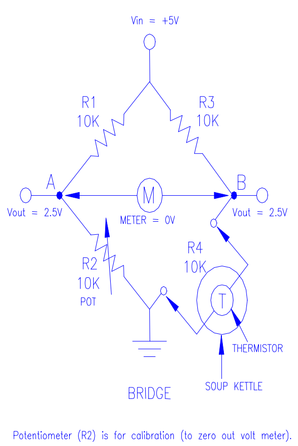


Fig.4

Remember, the meter will only read zero when the voltage level at point A equals the voltage level at point B. Ok, our bridge is balanced and ready to do some work. Let's say you work for the ACME Soup Co. and you're in charge of maintaining the temperature of a large kettle of chicken soup. Assume for the moment that our thermistor (probe) has just been place inside the heated pot of soup. After a short period of time, our voltmeter would show a voltage change that is proportional to the temperature of the chicken soup. In other words, as the temperature of the soup rises it lowers the thermistors' resistance and, in turn, throws one side of the bridge circuit (point B) out of balance with point A. If a graph is plotted showing the relationship between the temperature of the soup and the voltage reading on the meter, you could tell how hot the soup is at any point in time during the cooking process. Again, all this happens because the thermistor's resistance change throws the bridge out of balance in direct proportion to the temperature of the soup. This creates a *difference* in potential (voltage) at points A and B, which then produces a voltage reading on the meter.

Let's move on to the Differential Amplifier.

Differential Amplifier

The circuit in Fig. 5 is a differential amplifier (simplified for sake of clarity). Look familiar? Yes, it's just a couple of voltage dividers (or a bridge) with two transistors. In this

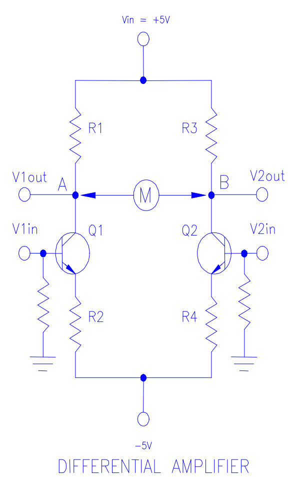


Fig.5

configuration, the transistors act like two potentiometers; manipulating the voltage levels at points A and B by raising or lowering the resistance of the lower legs of the circuit.

From what you have learned so far, you should have an idea on how the differential amplifier operates. Voltage out (V1out, V2out) is controlled by transistors Q1 and Q2 (Fig. 5). If the input voltage at V1in or V2in is larger than the other, the voltage imbalance between point A and point B will register on the meter. But, *more importantly*, is the fact that any common input signal (60Hz noise signal for example) connected to the base of Q1 ***AND*** Q2 will NOT be "seen" at the outputs (V1out, V2out) of the amplifier. Why? Because, with the 60Hz noise signal common to both transistor inputs, there is no "difference in potential" between output points A and B as the input signal varies over time. This point can not be overstated! As the 60Hz noise signal enters the base of Q1 *AND* Q2, it throws 'both' sides of the bridge/voltage divider circuit (points A and B) out of balance in **equal** amounts so that the output voltage remains at zero volts. Don't forget, the differential amplifier is just a bridge circuit that is controlled by two transistors instead of two potentiometers.

As you can imagine, the differential amplifier's ability to reject noisy (unwanted) input signals has led to its wide spread use in the electronics industry. In fact, some of the most popular operational amplifiers (Op Amps) in use today were specifically designed around the differential amplifier circuit because of its ability to reject noise common to both inputs.

There you have it, both the bridge and differential amplifier circuit dissected down to its basic part – a voltage divider.