UCI STUDY GROUP (2021)

WORKING WITH VOLTAGE DIVIDERS

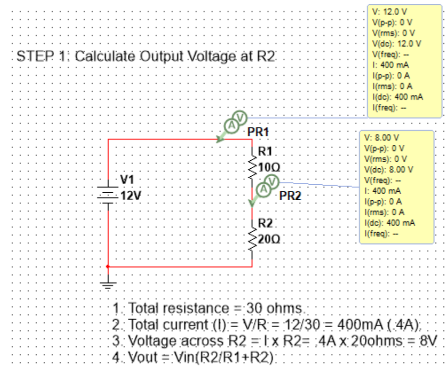

Figure 1: Simulation of simple voltage divider with NO load. Voltage is half the Vin.

"A voltage divider is a passive linear circuit that produces an output voltage (Vout) that is a fraction of its input voltage (V1). Voltage dividers are used to make signal level adjustments, for active device and amplifier bias, and for measuring voltages.

[Ohm's Law](#) explains the relationship between voltage, current, and resistance by stating that the current through a conductor between two points is directly proportional to the potential difference across the two points.

A law is relating the voltage difference between two points, the electric current flowing between them, and the resistance of the path of the current. Mathematically, the law states that V = IR, where V is the voltage difference, I is the current in amperes, and R is the resistance in ohms. For a given voltage, higher resistance entails lower current flow." ([Digi-Key Electronics](#))

Figure 1 shows a basic divider circuit without any load. Notice both resistors are the same value. In this situation, the output voltage is always ½ of V1 under NO LOAD. This holds true for any resistor value pairs. The resistor values of R_1 and R_2, are chosen to limit current in the output. Higher values equates to lower current and visa versa since Ohms law states current $I = \frac{E}{R}$.

But what happens when we *do* have a load connected? Well, Figure 2 shows a circuit but with a load (R3) connected. This is because R_2 and R_L are connected in parallel.

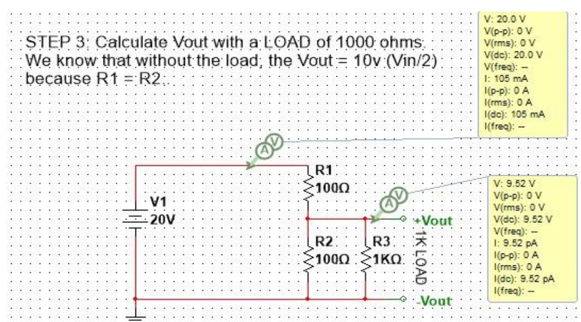

Figure 2: Simulation WITH a load. Notice the change in voltage. R2 and RL are in parallel which lowers the equivalent resistance.

Whereas resistors in series form a total resistance that equals their sum, resistors in parallel combine to reduce the total resistance. This is called ***equivalent resistance.*** The total resistance is always less than the smallest resistor. In our case we only have two resistors so, equivalent resistance is calculated with this formula: $R_{EQ} = \frac{100 X 1000}{1100} = 90.9$ ohms.

Therefore, $R_2||R_3$ in parallel is equivalent to an R_2 of 90.9Ω instead of the 100 Ω. This explains why the V_{OUT} is less than the 10 volts we would expect with two equal value resistors. When resistors in parallel are shown in formulas, they are denoted like this: $R_2||R_L$ where the "||" symbol means "*in parallel with*".

When more than 2 resistors are in parallel, we use this formula: $RT = \frac{1}{\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}}$

When only 2 resistors are in parallel, use this formula: $R_{EQ} = \frac{R1 \, x \, R2}{R1+R2}$

Fortunately, there are online [calculators](#) that compute this for us.

Look at the circuit in Figure 3. I want you to see the steps taken to analyze this circuit. I also show how this circuit wastes a lot of energy. We will see how to fix that very soon.

TIP: Recall that we can use a simpler formula when only 2 resistors are in parallel:

$R_{EQ} = \frac{R1 \times R2}{R1+R2}$

So, $R_{EQ} = \frac{100 \times 1000}{1100}$

$= \underline{90.9 \text{ ohms}}$

So $V_{out} = V_{in} \left[\frac{90.9}{90.9+100}\right]$

$= \underline{9.95v}$

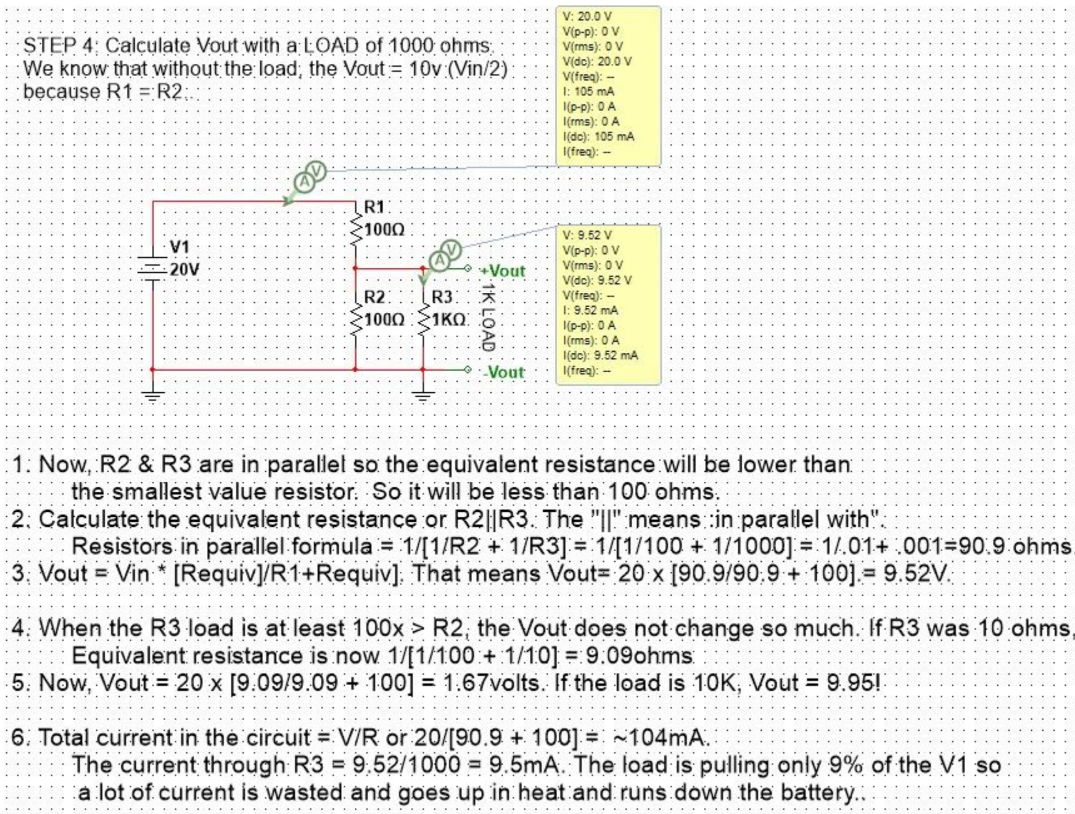

Figure 3: Equivalent resistance for R2 and R3 wastes energy.

Figure 4 shows how to make the circuit more efficient by simply replacing R_2 with the 1K load device (R_3) as shown. This not only simplifies the circuit, but it also uses significantly less current.

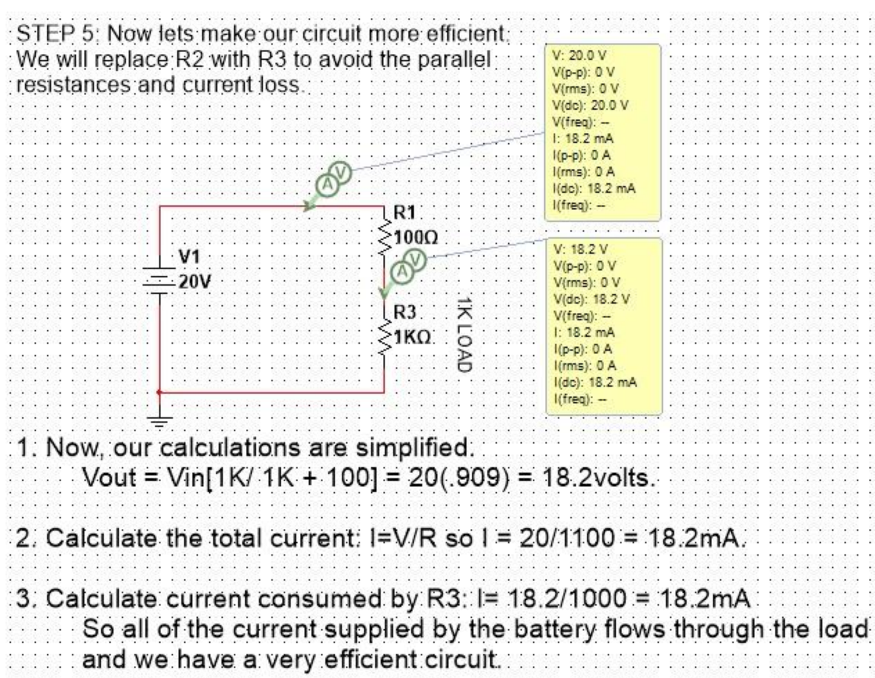

Figure 4: Efficient version with the load replacing R2.

Voltage Dividers with Three Matching Resistors

There are many situations where we need two different voltages from our divider. The 555 timer is such an example. When we discuss the 555 timer IC, you will discover how clever this divider is used to monitor the charge across a capacitor.

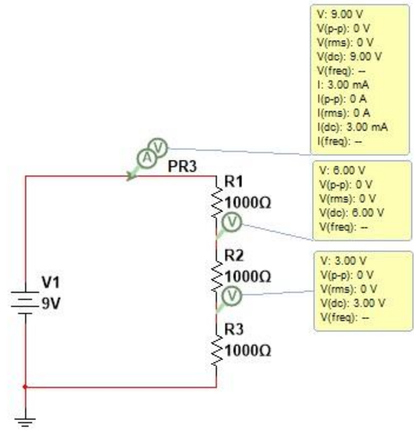

Figure 5: Three identical resistors can be used as a 1/3 and 2/3 voltage divider when two different voltages are required.

Try to picture a situation where you have a 9v power source and you need 6v to power a servo and 3v to power a sensor board. Rather than adding a large power supply to your project, you can use a voltage divider configured like the one in Figure 5. A word of caution. Never use a divider to supply high amounts of current. These are perfectly suited to working with Arduino projects and other low voltage, low current circuits. Resistors are not efficient, they convert energy into heat, and cannot regulate voltage if the Vin goes up or down. These never take the place of a linear regulator! This configuration divides the V_{in} into thirds. The 9v supply provides 6v and 3v for you project needs. Let's figure out how this works in more detail.

In previous discussions, we learned that in series circuit, the current that flows through each component is the same. There is only one path for it to flow. However, the voltage *across* each resistor is related to the resistor's value. When all the resistors are the same value, then the voltage across them is equal and the V_{in} is divided equally across them. Also, the total resistance = $R_1 + R_2 + R_3$ which equals 3K in this case. The total current in the circuit is therefore I = 9/3000 = .003A or 3mA as shown in Figure 5.

Since V = IR, the voltage across each resistor = .003A x 1000Ω = 3v. The voltage law says *all* voltages applied to a circuit are consumed by the components. Take your voltmeter and place the probes across each individual resistor and you will read 3v. Since R_1 drops 3v we read 9-3 or 6v at the bottom of R_1. We read 3v at the top of R_3 because R_1+R_2 = 6KΩ and thus twice as much voltage is consumed.