CLASS NOTES: SESSION 1

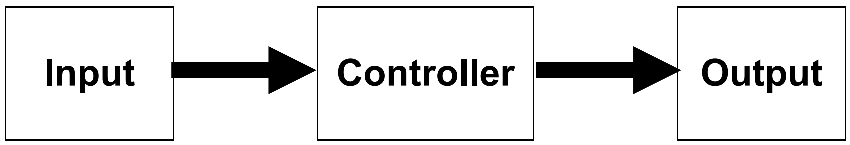
Class Notes will not be supplied for all classes. This session covers crucially important basic definitions, math and concepts the highlights of which are summarized here.

WHY MSCI321 "Introduction to Electronics?

This course is designed to familiarize you with various types of electronic components, how to read a schematic diagram to interconnect those components, and even a bit of troubleshooting the resulting circuit if it doesn't work the first time.

CREATING A CIRCUIT

A circuit is just a collection of interconnected components. Once connected (properly) a 'system' is created. All systems can be broken down into three parts: the input, an output, and e controller. The simplest of these systems have no feedback to tell the controller what is happening and look something like this:



An example of this system might be the light switch on the wall. It is the controller that connects the input – 120 volts AC – to the output – the lights – when the switch – the controller - is in the correct "ON" position. Turning the switch to the ON position completes the circuit and has the AC current and voltage powering the lights. We need to know a bit about the units we will be using in electronic systems so we can quantify what is happening in our circuits before we can design our own circuits. We'll look at basic circuit components and their symbols later in this lesson. *It is important to note that MOST block diagrams do NOT include the actual power and ground connections*.

DIMENSIONS and UNITS

"**Length**" is a dimension. Inches, feet, centimeters (cm), meters, etc., are ***units of length***. "**Area**" is also a dimension. Square inches, square cm and square miles are ***units of area*****. For electrical work we are most interested in the following units:**

Dimension	Unit Name	Units	Named After	Comments
charge	Coulombs	**C**	Charles **Coulomb** (1736-1806)	1 coulomb equals 6.242 E18 electrons
current	Amperes (amps)	**A**	André-Marie **Ampère** (1775-1836)	
voltage	Voltage (volts)	**V**	Alessandro **Volta** (1745-1827)	
power	Watts	**W**	James **Watt** (1736 –1819)	
energy	Watt-seconds or kilowatt hours	**W-sec KWH**	--	**$/KWH** *is the rate that you pay Con-Ed at the end of the month*
resistance	Ohms	**Ω**	Georg **Ohm** (1787-1854)	

Table 1.1 Dimensions and Units of Measure used in Electronics

CURRENT

Current, **I**, is measured in amperes or amps, **A**, and is defined in physics as the flow of electrons or charge, **Q**, in coulombs, over time **t**:

$$I = Q / t$$

Using water as an analogy *(strictly speaking one should **not** say current flows but this is a generally accepted way to look at current flow)* ***electrical current is like a water current of a certain number of molecules flowing past you per second, thus***.

1 ampere = 1 coulomb/sec = 6.242 E18 electrons/second

where **6.242 E18** is the scientific notation for the number **6.242×10^{18}** or **6.242 x 10^18**. Written out this is the number **6,242,000,000,000,000,000** *(where "**6.242**" is the number to **four significant digits** and "E18" or "E+18" is a more convenient way of writing 10 to the power 18 which equals a 1 followed by 18 zeroes, a huge number*.)

More useful units for the electronics projects we will use in our class are the quantities **milliamp** or milliampere (where **1 mA** is 1/1000 of an amp = **0.001A** or E-3 amperes), and **microamp** or microampere (where **1 uA – or 1 μA –** is one millionth of an amp or **0.000001A** or E-6 amperes).

VOLTAGE

The formal definition of voltage from physics goes something like this: Bringing a positive test charge **Q** from point **B** to point **A** requires a certain amount of work (**W**):

$$V_{ab} = W / Q$$

Note that if the voltage at point **A** (**V_a**) is much greater than the voltage at point **B** (**V_b**) then a lot of work will be required and **V_{ab}** will be a large number. We typically use the units of volts for our power sources.

Using a water analogy, ***voltage is like the pressure that drives water through a pipe.*** Voltage could then be said to drive electrons through a wire or device.

Voltage (**V**), is measured in volts (**V**), and is always defined between two points, *i.e., the voltage **V_{ab}** is the voltage from point **a** to point **b***. We ALWAYS measure voltage ACROSS a power source (voltage rise) or component (voltage drop). For a **direct current** (**DC**) voltage source we use the schematic symbol to the right.

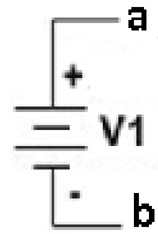


Figure 1.1 Schematic Symbol for a Voltage Source

Typical numbers we will see for voltages are**:**

1.5 volts DC for a single cell AA, AAA, C, or D flashlight battery
9 volts DC for the small rectangular battery often used in portable electronics
9-17 volts DC from the output of the 'ac adapter' we will use in this course
12-15 volts DC for an automobile battery
"120vac" – the 117 volts **alternating current** (**AC**) from the wall socket in your home

SAFETY FIRST: VOLTAGE AND ELECTRICAL SHOCK

Holding the output wires from a common battery or from an ac adapter or ‘battery eliminator’ is ***normally*** harmless. Electrical ‘shocks’ are a function of the voltage and the amount of current flowing through the body. In general, other than through a cut or scrape, voltages above 50 volts (ballpark value) are necessary to travel through the human skin. As we will be using voltages well below 50 volts, there should be no risk of shocks in this course.

Sparks seen when connecting plugs into AC outlets are not from high voltage (see next paragraph), but rather due to the high current (surge current) that flows for an instant when a device that is turned ON is plugged into the socket. For safety, ALWAYS turn OFF electrical devices before plugging them into the wall outlets. There should NOT be any challenges plugging and unplugging our ac adapters into the wall sockets, but we will use switched power strips for added safety.

HIGH VOLTAGES AND ARCS

The hallmarks of high voltage are sparks, as seen in lightning strikes. Thousands of volts are required to ‘jump’ or arc across a gap between wires or a spark plug. Although you will NOT be using voltages higher than about 20 volts in our class, we will discuss and may have a demonstration that shows use of a low voltage (5 volts) to control a device that requires the 120 VAC line voltage. One type of this device is a relay.

POWER

Power (**P**) is the rate of delivering energy or doing work. We can define the work that a healthy horse can deliver as being “**1 horsepower**.” More convenient for electrical work is the unit called the “watt” which is equal to ***1/746 of one horsepower***.

The exact definition of electrical power is:

One watt, **P,** equals One volt, **V,** times One ampere, **I**

For the DC circuits we work with in this course we will use the equation:

$$P = V\,I$$

RESISTANCE

Resistors exhibit resistance (**R**), measured in Ohms (**Ω**). This resistance to electrical current that flows in a circuit reduces the overall current flow. For a given voltage, a high resistance yields a low current in the circuit, and similarly, a low resistance yields a high current flowing in the circuit. The schematic symbol for a resistor is shown here.

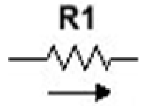
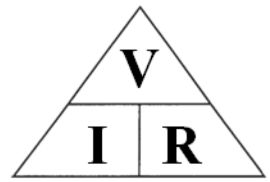


Figure 1.2 Schematic Diagram of a Resistor

Note that the arrow shows the direction of current flow in a resistor. We would have to break the circuit and insert a meter to measure the current flowing in the circuit with an Ammeter. Conversely, we would use a Voltmeter to measure the voltage drop across the resistor.

OHMS LAW FOR RESISTORS: V = I R

OHM'S LAW is the relationship between the voltage **V**, in volts, across the circuit, the current **I**, in amperes, flowing in the circuit, and the overall resistance **R**, in ohms, of the circuit. Sometimes a triangle is useful in remembering these three Ohm's Law relationships:



The basic formula finds the voltage drop, in volts, as defined by **V = I R**
For resistance, in ohms, it is defined as **R = V / I**
Finally, the current, in amperes, can be calculated as **I = V / R**

Figure 1.3 Ohm's Law Triangle

POWER IN A RESISTOR: P = I V

Using Ohm's Law we can calculate the power used, or ***dissipated***, in a resistor when its value and either the *voltage dropped across* it, or the *current flowing in it* is known by using substituting either **I** or **V** from Ohm's Law in the **P = I V** equation yielding:

$$P = I^2 R \quad \textit{or} \quad P = V^2/R$$

REAL RESISTORS: DEVICE TOLERANCE

Whenever we do problems in textbooks all values are considered to be exact. Thus a 100 ohm resistor would be expected to measure exactly 100 ohms regardless of the temperature or any other characteristics. We will see that this is not the case in real life.

Physical resistors, like the 5% resistors we will be using in this week's lab and throughout the course, have a value tolerance expressed in percentage of 'printed' value. A 100 ohm resistor with a 5% tolerance could have an actual value at room temperature of anywhere from 95-105 ohms. Table 1.1 shows some other tolerances.

Resistor Value	1%	5%	10%
100 Ohms	99-101	95-105	90-110

Table 1.2 100 Ohm Resistor Tolerances

BASIC CIRCUIT ANALYSIS

When one connects (or wires) a voltage source (battery or adapter) to a load device (e.g., a small lamp) and then connects that device back to the source as shown in Figure 1.4, the result is called a 'closed loop' or complete circuit where current flows.

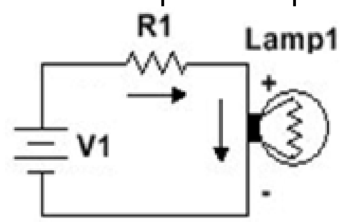


Figure 1.4 Simple Closed Loop Circuit

This is a very simple circuit showing a battery or power source, $\mathbf{V_1}$, connected through a resistor, $\mathbf{R_1}$, connected directly to a lamp, $\mathbf{Lamp_1}$. Please note that we could have called the resistor components by ANY name: $\mathbf{R_1}$, **R**, $\mathbf{R_a}$, $\mathbf{R_{42}}$, or so on. We typically number components from the left to the right for ease in identifying them, especially when we have several resistors with the same component value.

OPEN CIRCUITS:
Our basic circuit had no switch to turn current on and off. When we include a switch in the circuit, or if a resistor or wire breaks we have an **Open Loop** which has a current flow of zero. The switch is an easier way to close or open the circuit.

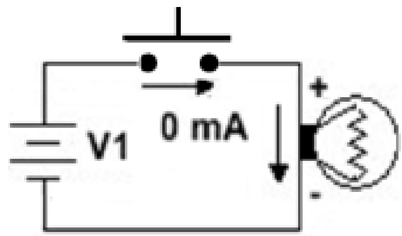


Figure 1.5 Switch/Open Loop Circuit

SHORT CIRCUITS:
Current flowing in a circuit always takes the '***path of least resistance***.' Thus, when a wire is connected directly across the power source as shown in Figure 1.6., it results in a **Short Circuit** which produces a maximum current in the shorting wire (which may well cause the battery to explode!) but zero current flowing in the rest of the circuit. Thus whether an open circuit or a short circuit, the lamp won't light. The difference: in the short circuit, a component could be burning up…

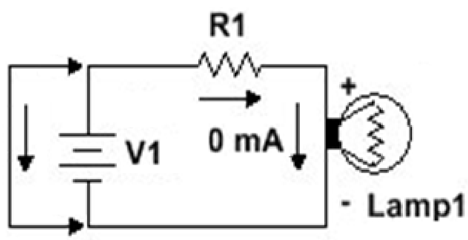


Figure 1.6 Creating a Short Circuit

REAL RESISTORS: POWER DISSIPATION

We will be using ½ Watt, 5% tolerance resistors throughout this course. *If the current flowing through the resistors multiplied by the voltage dropped across the resistor approaches or exceeds 500 milliwatts (½ Watt) dissipated by the resistor it **WILL** be very hot and may '**burn up**' due to overheating. This is possible!*

Indeed, short-circuiting our ac adapter voltage would result in a maximum of up to 17 volts at 150 milliamperes of current in the adapter (this is the adapter's rated output). The math for this is:

$$\mathbf{P = V\ I}$$

$$\mathbf{P = (17v) * (0.150A) = 2.55\ Watts}$$

This is more than enough power to fry a low value resistor…
We can short out a specific component, accidentally or on purpose, but bear in mind that the component will get very hot, very quickly, and could even burn your fingers...

OHM'S LAW, POWER LAW, etc. RELATIONSHIPS WHEEL

Putting all these relationships together can be accomplished using a wheel:

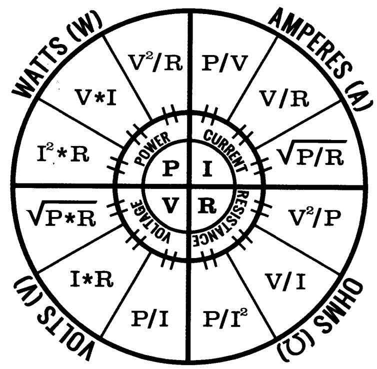


Figure 1.7 Relationships Wheel

KIRCHOFF'S VOLTAGE LAW: KVL

The sum of all the voltage rises and voltage drops in a single loop equals zero volts.

SERIES CIRCUITS

A series circuit is one in which the same CURRENT flows through each device. The power source provides a voltage which is portioned across each device based on its characteristics. Per KVL, these voltage drops must add up to the total incoming voltage.

RESISTORS IN SERIES ADD

The net equivalent resistance $\mathbf{R_{ab}}$ (measured from **a** to **b**) in this series circuit would be

Figure 1.8 Pictorial Diagram and Schematic for Series Circuit

$$R_{ab} = R_1 + R_2 + R_3$$

The value for three 100 ohm resistors in series would be ideally 300 ohms. Using our 100 ohm +/- 5% resistors the overall actual equivalent value of resistance of the circuit would be between 285 and 315 ohms.

In general, "**n**" equal resistors **R** in series would be calculated as

$$R_{ab} = nR$$

since $$R_{ab} = R_1 + R_2 + R_3 + \ldots + R_{n-1} + R_n$$

KIRCHOFF'S CURRENT LAW: KCL

The sum of all the currents flowing into any point in a circuit must equal the sum of all the currents flowing out of that point.

PARALLEL CIRCUITS

A parallel circuit is one in which the same VOLTAGE is applied to each device in the circuit. The power source must provide sufficient current to power each device, therefore the currents in parallel 'branches' add.

RESISTORS IN PARALLEL

The net resistance $\mathbf{R_{ab}}$ from **a** to **b** in a two resistor parallel circuit is:

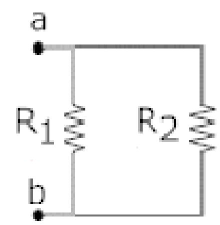


Figure 1.9 Parallel Circuit

$$1/R_{ab} = 1/R_1 + 1/R_2$$

Doing the math we can simplify equation to:

$$R_{ab} = (R_1R_2) / (R_1+R_2)$$

Thus the equivalent resistance in a two-resistor parallel circuit is calculated by taking the product of the two resistors over the sum of the two resistors.
(NOTE:** *This calculation is valid for TWO resistor circuits only.)**

Using our two 100 ohm +/-5% resistors we would find the overall value would become 50 ohms +/-5% or between 47.5 and 52.5 ohms as shown here.

The Minimum Resistance of two parallel 100 ohm +/- 5% resistors would be:

$$R_{ab} = (95 \times 95) / (95+95) = 9{,}025 / 190 = 47.5\ \Omega$$

The Maximum Resistance of two parallel 100 ohm +/- 5% resistors would be:

$$R_{ab} = (105 \times 105) / (105+105) = 11{,}025 / 210 = 52.5\ \Omega$$

If you don't mind working with inverse values you could also use the general equation:

$$1/R_{ab} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 + \ldots + 1/R_n \ldots$$

for ANY NUMBER "n" of parallel resistors. The last step would be to invert $\mathbf{1/R_{ab}}$ to get the equivalent resistance $\mathbf{R_{ab}}$ of the parallel resistances. So you could combine any number of resistors in parallel with only 2 steps.
For the two 100 ohms resistors:

$$1/R_{ab} = 1/95 + 1/95 = 2/95$$

therefore…

$$R_{ab} = 95/2 = 47.5\ \Omega$$

which is what we calculated above using the product over the sum for two 95 ohm resistors in parallel.

USING THE "TWO RESISTORS IN PARALLEL" EQUATION

The 'product over the sum' two resistors in parallel equation is all you need to handle any number of resistors in parallel.

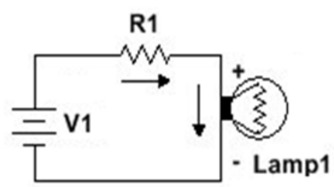
With three resistors in parallel, just combine $\mathbf{R_1}$ and $\mathbf{R_2}$ and then combine the result with $\mathbf{R_3}$. With four resistors, just combine $\mathbf{R_1}$ and $\mathbf{R_2}$ to get result $\mathbf{R_x}$ and then combine $\mathbf{R_3}$ and $\mathbf{R_4}$ to get result $\mathbf{R_y}$. Finally, combine $\mathbf{R_x}$ and $\mathbf{R_y}$ to get the equivalent resistance of all four resistors in parallel.

Of course if you need to do this often it pays to write a computer program and let the computer do all the work. As a practical matter, it is usually easier to write your own computer program than to figure out someone else's except where the program is really complex, such as in a full circuit analysis program.

BASIC MATH CALCULATIONS

We have shown some of the basic calculations you will need to understand during this course in the previous pages. In general, you should have taken a course in algebra and trigonometry before taking this course, however, combinations of addition, subtraction, multiplication and division are all that is typically needed.

Typically we would use Ohms Law to find the current flowing through a component in a given circuit. For example, what if we had a 9 volt power source and wanted to use it to power a 5 volt lamp that draws 1 ampere of current? The circuit might look like:



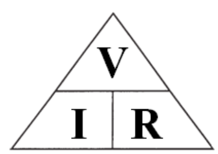


Figure 1.10 Simple Circuit and Ohm's Law Triangle

Here $\mathbf{V_1}$ is 9 volts, connected through a resistor $\mathbf{R_1}$ whose value we want to calculate, which is connected to a 5 volt lamp. As the lamp requires 5 volts and 1 ampere of current to work, we need the resistor to 'drop' the supply voltage by **9 – 5 = 4 volts**.

If the current flowing in the circuit is **1 ampere**, then using Ohm's Law

$$\mathbf{R_1 = (V_1 / I_1)}$$

We can find the value of a resistor that would have 1 ampere flowing through it and 4 volts dropped across it. Substituting in the equation we would get:

$$\mathbf{R_1 = (4\ volts / 1\ ampere) = 4\ \Omega}$$

Thus using a 4 ohm resistor in this circuit should solve our problem.

Note: *Since* ***P = I V;*** *we would need to use a resistor that was rated at* ***4 Watts*** *or higher in the circuit. A smaller power resistor, e.g., a* ***½ W****, could burn or explode here!*

ABOUT THE RESISTOR COLOR CODE

1/2-Watt Carbon Film Resistors (±5%)

Figure 1.11 Carbon Film Resistors

There are four (4) colored bands on the common carbon composition resistor as shown in figure 1.11, above. Please note that the overall **BODY COLOR** of a resistor has **NOTHING** to do with its resistance value or power handling capabilities.

The resistor's **SIZE** on the other hand has everything to do with the resistor's **POWER handling capacity**.

We use ½ Watt devices as their wire leads are stronger than those of a ¼ Watt device. Our circuits, however, do not require ½ Watt resistors. All our resistors have a GOLD colored fourth band. This represents that the resistor's value is +/- 5% of the value indicated by the first three colored bands. Please be careful – the colors red and orange can be confused as the colors used are not always 'pantone' colors. Use your Multimeter to test resistance values if you are not sure of the resistor's actual value.

The Resistor Color Code is based on the colors of the rainbow:

Band Color	1st Number	2nd Number	Multiplier	Tolerance
Black	**0**	**0**	1	
Brown	**1**	**1**	10	
Red	**2**	**2**	100	
Orange	**3**	**3**	1,000 (Kilo)	
Yellow	**4**	**4**	10,000	
Green	**5**	**5**	100,000	
Blue	**6**	**6**	1,000,000 (Mega)	
Violet	**7**	**7**	10,000,000	
Grey	**8**	**8**	100,000,000	
White	**9**	**9**		
GOLD				5%
SILVER				10%
(none)				20%

Table 1.3 Resistor Color Code

Resistor Color Code Examples: *(where Gold shows the resistance is +/- 5%)*

Brown-Black-Orange-Gold: *reads as 10 x 1,000 = 10,000 Ohms = 10Kohms*
Gold-Green-Black-Brown: *reverse color order = 10 x 100,000 = 1,000,000 Ohms = 1MΩ*
Yellow-Violet-Red-Gold: *reads as 47 x 100 = 4,700 Ohms = 4.7Kohms*

THE VOLTAGE DIVIDER EQUATION

There are circuit combinations that are common enough that a simple equation which gives the result without needing circuit analysis each time would be helpful. We basically analyze the circuit just once and then use the results whenever needed.

One such situation is where a voltage is applied to two resistors in series as in Figure 4 and we want to know how the circuit's input voltage **Vin** divides itself across the two resistors **R_1** and **R_2** yielding a divided voltage available across **R_2** which we call **Vout:**

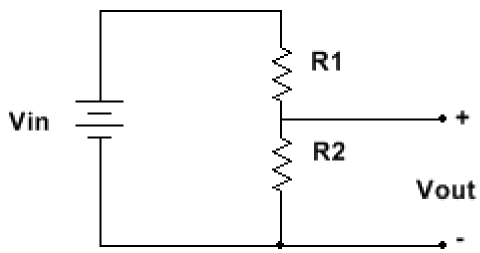


Figure 1.12 Simple Two Resistor Voltage Divider

We know that the total voltage must be the sum of the two voltage across **R_1** and **R_2** but how much of the voltage appears across each?

For Figure 1.12, assume the output is unloaded, (i.e., nothing in parallel with **R_2**) then as

$$I = V_{in} / (R_1 + R_2).$$
$$V_{out} = I\,R_2 = [V_{in} / (R_1 + R_2)]\,R_2$$

With a little reorganizing of terms we get what is called

The Voltage Divider Equation:

$$V_{out} = V_{in}\,[\,R_2 / (R_1 + R_2)\,]$$

In words: ***When a voltage is applied to two (or more) resistors in series, the voltage across a particular resistor is the applied voltage times a certain fraction and that fraction is the selected resistor divided by the sum of the resistors.*** *This is valid for two resistors, three resistors, or any number of resistors in series:*

THE "n" RESISTOR VOLTAGE DIVIDER

By KVL:

$$V_{R1} + V_{R2} + V_{R3} + \ldots + V_{Rn} + V = 0$$

Therefore:

$$V_1 = V_{R1}$$
$$V_2 = V_{R1} + V_{R2}$$
$$V_3 = V_{R1} + V_{R2} + V_{R3}$$
$$\ldots$$
$$V_n = V_{R1} + V_{R2} + V_{R3} \ldots + V_{Rn} = V$$

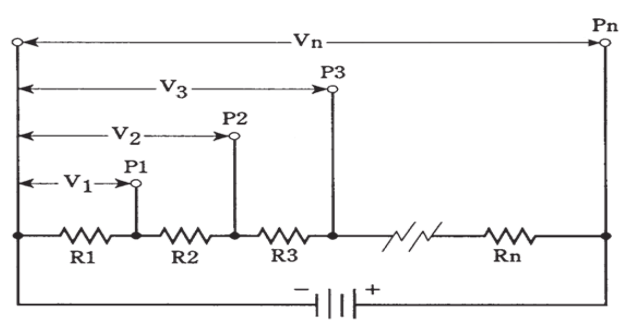


Figure 1.13 "n" Resistor Voltage Divider

VOLTAGE DIVIDER CALCULATIONS

Sometimes we can use variables rather than actual values to create a voltage divider. If we wish to obtain a 2.5 volt output across $\mathbf{R_1}$ in Figure 1.14., given we have a 9.0 Volt Input in the circuit, what should the ratio of resistors R_1 and R_2 be?

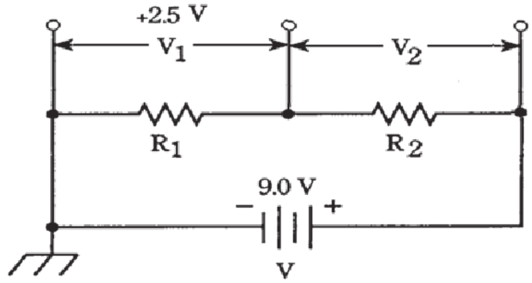


Figure 1.14 Two-Resistor Voltage Divider

Using the standard voltage divider equation we can calculate for V_1:

$$V_1 = V\left[\frac{R1}{R1+R2}\right]$$

For 2.5 volts to be measured across $\mathbf{R_1}$ we'll need:

$$V_1 = V\left[\frac{R1}{R1+R2}\right] = 2.5 \text{ volts}$$

Substituting the voltages we know:

$$V_1 = 9 \text{ volts } [R_1 / (R_1 + R_2)] = 2.5 \text{ volts}$$

This will be true anytime that $[R_1 / (R_1 + R_2)]$ *equals the ratio* **"0.278"**

Doing some more math to calculate the relationship between the two resistors:

$$R_1 = 0.278(R_1 + R_2) = 0.278R_1 + 0.278R_2$$

Reorganizing terms: $0.278R_2 = R_1 - 0.278R_1 = R_1\,(0.722)$

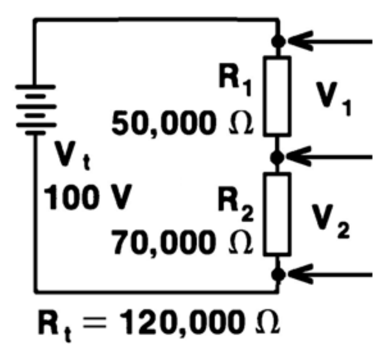
From which we derive: $R_2 = R_1\,(0.722/0.278) = 2.597\,R_1$

Thus, when $\mathbf{R_1}$ **= 10,000 ohms,** we will need an $\mathbf{R_2}$ of about **26,000 ohms**

For the voltage developed across R_1 to be 2.5 volts and across R_2 to be 7.5 volts.

ANOTHER EXAMPLE

In the example of Figure 1.15, we have an input voltage of 100 Volts and a total resistance of 120,000 Ohms split into a 50K resistance and a 70K resistance.
Let's find the voltages and currents in this circuit…



From Ohm's Law: $I_t = V_t / R_t = 100 \text{ volts}/120{,}000\Omega$

$I_t = 0.0008333$ **Amperes = 0.83mA**

From Ohm's Law we get $V_1 = I_1 R_1 = 0.83 \text{ mA} * 50{,}000\Omega$

$V_1 = 41.67$ **Volts** (*NOTE: The voltage ratio is 5/12*)

From KVL we get: $V_t = V_1 + V_2 = 100$ **volts**

Thus, $V_2 = V_t – V_1 = 100 – 41.67 = 58.33$ **volts** *(Ratio = 7/12)*

Figure 1.15 Another Two-Resistor Voltage Divider

ABOUT THE ELECTRONICS LEARNING LAB CONSOLE

The Radio Shack Electronics Learning Lab Console will be used throughout the course as a way for you to create circuits without soldering (*melting a low-temperature tin-lead wire to 'permanently' connect wires and component leads*) by using springs internally connected to a variety of electronic components that can be connected by wires and a solderless breadboard which allows an unlimited variety of devices to be connected into electronic circuits.

Figure 1.16 Learning Lab Console

THE SOLDERLESS BREADBOARD

USING THE AC ADAPTER

When the "9 volt" AC Adapter is plugged into the rear of the console and into 120 VAC power strip, power is turned **ON** and **OFF** using the switch at the top left of the console.

Your breadboard has a "**+**" row across the top where you can obtain the AC Adapter's **positive input voltage** from the five contacts to the LEFT of the number "**1**" – please note that the loops between columns **2**, **3**, **4**, and **5** indicate a modification that has these 25 contacts to the RIGHT of the number "**1**" connected together *INTERNALLY*.

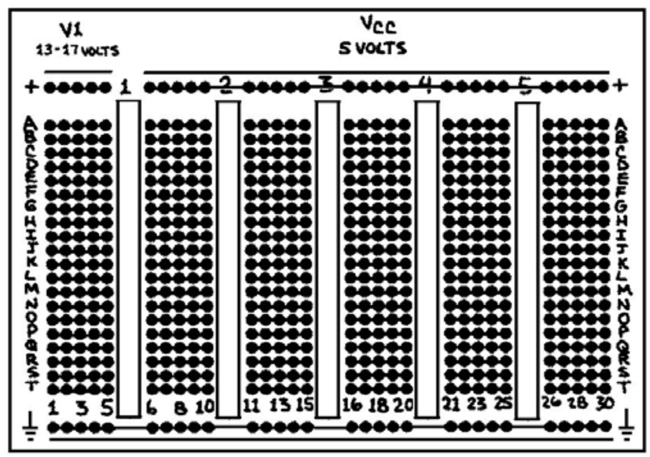


Figure 1.17 Solderless Breadboard on Console

In the second lab module you will assemble a voltage regulator circuit which will fix the positive output voltage for all future labs at approximately five (5) volts which will be available at any of these 25 contacts on the breadboard. The AC Adapter's **negative voltage**, or **GROUND**, connection is available from any of the 30 contacts across the bottom of the breadboard.

CONNECTING CIRCUIT ELEMENTS TOGETHER

The solderless breadboard of Figure 1.17 has an additional 600 contacts arranged as 20 rows (Rows **A** through **T**) of six columns with five interconnected contacts per column (Contacts **1** through **30**).

Components and wires are connected according to a schematic diagram by using the 5-contact columns. A wire or lead in any row in column **1** interconnects with points **2**, **3**, **4** and **5** in that same row. Column contacts **6-10**, **11-15**, **16-20**, **21-25** and **26-30** are similarly interconnected. Each contact can be uniquely identified by its row and column, e.g., **A1**, **R15**, **T30**. When we first use the breadboard you will be given the specific contacts to use for the various components.

Please note these are recommendations and similar connections would work as well…