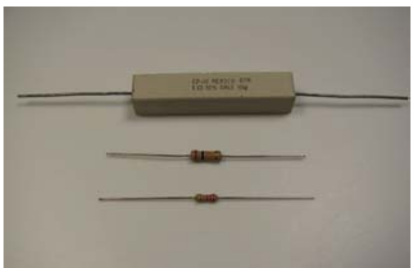
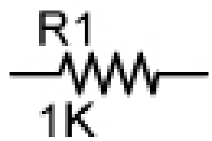
Resistors
Cornerstone Electronics Technology and Robotics I Week 9

- **Administration:**
  - Prayer
  - Turn in quiz
- **Resistors:**
  - Function: Resistors restrict the flow of electric current, for example a resistor is placed in series with a light-emitting diode (LED) to limit the current passing through the LED. They convert electrical energy into mechanical energy (heat).
    - Resistors are used to:
      - Provide a voltage drop
      - Provide a current limit
      - Dissipate (converting) electrical energy
      - Some electrical components have resistance that varies with temperature or light. They serve as sensors used in various applications.
  - When used in DC circuits the voltage drop produced is measured across their terminals as the circuit current flows through them because they obey Ohm's Law.
  - A larger value in ohms represents a larger resistance.
  - **Fixed Resistors:**
    - Examples and symbol with the value of its resistance given in Ohms, Ω:



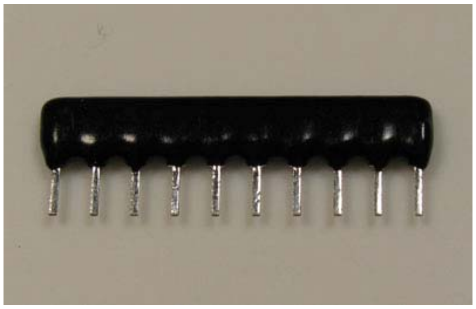
¼, ½, and 10 Watt Resistors



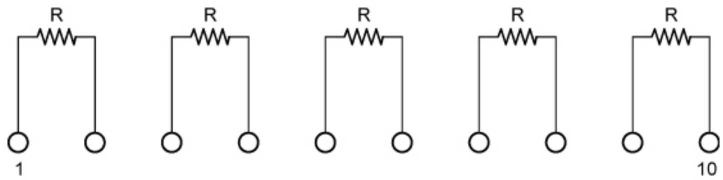
Resistor Symbol w/ Value of 1K Ohms

  - Varieties: There are many different resistor types and they are produced in a variety of forms because their particular characteristics and accuracy suit certain areas of application, such as high stability, high voltage, high current etc, or are used as general purpose resistors where their characteristics are less of a problem.
    - Carbon composite resistor: Made of carbon dust or graphite paste, low wattage values.
    - Film or cermet resistors: Made from conductive metal oxide paste, very low wattage values.
    - Wire wound resistors: Metallic bodies for heatsink mounting, very high wattage ratings.
    - Semiconductor Resistors: High frequency/precision surface mount thin film technology.
    - See: http://www.electronics-tutorials.ws/resistor/res_1.html

- o SIP and DIP Resistors Networks:
  - **S**ingle **I**n-line **P**ackage (SIP) Resistor Networks:

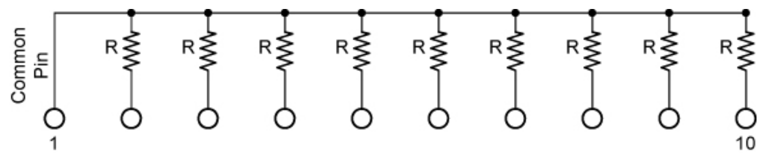


SIP Package



Isolated SIP Resistor Network

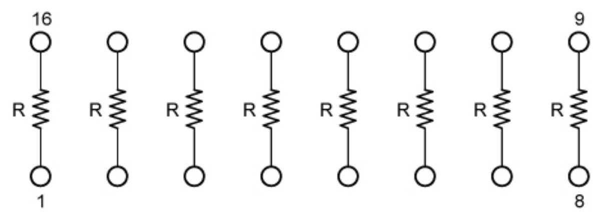
Single row, isolated, individual resistors,
each having two pins on the network.
All resistors have the same resistance value.



Bussed SIP Resistor Network

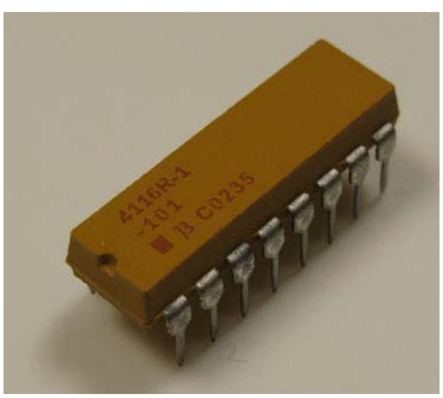
Single row, One common pin with all resistors
bussed to remaining pins.
All resistors have the same resistance value.

  - **D**ual **I**n-line **P**ackage (DIP) Resistor Networks:

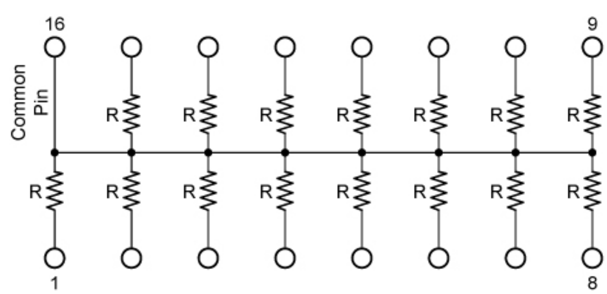


Isolated DIP Resistor Network

Dual row pins, isolated, individual resistors
each with 2 adjacent pins, ie. 1-14, 2-13 etc.
All resistors have the same resistance value.



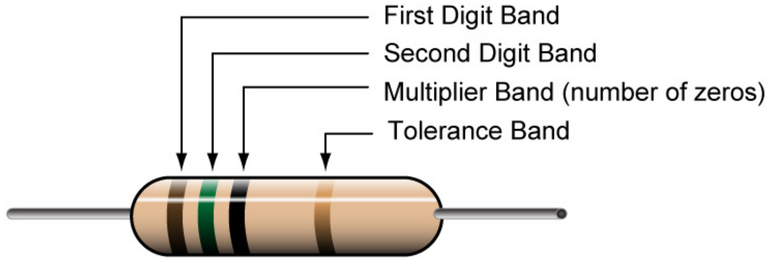
100 Ohm DIP Package



Bussed DIP Resistor Network

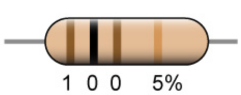
Dual row pins, One common pin with
all resistors bussed to remaining pins.
All resistors have the same resistance value.

4-Band Resistor Color Code



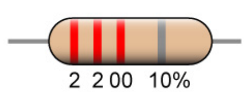
First Digit	Second Digit	Multiplier # of Zeros	Tolerance	Color
	0	no zeros		Black
1	1	1 zero		Brown
2	2	2 zeros	2 %	Red
3	3	3 zeros		Orange
4	4	4 zeros		Yellow
5	5	5 zeros		Green
6	6	6 zeros		Blue
7	7	7 zeros		Violet
8	8	n/a		Grey
9	9	n/a		White
		x 0.1	5%	Gold
		x 0.01	10%	Silver

Examples:



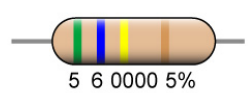
Brown - Black - Brown - Gold
1 0 0 5%

100 Ω +/- 5%



Red - Red - Red - Silver
2 2 00 10%

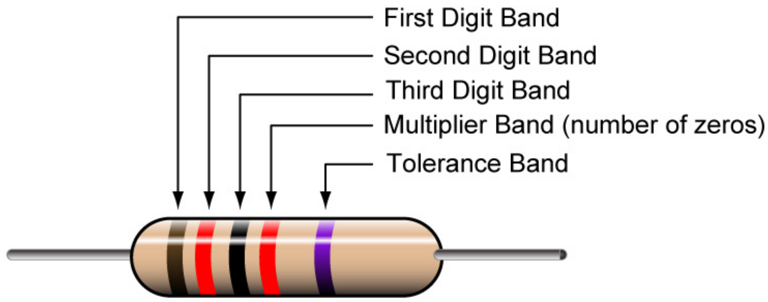
2,200 Ω (2.2K) +/-10%



Green - Blue - Yellow - Gold
5 6 0000 5%

560,000 Ω (560K) +/- 5%

5-Band Resistor Color Code



First Digit	Second Digit	Third Digit	Multiplier # of Zeros	Tolerance	Color
	0	0	no zeros		Black
1	1	1	1 zero	1%	Brown
2	2	2	2 zeros		Red
3	3	3	3 zeros		Orange
4	4	4	4 zeros		Yellow
5	5	5	5 zeros	0.5%	Green
6	6	6	6 zeros	0.25%	Blue
7	7	7	7 zeros	0.1%	Violet
8	8	8	n/a		Grey
9	9	9	n/a		White
			x 0.1		Gold
			x 0.01		Silver

Examples:

1 2 0 00 0.5%

Brown - Red - Black - Red - Green
1 2 0 00 0.5%

12,000 Ω (12.0K) +/- 0.5%

4 2 7 000 0.25%

Yellow - Red - Violet - Orange - Blue
4 2 7 000 0.25%

427,000 Ω (427KK) +/-0.25%

3 3 5 x0.1 0.1%

Orange - Orange - Green - Gold - Violet
3 3 5 x 0.1 0.1%

33.5 Ω +/- 0.1%

- See resistor color code applet:
  - http://www.dannyg.com/examples/res2/resistor.htm
- Percentage and Tolerance Calculations:
  - Percent means "out of 100 or per 100." For example, instead of saying "30 out of every 100 professional basketball players are female," we can say "30% of professional basketball players are female."
  - 1% of anything is one hundredth part of it.
  - Here are three ways to write the same thing:

$$25\% = 25/100 = 0.25$$

  To convert percent to a decimal, move the decimal to the left 2 places.

  - Find 10% of 470:
    - First change 10% to a decimal by moving the decimal point 2 places to the left.

$$10\% = 0.10$$

    - Then multiply,

$$0.10 \times 470 = 47$$

    - 10% of 470 is 47
  - Find the upper and lower limits for a 470 Ω resistor with a 10% tolerance:
    - The allowable resistance within tolerance can be from 470 Ω + 10% to 470 Ω – 10%.
    - From above, 10% of 470 is 47
    - Upper Limit: 470 Ω + 10% = 470 Ω + 47 = 517 Ω
    - Lower Limit: 470 Ω – 10% = 470 Ω – 47 = 423 Ω
    - Therefore the range for a 470 Ω resistor with a 10% tolerance is from 423 to 517 ohms.
- Perform Resistors Lab 1 – Resistor Color Code
- Resistor Failures:
  - If the power dissipated is more than the resistor can safely dissipate, the resistor may depart from its nominal resistance value and may become damaged by overheating.
  - Excessive power dissipation may raise the temperature of the resistor to a point where it burns out, which could cause a fire in adjacent components and materials. Complete failure is an open circuit; they do not create a short circuit.

- Power Rating of Resistors (Watts):
  - Not only is the resistance value in ohms important when choosing a resistor, but you must choose a resistor that does not become too hot when current is flowing through it. The resistor's wattage value (or power rating) must exceed the power it must dissipate. The wattage in a resistor is the maximum amount of heat energy it can safely dissipate without damage.
    - Demonstration: use a 150 ohm ½ watt and ¼ watt resistors with various currents from a robust power supply. Note how the heat from the resistors varies. Verify the value of the resistor as the voltage increases.
  - A resistor's larger size signifies a higher wattage rating. Resistors carrying large currents must be physically large so the heat can radiate quickly to the surrounding air.
    - Demonstration: use a small (1/4 watt) and a larger (10 watt) resistor, both having a resistance of 10 ohms. The current through each resistor will be the same. Note the variation in heat given off by the two resistors.
  - If a resistor operates at an elevated temperature, it can change its resistance value and even burn out to create an open circuit.
  - Wire-wound resistors are larger than carbon resistors and have a higher wattage rating.
  - The power formulas are covered in Lesson 10 Energy and Gears. See: http://cornerstonerobotics.org/curriculum/lessons_year1/ER%20Week10,%20Energy,%20Gears.pdf
- Resistance Decade Boxes:
  - A resistance decade box or resistor substitution box is a unit that can provide one resistor within a wide range of values. It contains resistors of many values, with one or more mechanical switches which allow any one of various discrete resistances offered by the box to be dialed in. Usually the resistance is accurate to high precision, ranging from laboratory/calibration grade accuracy of 20 parts per million, to field grade at 1%. Inexpensive boxes with lesser accuracy are also available.
- Complete Resistors Lab 2 – Resistors and Current

- Suggested homework, Student Activity Sheets 3-2, 3-3.

Electronics Technology and Robotics I Week 9
Resistor Lab 1 – Resistor Color Code

- **Purpose:** The purpose of this lab is to acquaint the student with the resistor color code and tolerance calculations.

- **Apparatus and Materials:**
    - 10 – Fixed Resistors Labeled 1 – 10

- **Procedure:**
    - Using the resistor color code, determine the value of 10 resistors and record the values in the table below.
    - Calculate the limits that are within tolerance
    - Measure the resistance of each resistor and compare with the coded value.

- **Results:**

Resistor	Coded Value	Tolerance	Product of Tol. x Value	Upper Limit	Lower Limit	Measured Value
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

- **Conclusions:**
    - Are the measured values of each resistor within the tolerance limits?

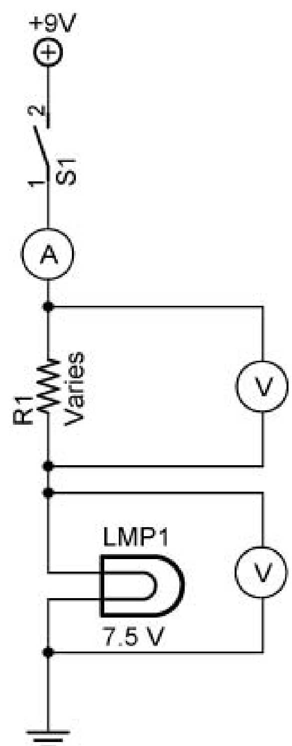
Electronics Technology and Robotics I Week 9
Resistor Lab 2 – Resistors and Current

- **Purpose:** The purpose of this lab is to demonstrate to the student that resistors restrict current and that an increase in resistance increases the voltage drop across the resistor.

- **Apparatus and Materials:**

  - 1 – Breadboard with 9 V Supply
  - 3 – Digital Multimeters
  - 1 – 1, 10, 22, 47, 68, and 100 Ohm Resistor
  - 1 – 7.5 V Lamp with Lamp Base
  - 1 – SPDT Switch

- **Procedure:**
  - Assemble the circuit below on the breadboard using 1, 10, 22, 47, 68, and 100 ohm resistors as R1.
  - Measure the current for each change in resistor value.
  - Calculate the voltage drop across R1 using Ohm's law.
  - Now measure the voltage drop across R1 and the lamp.
  - Compare the calculated voltage drop across R1 with the measured value.
  - Add the measured voltage drops across R1 and the lamp to get the total measured voltage drop.
  - Compare the total measured voltage drop with the measured source.
  - Note the brightness variation in each case.



- **Results:**

Voltage Drops Lab 2						
Circuit	**R1**	**Current**	**Calculate Voltage Drop R1**	**Measured Voltage Drop R1**	**Measured Voltage Drop LMP1**	**Total Measured Voltage Drop**
1						
2						
3						
4						
5						
6						

- **Conclusions:**
  - Is the calculated voltage drop across R1 close to the measured voltage drop across R1?
  - As the value of R1 is increased, what happens to the voltage drop across R1?
  - As the value of R1 is increased, what happens to the brightness of the lamp? Why?

Electronics Technology and Robotics I Week 9
Resistor Lab 3 – Making a Resistor

- **Purpose:** The purpose of this lab is to demonstrate to the student that carbon is a suitable material to make resistors.

- **Apparatus and Materials:**

  - 1 – Digital Multimeter
  - 1 – Piece of 5” x 8” Index Card
  - 1 – #2 Pencil

- **Procedure:**
  - Using a standard No. 2 pencil draw about a 7” long line on the blank side of the index card. Mark the 0” and 6” points about a half of an inch in from the ends of the line. It should look like this:

  - **Place all pencil filings from your work into a wastepaper basket.**
  - In 2 minutes using only the #2 pencil, make the line thicker and/or wider to give you the lowest resistance possible between the 0” and 6” points.
  - The student that measures lowest resistance between the 0” and 6” points at the end of the 2 minute period will be rewarded. The instructor must verify the measurement.