BASIC ELECTRIC POWER PART 1

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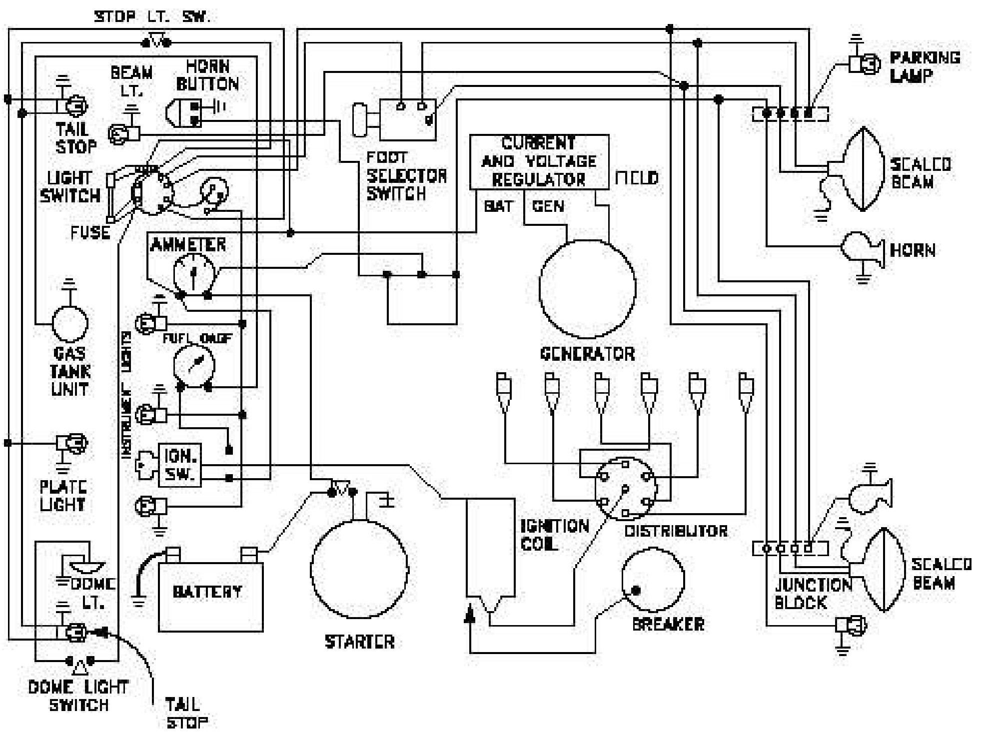
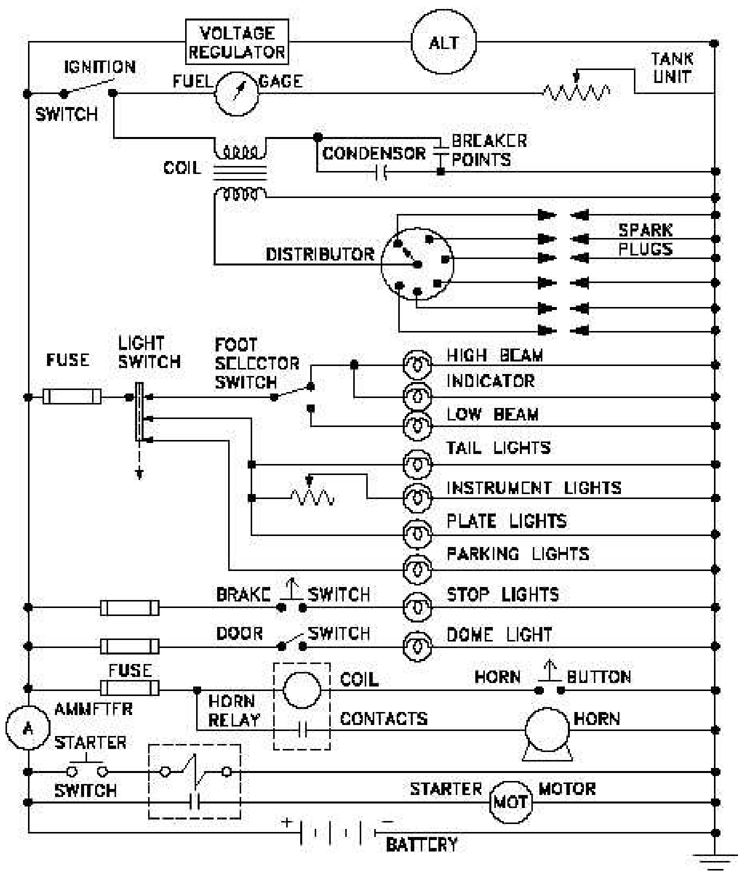




BASIC ELECTRIC POWER PART 1

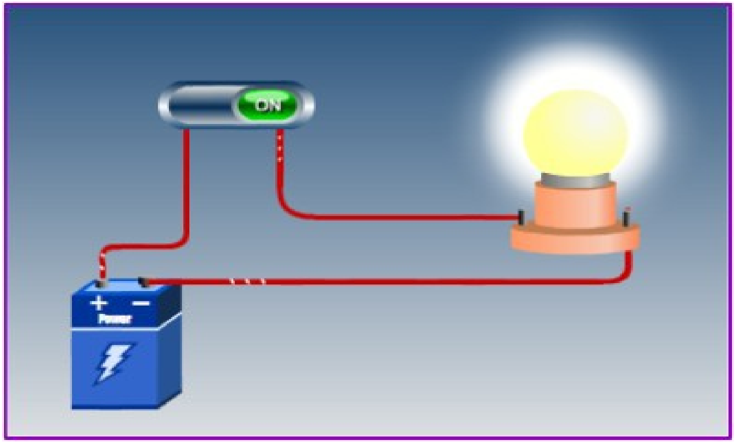
In this presentation, there will be two sub-parts:

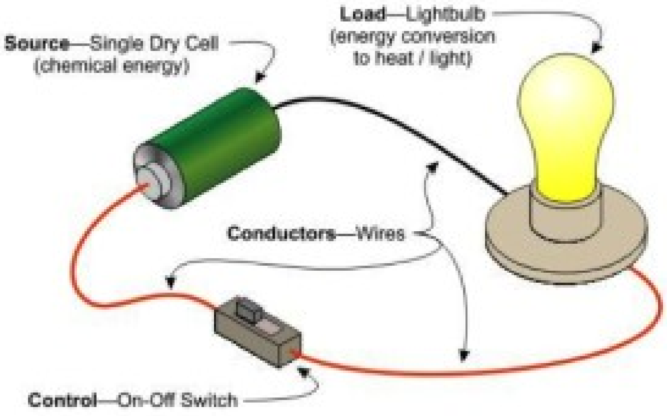
- Basic Electric Circuits Schematic Diagrams
- Basic Electric Power Concepts and Formulae

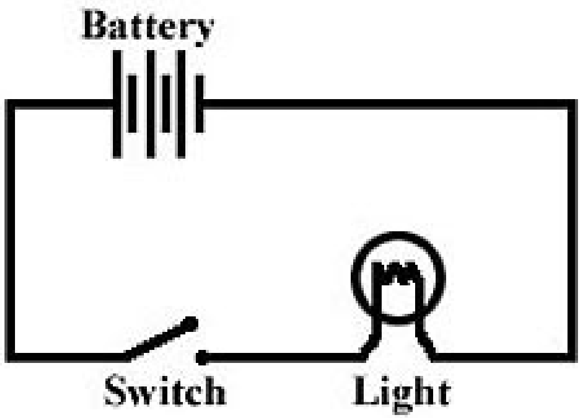
- Basic Electric Circuits Schematic Diagrams
  - Circuit Diagrams or Schematics
  - Symbols Legend
  - Simple Concepts in Electric Power & Control Schematics

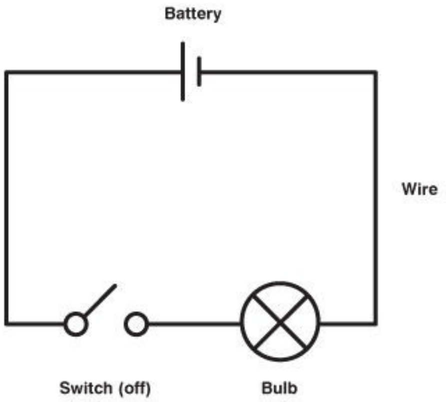
- Basic Electric Power Concepts and Formulae
  - Wiring
  - Basic Electrical Characteristics
    - Power – Watts
    - Volts, Amps, & Ohms
  - Electric Power Formulae – Circle Diagram

BASIC ELECTRIC POWER
PART 1





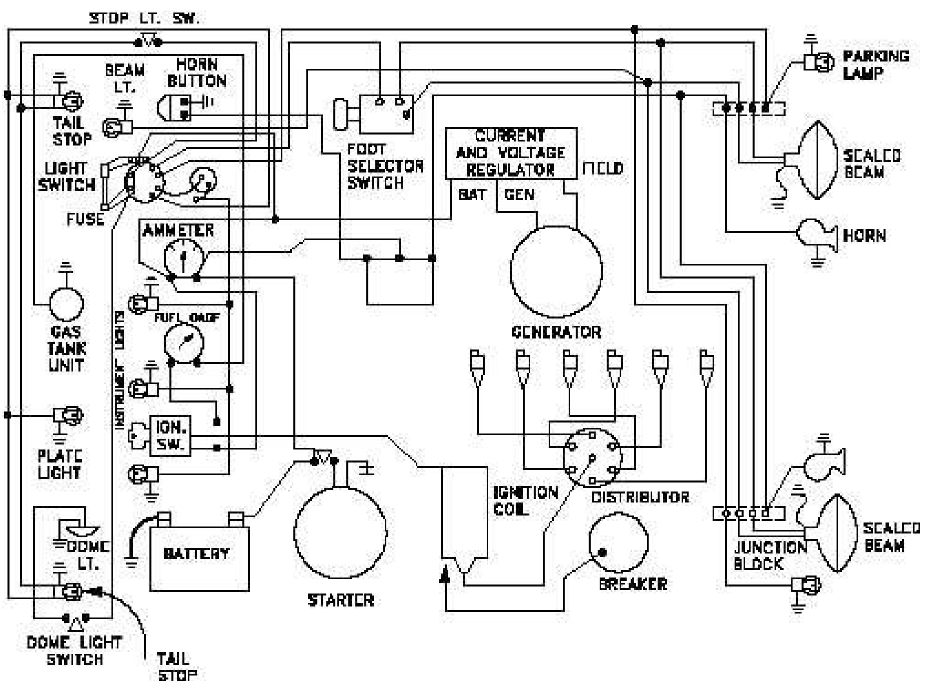


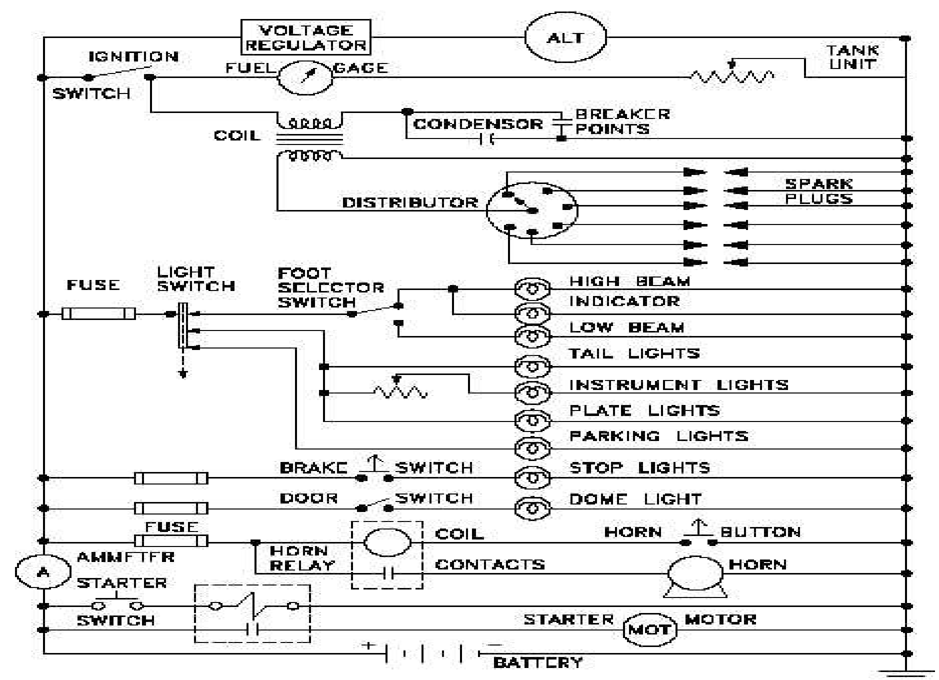


BASIC ELECTRIC POWER PART 1

Circuit Diagram or Schematic Diagram

- **Wiring Diagrams** represent **Electric Power/Control Circuits** using **Symbols**, and (usually) indicate **Wire Identifiers, Device Identifiers** and/or **Circuit Terminal Identifiers**
- **Schematic Diagrams** represent **Electric Control Circuits' Logic** using **Symbols**, **Device Identifiers**, **Device Terminal Identifiers**, and, sometimes, **Wire Identifiers**
- **BUT, NOT ALWAYS do the diagrams show all the identifiers!**

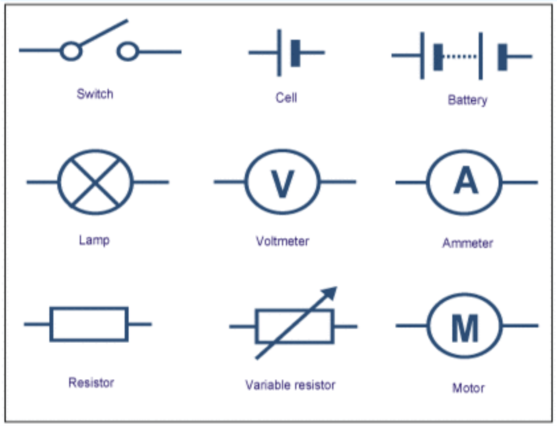


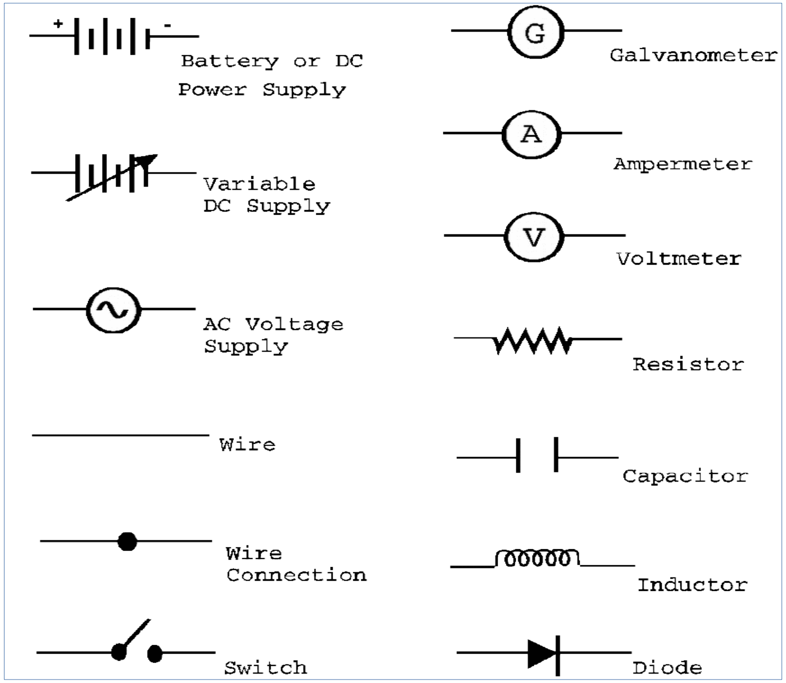


BASIC ELECTRIC POWER PART 1

Electric Schematic Diagram Symbols Legend

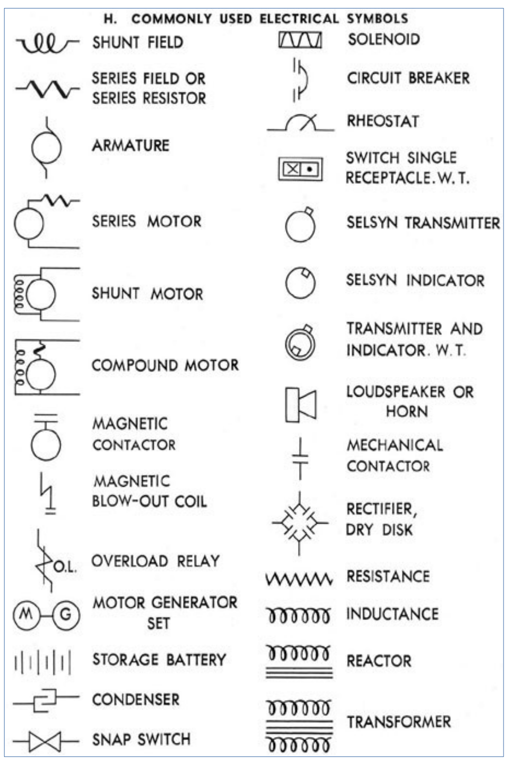
- All **components** are represented by **symbols** shown in a **Legend**
- **Sources** (of Electric Energy) **are omitted**; so, no source symbols

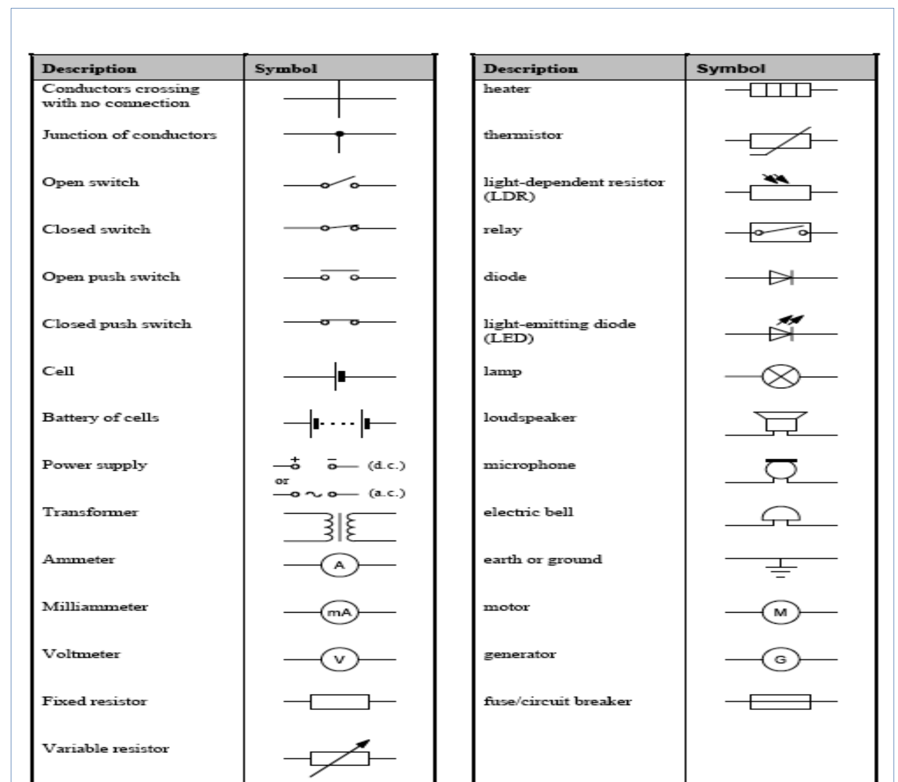




BASIC ELECTRIC POWER PART 1

Electric Schematic Diagram Symbols Legend

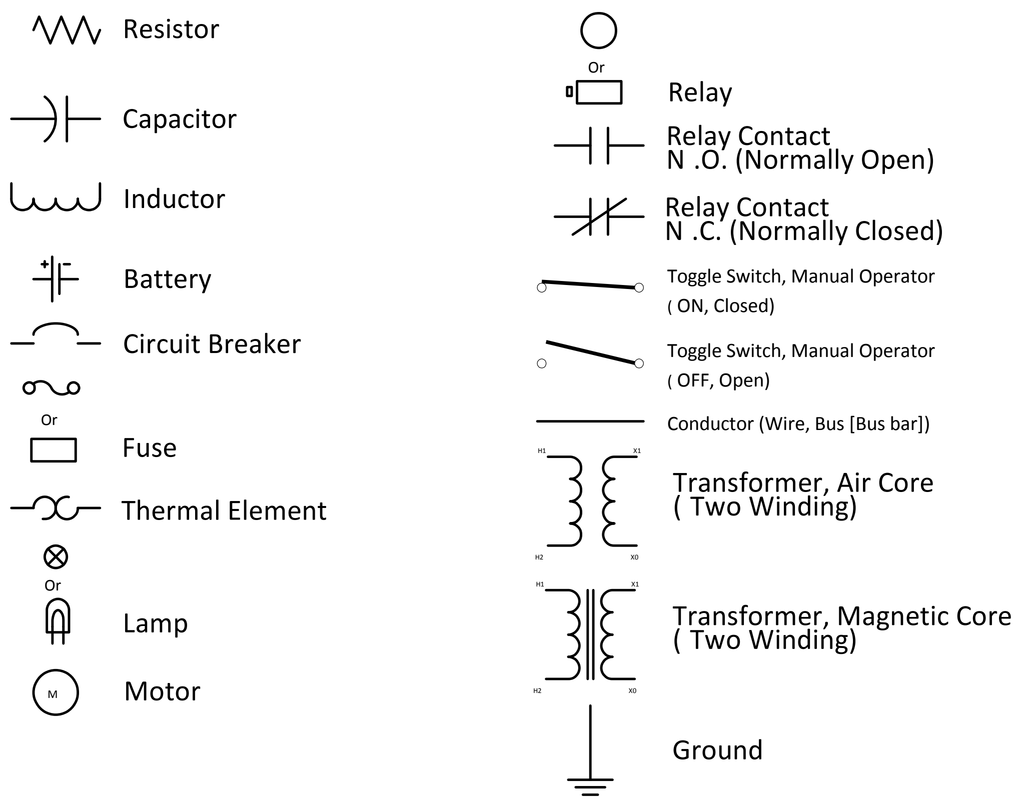




BASIC ELECTRIC POWER PART 1

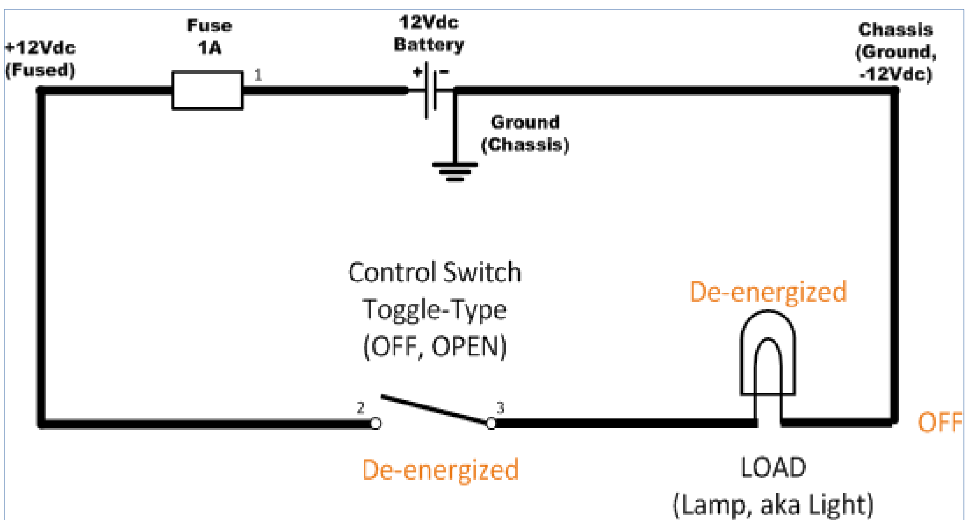
Electric Schematic Diagram Symbols Legend

SYMBOLS LEGEND SCHEMATICS

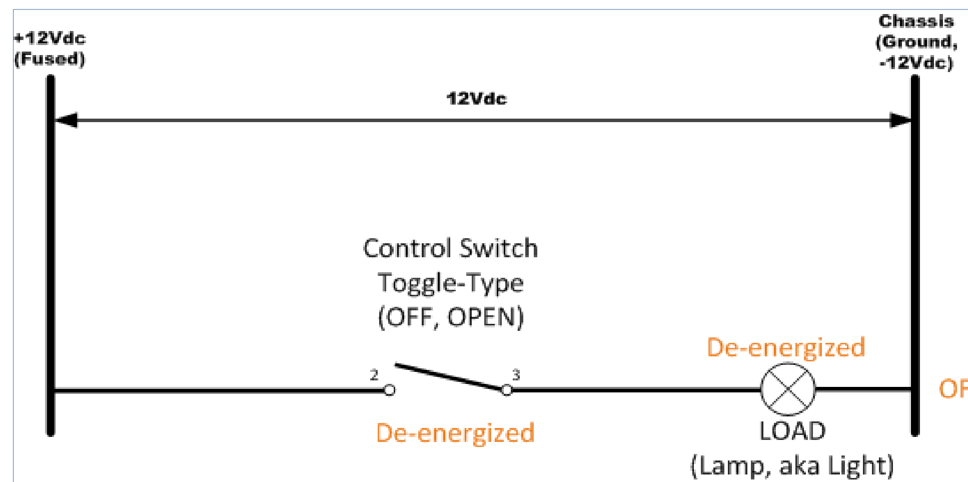


BASIC ELECTRIC POWER PART 1

SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS



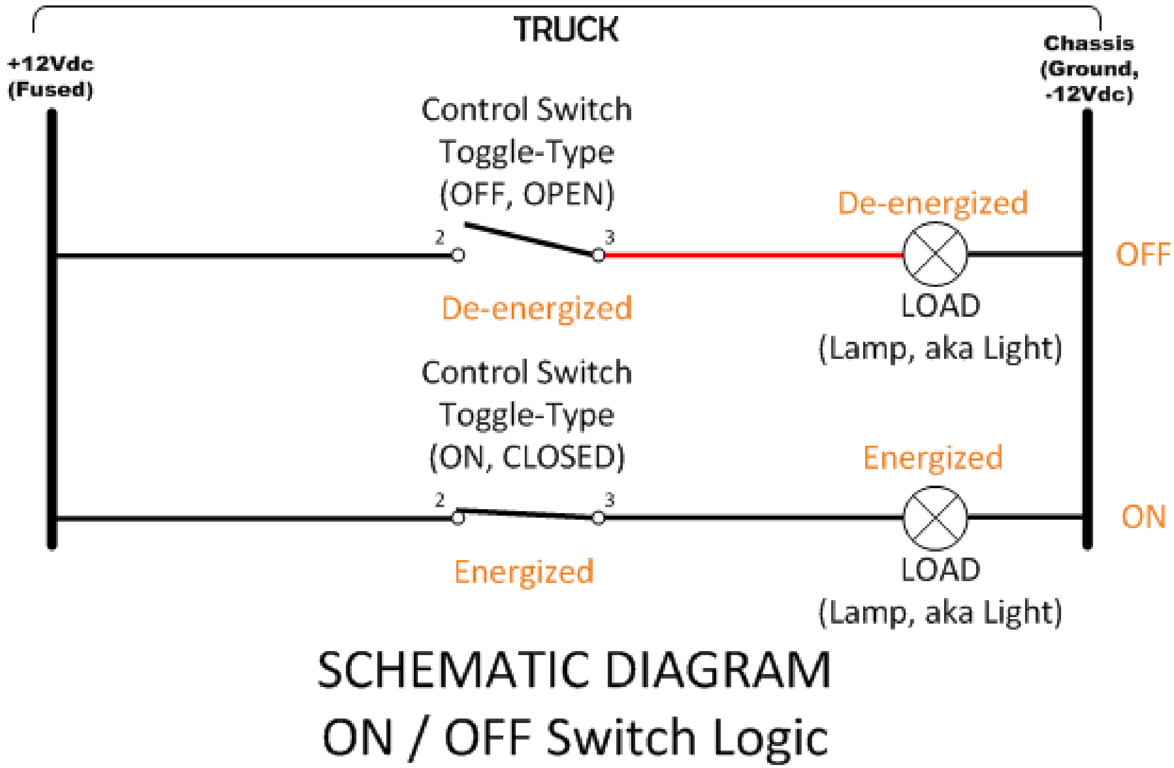
TYPICAL
ELECTRIC POWER/CONTROL
WIRING DIAGRAM



TYPICAL
ELECTRIC POWER/CONTROL
SCHEMATIC DIAGRAM
(aka, LADDER DIAGRAM)

BASIC ELECTRIC POWER PART 1

SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS



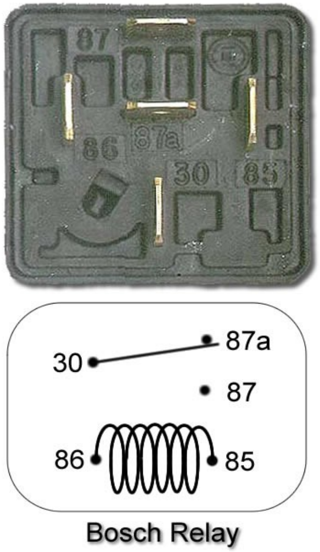
BASIC ELECTRIC POWER PART 1

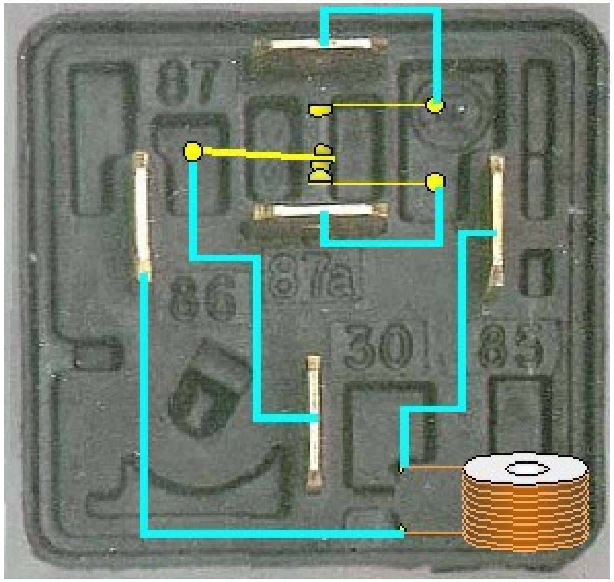
SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS

- Note that the **Current** due to the **Load** flows through the **Wiring** and through the **Switch**
- The **Current** flowing through the **Wiring** produces **Heat**; that heat may be acceptable for currents of less than 5A (five amps), but not acceptable for high power loads.
- Also, most switches are rated for 10A, 15A, or 20A at 12Vdc.
- So, for **high power loads**, we use **Relays** (also called **Contactors**); some folks refer to the high power relay as **"Solenoids"** due to the fact that the operating coil of a rely/contactor is the same design as for the coil in a solenoid valve (used in fluid piping systems).
- Also, **relays** allow logic to be incorporated in the circuit.

BASIC ELECTRIC POWER
PART 1

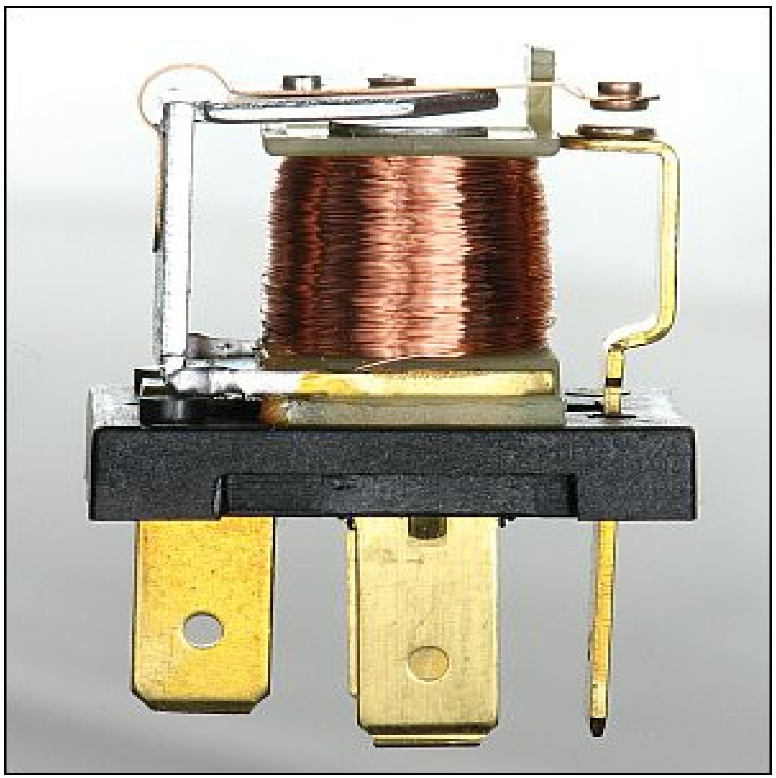
SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS

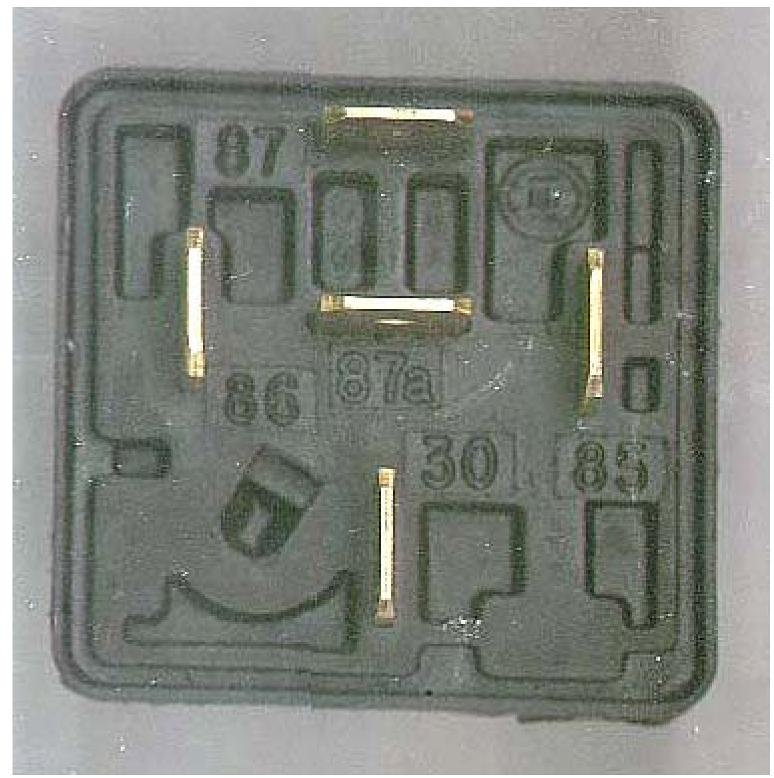




BASIC ELECTRIC POWER PART 1

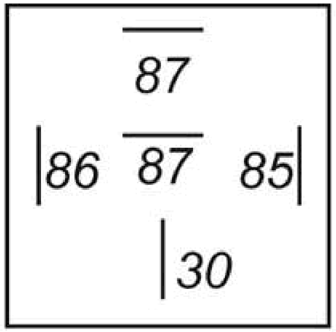
SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS

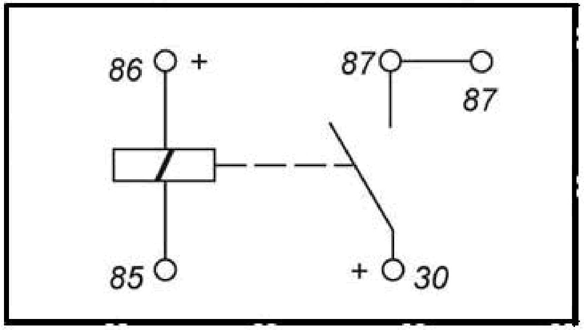


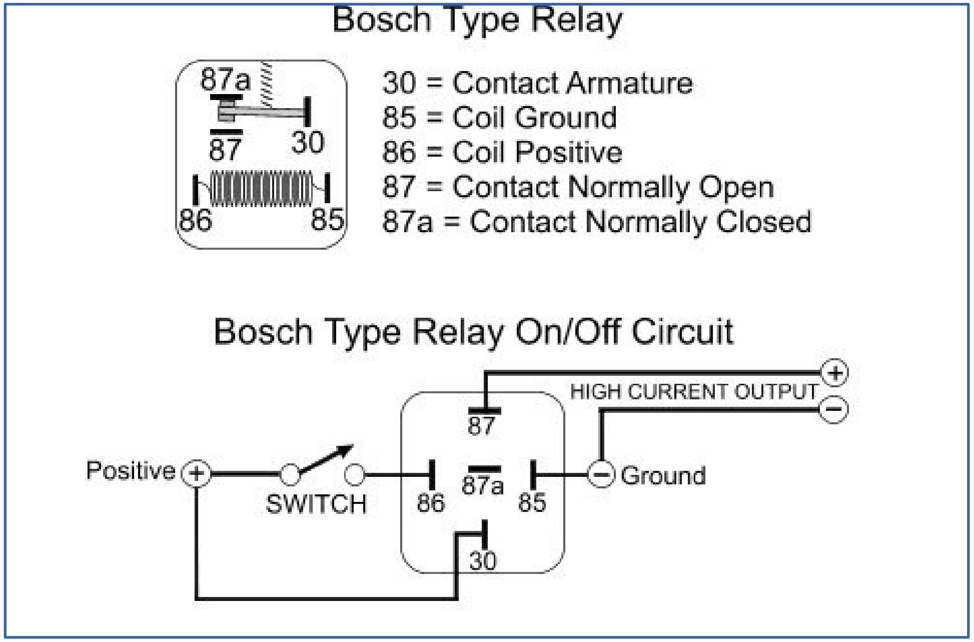


BASIC ELECTRIC POWER PART 1

SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS

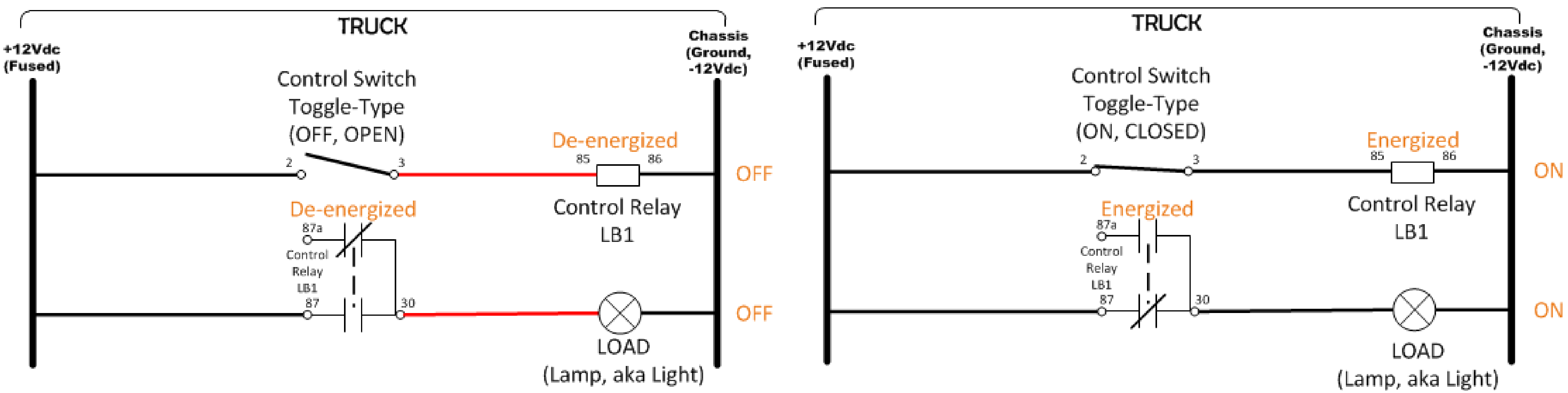






BASIC ELECTRIC POWER PART 1

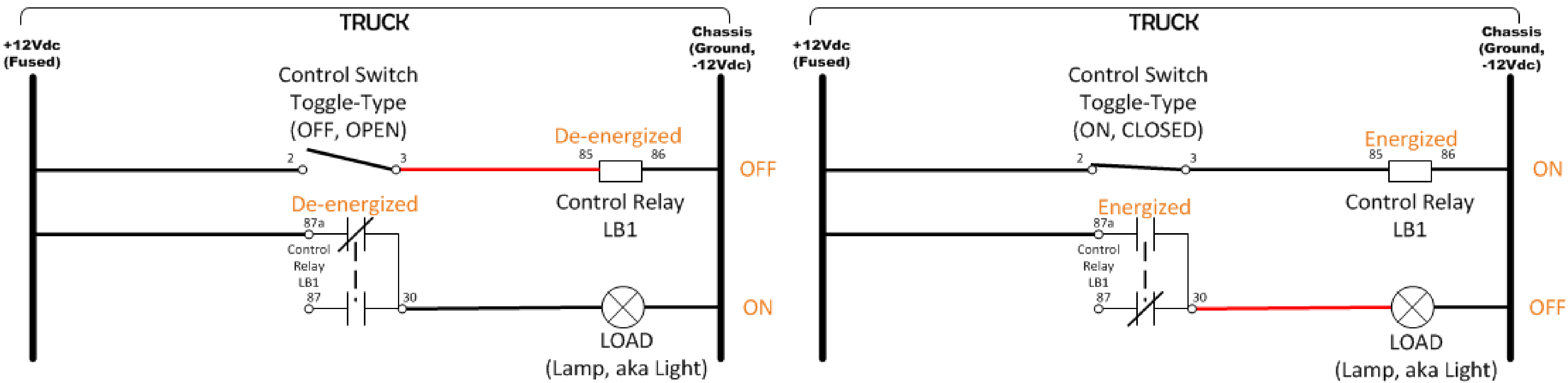
SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS



SCHEMATIC DIAGRAMS
1-RELAY LOGIC
N.O. (Normally Open) Logic

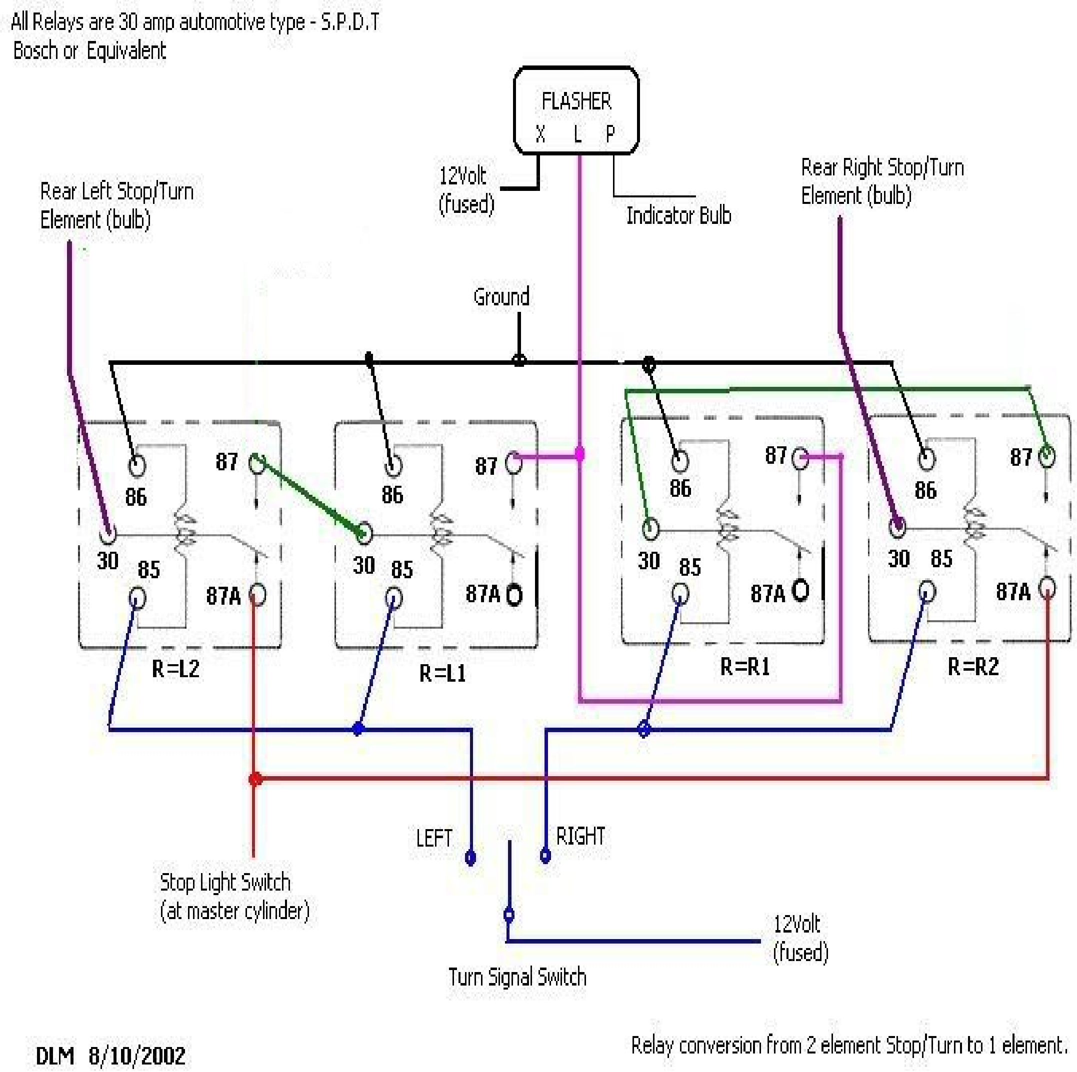
BASIC ELECTRIC POWER PART 1

SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS

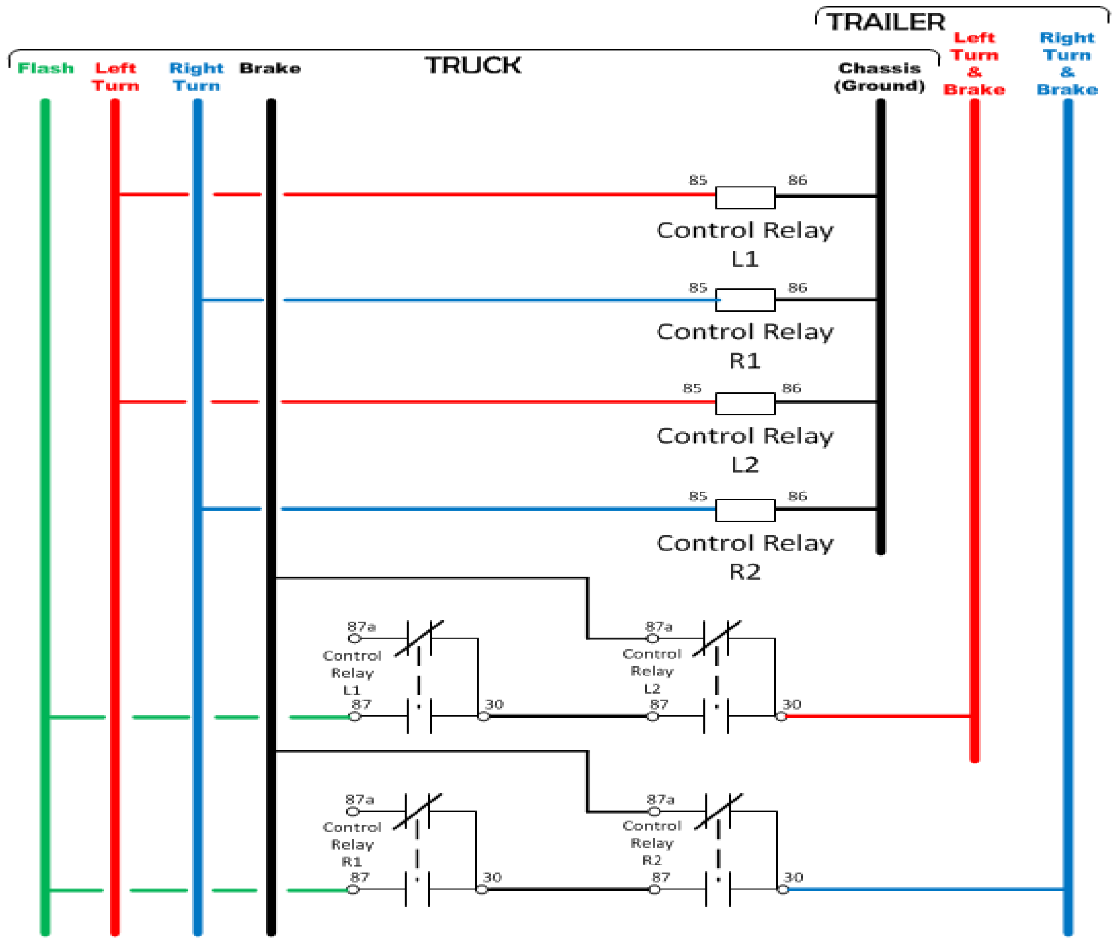


SCHEMATIC DIAGRAMS
1-RELAY LOGIC
N.C. (Normally Closed) Logic

BASIC ELECTRIC POWER PART 1



BASIC ELECTRIC POWER PART 1



SCHEMATIC DIAGRAM
4-RELAY LOGIC
TAIL LIGHT CONVERTER

BASIC ELECTRIC POWER PART 1

SIMPLE CONCEPTS IN ELECTRIC POWER AND CONTROL SCHEMATICS

ANY QUESTIONS ?

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductors (Wires)
  - Conductor Sizes
  - Conductor Ampacity

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductors (Wires)
    - Material – **Copper** or Aluminum (**USE COPPER, ONLY**!)
    - Solid or **Stranded**
    - Bare Conductors or **Insulated Conductors**
    - Weight
    - Cost
    - **Environment**

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductors (Wires)
    - Insulated Conductors –
      - Voltage (300V, **600V**, more than 600V)
      - Temperature Rating (60°C, 75°C, 90°C, etc.)
      - Insulation Types
        - Thermoplastic (THW, THWN, THHN, MTW, etc.)
        - Thermoset (XHHW, etc.)
        - Rubber (RHW, RHHW, etc.)
        - Specialty
    - Environment
      - Dry Locations or **Wet/Damp Locations**
      - **Ambient Temperature**

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductors (Wires)
    - A conductor is a wire suitable for carrying an electric current. A conductor, usually, consists of a conductive metal part (a wire) and a non-conductive insulation part. Strictly speaking, a wire refers to the metal part; but, wire, in general usage, will refer to the whole conductor.
    - Insulation type is associated with Temperature Rating
      - Temperature Ratings: 60°C, 75°C, 90°C, etc.
      - Temperature Ratings are the Temperature Rise over 30°C Ambient Temperature (86°F)
    - Ampacity (Per 2014 NEC, Article 100 Definitions)
      - The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - To compare the **resistance** and **size** of one conductor with that of another, we need to establish a standard or unit size.
      - A convenient **unit of measurement of the diameter** of a conductor is the **mil (0.001, or one-thousandth of an inch)**.
      - A convenient **unit of conductor length** is the **foot**.
      - **The standard unit of size in most cases is the MIL-FOOT**. A wire will have a unit size if it has a diameter of 1 mil and a length of 1 foot.
    - **To carry the same current, the cross-sectional area of a round conductor must be equal to the cross-sectional are of a rectangular (or, a square) conductor**.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **SQUARE MIL**
      - The **square mil** is a **unit of measurement** used to determine the **cross-sectional area of a square or rectangular conductor** (views A and B of figure 1-1). **A square mil is defined as the area of a square, the sides of which are each 1 mil.**
      - To obtain the cross-sectional area of a square, or rectangular conductor, multiply the length times the width of the end face of the conductor (side is expressed in mils).

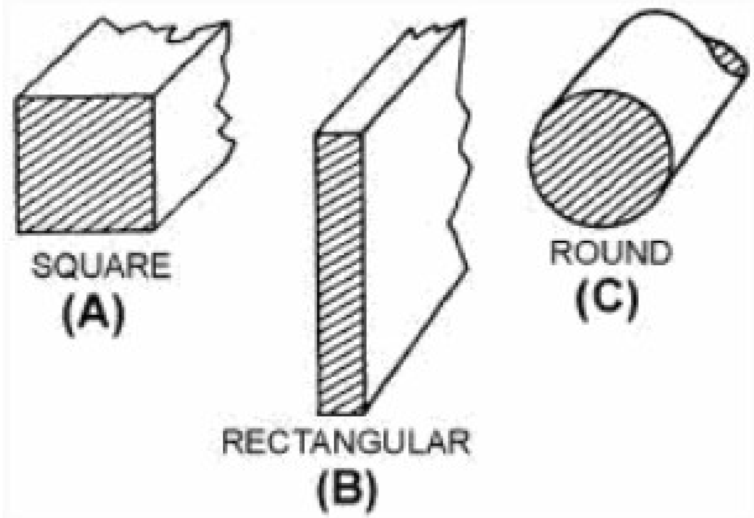


Figure 1-1.—Cross-sectional areas of conductors.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **CIRCULAR MILS**
      - The **circular mil** (CM) is the **standard unit of measurement of a round wire cross-sectional area** (view C of figure 1-1). This unit of measurement is found in American and English wire tables.
      - The diameter of a round conductor (wire) used to conduct electricity may be only a fraction of an inch. Therefore, it is convenient to express this diameter in mils to avoid using decimals.
      - For example, the diameter of a wire is expressed as 25 mils instead of 0.025 inch

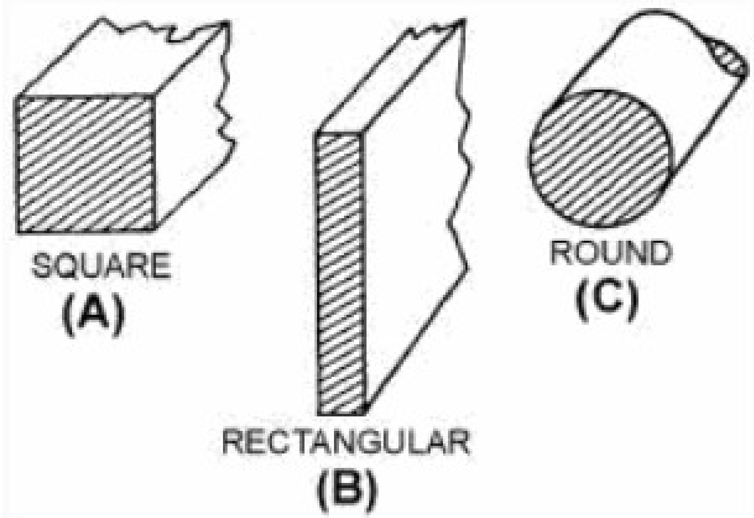


Figure 1-1.—Cross-sectional areas of conductors.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **CIRCULAR MILS**
      - **A circular mil is the area of a circle having a diameter of 1 mil**, as shown in view B of figure 1-2.
      - **The area, in circular mils of a round conductor, is obtained by squaring the diameter, measured in mils.**
      - Comparing square mils to circular mils as in view C, it can be seen that **a circular mil represents a smaller unit of area than the square mil**.

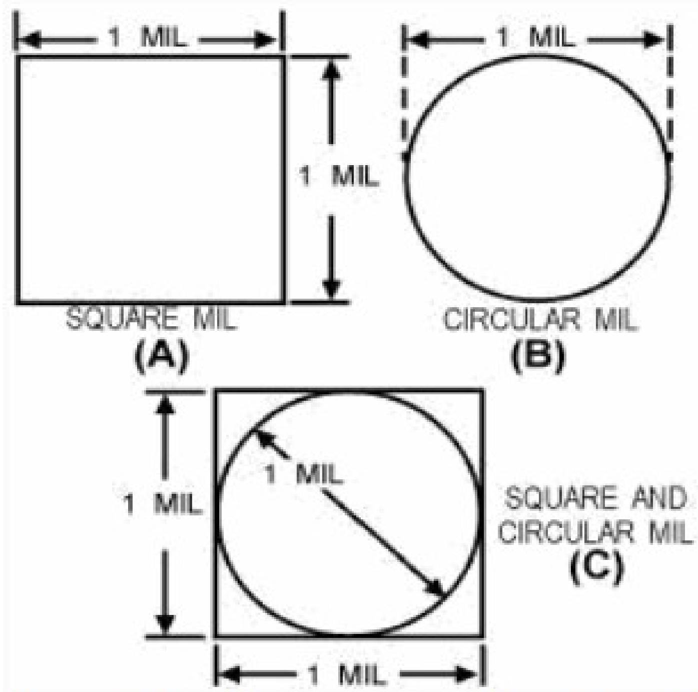


Figure 1-2.—A comparison of circular and square mils.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **STRANDED WIRE**
      - A wire is a single slender rod or filament of drawn metal. This definition restricts the term to what would ordinarily be understood as "solid wire." The word "slender" is used because the length of a wire is usually large when compared to its diameter.
      - If a wire is covered with insulation, it is an insulated wire. Although the term "wire" properly refers to the metal, it also includes the insulation.

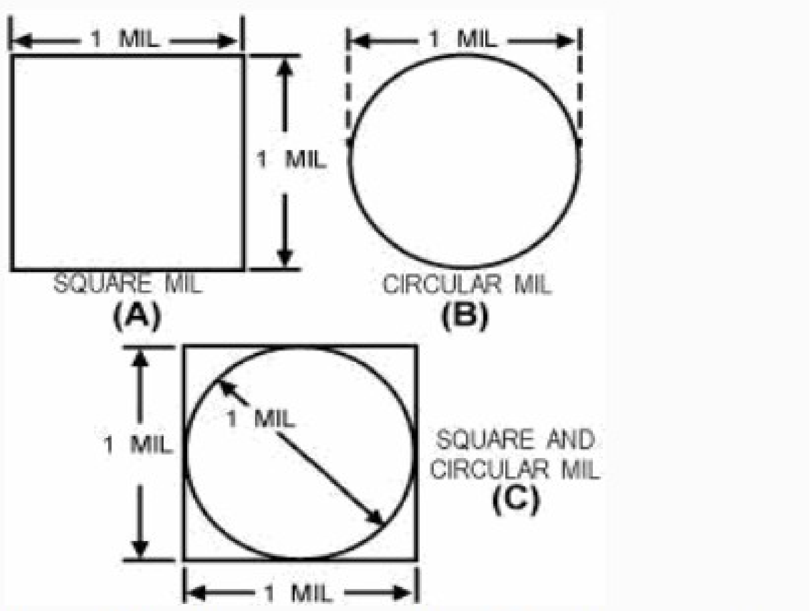


Figure 1-2.—A comparison of circular and square mils.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **STRANDED WIRE**
      - In large sizes, single, solid-conductor wire becomes difficult to handle. To increase its flexibility, it is stranded.
      - Strands are usually single, solid-conductor wires twisted together in sufficient numbers to make up the necessary cross-sectional area of the cable.
      - A stranded conductor is a conductor composed of a group of wires or of any combination of groups of wires. The wires in a stranded conductor are usually twisted together and not insulated from each other.
      - The total area of stranded wire in circular mils is determined by multiplying the area in circular mils of one strand by the number of strands in the conductor (or, cable).

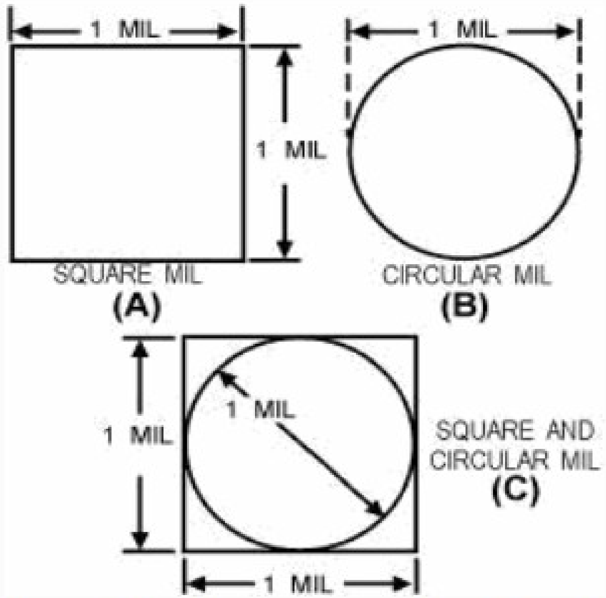


Figure 1-2.—A comparison of circular and square mils.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **STRANDED WIRE**
      - A cable is either a stranded conductor (single-conductor cable) or a combination of conductors insulated from one another (multiple-conductor cable). The term "cable" is a general one and usually applies only to the larger sizes of conductors. A small cable is more often called a stranded wire or cord (such as that used for a Kuerig® or a lamp cord). Cables may be bare or insulated; and, where multiple conductors form the cable will have an overall jacket.

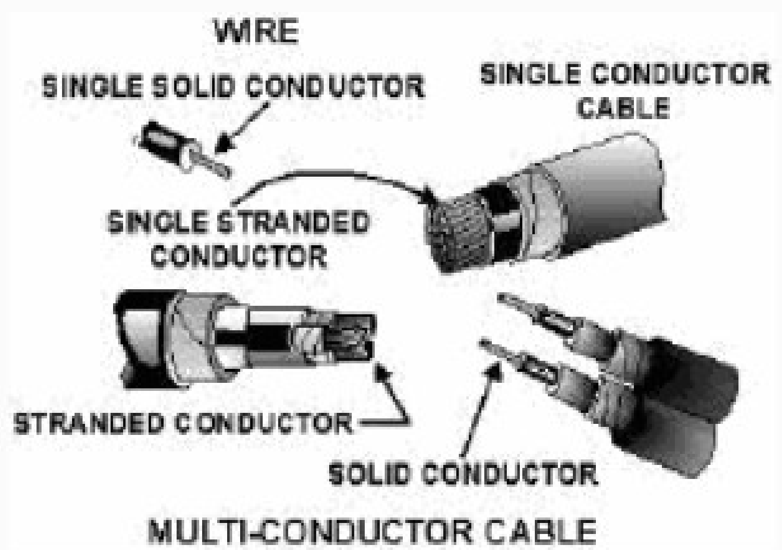


Figure 1-5.—Conductors.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **STRANDED WIRE (Welding Cable)**
      - Because of their greater flexibility, welding cable may be used for permanent installations where adequately supported in conduit or cable tray; but, only for sizes 1/0 and larger.
      - The table at the right is a typical specification table for a welding cable. [General Cable Company]

CAROLPRENE® 105°C WELDING CABLE – 600 VOLT – 30 AWG STRANDING

CATALOG NUMBER	AWG SIZE	NOMINAL STRAND	NOMINAL O.D. INCHES	NOMINAL O.D. mm	APPROX. NET WT. LBS/M'(5)	STD. CTN.
01758*	6	259/30	0.430	10.92	152	1000'
01757*	4	418/30	0.475	12.07	215	1000'
01756*	2	646/30	0.540	13.72	296	1000'
01755*	1	836/30	0.580	14.73	360	1000'
01754*	1/0	1032/30	0.615	15.62	424	1000'
01753*	2/0	1290/30	0.655	16.64	513	1000'
01752*	3/0	1672/30	0.720	18.29	644	1000'
01751*	4/0	2066/30	0.780	19.81	824	1000'

* Non-stock item; minimum quantity required.
(5) Actual shipping weight may vary.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **CIRCULAR MIL - FOOT**
      - A circular-mil-foot (figure 1-3) is a unit of **volume**. It is a unit conductor 1 foot in length and has a cross-sectional area of 1 circular mil.
      - Because it is a unit conductor, the circular-mil-foot is useful in making comparisons between wires consisting of different metals.
        - For example, a basis of comparison of the RESISTIVITY (to be discussed shortly) of various substances may be made by determining the resistance of a circular-mil-foot of each of the substances.

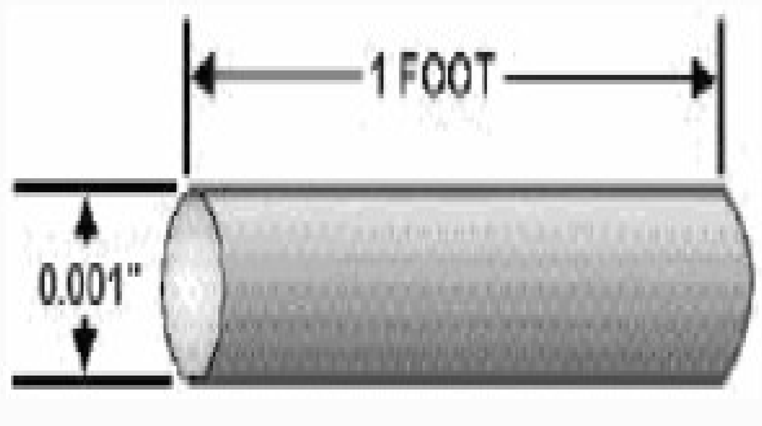


Figure 1-3.—Circular-mil-foot.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **CIRCULAR MIL - FOOT**
      - In working with square or rectangular conductors, such as ammeter shunts and bus bars, you may sometimes find it more convenient to use a different unit volume.
      - A bus bar is a heavy copper strap or bar used to connect several circuits together. Bus bars are used when a large current capacity is required. Unit volume may be measured as the centimeter cube. Specific resistance, therefore, becomes the resistance offered by a cube-shaped conductor 1 centimeter in length and 1 square centimeter in cross-sectional area. The unit of volume to be used is given in tables of specific resistances.

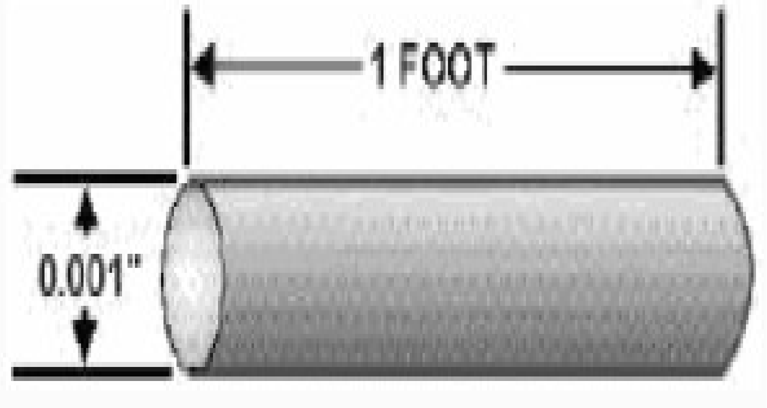


Figure 1-3.—Circular-mil-foot.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **SPECIFIC RESISTANCE OR RESISTIVITY**
      - Specific resistance, or resistivity, is the resistance in ohms offered by a unit volume (the circular-mil- foot or the centimeter cube) of a substance to the flow of electric current.
      - Resistivity is the reciprocal of conductivity. A substance that has a high resistivity will have a low conductivity, and vice versa.
      - Thus, the resistivity of a substance is the resistance of a unit volume of that substance.

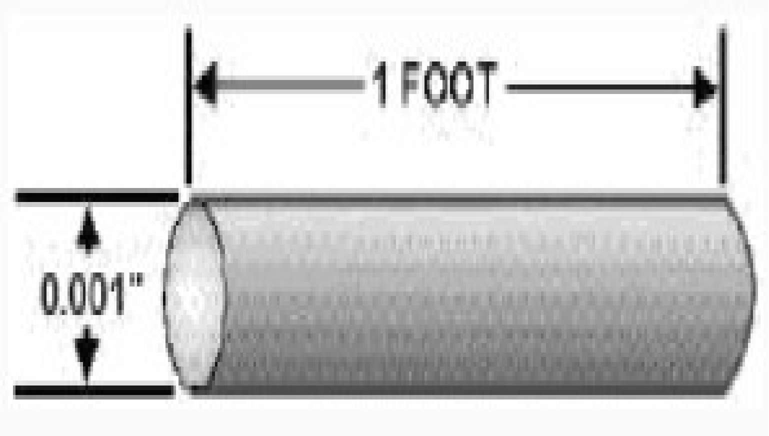


Figure 1-3.—Circular-mil-foot.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **SPECIFIC RESISTANCE OR RESISTIVITY**
      - Many tables of specific resistance are based on the resistance in ohms of a volume of a substance 1 foot in length and 1 circular mil in cross-sectional area.
      - The temperature at which the resistance measurement is made is also specified (usually, **20°C**). If you know the kind of metal a conductor is made of, you can obtain the specific resistance of the metal from a table.
      - The specific resistances of some common substances are given in table 1-1.

Table 1-1.—Specific Resistances of Common Substances

Substance	Specific resistance at 20°C.	
	Centimeter cube (microhoms)	Circular-mil-foot (ohms)
Silver	1.629	9.8
Copper (drawn)	1.724	10.37
Gold	2.44	14.7
Aluminum	2.828	17.02
Carbon (amorphous)	3.8 to 4.1	....
Tungsten	5.51	33.2
Brass	7.0	42.1
Steel (soft)	15.9	95.8
Nichrome	109.0	660.0

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **SPECIFIC RESISTANCE OR RESISTIVITY**
      - The resistance of a conductor of a uniform cross section varies directly as the product of the length and the specific resistance of the conductor, and inversely as the cross-sectional area of the conductor.
      - Therefore, you can calculate the resistance of a conductor if you know the length, cross-sectional area, and specific resistance of the substance. Expressed as an equation, the "R" (resistance in ohms) of a conductor is

Table 1-1.—Specific Resistances of Common Substances

Substance	Specific resistance at 20°C.	
	Centimeter cube (microhms)	Circular-mil-foot (ohms)
Silver	1.629	9.8
Copper (drawn)	1.724	10.37
Gold	2.44	14.7
Aluminum	2.828	17.02
Carbon (amorphous)	3.8 to 4.1	....
Tungsten	5.51	33.2
Brass	7.0	42.1
Steel (soft)	15.9	95.8
Nichrome	109.0	660.0

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **SPECIFIC RESISTANCE OR RESISTIVITY**
      - Expressed as an equation, the "R" (resistance in ohms) of a conductor is

$$R=\rho\cdot(L/A)$$

      - Where:
      - ρ = (Greek rho) the specific resistance in ohms per circular-mil-foot (from table 1-1)
      - L = length in feet
      - A = the cross-sectional area in circular mils

Table 1-1.—Specific Resistances of Common Substances

Substance	Specific resistance at 20°C.	
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Nichrome	109.0	660.0

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **WIRE SIZES**
      - The most common method for measuring wire size in the USA (North America) is by using the **American Wire Gauge (AWG)**.
      - Wire is manufactured in sizes numbered according to the standardized AWG tables.
        - In wire tables, the wire diameters become smaller as the gauge numbers become larger.
        - Numbers are rounded off for convenience but are accurate for practical application.
        - The largest wire size shown in the table is 0000 (read "4 naught"), and the smallest is number 40.
        - Larger and smaller sizes are manufactured, but are not commonly used for our applications.
        - AWG tables show the diameter in mils, circular mil area, and area in square inches of AWG wire sizes. They also show the resistance (ohms) per thousand feet and per mile of wire sizes at specific temperatures (usually, 25°C). The last column shows the weight of the wire per thousand feet.
        - An AWG table for copper wire is shown at table 1-2; and, similar information (with revised data) is shown in Table 8, 2014 National Electrical Code® (NEC®).

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

Table 1-2.—Standard Solid Copper (American Wire Gauge)

Gage number	Diameter (mils)	Cross Section		Ohms per 1,000 ft		Ohms per mile 25°C. = 77°F.	Pounds per 1,000 ft.
		Circular mils	Square inches	25°C. = 77°F.	65°C. = 149°F.		
0000	460.0	212,000.0	0.166	0.0500	0.0577	0.264	641.0
000	410.0	168,000.0	.132	.0630	.0727	.333	508.0
00	365.0	133,000.0	.105	.0795	.0917	.420	403.0
0	325.0	106,000.0	.0829	.100	.116	.528	319.0
1	289.0	83,700.0	.0657	.126	.146	.665	253.0
2	258.0	66,400.0	.0521	.159	.184	.839	201.0
3	229.0	52,600.0	.0413	.201	.232	1.061	159.0
4	204.0	41,700.0	.0328	.253	.292	1.335	126.0
5	182.0	33,100.0	.0260	.319	.369	1.685	100.0
6	162.0	26,300.0	.0206	.403	.465	2.13	79.5
7	144.0	20,800.0	.0164	.508	.586	2.68	63.0
8	128.0	16,500.0	.0130	.641	.739	3.38	50.0
9	114.0	13,100.0	.0103	.808	.932	4.27	39.6
10	102.0	10,400.0	.00815	1.02	1.18	5.38	31.4
11	91.0	8,230.0	.00647	1.28	1.48	6.75	24.9
12	81.0	6,530.0	.00513	1.62	1.87	8.55	19.8
13	72.0	5,180.0	.00407	2.04	2.36	10.77	15.7
14	64.0	4,110.0	.00323	2.58	2.97	13.62	12.4
15	57.0	3,260.0	.00256	3.25	3.75	17.16	9.86
16	51.0	2,580.0	.00203	4.09	4.73	21.6	7.82
17	45.0	2,050.0	.00161	5.16	5.96	27.2	6.20
18	40.0	1,620.0	.00128	6.51	7.51	34.4	4.92
19	36.0	1,290.0	.00101	8.21	9.48	43.3	3.90

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

Table 1-2.—Standard Solid Copper (American Wire Gauge)

Gage number	Diameter (mils)	Cross Section		Ohms per 1,000 ft		Ohms per mile 25°C. = 77°F.	Pounds per 1,000 ft.
		Circular mils	Square inches	25°C. = 77°F.	65°C. = 149°F.		
20	32.0	1,020.0	.000802	10.4	11.9	54.9	3.09
21	28.5	810.0	.000636	13.1	15.1	69.1	2.45
22	25.3	642.0	.000505	16.5	19.0	87.1	1.94
23	22.6	509.0	.000400	20.8	24.0	109.8	1.54
24	20.1	404.0	.000317	26.2	30.2	138.3	1.22
25	17.9	320.0	.000252	33.0	38.1	174.1	0.970
26	15.9	254.0	.000200	41.6	48.0	220.0	0.769
27	14.2	202.0	.000158	52.5	60.6	277.0	0.610
28	12.6	160.0	.000126	66.2	76.4	350.0	0.484
29	11.3	127.0	.0000995	83.4	96	440.0	0.384
30	10.0	101.0	.0000789	105.0	121.0	554.0	0.304
31	8.9	79.7	.0000626	133.0	153.0	702.0	0.241
32	8.0	63.2	.0000496	167.0	193.0	882.0	0.191
33	7.1	50.1	.0000394	211.0	243.0	1,114.0	0.152
34	6.3	39.8	.0000312	266.0	307.0	1,404.0	0.120
35	5.6	31.5	.0000248	335.0	387.0	1,769.0	0.0954
36	5.0	25.0	.0000196	423.0	488.0	2,230.0	0.0757
37	4.5	19.8	.0000156	533.0	616.0	2,810.0	0.0600
38	4.0	15.7	.0000123	673.0	776.0	3,550.0	0.0476
39	3.5	12.5	.0000098	848.0	979.0	4,480.0	0.0377
40	3.1	9.9	.0000078	1,070.0	1,230.0	5,650.0	0.0299

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

TABLE 8 Conductor Properties

			Conductors							Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall				Copper					
Size (AWG or kcmil)	Area			Diameter		Diameter		Area		Uncoated		Coated		Aluminum	
	mm^2	Circular mils	Quantity	mm	in.	mm	in.	mm^2	$in.^2$	ohm/km	ohm/kFT	ohm/km	ohm/kFT	ohm/km	ohm/kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	10.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.006	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013	2.506	0.764	2.579	0.786	4.125	1.26
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017	2.551	0.778	2.653	0.809	4.204	1.28
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027	1.608	0.491	1.671	0.510	2.652	0.808
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042	1.010	0.308	1.053	0.321	1.666	0.508
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053	0.802	0.245	0.833	0.254	1.320	0.403
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067	0.634	0.194	0.661	0.201	1.045	0.319
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087	0.505	0.154	0.524	0.160	0.829	0.253
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109	0.399	0.122	0.415	0.127	0.660	0.201
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137	0.3170	0.0967	0.329	0.101	0.523	0.159
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173	0.2512	0.0766	0.2610	0.0797	0.413	0.126
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219	0.1996	0.0608	0.2050	0.0626	0.328	0.100

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **Environmental Considerations**
      - Dry Locations vs Wet Locations (per 2014 NEC®)
        - **Dry location**: A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction.
        - **Damp location**: Locations protected from weather and not subject to saturation with water or other liquids but subject to moderate degrees of moisture. For example, partially protected locations under canopies, marquees, roofed open porches, and like locations, and interior locations subject to moderate degrees of moisture, such as some basements, some barns, and some cold-storage warehouses.
        - **Wet location**: Installations underground or in concrete slabs or masonry in direct contact with the earth; in locations subject to saturation with water or other liquids, such as vehicle washing areas; and in unprotected locations exposed to weather.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **Environmental Considerations**
      - Temperature
        - The location of a wire in a circuit determines the temperature under which it operates. A wire may be located in a conduit, bundled with other wires in a cable, or routed with other wires and cables.
        - Because it is confined in such locations, the wire operates at a higher temperature than if it were open to the free air. The higher the temperature under which a wire is operating, the greater will be its resistance. And, its capacity to carry current is also lowered. Note that, in each case, the resistance of a wire determines its current-carrying capacity. The greater the resistance, the more power it dissipates in the form of heat energy.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical WIRING**
  - Conductor Sizes (in The USA)
    - **Environmental Considerations**
      - Temperature
        - Conductors may also be installed in locations where the ambient (surrounding) temperature is relatively high. When this is the case, the heat generated by external sources is an important part of the total conductor heating.
        - The temperature rating of a conductor is the maximum temperature, at any location along its length, that the conductor can withstand over a prolonged time period without serious degradation.
        - The current rating of a cable or wire indicates the Ampacity (current capacity) that the wire or cable can safely carry continuously. If this limit, or current rating, is exceeded for a length of time, the heat generated may burn, or melt, the insulation. The current rating of a wire is used to determine what size is needed for a given load.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical Characteristics**
  - Power (Watts)
  - Voltage (Volts)
  - Current (Amps or Amperes)
  - Resistance (Ohms)

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **Electrical Characteristics**
- **Circuit Diagrams**
  - Sources (Batteries, etc.)
  - Resistances
  - Loads
  - Devices

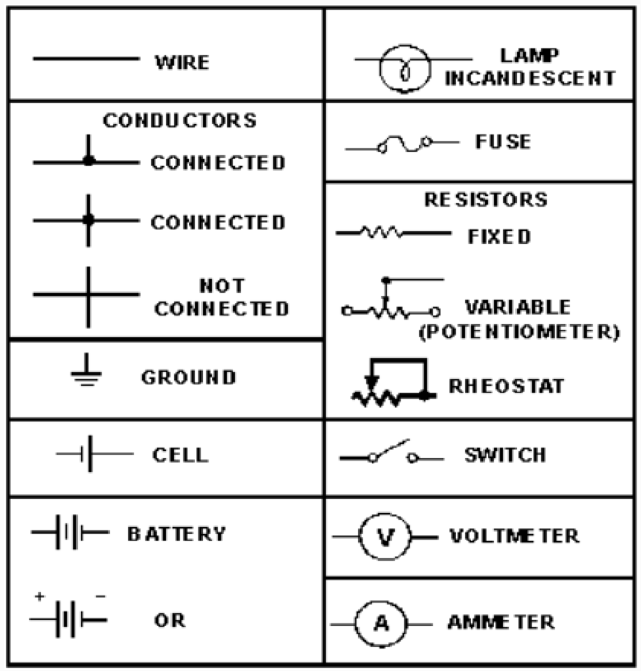


Figure 1-6.—Symbols commonly used in electricity.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

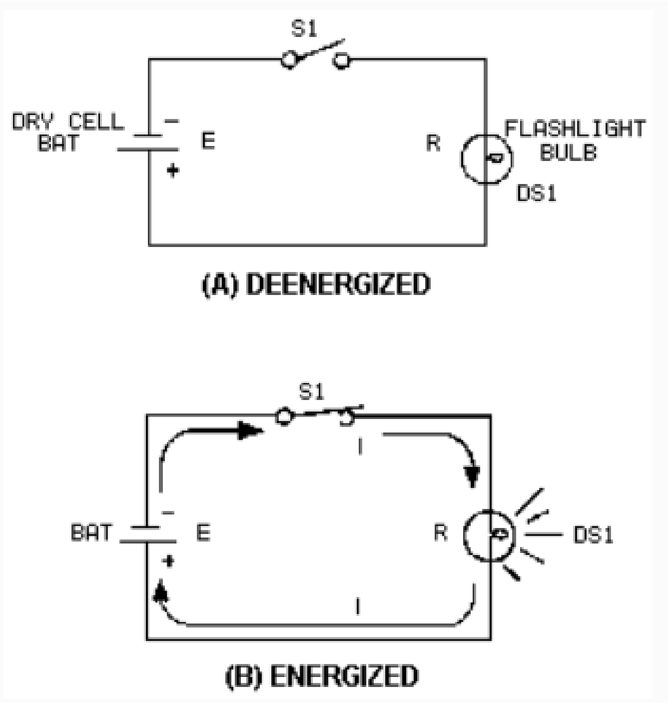


Figure 1-7 — **Basic Light Circuit**

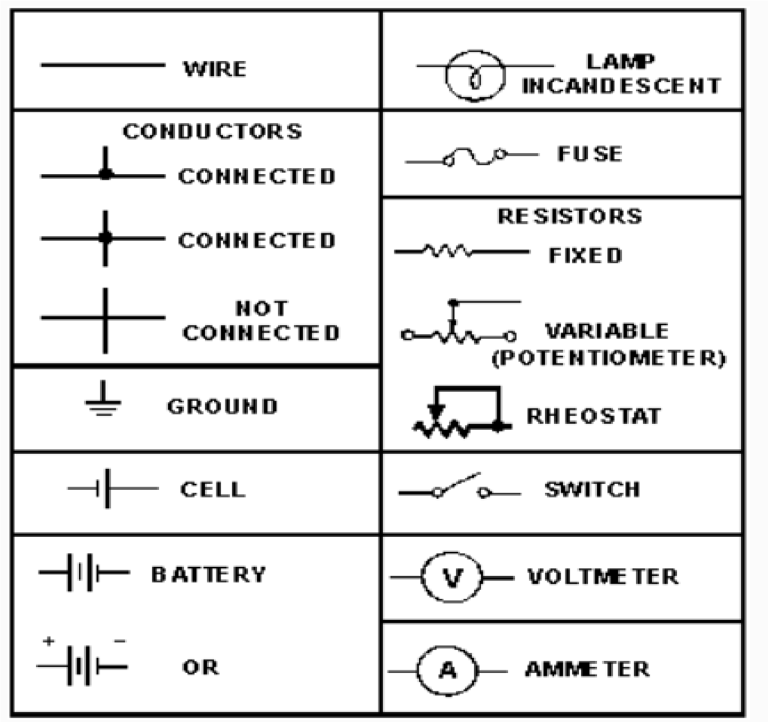
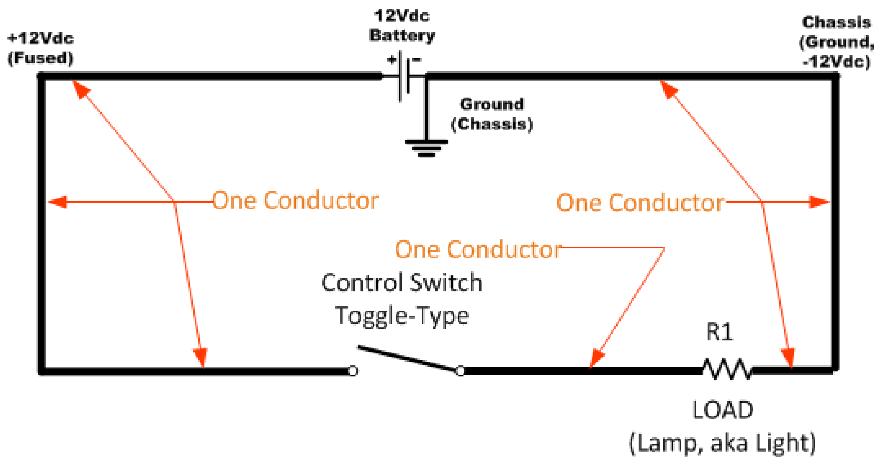


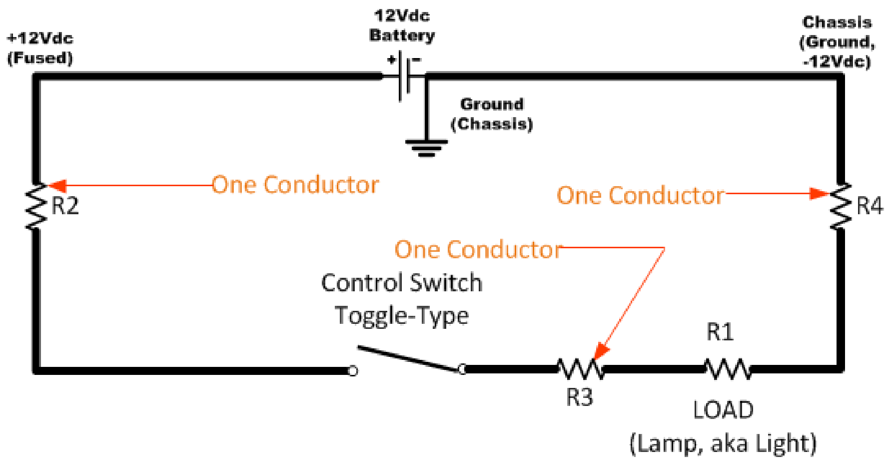
Figure 1-6.—Symbols commonly used in electricity.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **OHM'S LAW**
  - George Simon Ohm proved by experiment that a precise relationship exists between current, voltage, and resistance. This relationship is called Ohm's law and is stated as follows:
  - The current in a circuit is DIRECTLY proportional to the applied voltage and INVERSELY proportional to the circuit resistance. Ohm's law may be expressed as an equation:

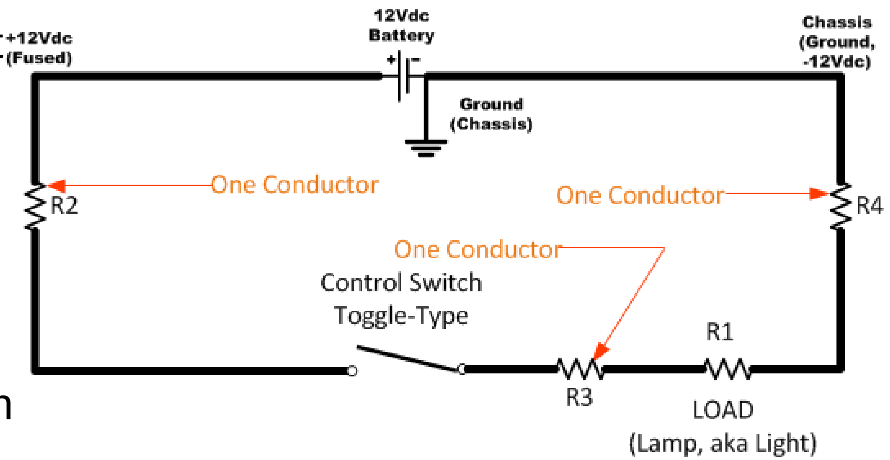
$$I = \frac{E}{R}$$

where,

I = Current in Amps;

E = Voltage in Volts; and,

R = Resistance in Ohms



BASIC LIGHT CIRCUIT

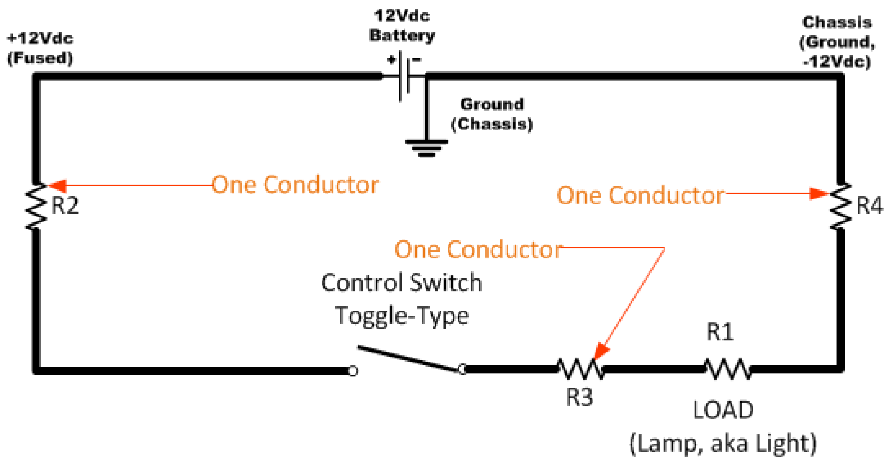
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **OHM'S LAW**
  - In any equation, if all the variables (parameters) are known except one, that unknown can be found.
  - **For example**, using Ohm's law, if current (I) and voltage (E) are known, resistance (R) the only parameter not known, can be determined, using the following steps:
  - Basic Ohm's Law Equation

$$I = \frac{E}{R}$$



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **OHM'S LAW** $I = \frac{E}{R}$
  - Remove the divisor by multiplying both sides by R:

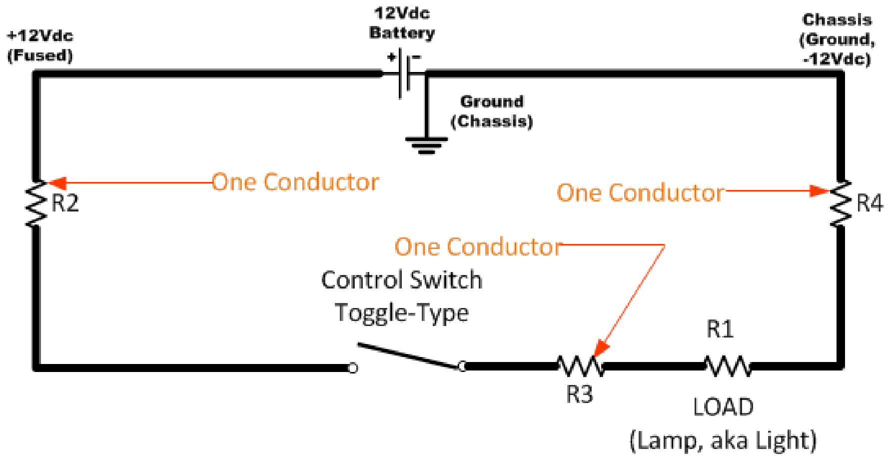
    $$R \times I = \frac{E}{\cancel{R}} \times \frac{\cancel{R}}{1}$$

  - To get R alone (on one side the equation) divide both sides by I:

    $$\frac{R\cancel{I}}{\cancel{I}} = \frac{E}{I}$$

  - The basic formula, transposed for R, is:

    $$R = \frac{E}{I}$$



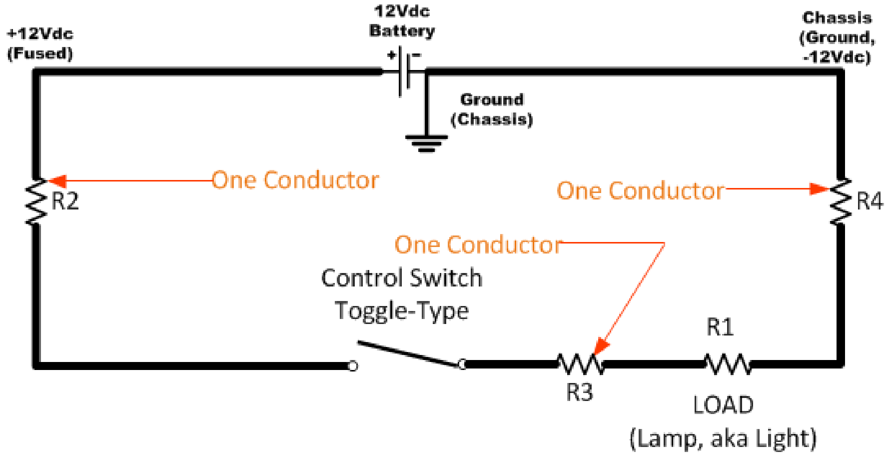
BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **OHM'S LAW** $I = \frac{E}{R}$ $R = \frac{E}{I}$
  - Likewise, if current (I) and resistance (R) are known, voltage (E) the only parameter not known, can be determined, using the following steps:
  - Basic Ohm's Law Equation

$$I = \frac{E}{R}$$



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

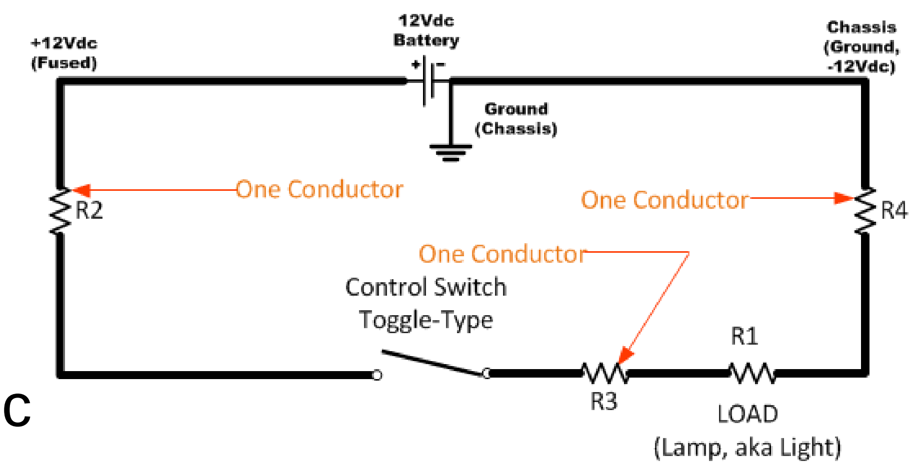
BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **OHM'S LAW** $I = \frac{E}{R}$
  - Remove the divisor by multiplying both sides by R:

$$R \times I = \frac{E}{\cancel{R}} \times \frac{\cancel{R}}{1}$$

  - That leaves E alone (on one side the equation); i.e., the basic formula, transposed for E is:

$$E = I \cdot R$$



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **OHM'S LAW**
  - Now, we have Ohm's Law equation in three formats:

    The original, solving for I:

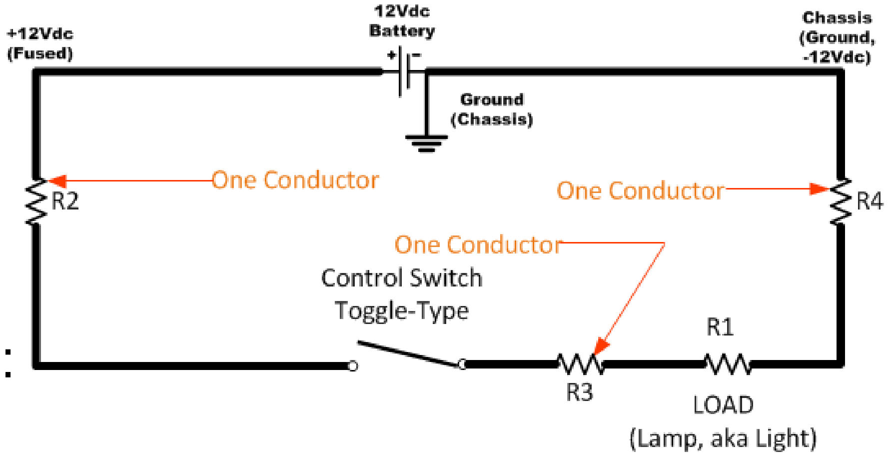
$$I=\frac{E}{R}$$

  - The transposed formula, solving for R:

$$R=\frac{E}{I}$$

    And, the transposed formula, solving for E:

$$E=I\cdot R$$



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

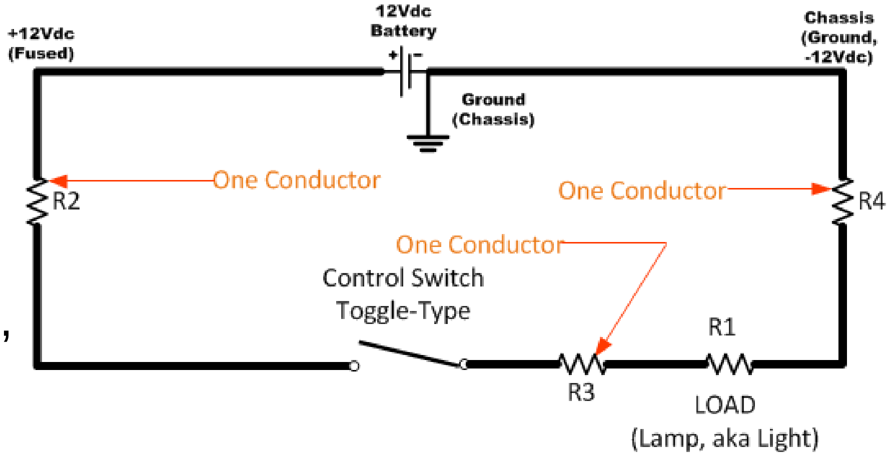
BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **OHM'S LAW**
  - Now, we have Ohm's Law equation in three formats:

$$I=\frac{E}{R} \qquad R=\frac{E}{I} \qquad E=I\cdot R$$

  - The following, easy-to-remember, diagram, Figure 1-8, can be used for solving for each of the three unknown variables:

Figure 1-8.—Ohm's law in diagram form.

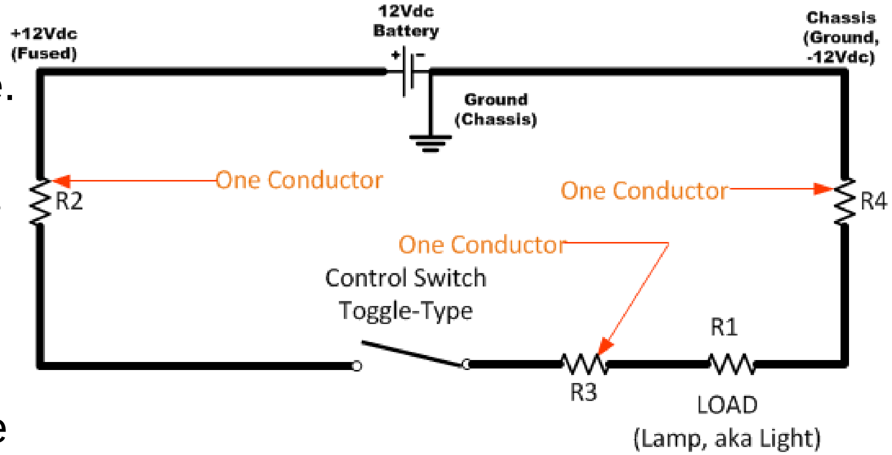


BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - Power, whether electrical or mechanical, pertains to the rate at which work is being done.
  - Work is energy and is expressed in units of joules, British Thermal Units (BTU), kilocalories (kcal, also Cal for nutrition), Watt-Hours (WHr), Horsepower-hours (HPh), etc.
  - Work is done whenever a force causes motion.
  - When a mechanical force is used to lift or move a weight, work is done.
  - However, force exerted WITHOUT causing motion, such as the force a compressed spring acting between two fixed objects, does not constitute work.

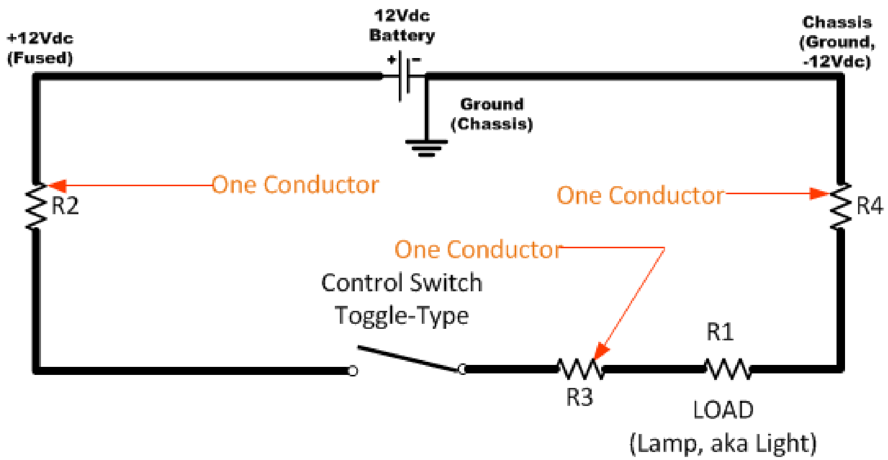


BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - Voltage is an electrical force; and, voltage forces current to flow in a closed circuit.
  - However, when voltage exists but current does not flow because the circuit is open, no work is done. This is similar to the spring under tension that produced no motion.
  - When voltage causes electrons to move, work is done; i.e., energy is produced and expended.
  - The instantaneous RATE at which this work is done is called the electric power, and is measured in WATTS.

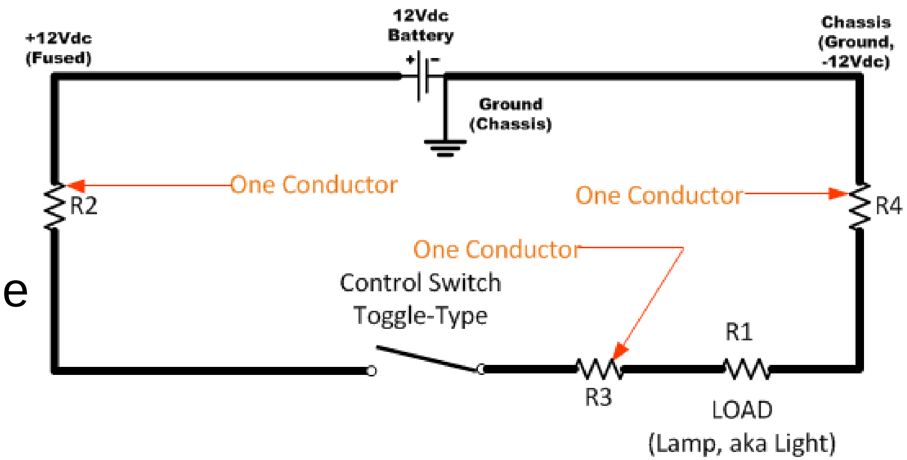


BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - A total amount work may be done in different lengths time.
  - For example, a given number electrons may be moved from one point to another in 1 second or in 1 hour, depending on the RATE at which they are moved.
  - In both cases, total work done is the same.
  - However, when the work is done in a short time, the wattage, or INSTANTANEOUS POWER, is greater than when the same amount work is done over a longer period time.



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

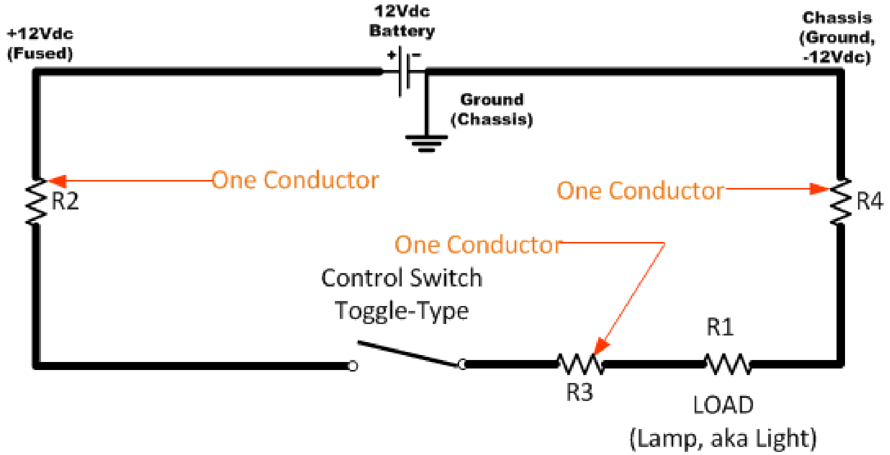
BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - The basic unit power is the watt. And, the symbol P is used to indicate electrical power.
  - Power in watts is equal to the voltage across a circuit multiplied by current through the circuit.
  - This represents the rate at any given instant at which work is being done.
  - Thus, the **basic power formula** is

    P = E x I,

    where E is voltage and I is current in the circuit.
  - The amount power changes when either voltage or current, or both voltage and current, are caused to change.

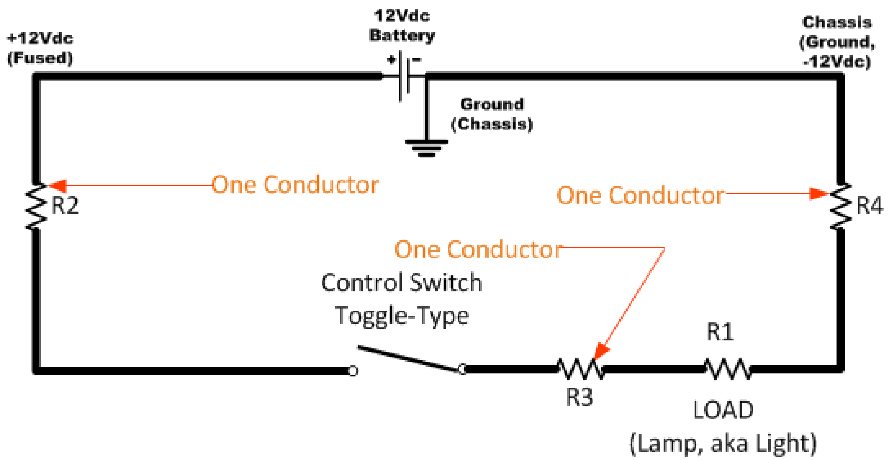


BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - In practice, the ONLY factors that can be changed are voltage and resistance.
  - In explaining the different forms that formulas may take, current is sometimes presented as a quantity that is changed.
  - But, remember, if current is changed, it is because either voltage or resistance has been changed.



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - The basic formula for electric power is:

$$P = E \times I$$

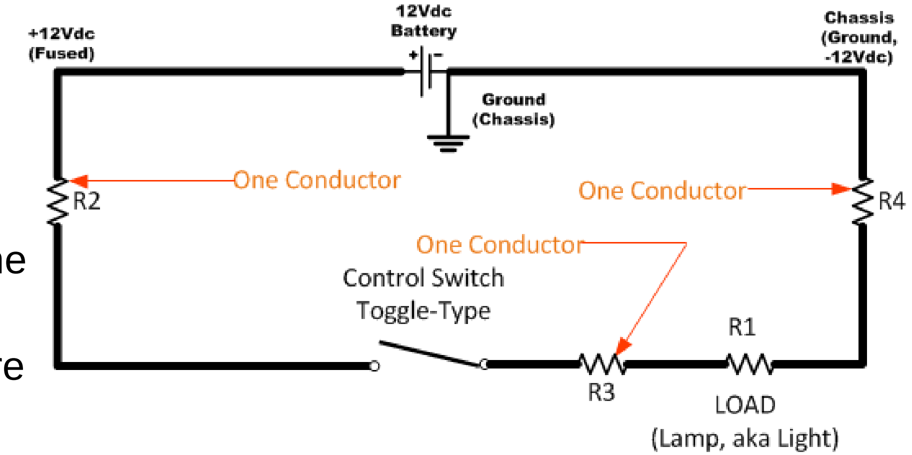
    By using algebraic manulations into the basic electric power formula, we can directly calculate the power, when only two variables are known.

  - So, if the only the power (P) and the voltage (E) are known, we can calculate the current (I):

$$P = E \times I \Rightarrow I = \frac{P}{E}$$

  - And, if only the Power (P) and the current (I) are known, we can calculate the voltage (E):

$$P = E \times I \Rightarrow E = \frac{P}{I}$$



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - The basic formula for electric power is:

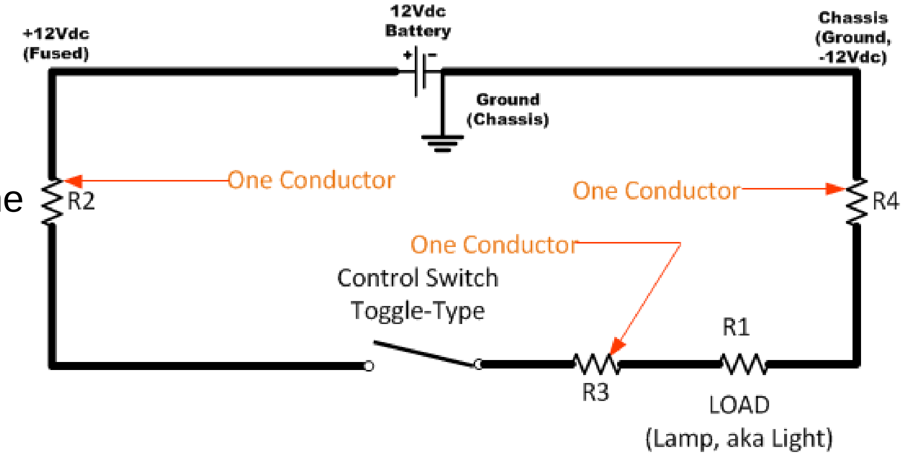
$$P = E \times I$$

  - By substituting the various forms of Ohm's Law into the basic electric power formula, we can directly calculate the power, when only two variables are known.
  - So, if the only the voltage and the resistance are known:

$$P = E \times I = E \times \left(\frac{E}{R}\right) = \frac{E^2}{R}$$

  - And, if only the current (I) and the resistance (R) are known:

$$P = E \times I = (I \times R) \times I = I^2 \times R$$



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- **POWER**
  - Therefore, to summarize, using the previous formulae for electric power, we can generate several other forms of the basic electric power formula, when only two variables the four variables are known; i.e., Power (P), Voltage (E), current (I), and Resistance (R).

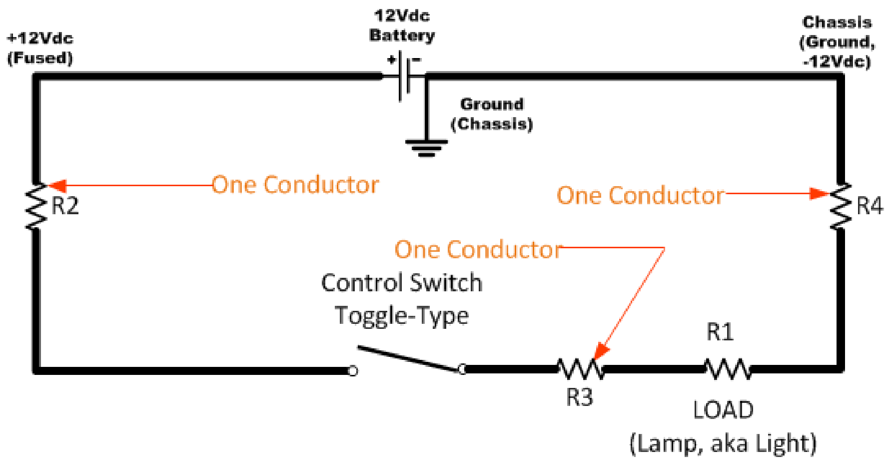
$$P=\frac{E^2}{R} \quad \Rightarrow \quad R=\frac{E^2}{P}; \quad \text{and,}$$

$$P=\frac{E^2}{R} \quad \Rightarrow \quad E=\sqrt{P\times R}$$

Also,

$$P=I^2\times R \quad \Rightarrow \quad R=\frac{P}{I^2}; \text{ and,}$$

$$P=I^2\times R \quad \Rightarrow \quad I=\sqrt{\frac{P}{R}}$$



BASIC LIGHT CIRCUIT
CIRCUIT WIRING DIAGRAM

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

- POWER and OHM'S LAW
  - The easy-to-use diagram, Figure 1-9, (at the right) can be used for solving for each of the four unknown variables:

    For example, in the upper left hand quadrant of the circle, **P** is the unknown and can be calculated using

    $$P = E \times I$$

    if voltage (E) and current (I) are known; or, can be calculated using

    $$P = I^2 \times R$$

    if current (I) and resistance (R) are known; etc.
  - And, so on, for each unknown variable, represented by a quadrant of the circle.

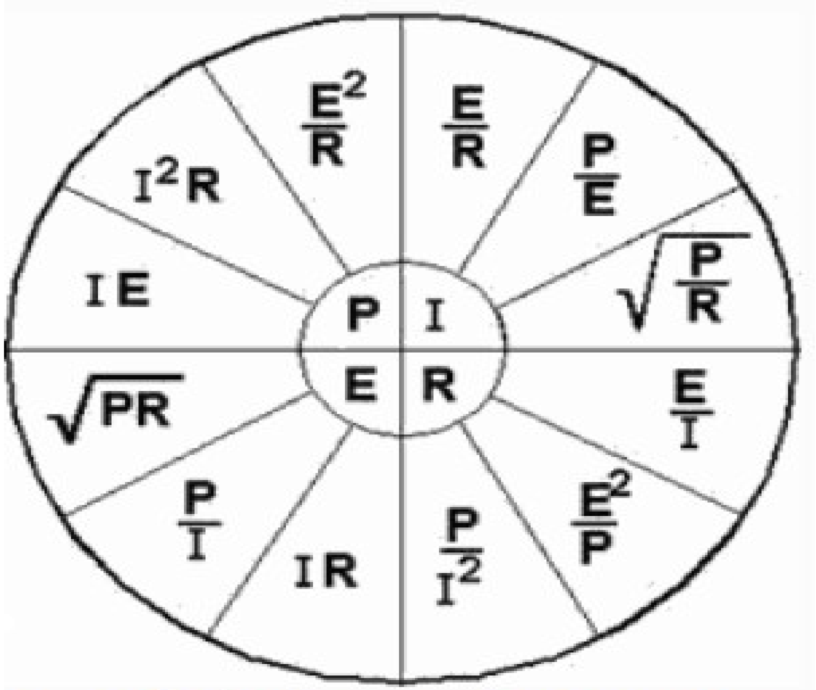


Figure 1-9.—Summary basic formulas.

BASIC ELECTRIC POWER PART 1

BASIC ELECTRIC POWER CONCEPTS AND FORMULAE

ANY QUESTIONS

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