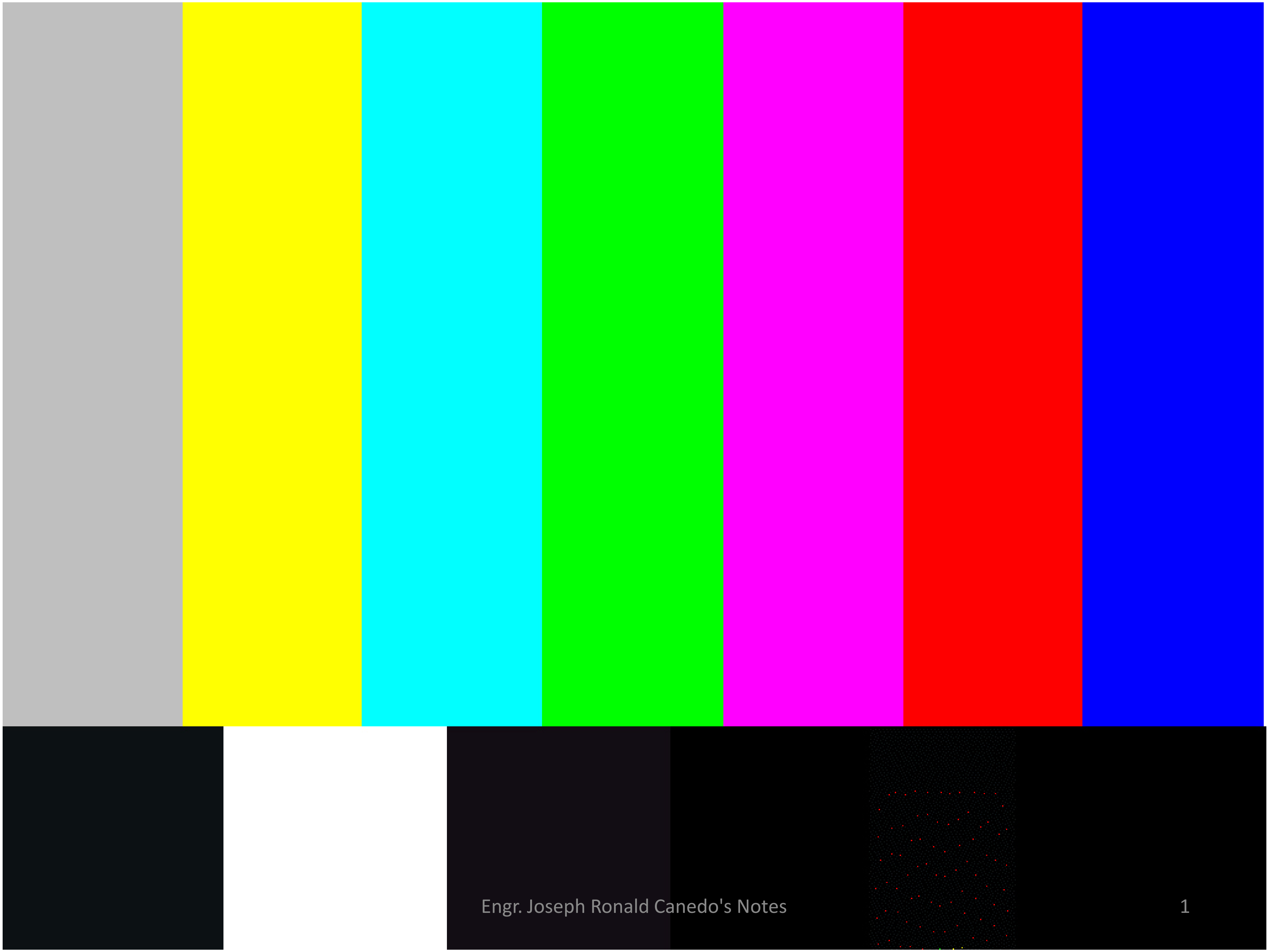


Electronics 101

By:

Joseph Ronald Cañedo

Voltage and Current

- Current
  - is the flow of electrons through a conductor or a semiconductor.
  - is measured in Amperes, more commonly called just plain Amps (with the unit symbol "A," equation symbol "I").
- Voltage
  - For current flow to occur between two points, there must exist an imbalance between electrons at one end and holes at the other.
  - is known as the potential difference, or voltage difference, between two points. (It is also sometimes termed "the voltage drop across an electronic component.") The unit of voltage difference is the Volt (unit symbol "V").

Note

- A common beginner's mistake in testing electronic circuits is to wire up only one lead of a piece of test equipment. Without both leads, there is no common reference point, and, therefore, any measurement taken is meaningless.

Analog Signals

- An analog signal can have an amplitude of any voltage within a range, unlike a digital signal, which can be in one of two defined voltage states (either high or low).

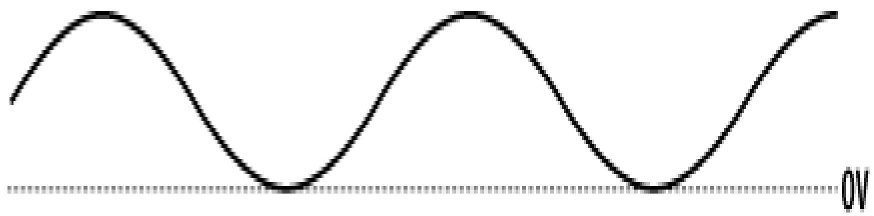
- The voltage of a signal may vary over time, or it may be constant. If the voltage varies, it may repeat at regular intervals, in which case the signal is said to be periodic. The period is the interval of time it takes the signal pattern to repeat (for example, from one wave crest to another). The frequency of the signal is the number of times per second that the pattern repeats.
- Frequency is measured in Hertz (Hz) and relates to the period in the following way:

  Frequency = 1 / Period

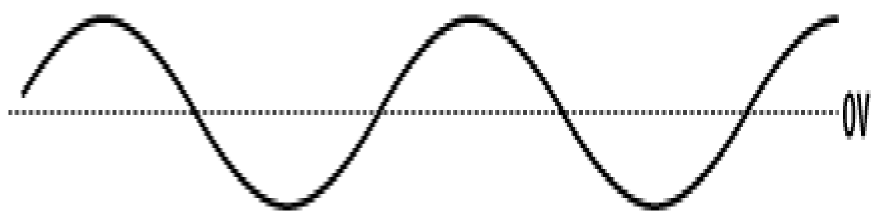
- Thus, a signal with a period of 1 ms has a frequency of 1 kHz.

Analog Signals

- A unipolar signal has component voltages that are either all positive or all negative.

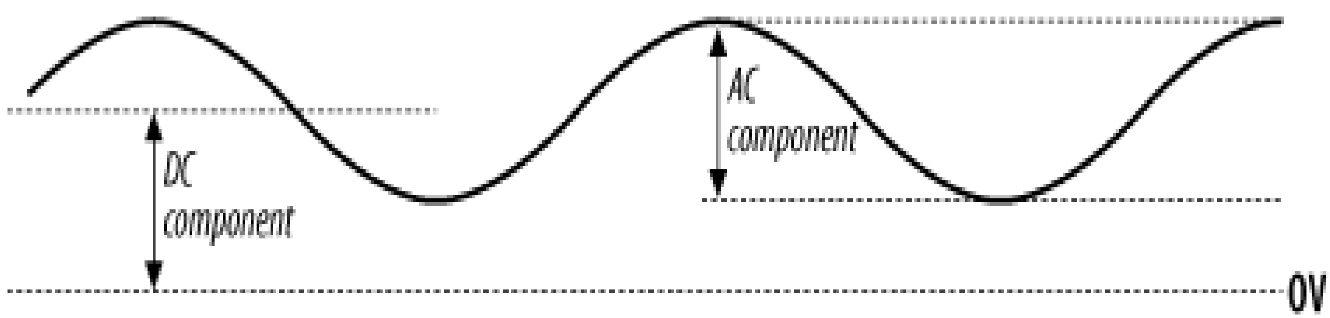


- A bipolar signal has both positive and negative voltages.



Analog Signals

- A typical analog signal will have both an AC component and a DC component. The DC component is the fixed voltage of the signal. The AC component is a varying voltage imposed on the DC component. The AC component is sometimes referred to as the peak-to-peak amplitude of a signal and is denoted with the suffix "pp."



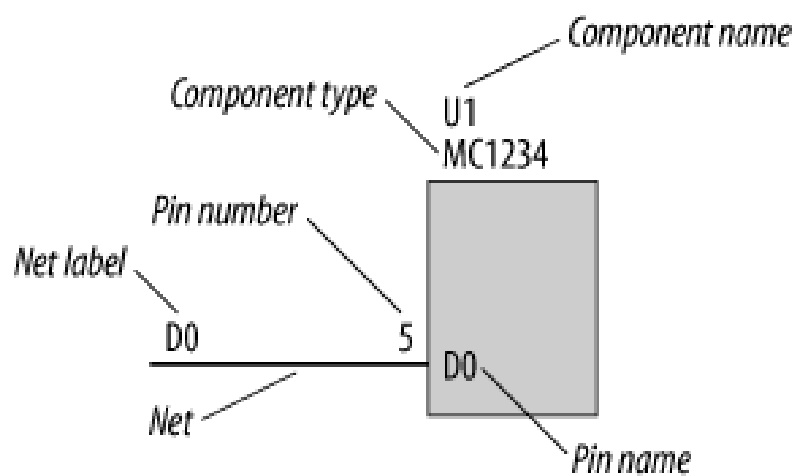
Power

- Power is the amount of work per time (Joules per second) and is measured in Watts (unit symbol "W").
- The equation for calculating power is simply:

$$P = V * I$$

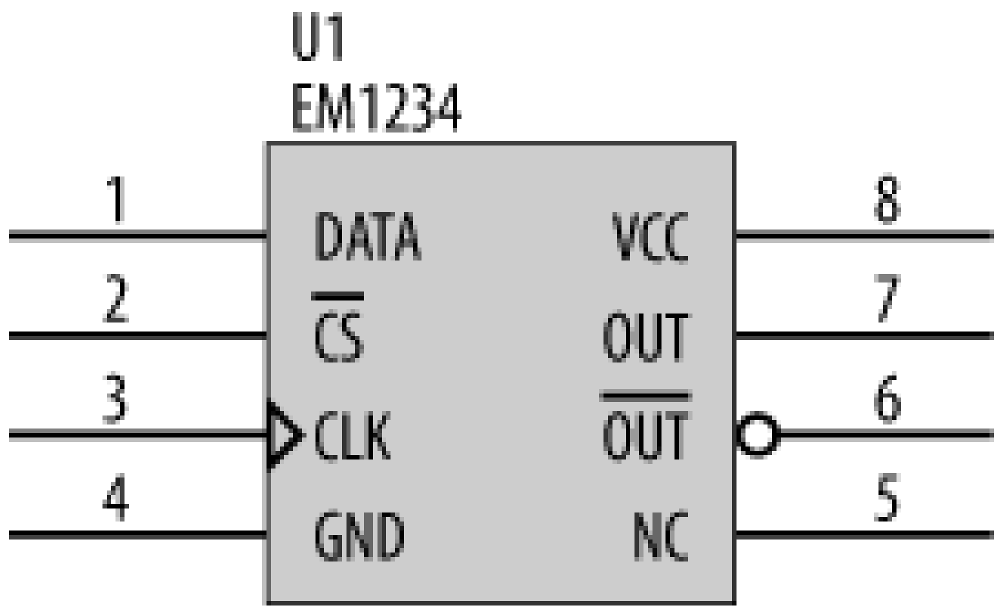
Reading Schematics

- Two types of schematics
  1. Found in the datasheets
  2. Actual drawing(s) used to generate a Printed Circuit Board (PCB).
- Two types of objects on a schematic:
  1. component symbols, and
  2. nets.



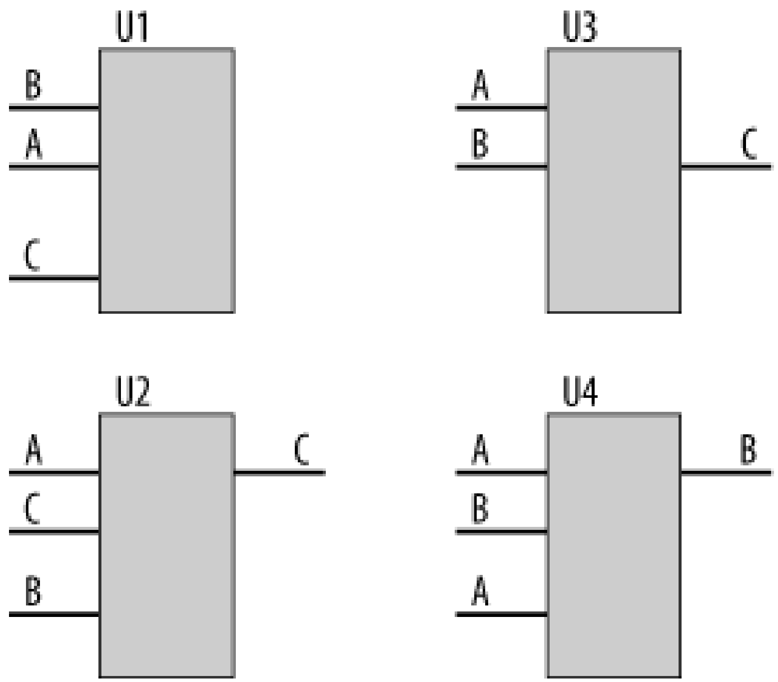
Reading Schematics

- Component pins may have names and symbols that indicate their characteristics.



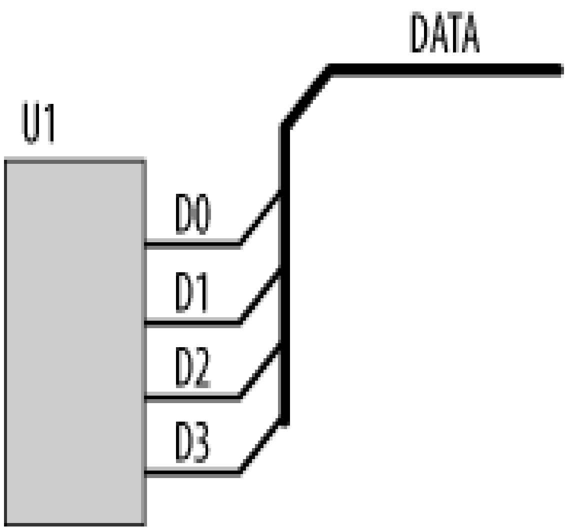
Reading Schematics

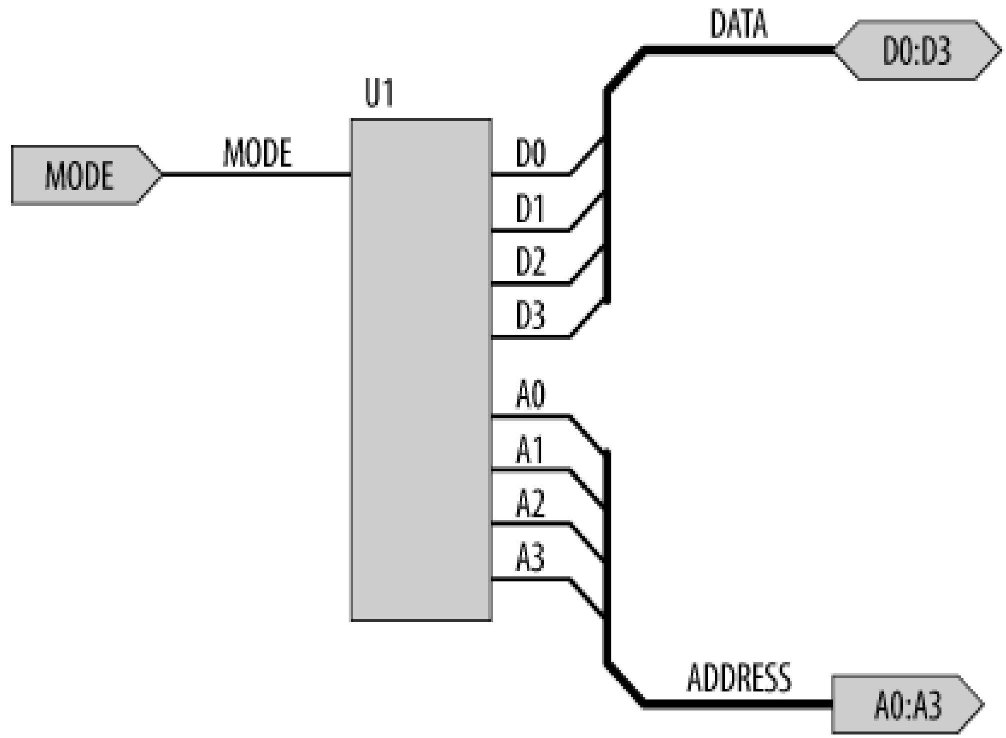
- A net may be drawn between two components or may simply have a net label giving the net a name and indicating that it is connected to every other net with the same name.



Reading Schematics

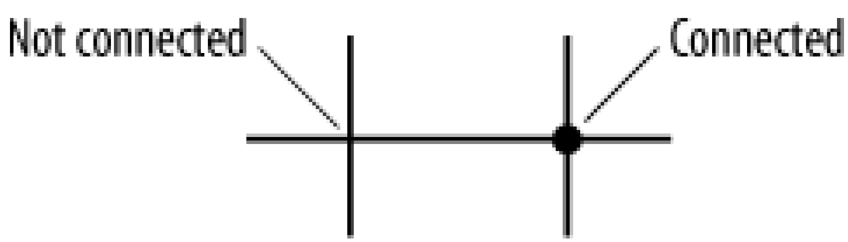
- Signals that are functionally related, such as buses, are drawn using a bus net.

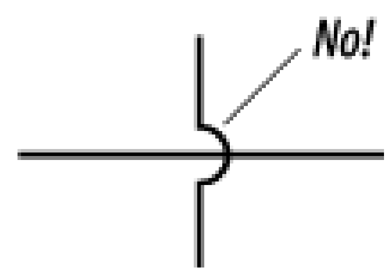




Reading Schematics

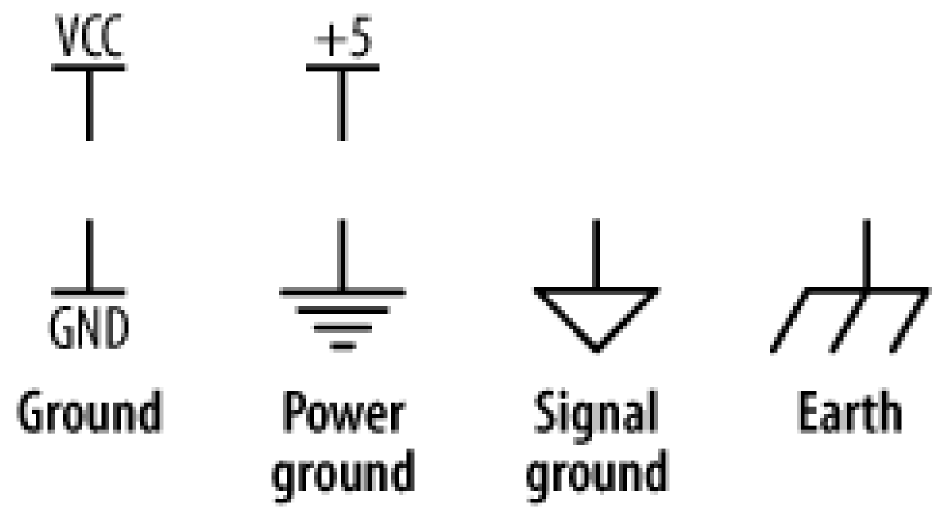
- Shows nets crossing each other. The vertical net on the left is not connected to the horizontal net. It simply crosses over on its way to another part of the circuit. The vertical net on the right is connected to the horizontal net, and this is indicated by a junction dot.





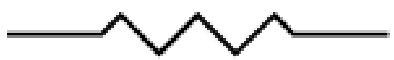
Reading Schematics

- Shows common power ports. These indicate connections to voltage sources (power supplies) and grounds. The ground symbols all mean a potential of zero volts. The different symbols are used to differentiate between different ground networks



Resistors

- The component is said to resist the current flow.



- The relationship between voltage, current, and resistance is known as Ohm's Law, and is given by:

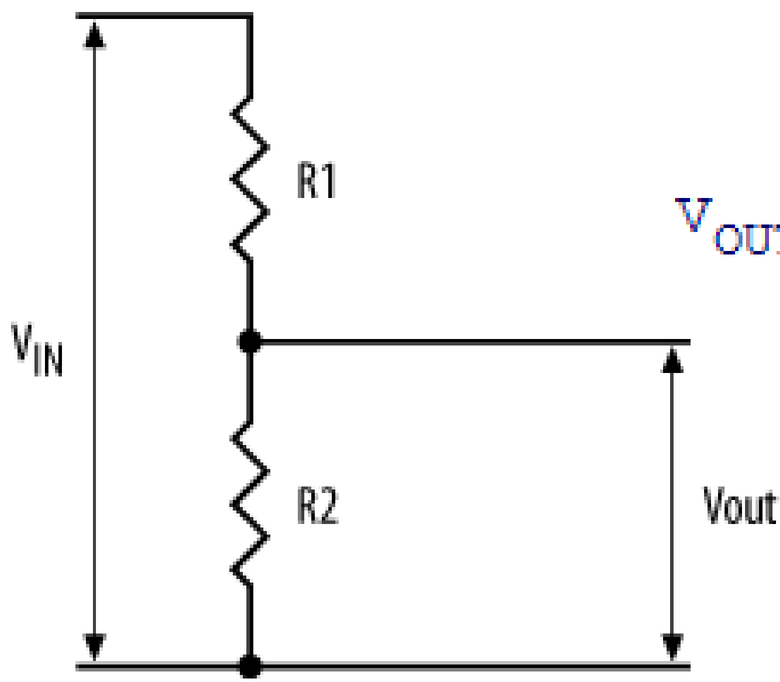
$$V = I * R$$

Resistors

- Kirchhoff's Current Law:
  - The current flowing through a given circuit point is equal to the sum of the currents flowing into that circuit point, and is also equal to the sum of currents flowing out of that circuit point.
  - In other words, what flows in must flow out.

Resistors

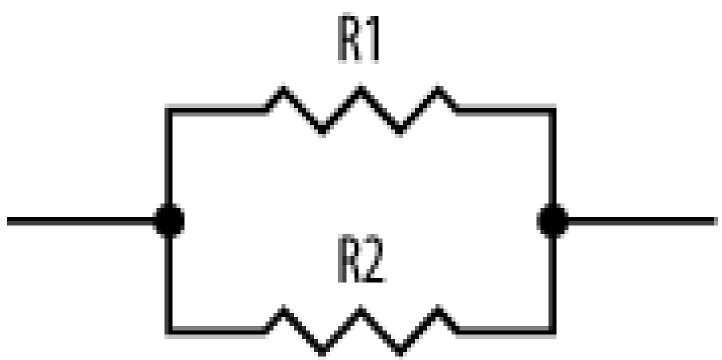
- Series resistors may be used to create a voltage divider to provide an intermediate voltage.



$$V_{OUT} = V_{IN} * R2 / (R1 + R2)$$

Resistors

- Resistors combined in parallel will decrease the total resistance.



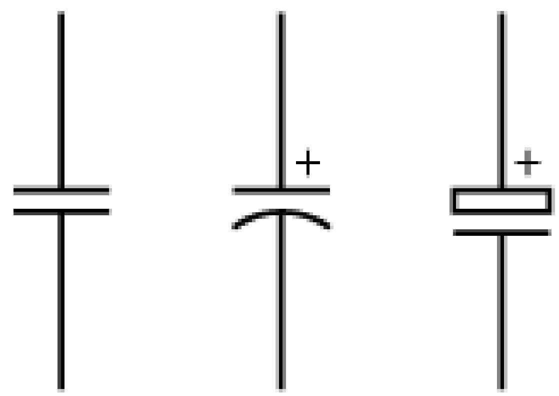
$$R_{TOTAL} = 1 / (1/R1 + 1/R2)$$

Capacitors

- a capacitor stores charge. Capacitance is measured in Farads (or more formally, "Faradays") with an equation symbol "C" and a unit symbol "F." Typical capacitors you will use range in value from uF (micro-Farads) down to pF (pico-Farads).
- The relationship between current, capacitance, and voltage is given by:

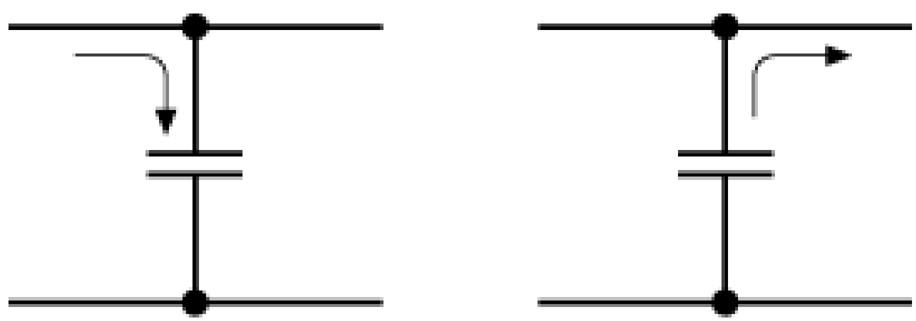
  I = C * dV/dt

  where dV/dt is the rate of voltage change over time.

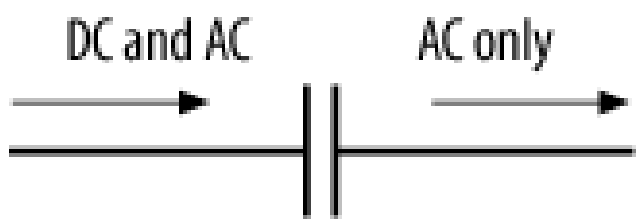


Capacitors

- Applications:



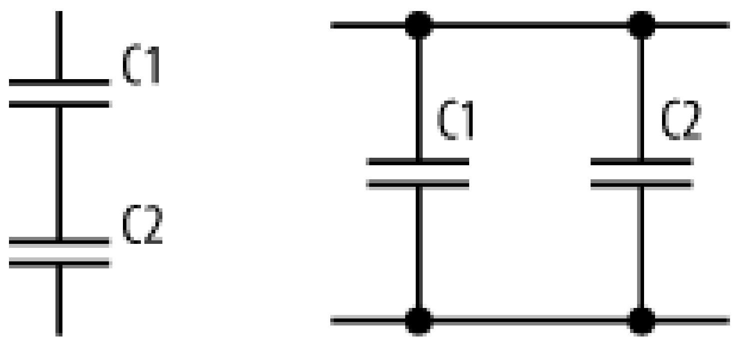
Charging and Discharging



Blocking Capacitor

Capacitors

- Capacitors may also be used in series or parallel



Capacitors in Series and Parallel

Series:

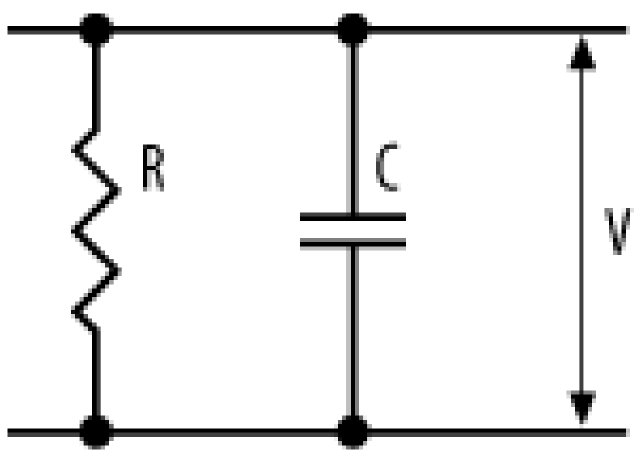
$$C_{TOTAL} = C1 * C2 / (C1 + C2)$$

Parallel:

$$C_{TOTAL} = C1 + C2$$

RC Circuits

- Combining resistors and capacitors can yield some interesting and useful effects. A resistor-capacitor combination is known as an RC circuit, and it can take one of three forms. The first form is where the resistor and capacitor are in parallel.



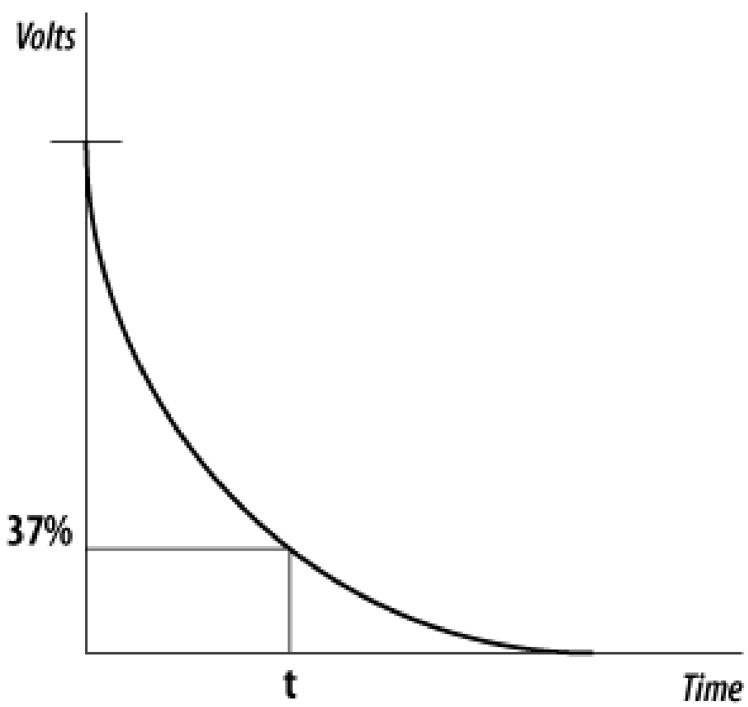
$$I = -V / R$$

$$I = C * dV/dt$$

$$dV/dt = -V / RC$$

RC Circuits

- Integrating this with respect to time, with zero initial conditions, gives us:



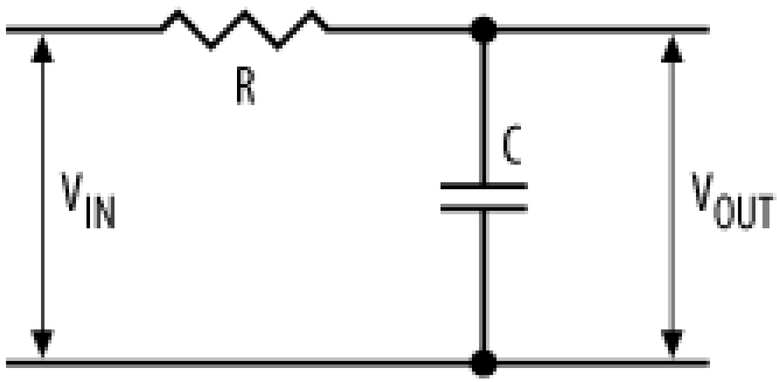
$$V = e^{-t/RC}$$

A parallel RC circuit will provide an exponential decay in the output voltage. The value for t when the output voltage is at 37% of the maximum is known as the time constant for the circuit and is simply the product of R and C:

$t = R * C$

RC Circuits

- The second form of RC circuit is the series RC circuit:



$$I = C * dV/dt$$

$$I = (V_{IN} - V_{OUT}) / R$$

$$dV / dt = (V_{IN} - V_{OUT}) / RC$$

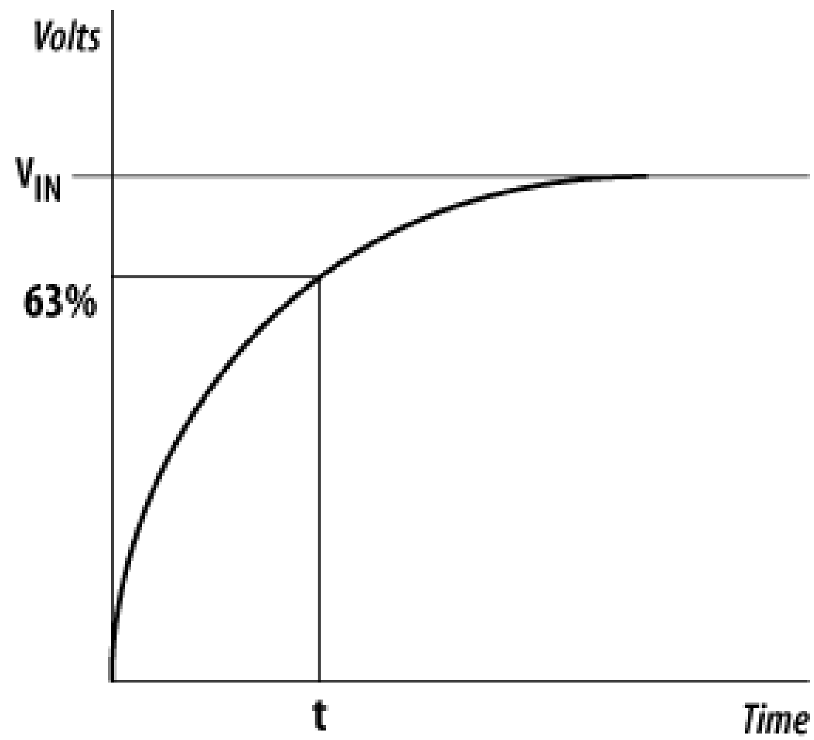
This form of RC circuit is a simple type of low-pass filter. This is a circuit that provides a path to ground for high-frequency components of a signal, thereby attenuating them from the main signal, while the low-frequency components suffer far less attenuation. This type of circuit is very useful for removing high-frequency noise that may be superimposed on a signal.

RC Circuits

- Integrating this gives us the voltage at the capacitor as:

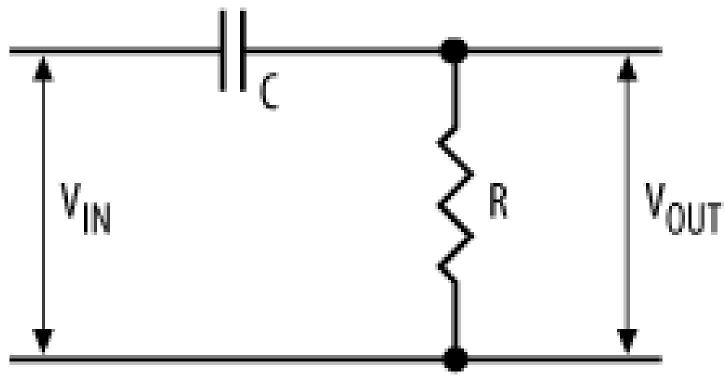
$$V_{OUT} = V_{IN}\ (1 - e^{-t/RC})$$

In this case, the time constant is the time for the voltage at the capacitor to reach 63% (total - 37%) of the input voltage. As before, this time constant is simply the product of R and C.



RC Circuits

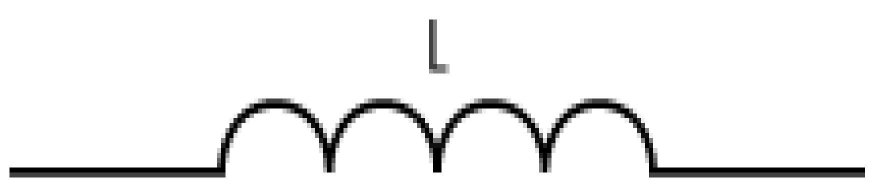
- The third form of an RC circuit is RC Filter:



This type of circuit is a simple form of a high-pass filter, since it passes only the high frequencies through to the output. The capacitor in such a circuit is known as a blocking capacitor.

Inductors

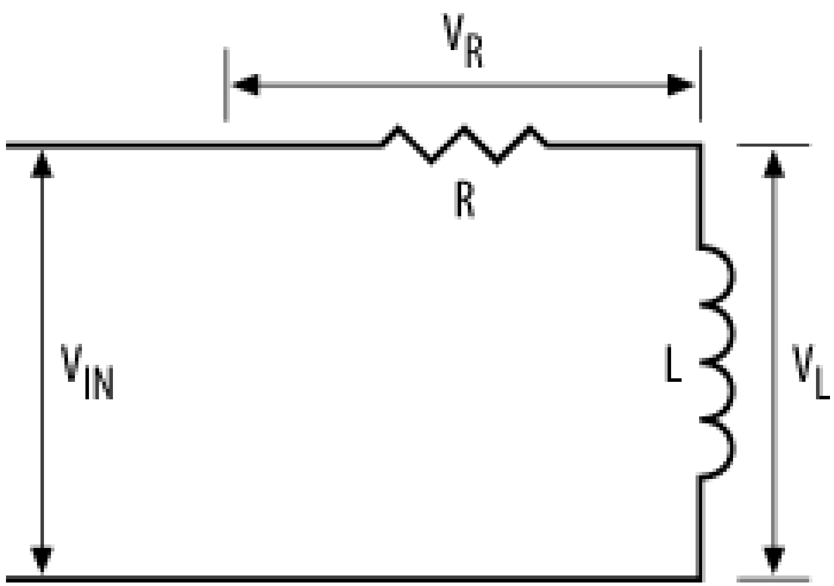
- Inductors are passive components that are essentially coils of conductive wire. Inductance is measured in Henries, with an equation symbol "L" and a unit symbol "H."

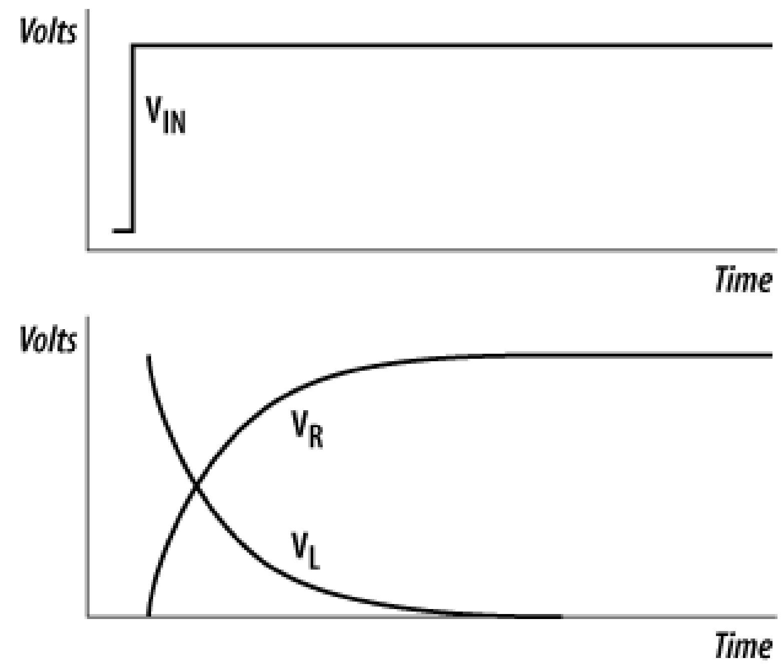


Inductors

- The voltage across an inductor changes the current flow through it, measured with the following relation:

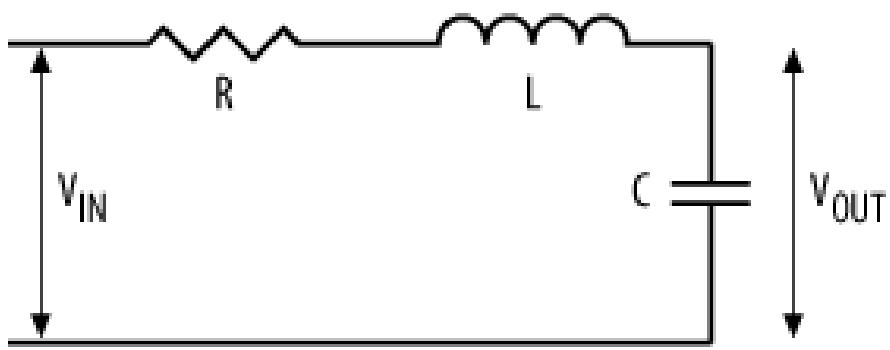
$$V = L * dI / dt$$

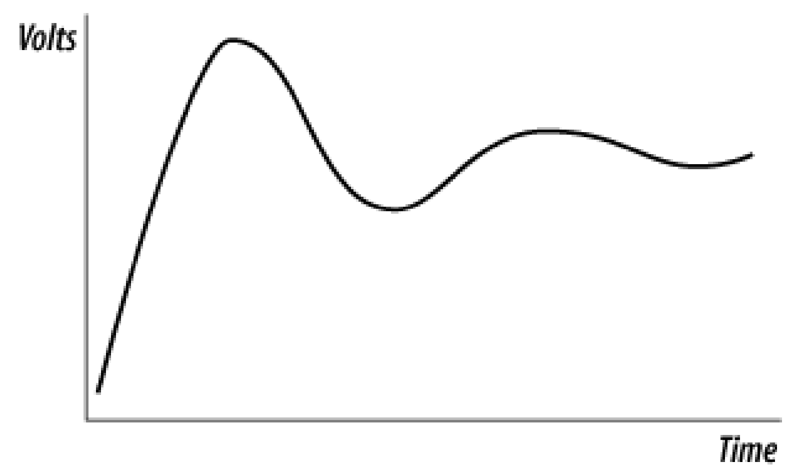




Inductors

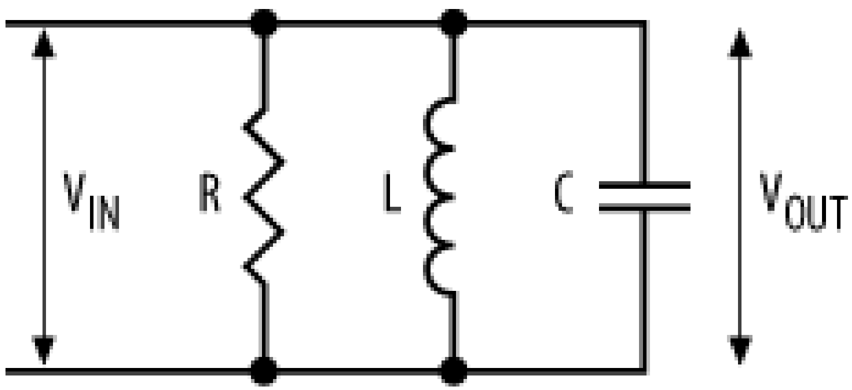
- a series R-L-C circuit.

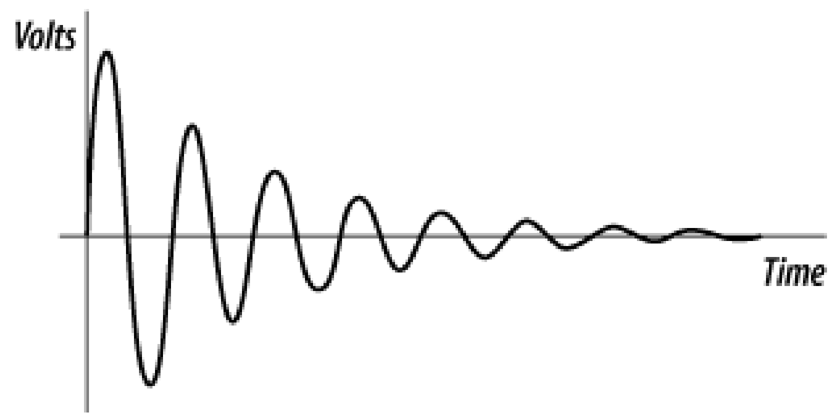




Inductors

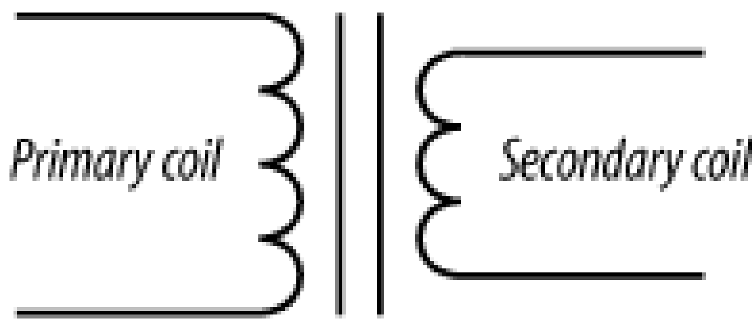
- an R-L-C circuit where all the components are in parallel.





Transformers

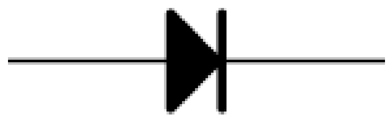
- A transformer consists of two coils of wire, known as the primary and the secondary, that are closely coupled magnetically.

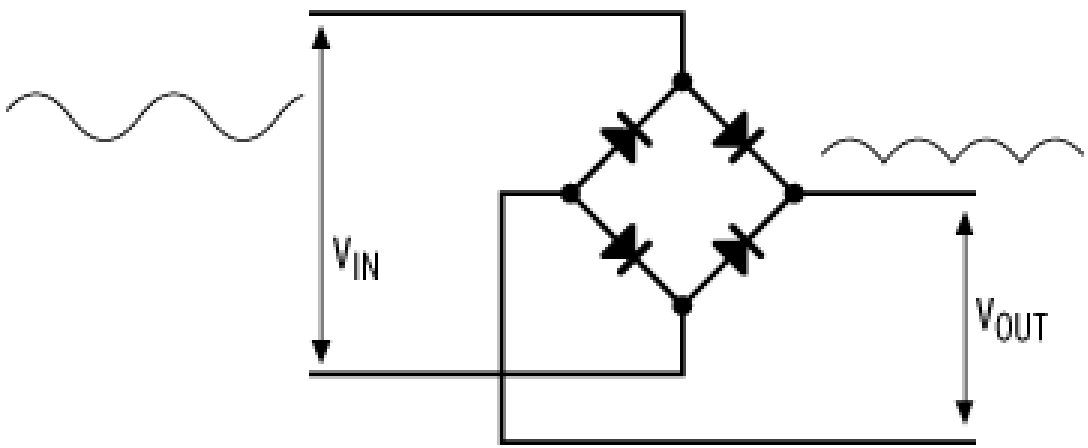


- Step-down transformer for power supplies.
- Impedance matching

Diodes

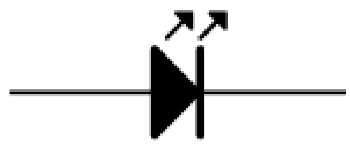
- Diodes are semiconductor devices that are extremely useful.



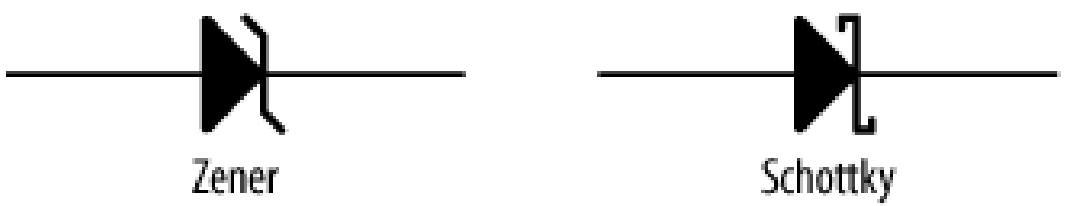


Diodes

- LED (Light Emitting Diode)

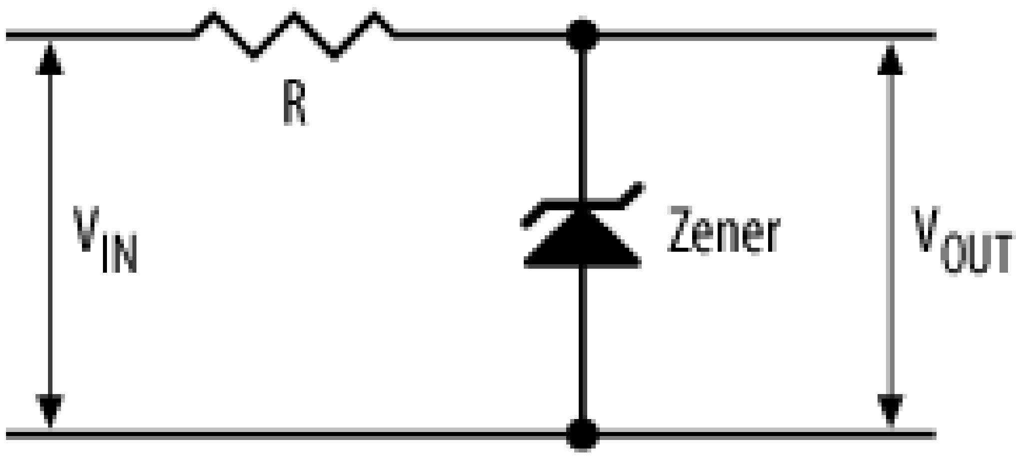


- Zener diodes and Schottky diodes



Diodes

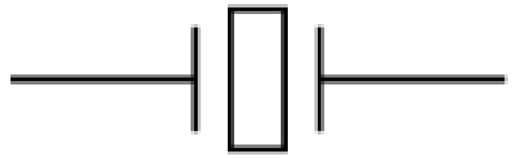
- Zener diodes



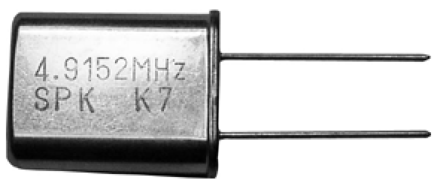
$$(V_{IN} - V_{OUT}) = I * R$$

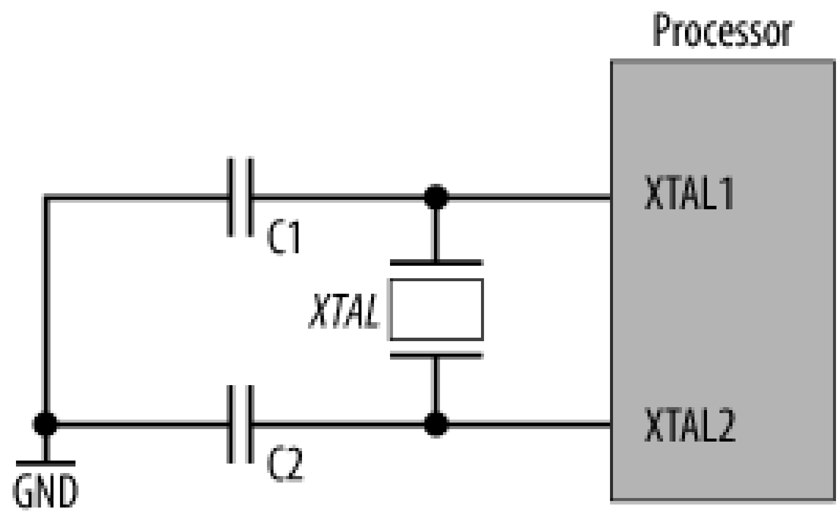
Crystals

- The schematic symbol for a crystal:



- a real crystal:





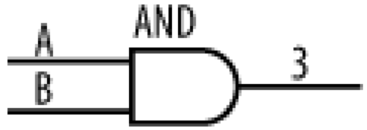
Digital Signals

- An output pin of a digital device can be in one of three states. It can be high (logic 1), low (logic 0), or tristate (high-impedance, also known as floating).
- A logic high is defined as the output voltage at the pin being higher than a given threshold. When a device's pin is outputting a high, it is said to be sourcing current to that connection.
- Similarly, a logic low is where the output voltage is below a given threshold, and the device's pin is said to be sinking current.

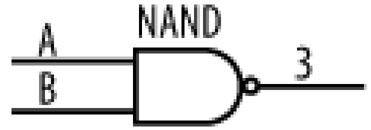
Electrical Characteristics

- Pick up any chip datasheet and you will find three sections, labeled
  - Absolute Maximum Ratings,
  - DC Electrical Characteristics, and
  - AC Electrical Characteristics.
- These are vitally important, but often poorly understood. So let's see what it all means, and how you work with that information to produce a reliable and effective embedded system.

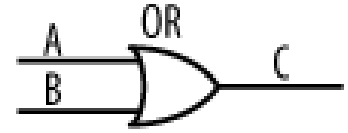
Logic Gates



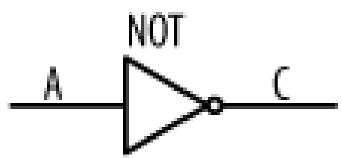
A	B	C
0	0	0
1	0	0
0	1	0
1	1	1



A	B	C
0	0	1
1	0	1
0	1	1
1	1	0



A	B	C
0	0	0
1	0	1
0	1	1
1	1	1



A	C
0	1
1	0

A	B	C
0	0	0
1	0	1
0	1	1
1	1	0

The Importance of Reading the Datasheet

- Before starting any design, you need to work out the basic requirements for your system (what it will do, how much it will cost) and select the major components you will need (such as a processor, I/O, and memory).
- Before you do anything else, obtain the datasheets for these components and read them from beginning to end.
- These can typically be found on manufacturers' web sites.