ELECTRONICS BASIC

By
Prof.Dr. R.K.Das

Basic definitions

Components

Ohm's Law

LEDs and Transistors

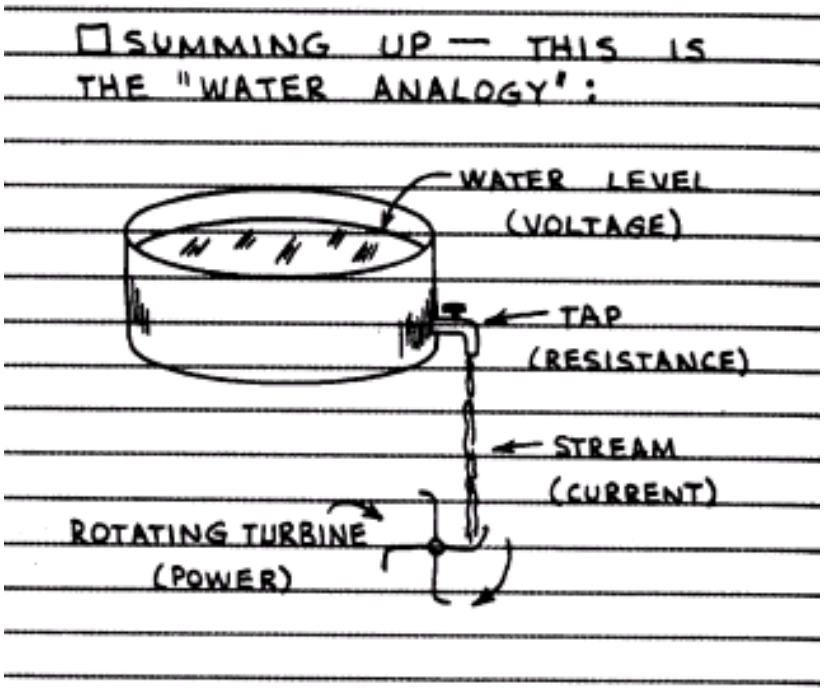
Additional electronics tutorials

Basic Electronics

Current (I): Amount of charge passing a given point per unit time

Voltage (V): Electrical pressure or force. If we compare current to water flowing through a pipe then voltage is the the water pressure.

Resistance (R): Conductors are not perfect. They resist the flow of current.



Ohm's Law

$$V = I * R \text{ !!!!!}$$

$$V = I * Z \text{ !!!!!}$$

DC

An electrical current can flow in either of two directions. If it flows in only one direction, it is called direct current (DC).

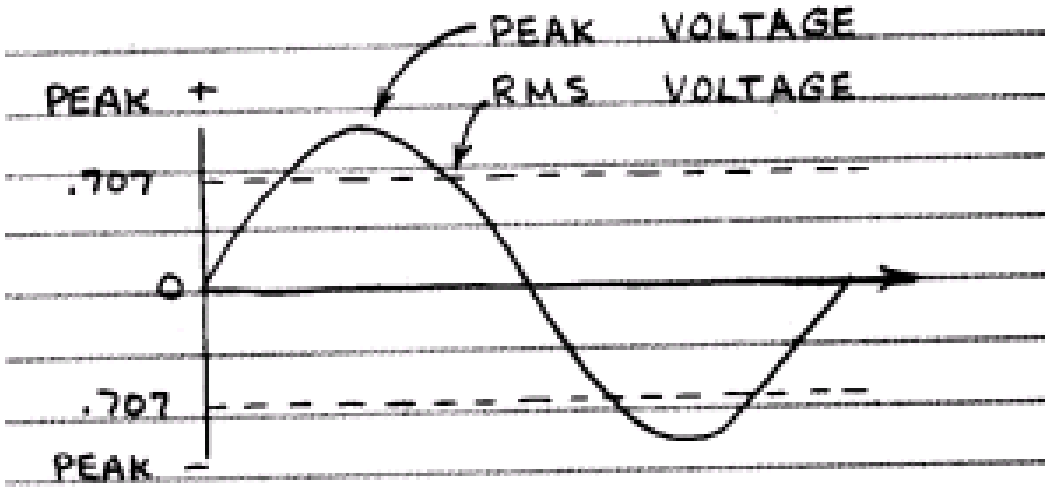
A battery is an example of a DC voltage that can supply DC current!

Electrical engineers also use the term DC to refer to an average (or constant part of) a voltage or current signal.

AC

A current which alternates in direction or polarity is called an alternating current (AC).

The current flowing from a wall outlet is an example of an AC current!

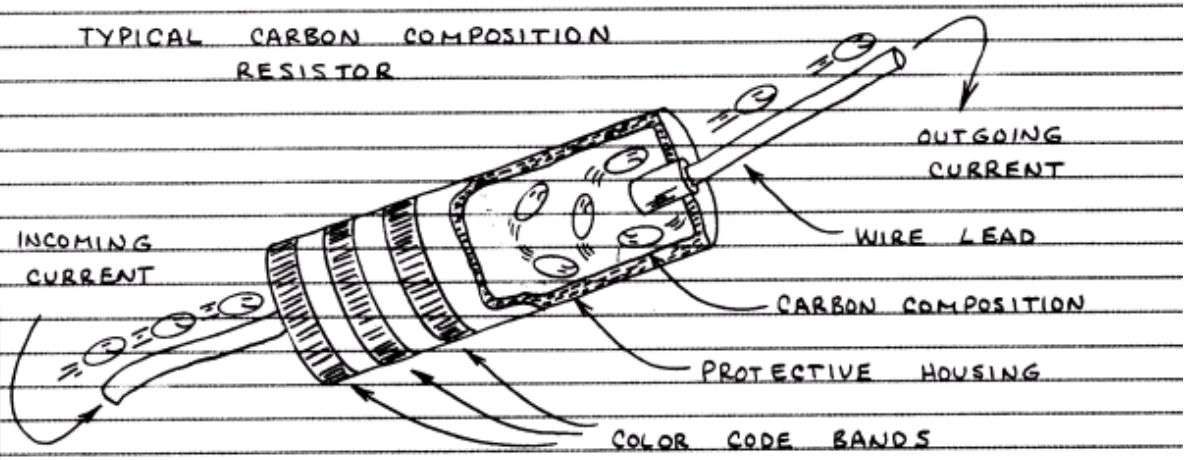


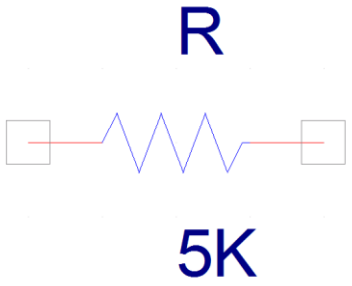
Resistors

RESISTORS COME IN DOZENS OF SIZES AND SHAPES BUT THEY ALL DO THE SAME THING: LIMIT* CURRENT. MORE ABOUT THAT LATER. FIRST, LET'S SEE HOW A TYPICAL RESISTOR IS MADE:

*OR RESIST

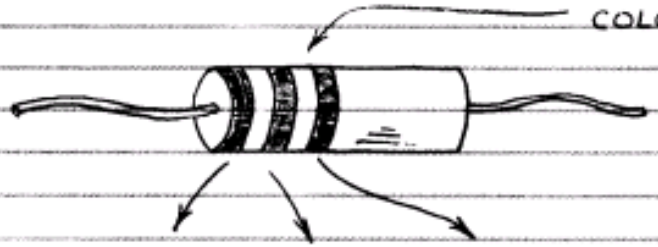
TYPICAL CARBON COMPOSITION RESISTOR





Resistor Color Code

☐ RESISTOR COLOR CODE — SEE THOSE COLOR CODE BANDS ON THE RESISTOR PICTORIAL? IN REAL LIFE THEY'RE KIND OF PRETTY. BUT THEY HAVE A FAR MORE IMPORTANT PURPOSE: THEY INDICATE THE RESISTANCE OF THE RESISTOR THEY DECORATE. HERE'S HOW:



COLOR	1	2	3 (MULTIPLIER)
BLACK	0	0	1
BROWN	1	1	10
RED	2	2	100
ORANGE	3	3	1,000
YELLOW	4	4	10,000
GREEN	5	5	100,000
BLUE	6	6	1,000,000
VIOLET	7	7	10,000,000
GRAY	8	8	100,000,000
WHITE	9	9	(NONE)

NOTE: SOMETIMES THERE'S A FOURTH BAND. IT INDICATES THE TOLERANCE* OF THE RESISTOR:

GOLD = ±5 %
SILVER = ±10 %
NONE = ±20 %

* OR ACCURACY

Kirchoff's Voltage Law

There must always be a closed path (or loop) for current to flow!

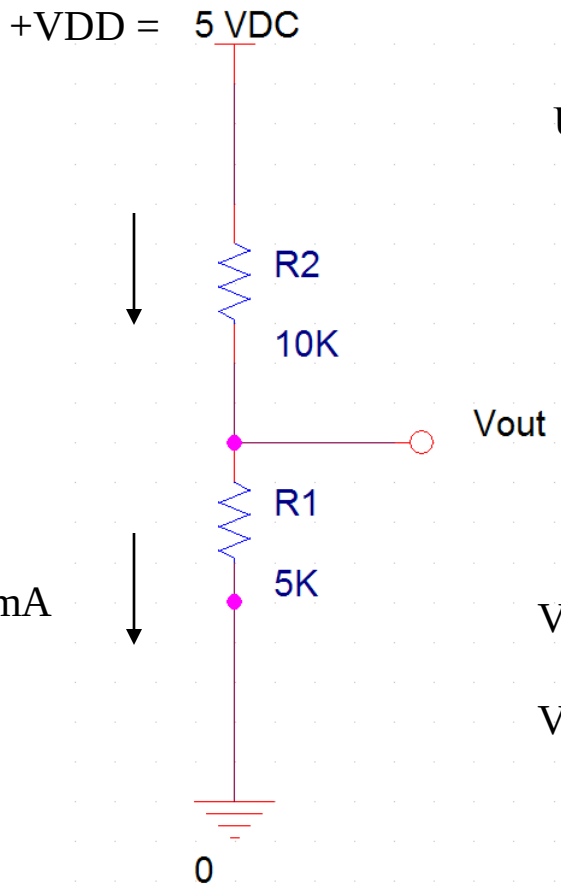
Summation of voltages around any closed loop is 0!

Kirchoff's Current Law

Summation of currents into a node must equal 0.

Electrons cannot just suddenly appear or disappear!

Voltage Divider



Use Ohm's Law, KCL, KVL!

I_2= 5 / (15K) = 0.33 mA

I_1= VDD / (R1 + R2) = 0.33 mA

I_1= 5 / (15K) = 0.33 mA

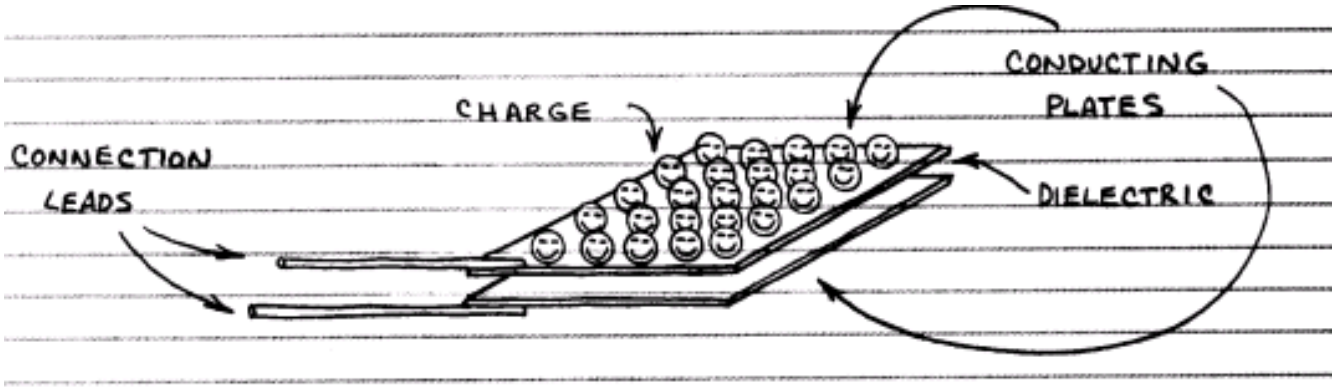
Vout = [R1 / (R1 + R2)] * VDD

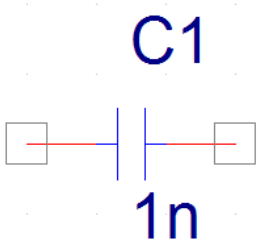
Vout = 5/3 Volts

Capacitors

There are many kinds of capacitors but they all do the same thing: store charge.

The simplest kind of capacitor is two conductors separated by an insulating material.

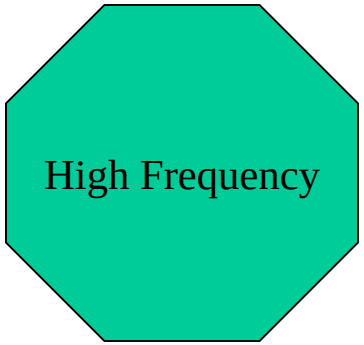


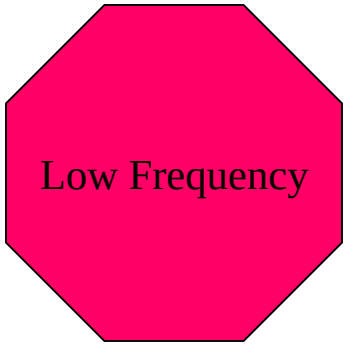


Difference Between R and C

Like resistors, capacitors can impede the flow of current. Unlike resistors, which resist the flow of both DC and AC currents in exactly the same way, capacitors can be used to COMPLETELY BLOCK the flow of DC currents.

As the frequency of the alternations associated with the flow of AC currents increases, capacitors impede the flow of current to a lesser degree!





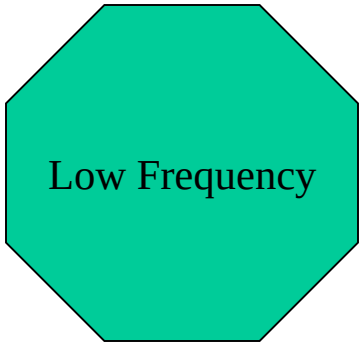
Inductors (Coils)

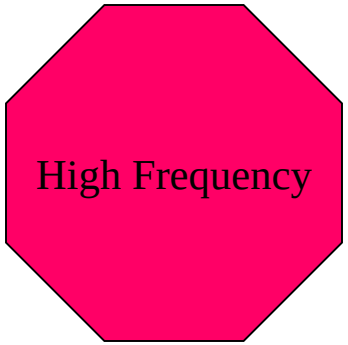
Inductors are formed by taking a wire and wrapping it as a coil.

Like resistors, inductors can impede the flow of current.

Inductors, however, resist rapid changes in the current flowing through them while freely passing DC currents.

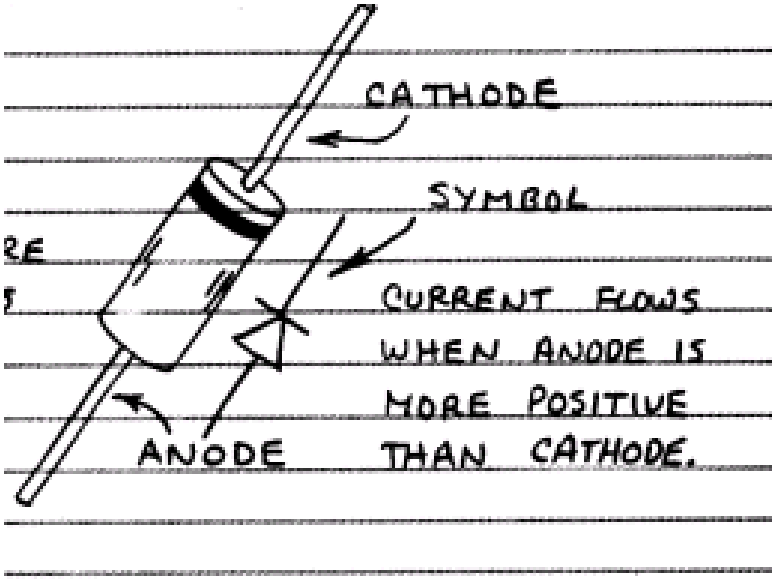
When current is passed through the coil, an electromagnetic field encircles it. The coil can act like a magnet!





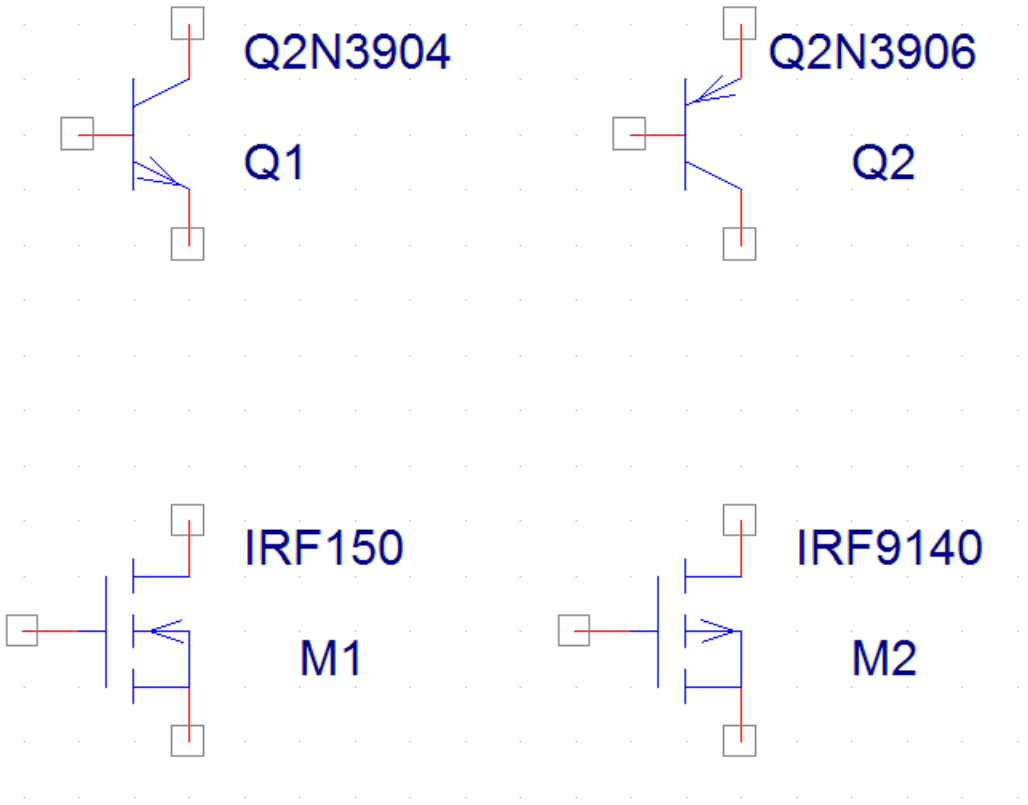
Diodes

A diode is like and electronic one-way valve. It will allow current to flow in only one direction! Clearly, diodes can be used to convert AC currents to DC!



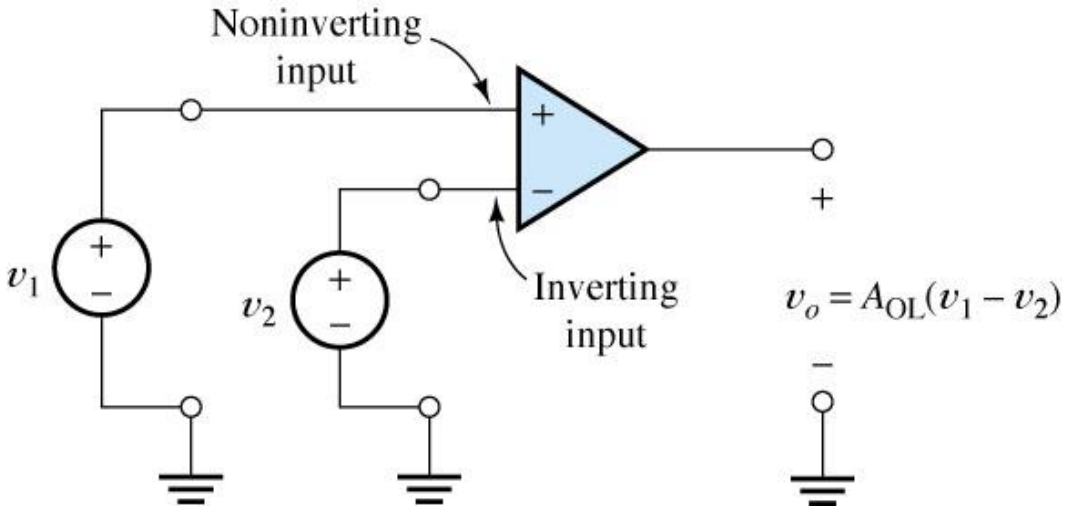
Transistors

Transistors are three terminal devices. A very small current or voltage at one terminal can control a much larger current flowing between the other two leads.



Operational Amplfier

Operational Amplifiers take small voltages and make them MUCH larger.



Golden Rules (Op amp with negative feedback):

(1) No-current flows into either (+) or (-) inputs.

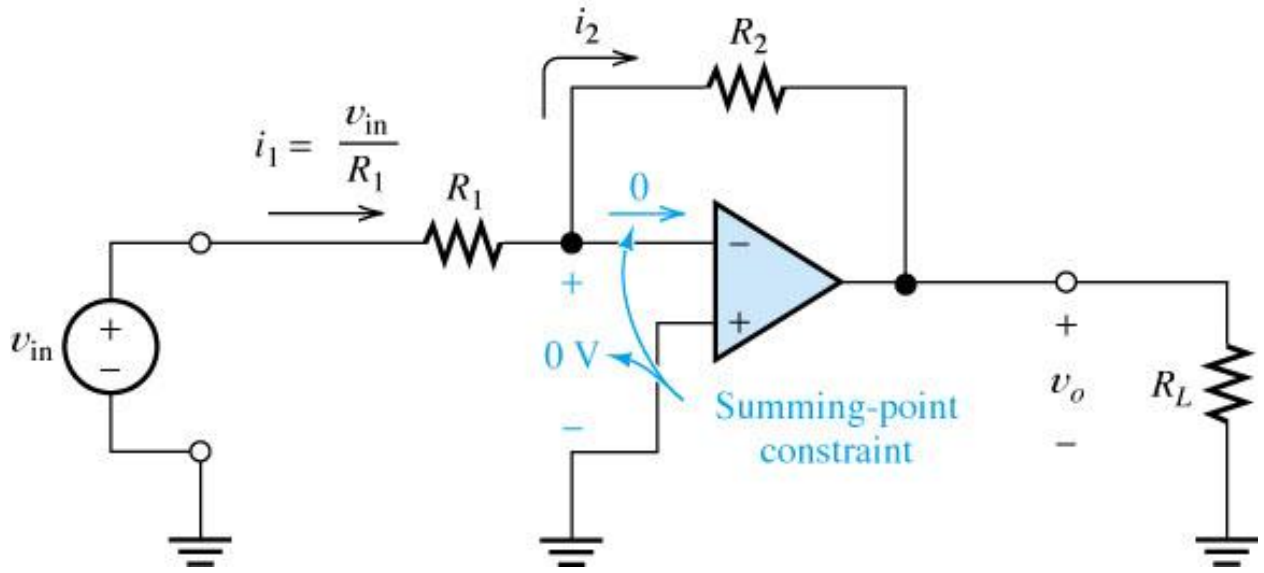
(2) The (+) and (-) inputs are at the same voltage.

Signal Conditioning

Electrical engineers use operational amplifiers (Op Amps), resistors, capacitors, diodes, transistors, *etc*. to perform mathematical operations like

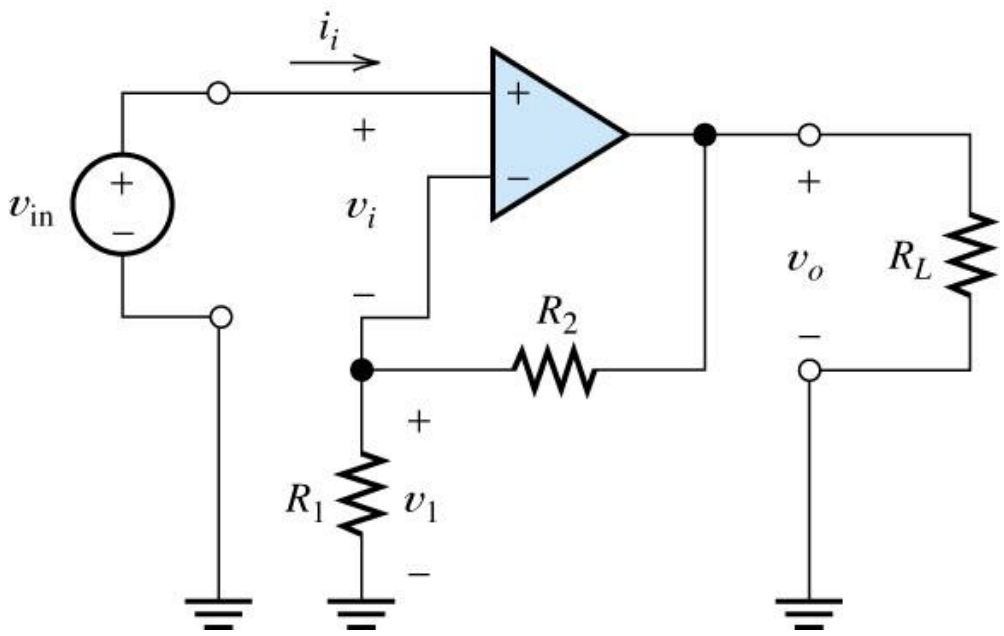
- Multiplication/Division
- Addition/Subtraction
- Absolute Value
- Natural Log
- Filters

Inverting Gain Amplifier



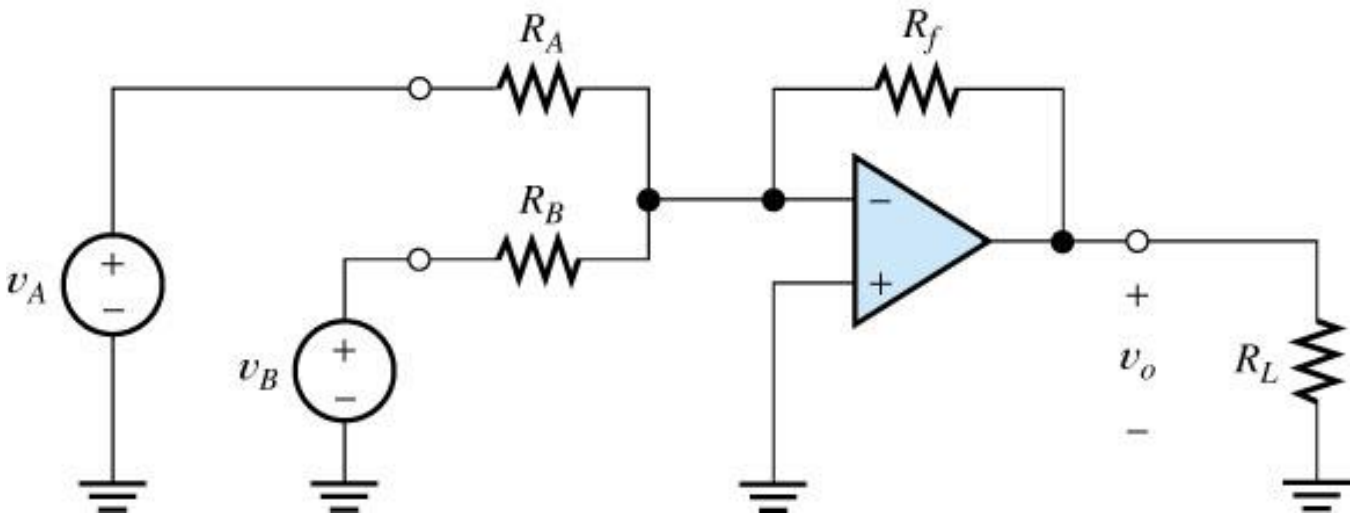
Gain = - R_2 / R_1

Non-Inverting Gain Amplifier

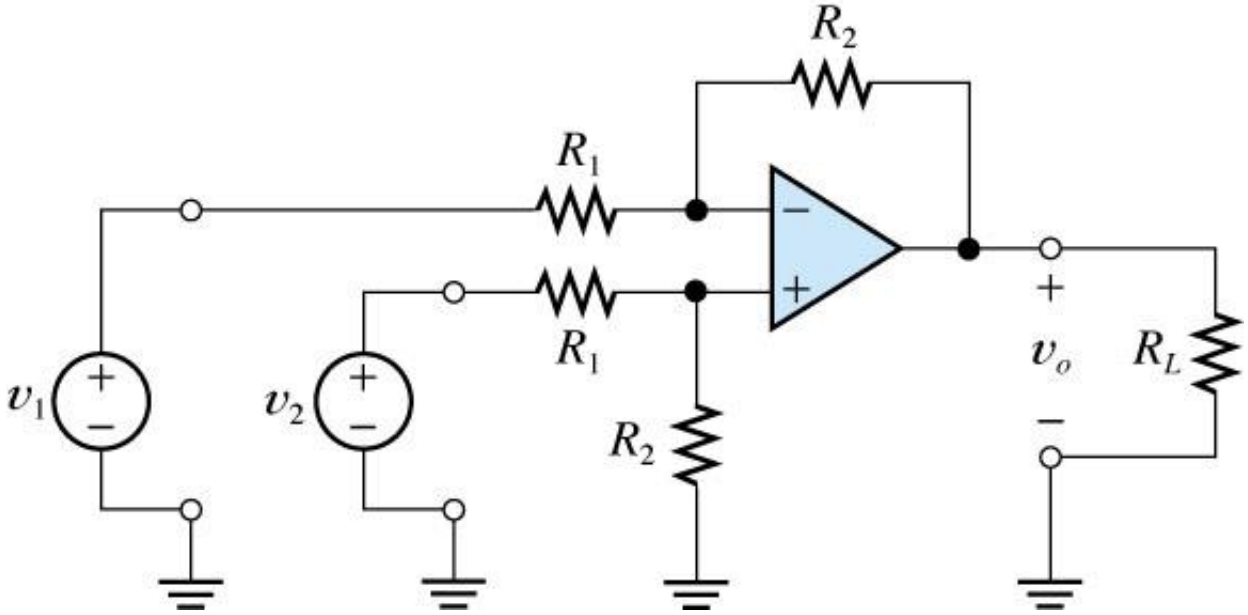


Gain = $(1 + R_2 / R_1)$

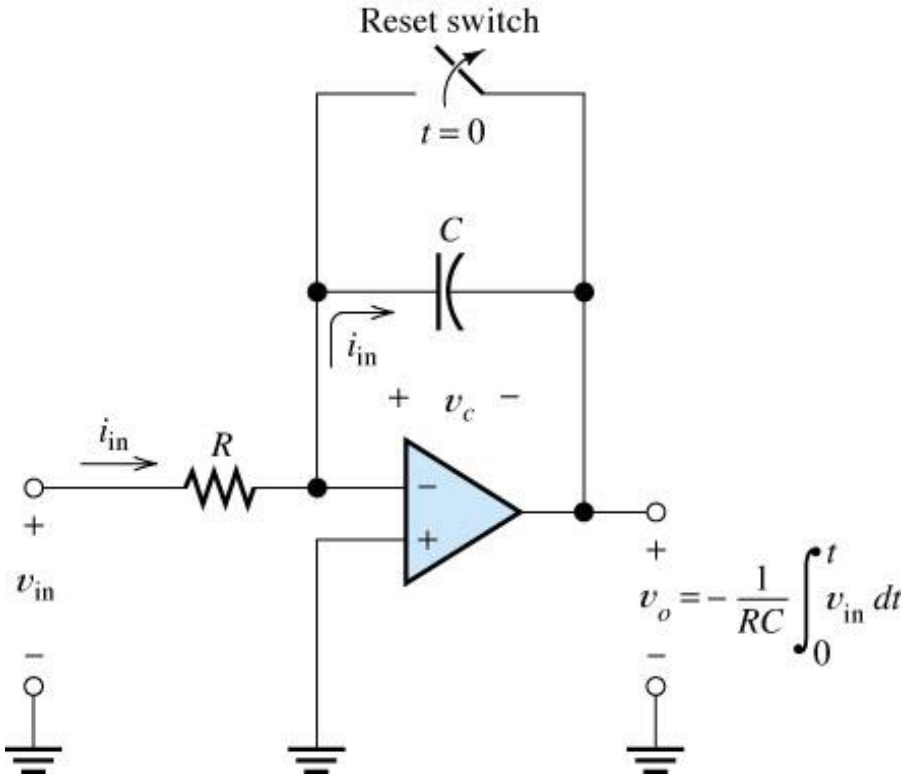
Summing Amplfier



Difference Amplfier



Integrator


Reset switch
$t = 0$
C
i_{in}
$+ \quad v_c \quad -$
i_{in}
R
$+$
v_{in}
$-$
$+$
$v_o = -\frac{1}{RC}\int_0^t v_{in}\, dt$
$-$

Sensor Fundamentals

How do sensors function?

Common and useful robotic sensors:

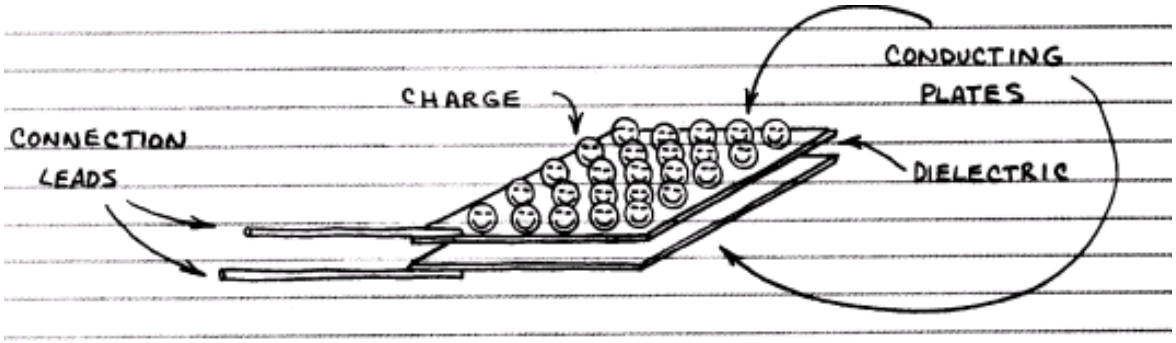
- Touch Sensor
- Resistive Position Sensor
- Photocell Light Sensor
- Phototransistor Light Sensor
- Shaft Encoder

Transducer

A transducer is a device or structure that transforms a physical quantity into an electrical one or a device / structure that transforms an electrical quantity into a physical one.

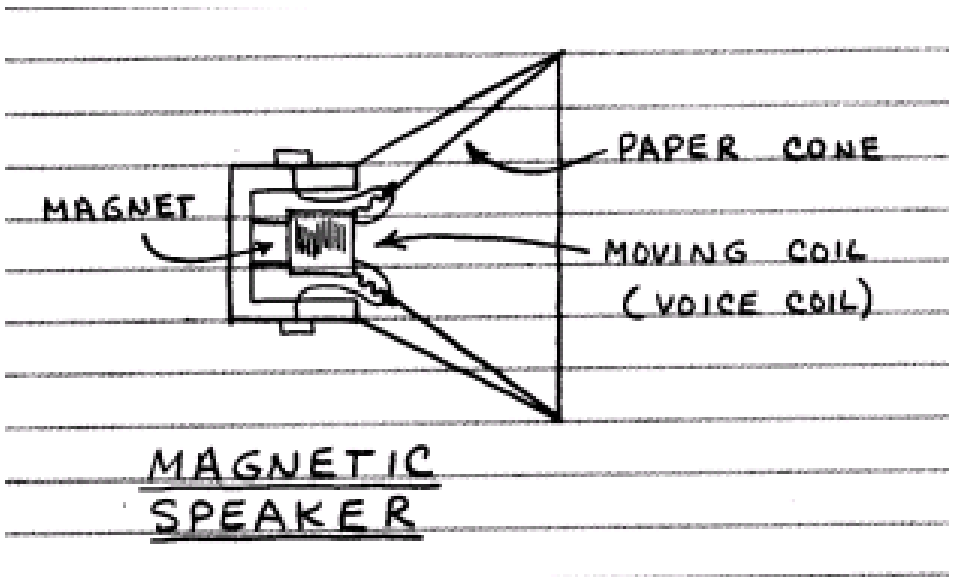
For example: A microphone transforms changes in sound pressure level into changes in voltage.

A condenser microphone is one in which a moving diaphragm alters the distance between two metal plates. This results in a proportional change in the capacitance of the plates.



Another Transducer Example

A speaker transforms changes in voltage into sound pressure waves.



Sensor

We will use the term *sensor* in this class to denote any device used to sense the robot's environment.

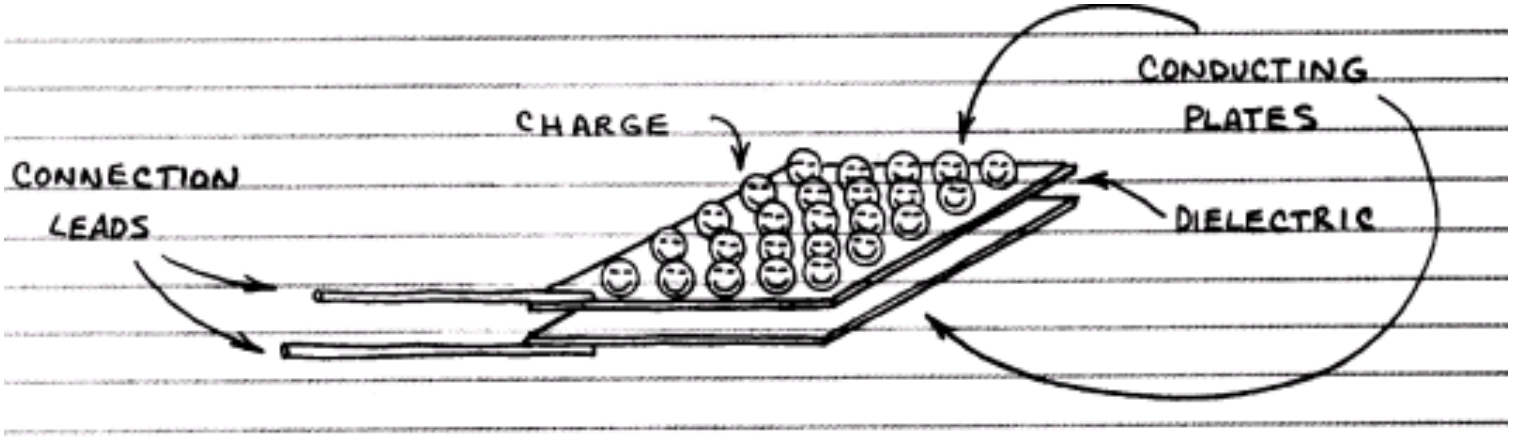
A senor is the **transducer** and any associated electronics needed to interface the transducer to the Handy Board.

For example, even though a microphone converts changes in sound pressure level into changes in voltage, we can not directly connect a microphone to the Handy Board.

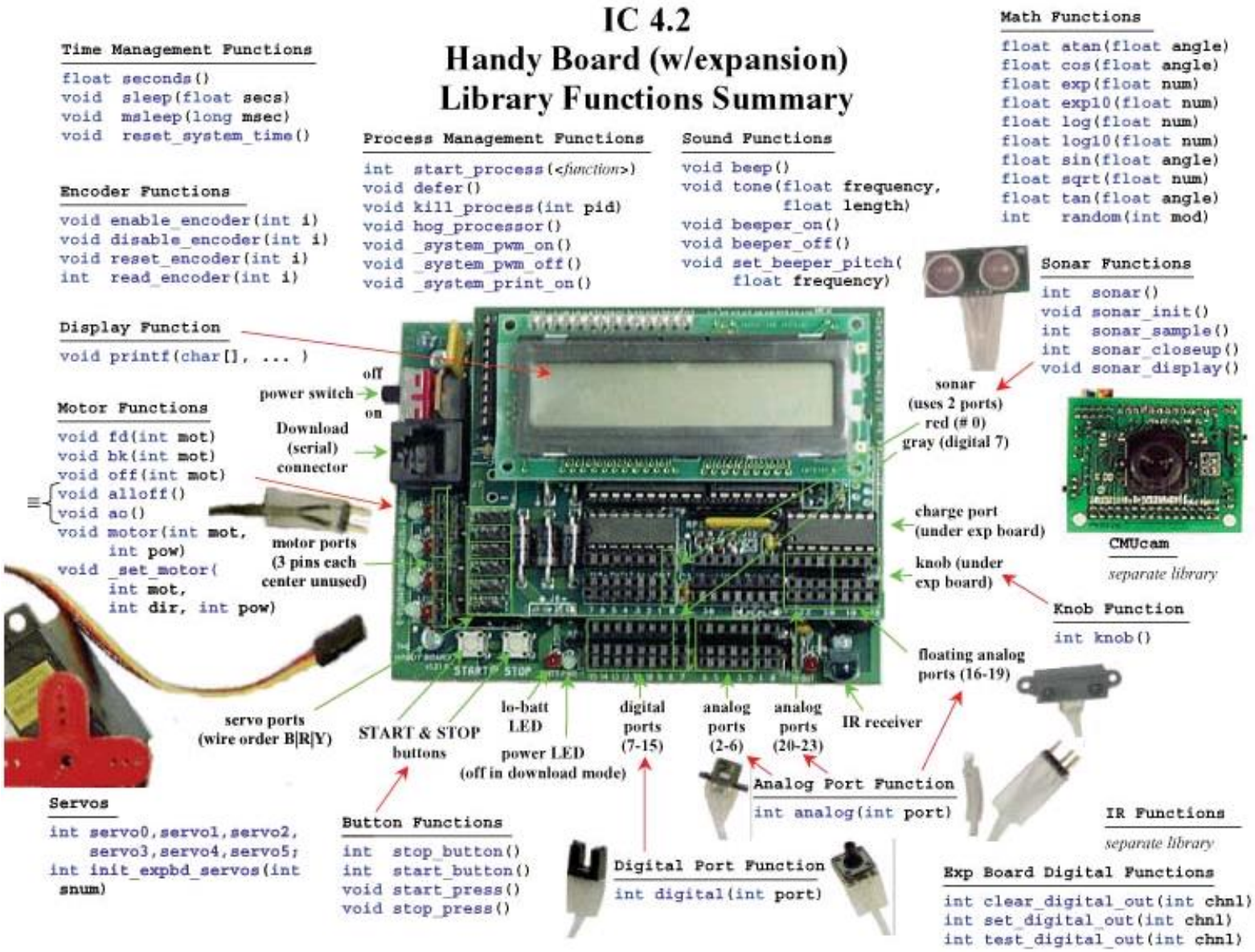
The voltage levels are **TOO SMALL**. The microphone output must first be amplified and perhaps filtered!

Other Examples Where Capacitive Transducers Are Used

- Accelerometer
- Fluid Level Sensor

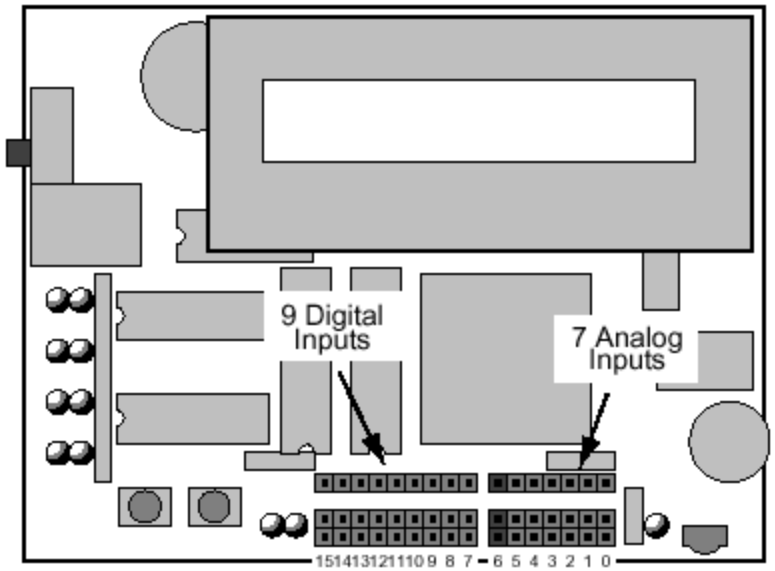


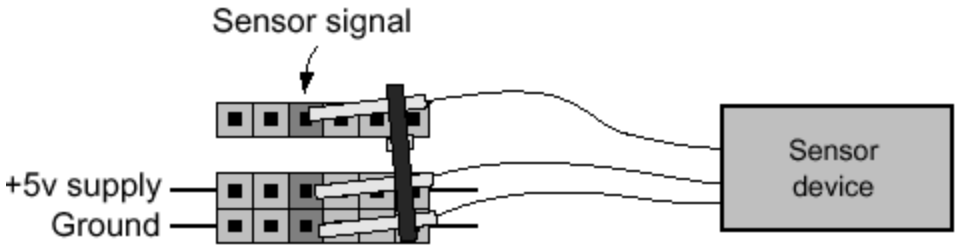
Handy Board Reference



Interfacing

Handy Board's Sensor Input Banks





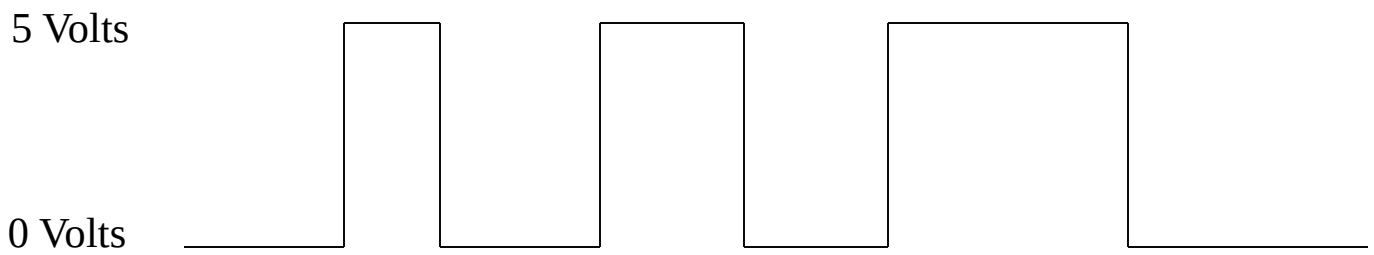
Each sensor ports provides three signals to the sensor:

- **+5v power** - middle row
- **Ground** - lower row
- **Sensor signal line** - upper row

Digital Signals

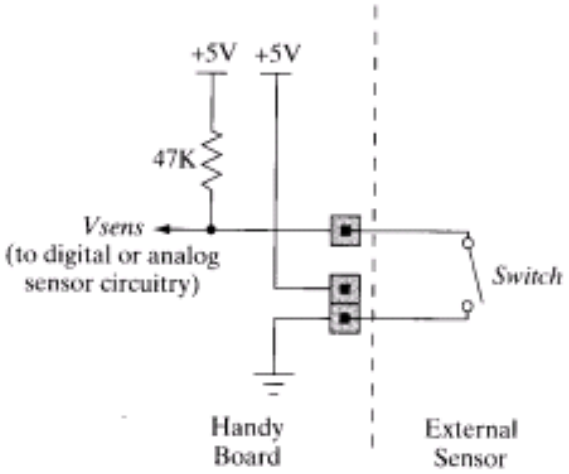
A digital signal can take on only one of two voltages: 0 Volts and 5 Volts.

The Handy Board treats 0 Volts as logical TRUE and the 5 Volt signal as logical FALSE.

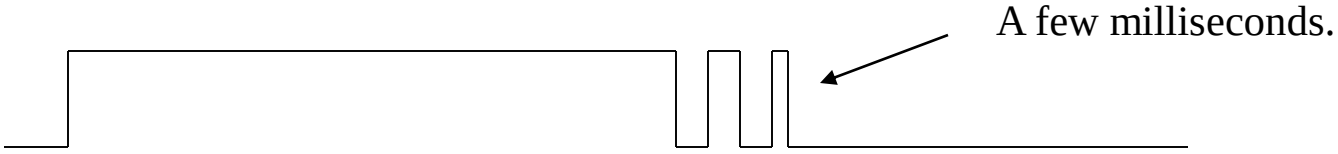


A Simple Touch Sensor (Digital)

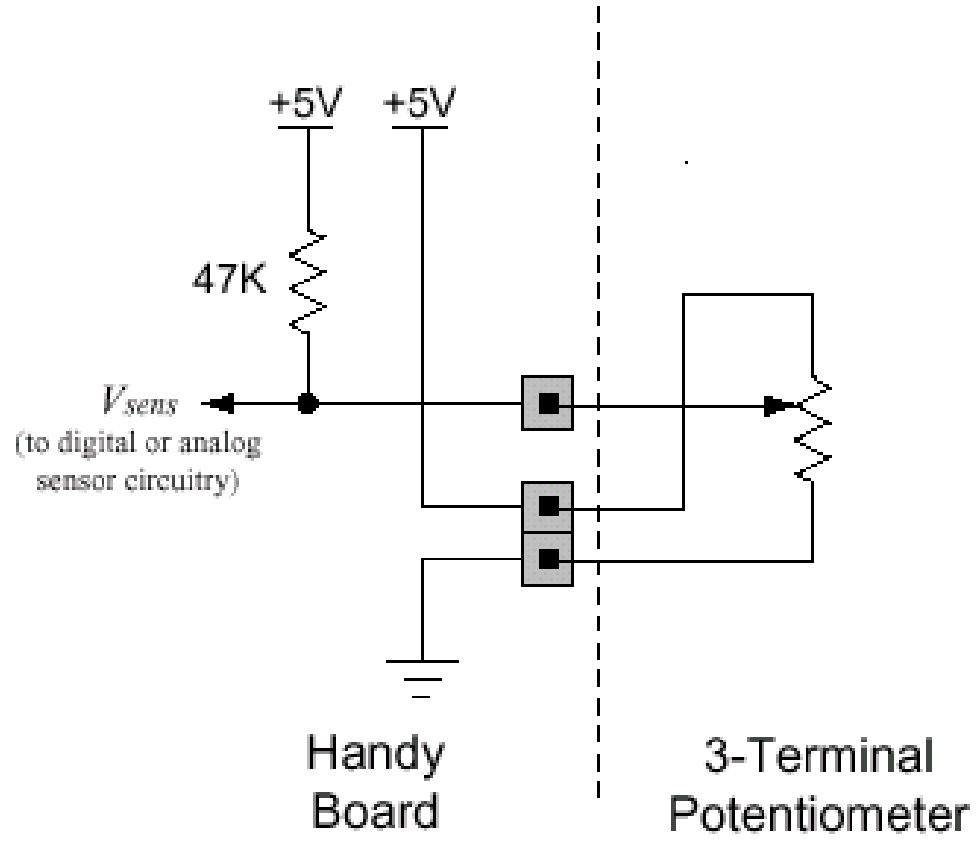
Mechanical switches permit or interrrupt the flow of current.



WARNING: Mechanical switches BOUNCE!!!!!

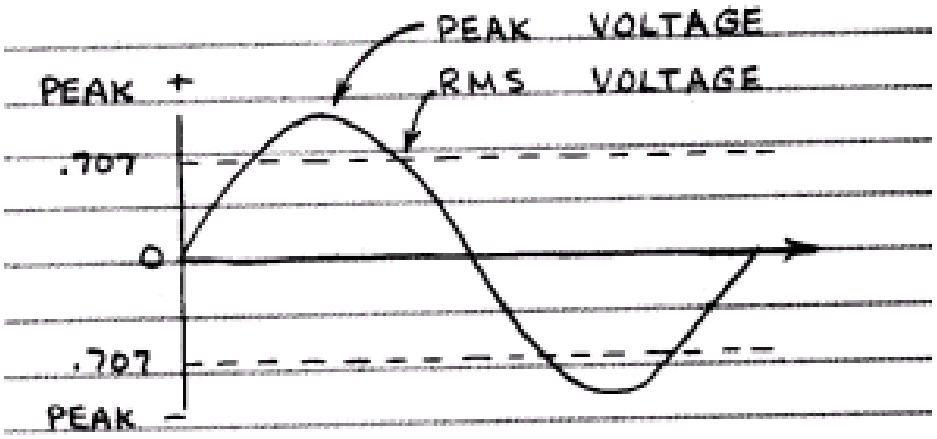


Simple Position Sensor (Analog)

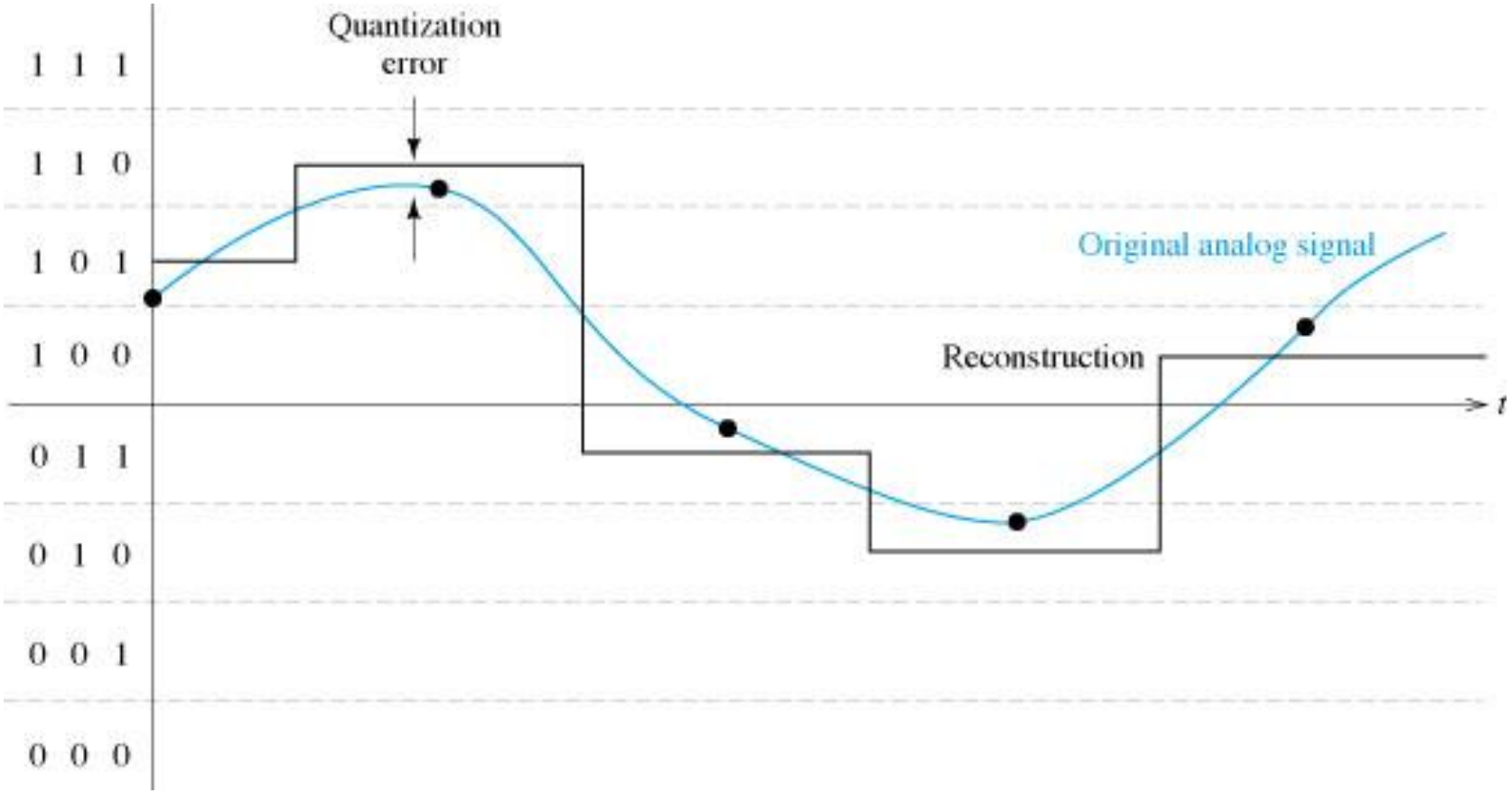


Analog Signals

An analog voltage can take on *any* value between 0 and 5 Volts. An Analog-to-Digital Converter (ADC) within the Handy Board will, however, will quantize the analog signal. The HandyBoard ADC is 8 bits wide.

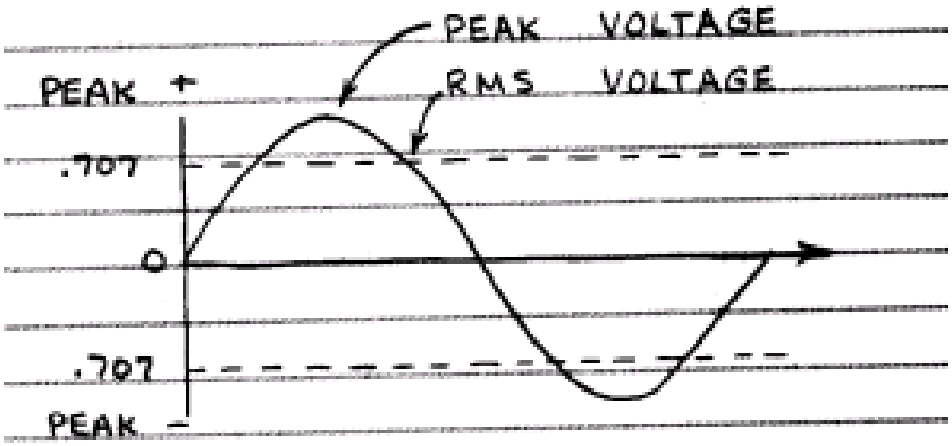


Quantization



Sampling Theorm

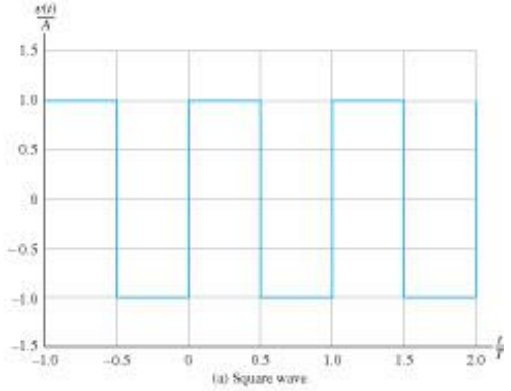
In order to avoid a non-linear phenomenon known as *aliasing*, an electrical signal must be sampled at a rate of at least TWICE the highest frequency component present in the signal.



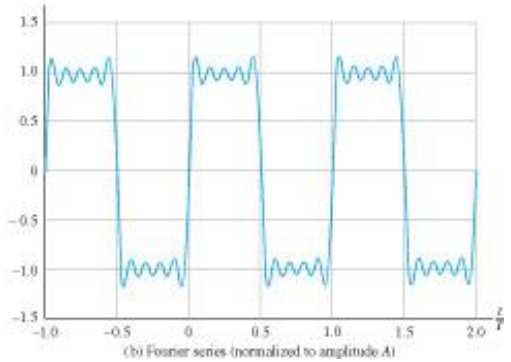
$$F_s >= 2 * F_h$$

Complex Signals

Complex signals (like square waves) are actually linear combinations of sinusoids.



(a) Square wave



(b) Fourier series (normalized to amplitude A)

Bandlimiting

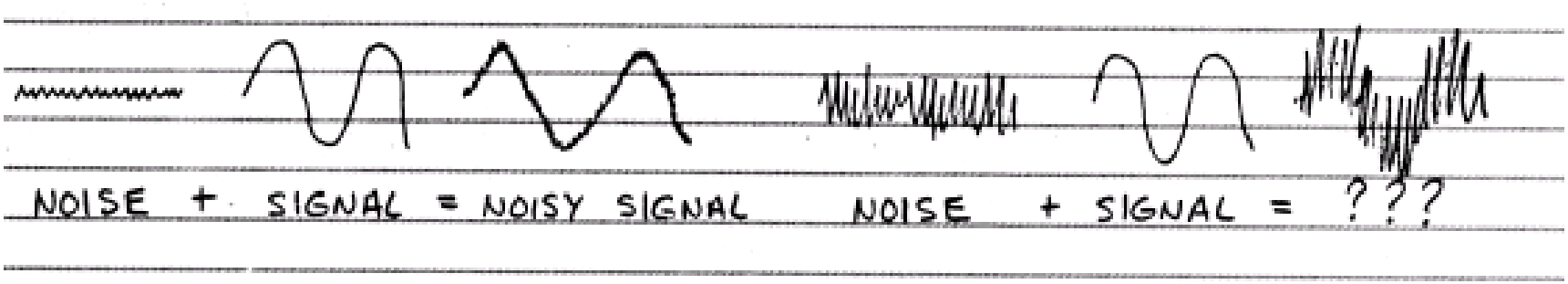
Once a sampling rate has been determined, the input must be ***bandlimited***. This means that the incoming electrical signal is filtered so that all frequency components above one-half the sampling frequency are removed!

Filtering not only prevents aliasing but also can be used to remove unwanted noise.

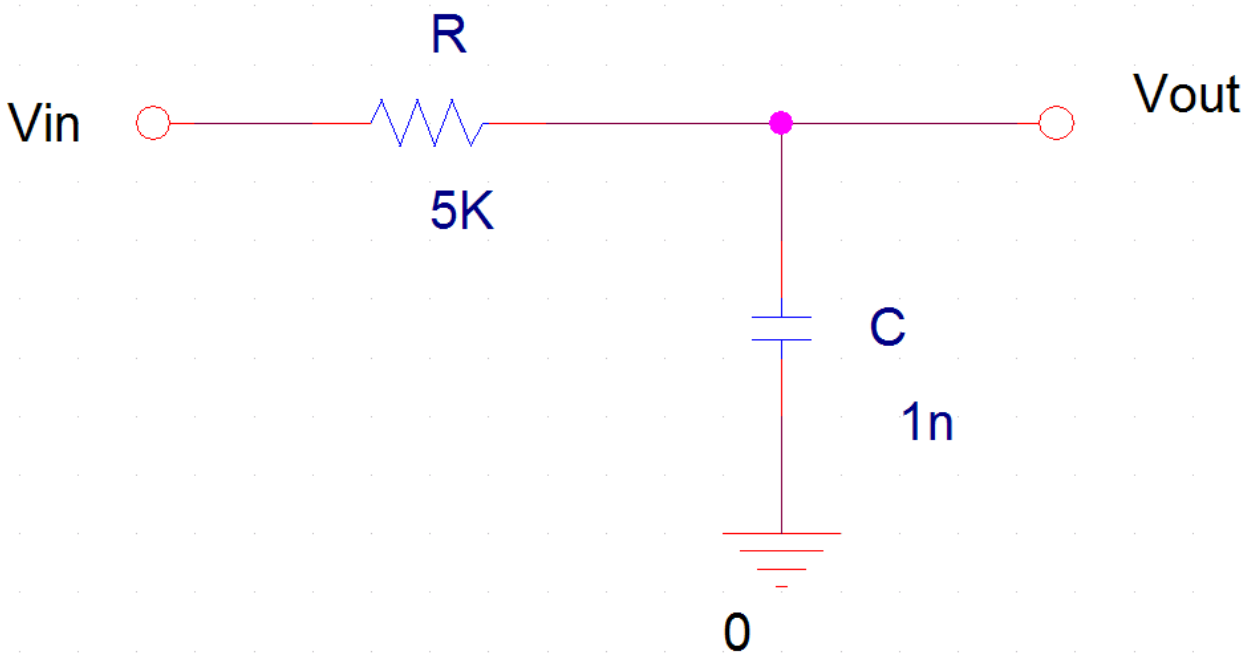
Noise

Filtering not only prevents aliasing but also can be used to remove noise.

All electronics circuits generate small, random electrical currents or voltages. Noise can also enter electronic circuits by means of electromagnetic waves generated by things such as electric motors, radio stations, electric outlets. The HandyBoard digital circuits also serve as a noise source which may corrupt your sensor signals.

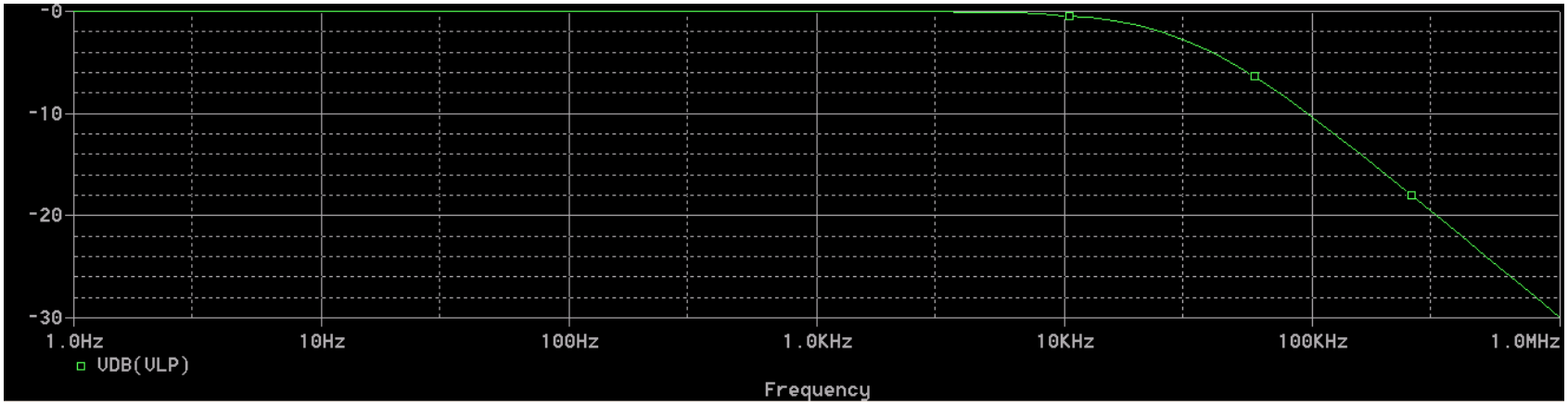


Passive, RC, Lowpass Filter

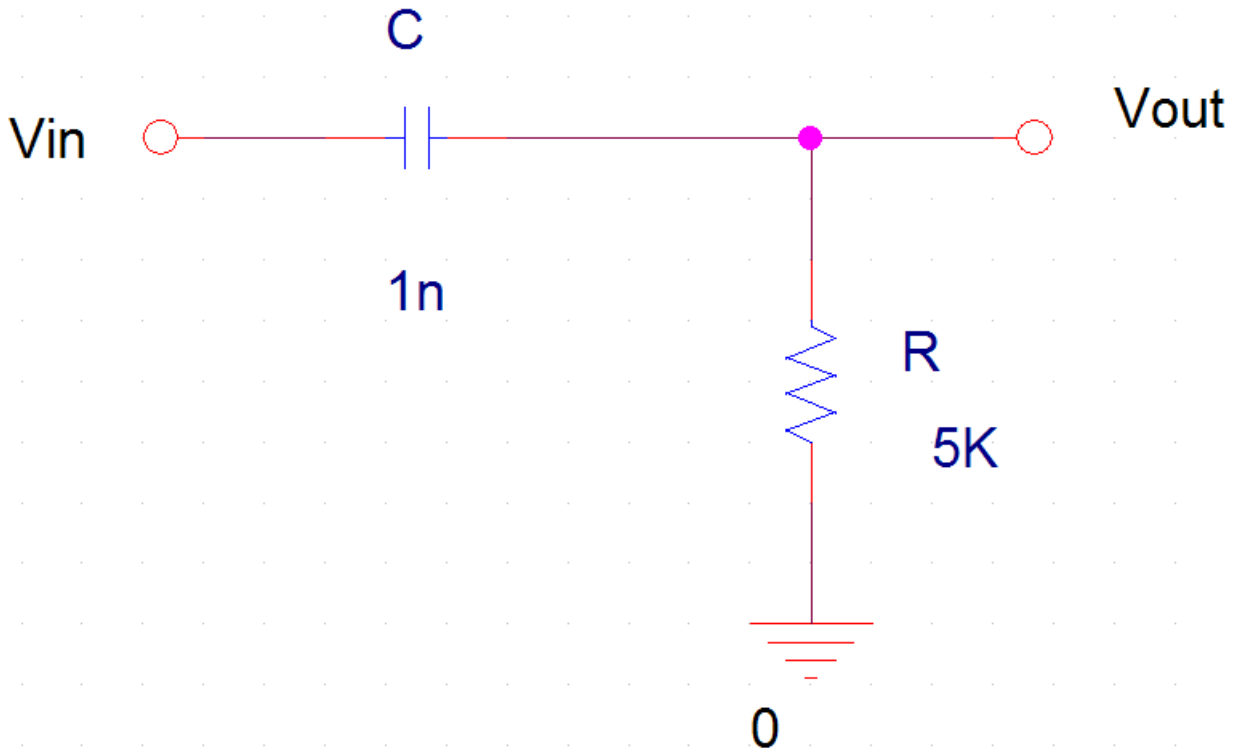


$$f_{3dB} = 1 / (2\pi RC)$$

Lowpass Filter Simulation



Passive, RC, Highpass Filter



$$f_{3dB} = 1 / (2\pi RC)$$

Highpass Filter Simulation