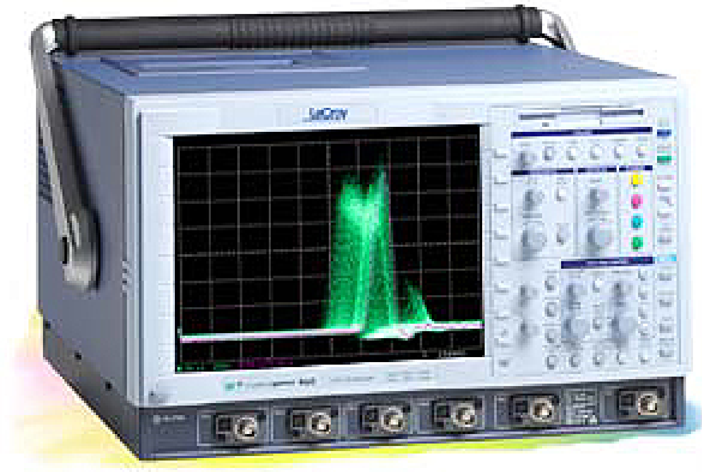
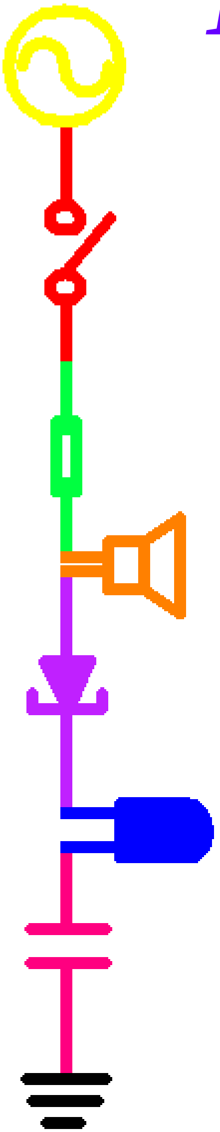
 

Electronic Instrumentation

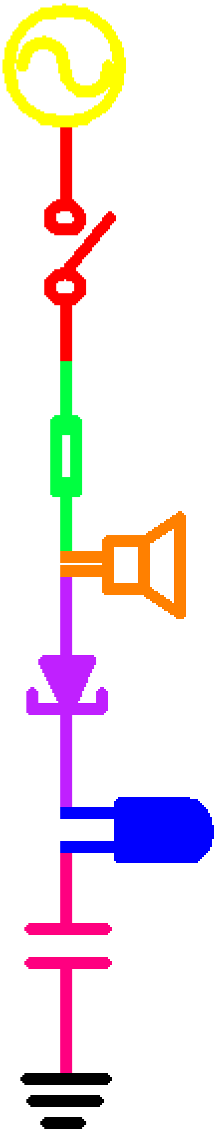
Experiment 1

* Part A: Circuit Basics, Equipment, Sound Waves
* Part B: Resistors, Circuit Analysis, Voltage Dividers
* Part C: Capture/PSpice

Motivation



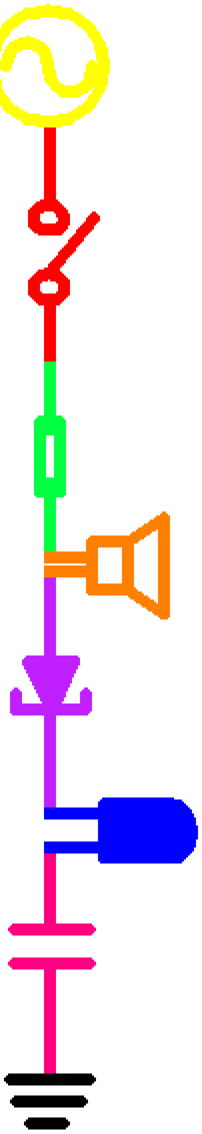
- Modern Systems
  - mechanical component
  - electrical component
  - (computer component)
- You will be able to communicate with EE’s
- You will be able to take the electronics sections of the FE exam
- You will be using Engineering problem solving skills.

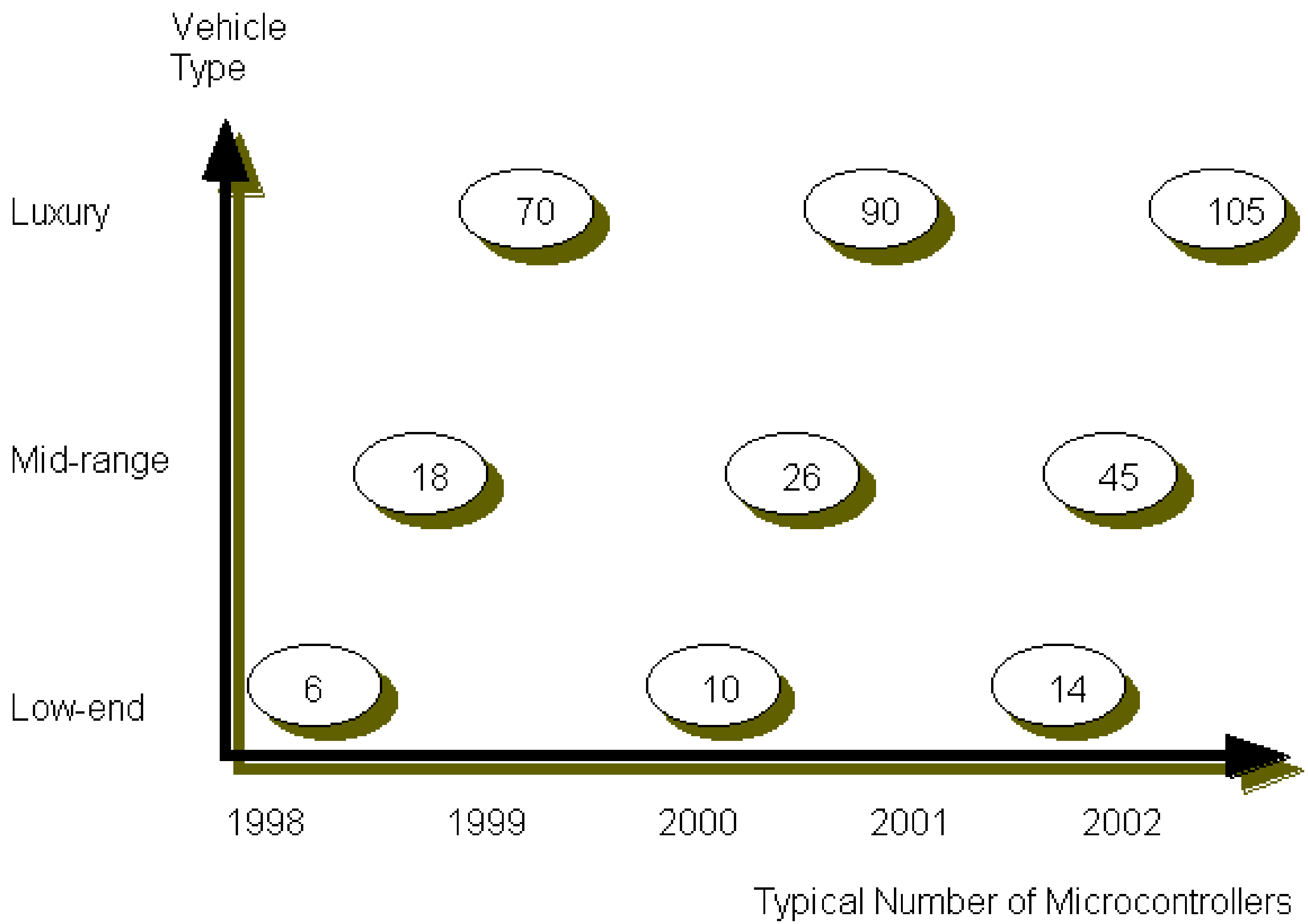


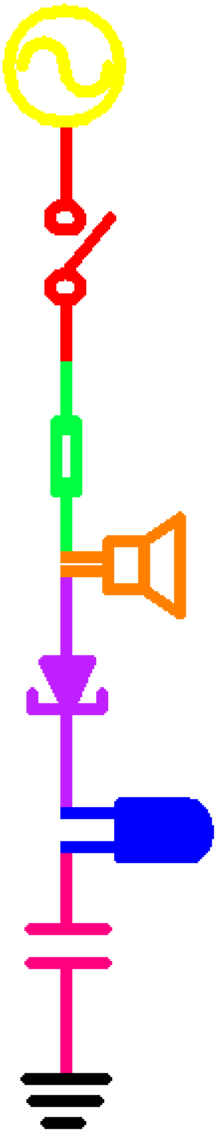
Automobile Electronics

- Previously all mechanical systems have become increasingly electronic
- Over the past few years, for example, the automobile has begun to use more computers (microcontrollers)
- How many microcontrollers are typically found in a modern automobile?

Automobile Electronics



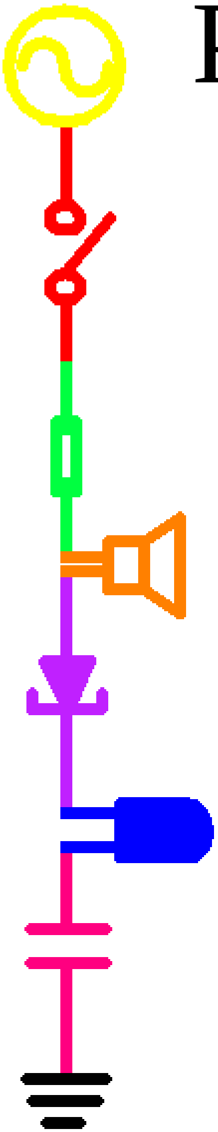


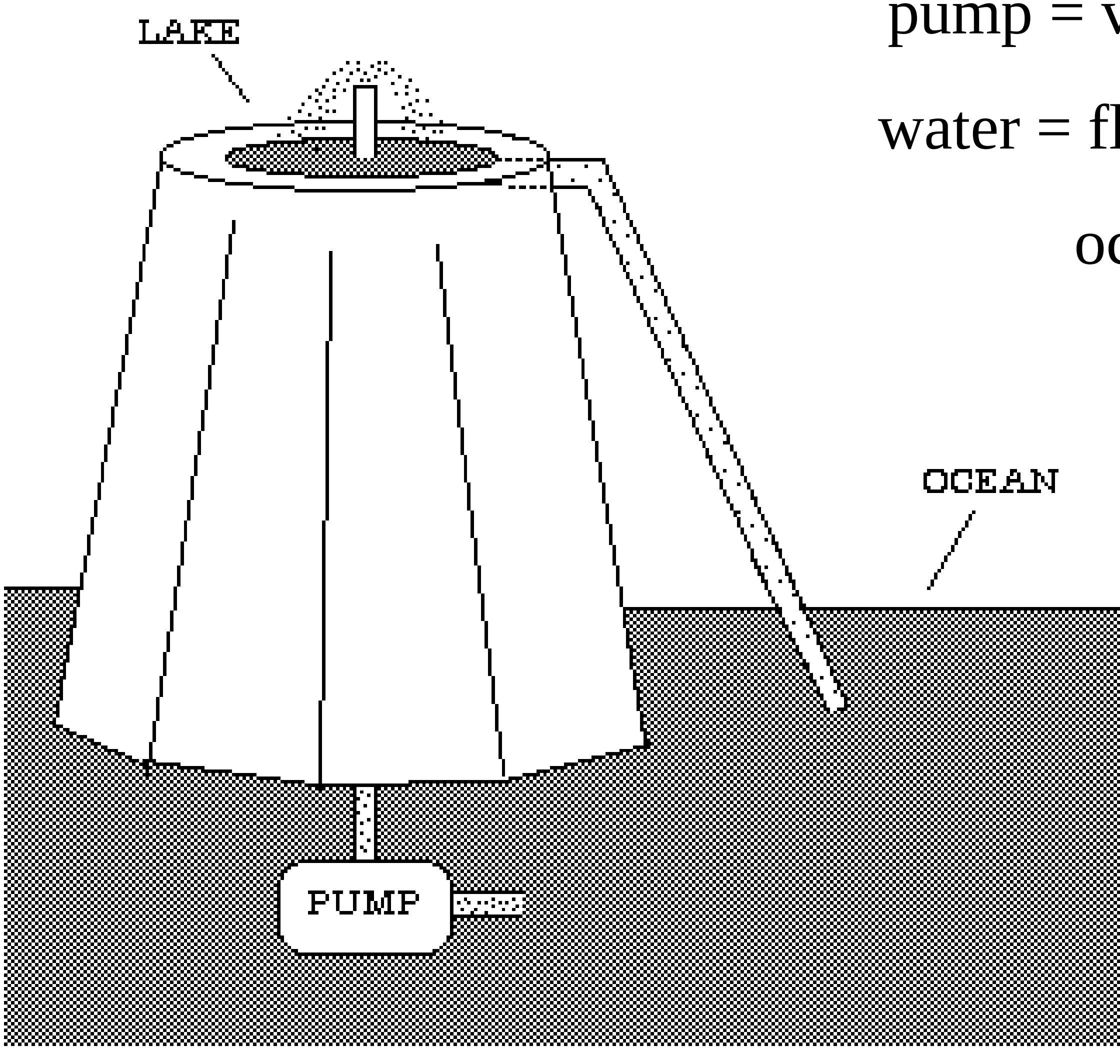


Part A

- Circuit Basics
- Equipment
- Sound Waves

Physical Model for a DC circuit





pump = voltage source

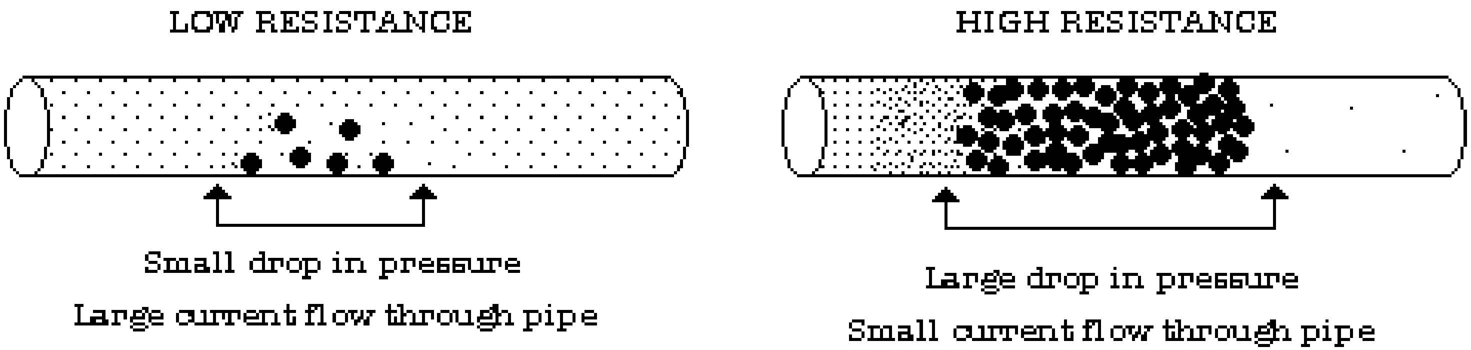
water = flow of current

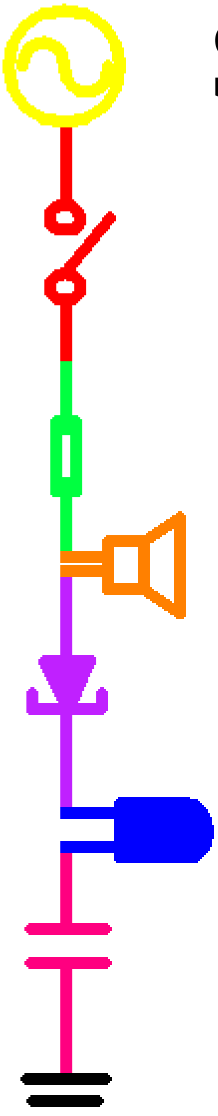
ocean = ground

pipe = wire

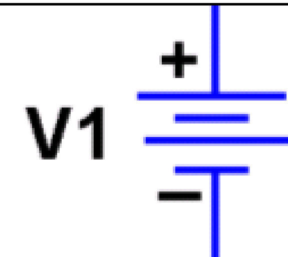
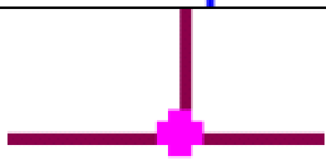
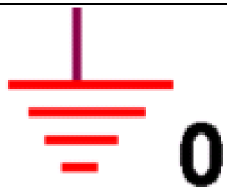
Physical Model for Resistance

pebbles in pipe = resistance to flow of current



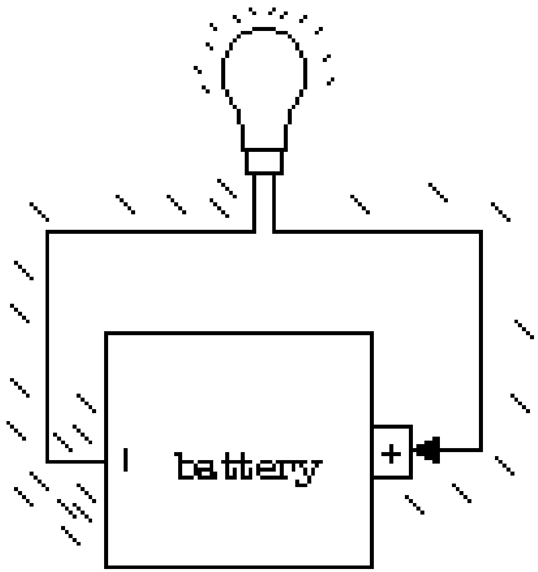


Symbols

	symbol	*units*	*analogy*	*icon*
voltage	V	volts	pressure	
current	I	amps	flow of water	
resistance	R	ohms (Ω)	pebbles in pipe	
ground	GND		ocean	

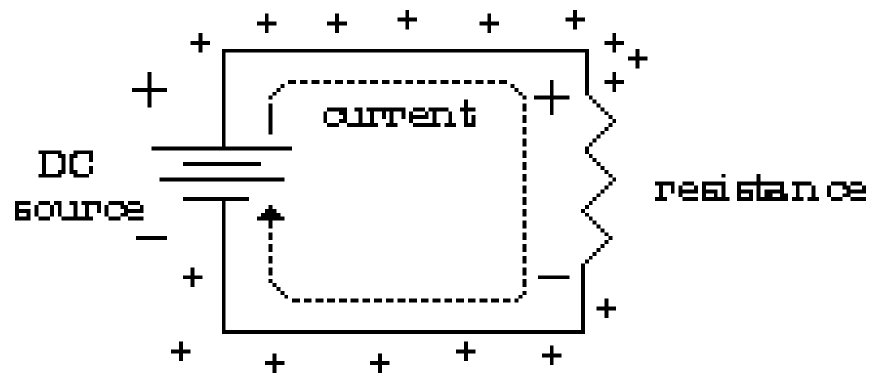
Physics vs. Electronics

PHYSICS

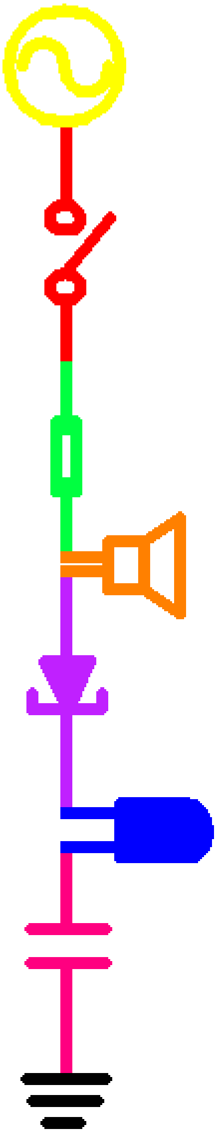


Flow of electrons from negative to positive

ELECTRONICS

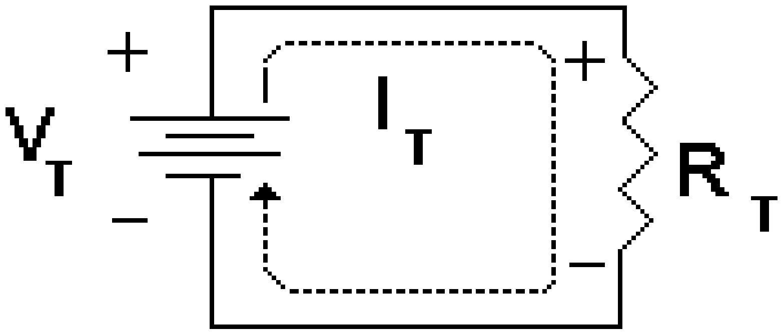


Flow of current (positive charge) from positive to negative



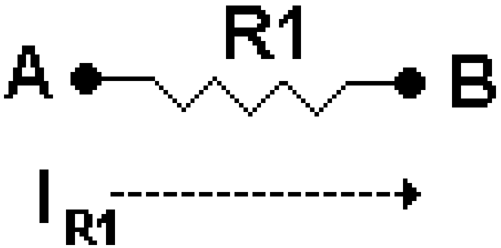
Ohm's Law : $V = IR$

CIRCUITS



$$V_T = I_T R_T$$

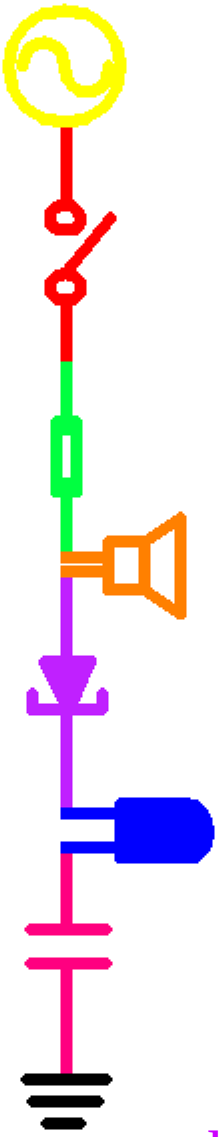
COMPONENTS

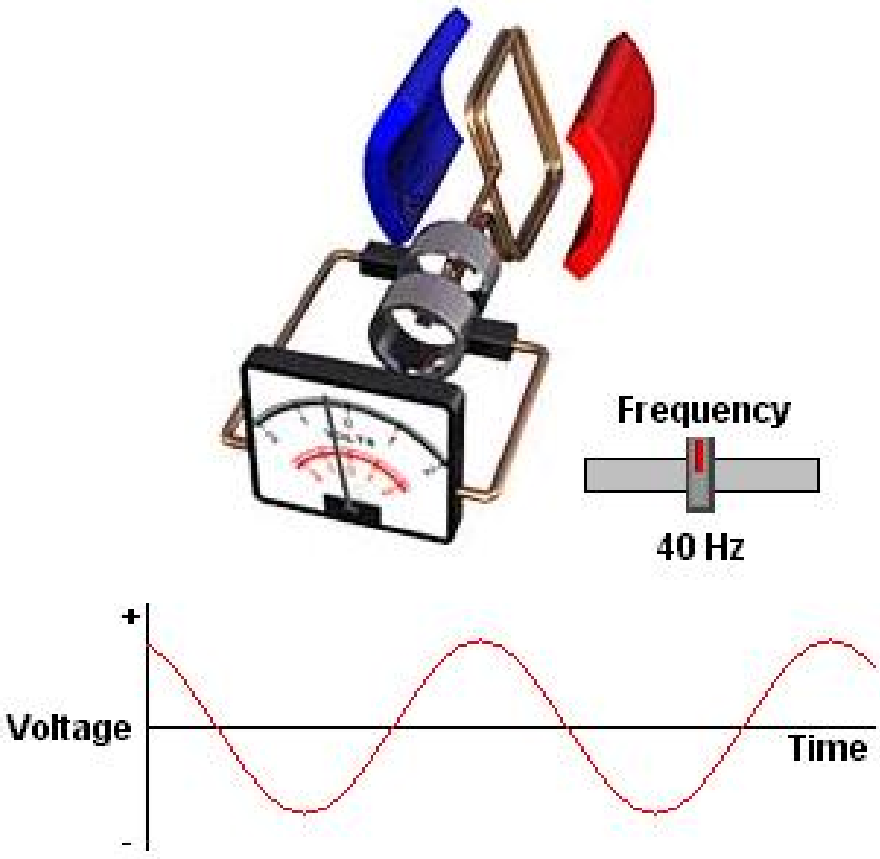


$$V_{R1} = V_A - V_B$$

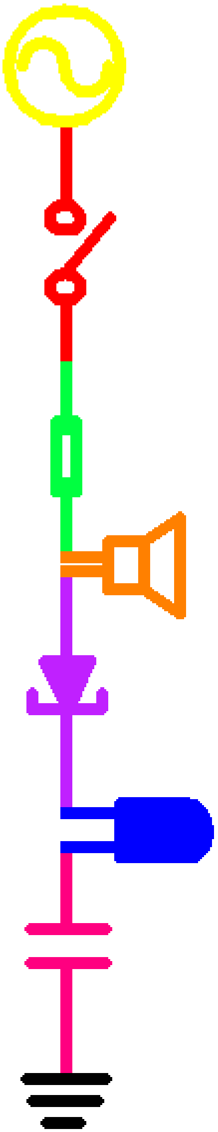
$$V_{R1} = I_{R1} R1$$

Alternating Current Generators



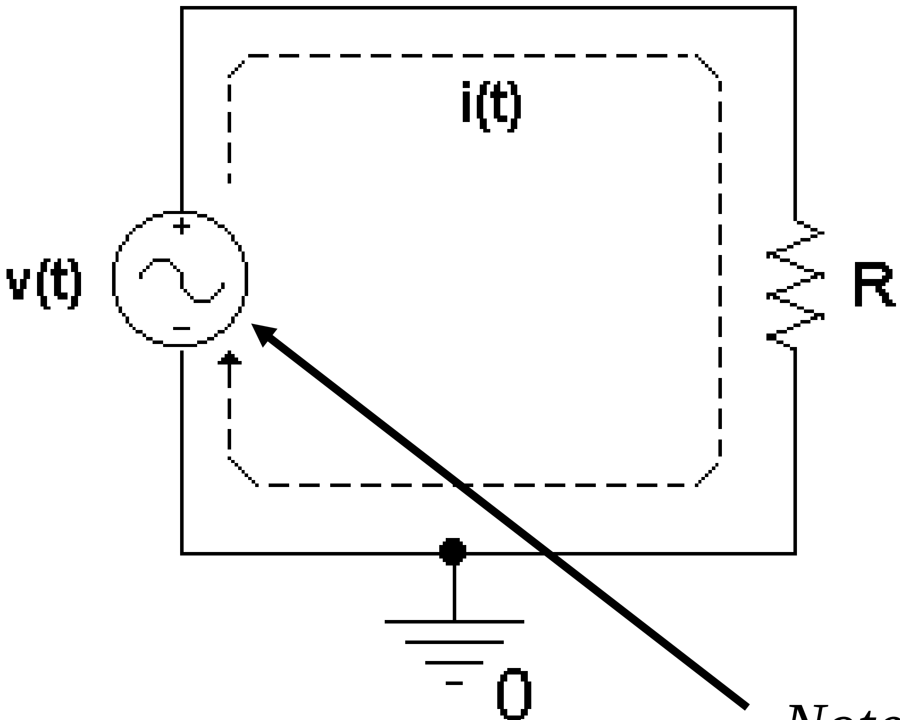


http://micro.magnet.fsu.edu/electromag/java/generator/ac.html



AC Circuits

$$v(t) = i(t) \cdot R$$



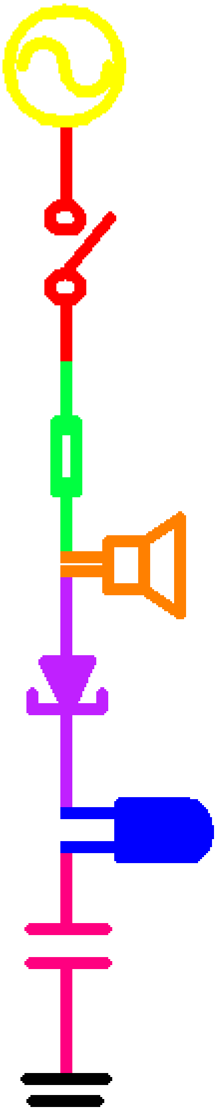
$$v(t) = A \sin(\omega t + \phi)$$

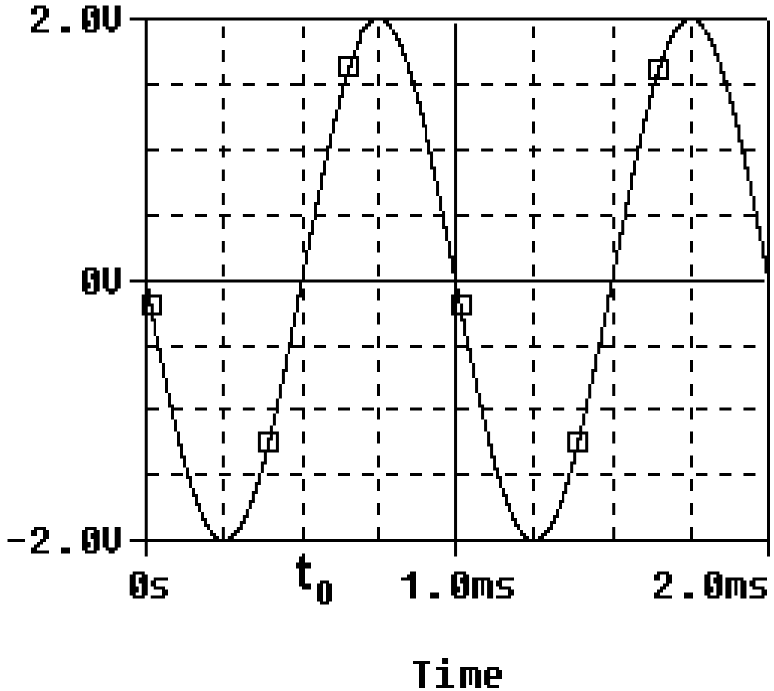
$$i(t) = i_{max} \sin(\omega t + \phi)$$

$$i_{max} = \frac{A}{R}$$

Note symbol for AC voltage source

Review of Sinusoids





$v(t) = A \sin(\omega t + \phi)$

$T = 1.5\text{ms} - 0.5\text{ ms} = 1\text{ms}$

$f = 1/1\text{ms} = 1\text{K Hz}$

$\omega = 2\pi f = 2\text{K}\pi$ rad/sec

$\phi = -\omega t_0 = -2\text{K}\pi\ 0.5 = -\pi$ radians

$\phi = -2\pi$ (1/2 cycle) $= -\pi$ radians

$A = 2\text{V}$

$V_{p\text{-}p} = 4\text{V}$

$V_{ave} = 0\text{V}$

$V_{rms} = \dfrac{A}{\sqrt{2}} = 1.41\text{ V}$

$$(\omega t + \phi) = \omega(t - t_0)$$

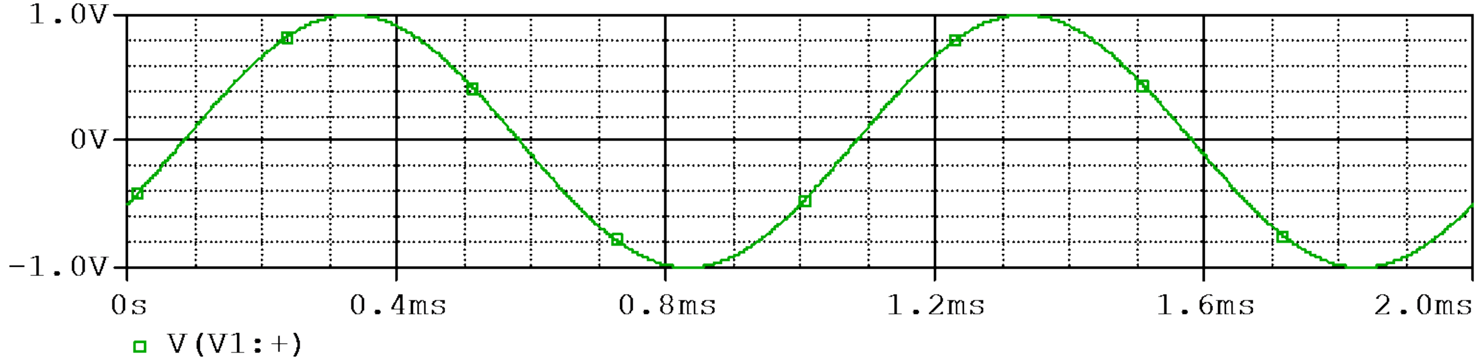
$$\phi = -\omega t_0$$

More on Phase Shift

$$(\omega t + \phi) = \omega(t - t_0)$$

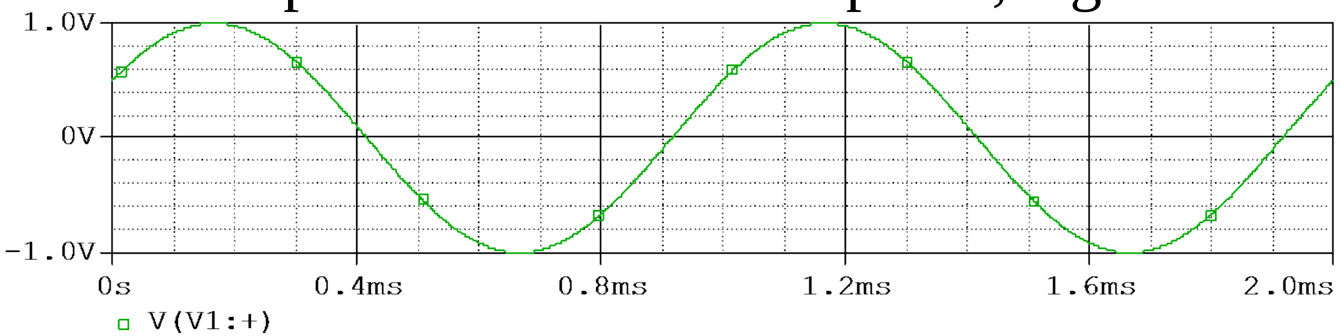
$$\phi = -\omega t_0$$

Negative phase shift: "Lag in phase, lead in time"



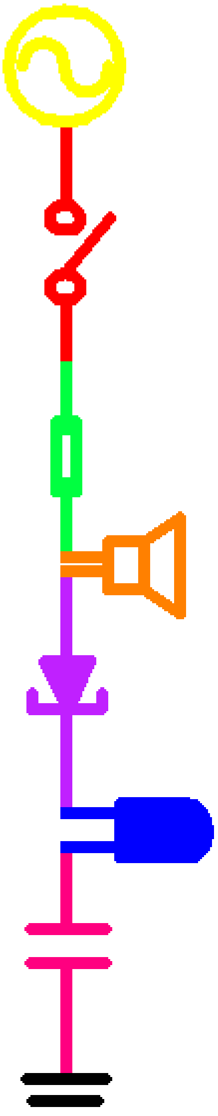
$$t_0 = 0.08ms \quad \omega = 2\pi(1K) \quad \phi = -(0.08m)(2K)(\pi) = -0.5\,rad$$

Positive phase shift: "Lead in phase, lag in time"



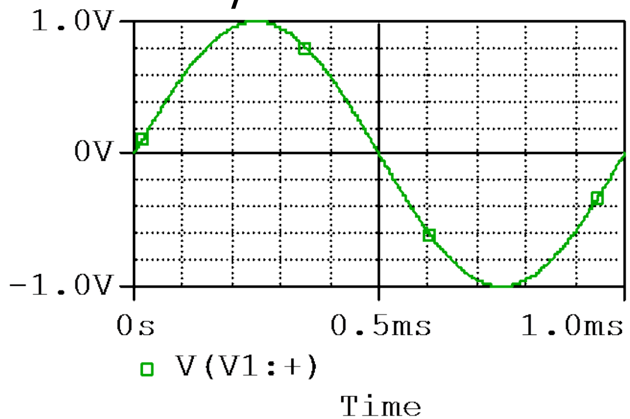
$$t_0 = -0.08ms \quad \omega = 2\pi(1K) \quad \phi = -(-0.08m)(2K)(\pi) = +0.5\,rad$$

Special Cases of Phase Shift

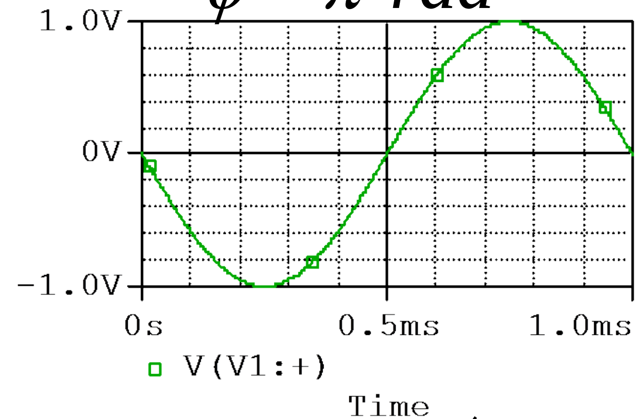


$$\phi = -\omega t_0 = -2\pi f t_0 = -2\pi\left(\frac{t_0}{T}\right)$$

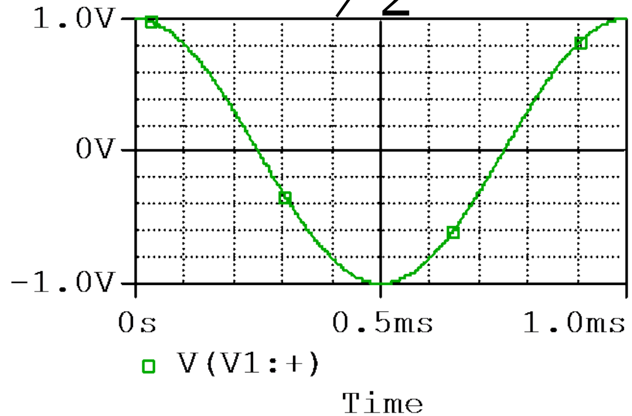
$\phi = 0\, rad$



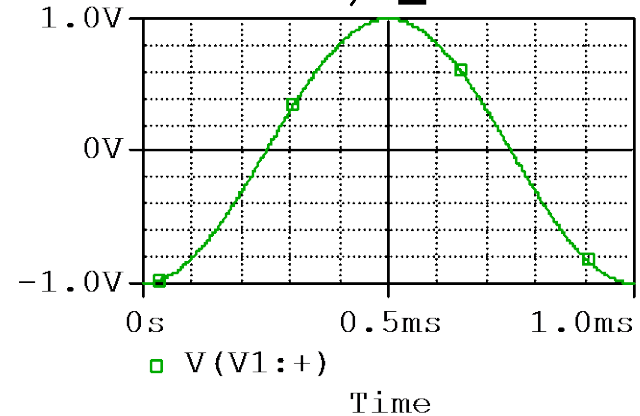
$\phi = \pi\ rad$



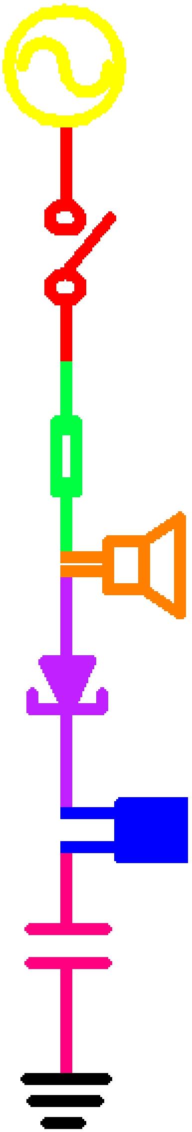
$\phi = +\pi/2\ rad$

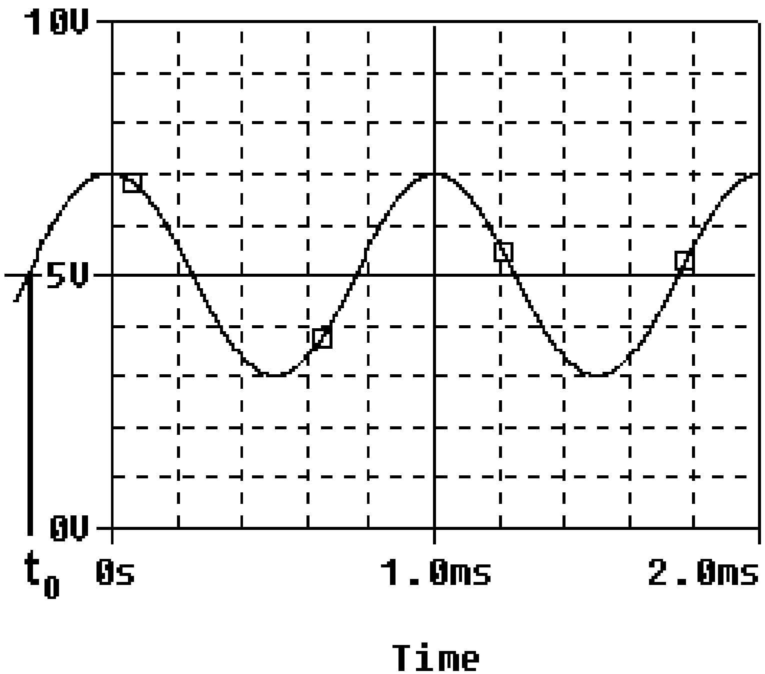


$\phi = -\pi/2\ rad$



General form of the Sinusoid





$v(t) = A \sin(\omega t + \phi) + V_{DC}$

$$(\omega t + \phi) = \omega(t - t_0)$$

$$\phi = -\omega t_0$$

$T = 1.75ms - .75ms = 1ms$

$f = 1/1ms = 1K\ Hz$

$\omega = 2\pi f = 2K\pi$ rad/sec

$\phi = -\omega t_0 = -2K\pi(-.75) = \pi/2$ radians

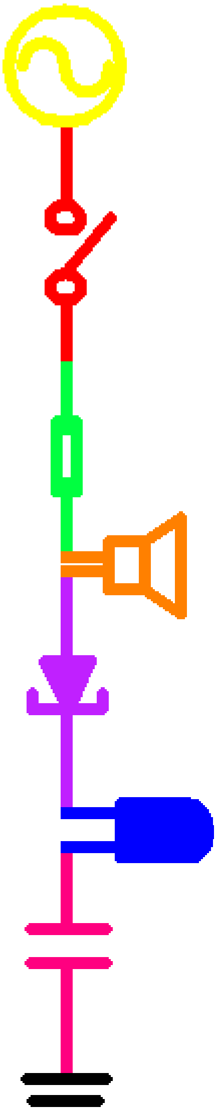
$\phi = -2\pi(-1/4$ cycle$) = \pi/2$ radians

$A = 2V$

$V_{p\text{-}p} = 4V$

$V_{ave} = V_{DC} = 5V$

$$V_{rms} = \frac{A}{\sqrt{2}} = 1.414\ V$$

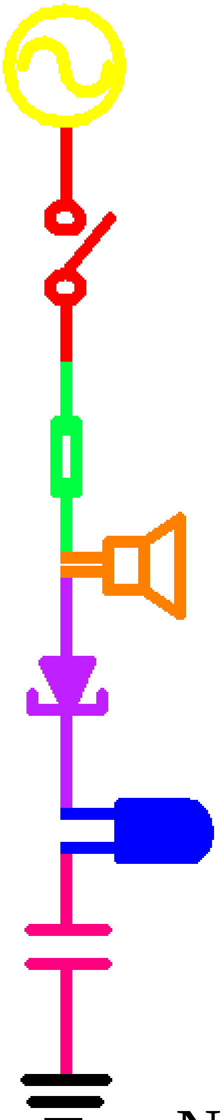


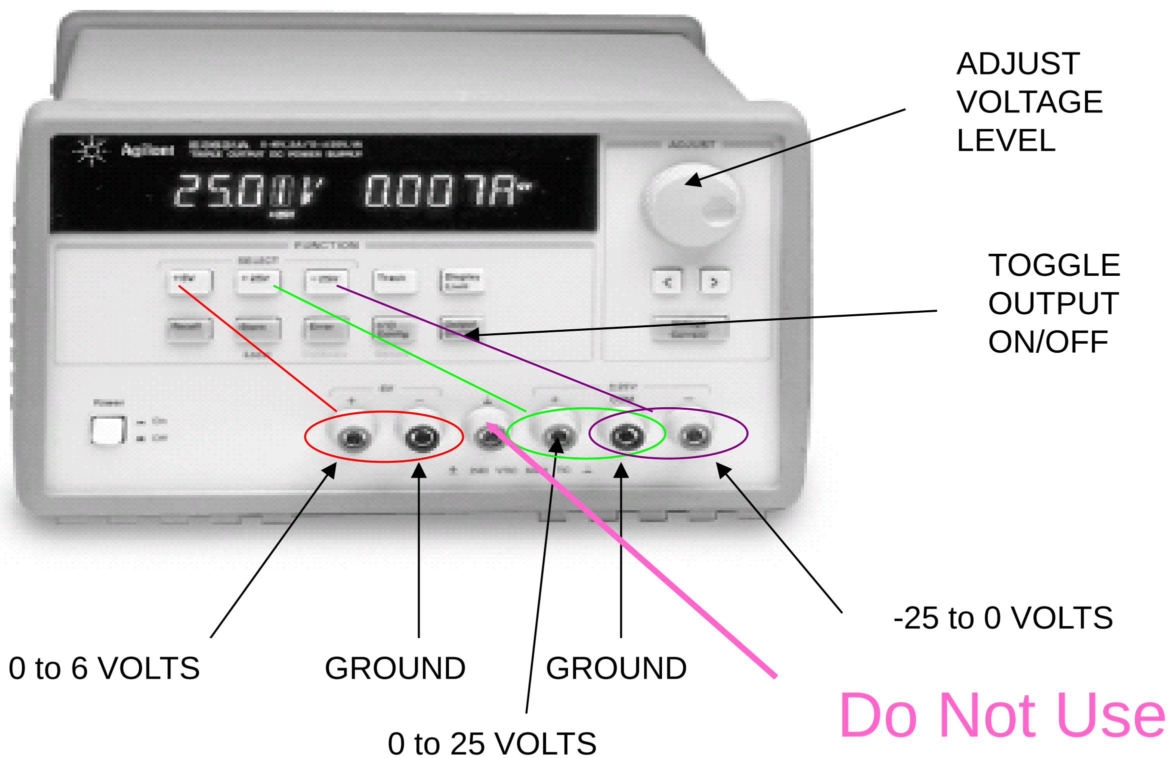
Sinusoid Units

	symbol	units
amplitude	A	volts (V) or amps (A)
frequency	f	1/sec = Hertz (Hz)
period	T	seconds (s)
phase	ϕ	radians (rad)
angular frequency	ω	rad/s

Note: In physics, ω is called angular velocity.

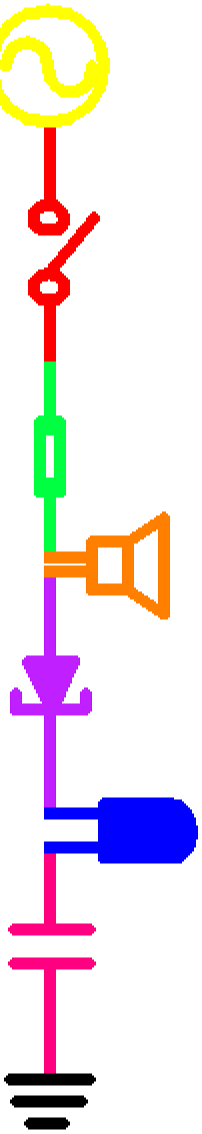
DC Source E3631A – Only for section 2



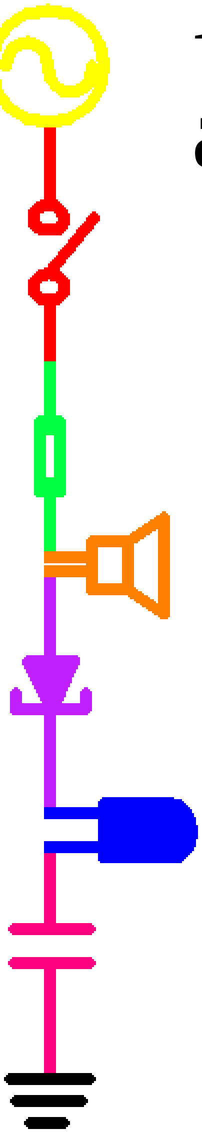


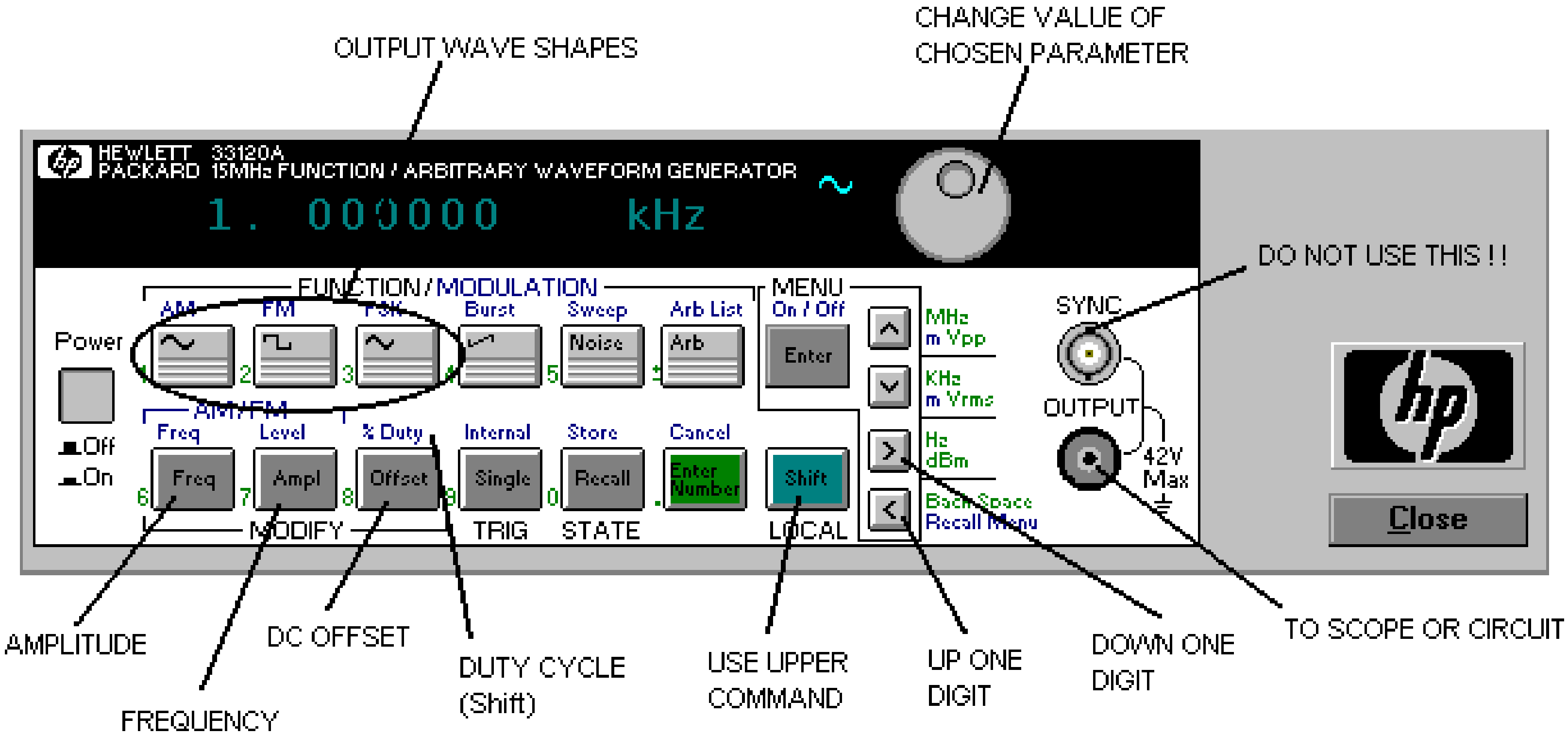
Note: The connection that looks like the ground symbol is the ground for the building, not the return path for the circuit.

DC Source for section 1

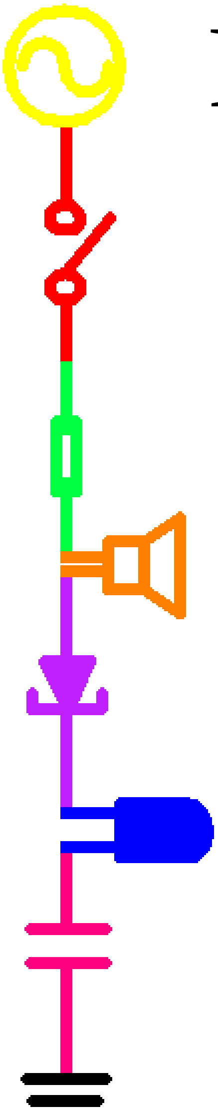


Function Generator 33120A – Only available in JEC 4107

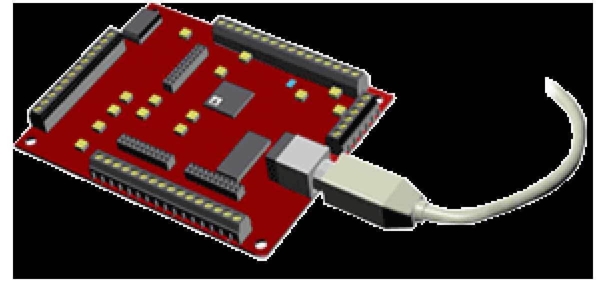


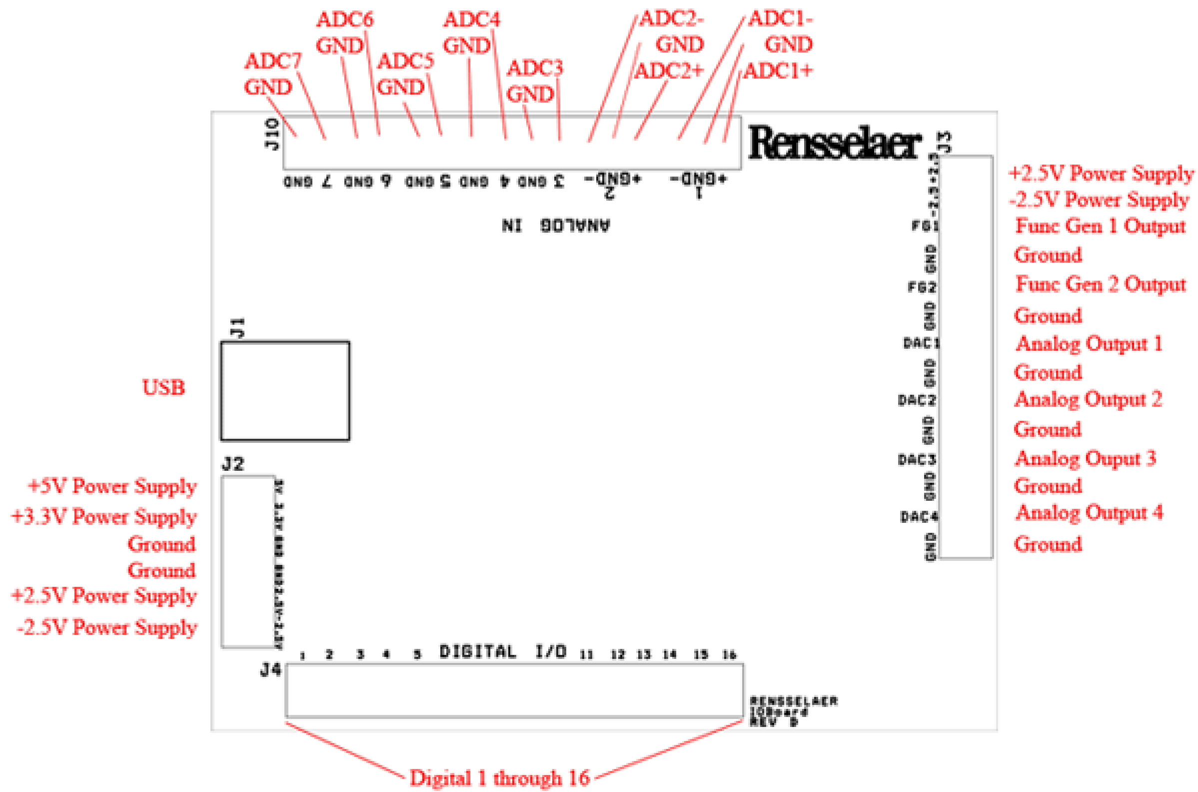


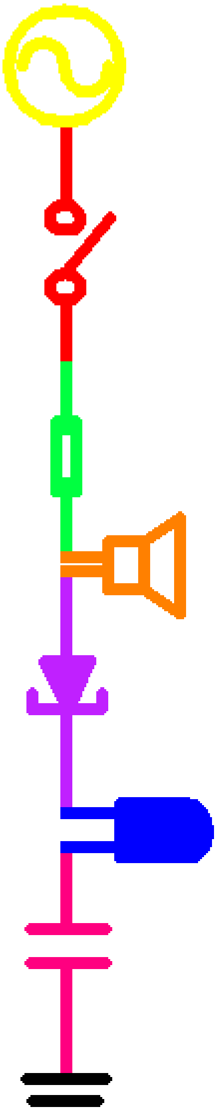
Note: The SYNC connection will give you a signal, but it will not be the one you have set the function generator to display. Do not accidentally plug into it.



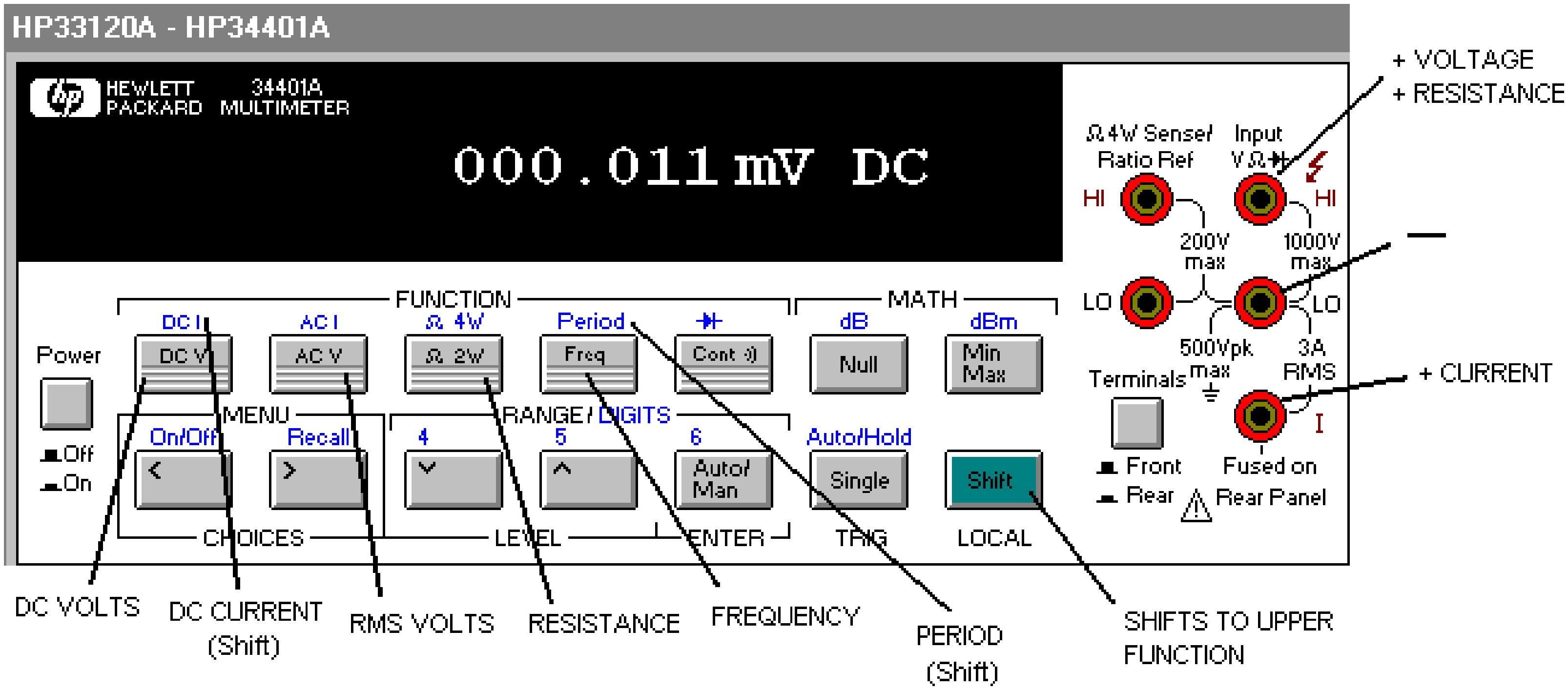
Function Generator



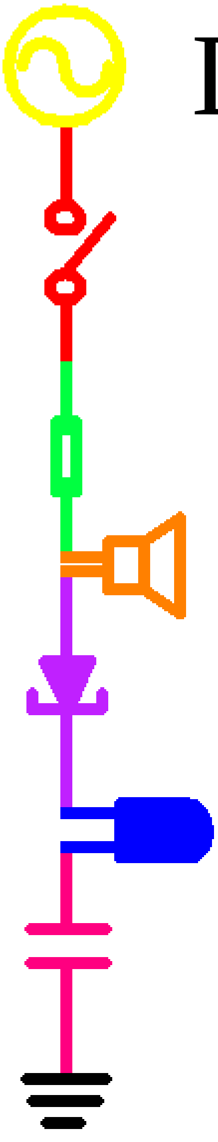




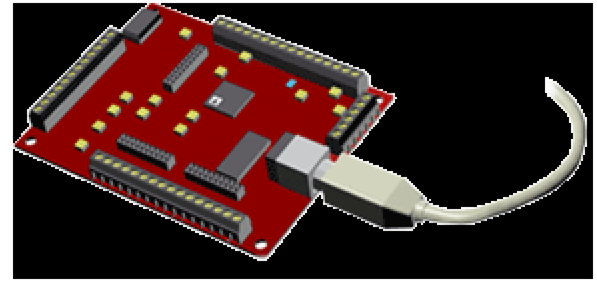
Digital Multimeter 34401A – We will have some hand held meters in section 1 for resistance measurements

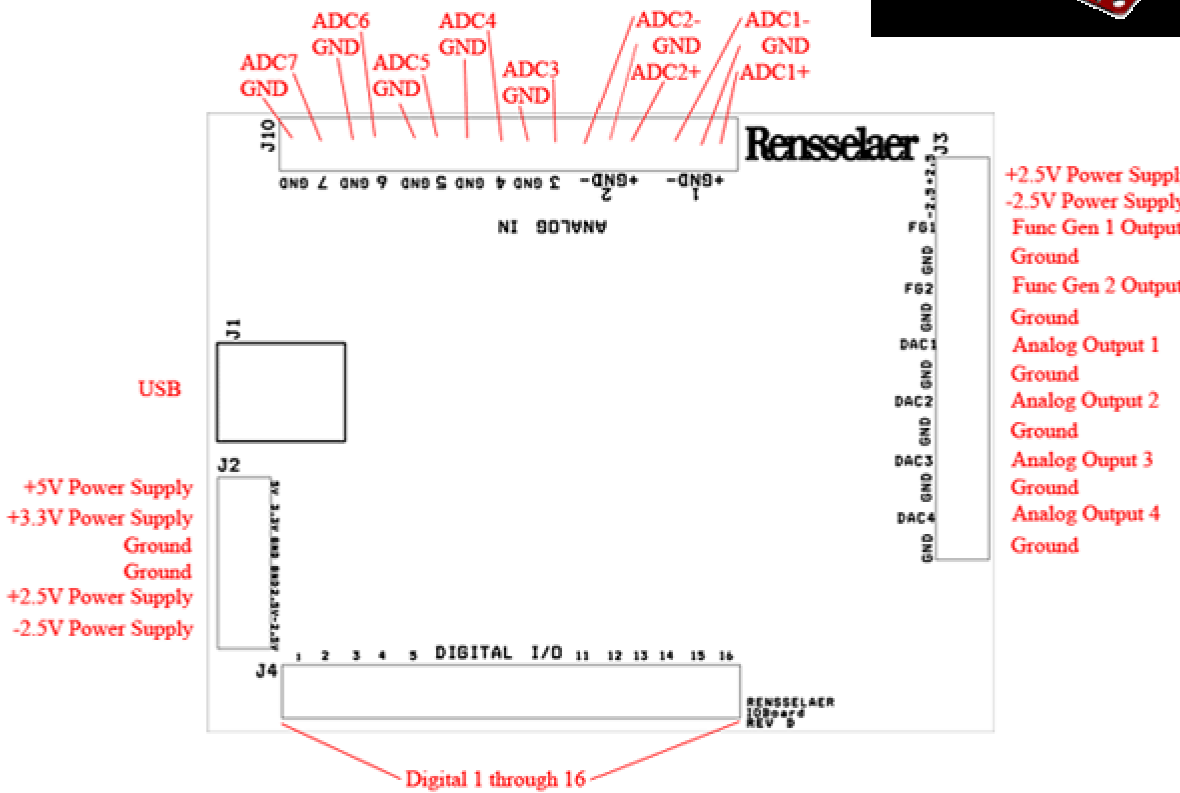


Note: Always use the voltage plugs on the right as indicated.



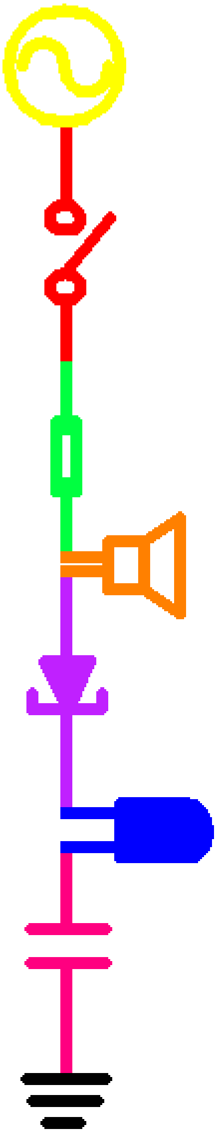
Digital Multimeter

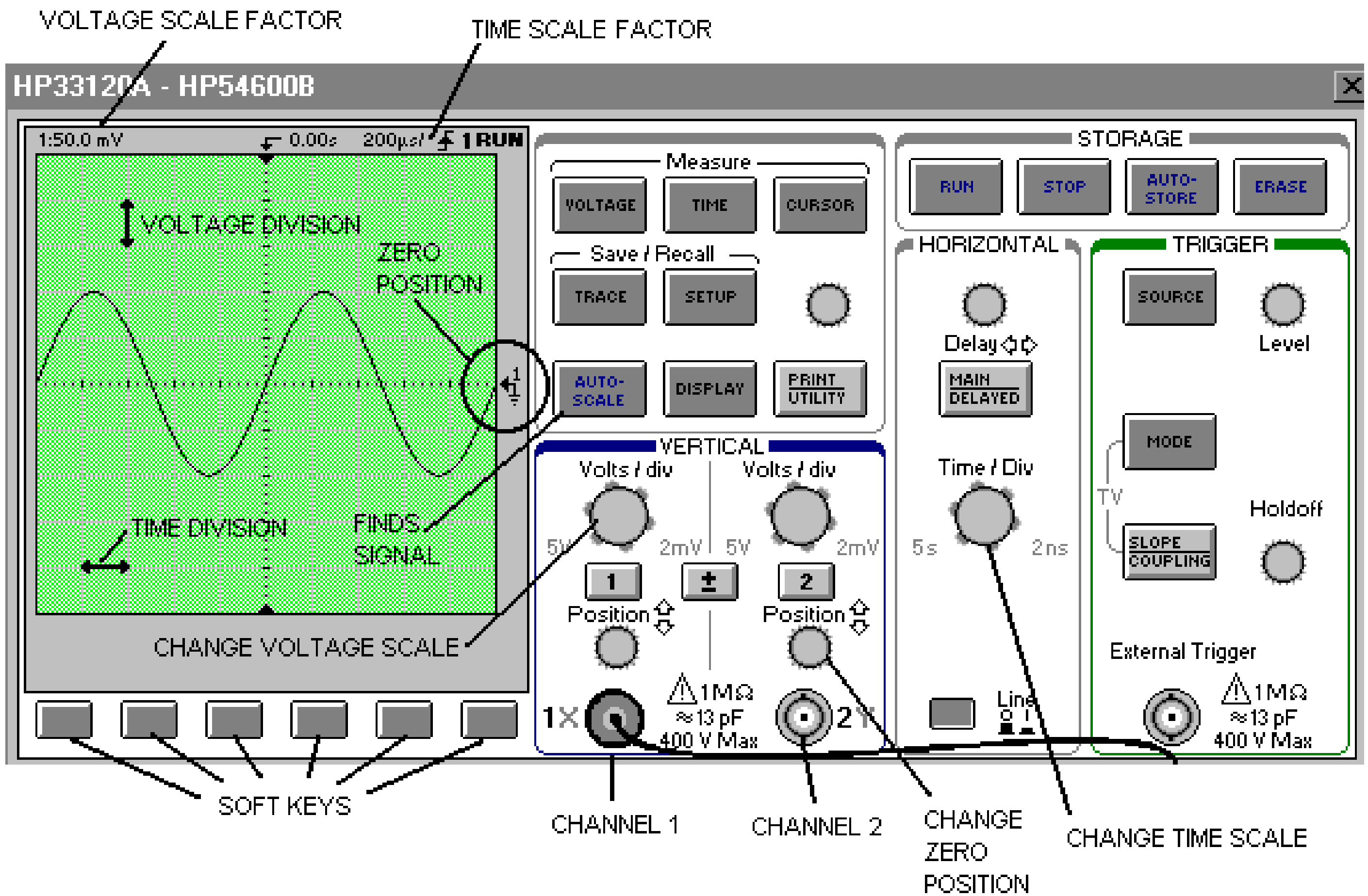




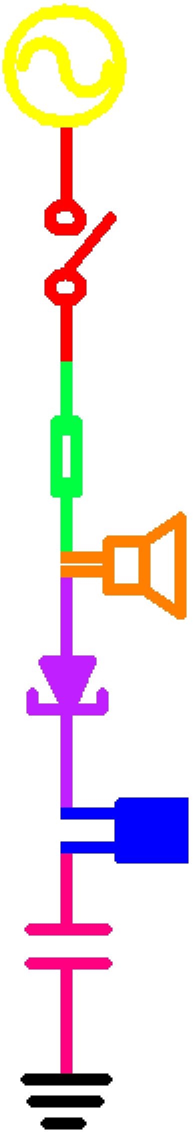
The IOBoard can read voltages but it isn't an Ohmmeter, We will use hand held meters for resistance measurements

Oscilloscope 54600B – you guessed it – JEC 4107

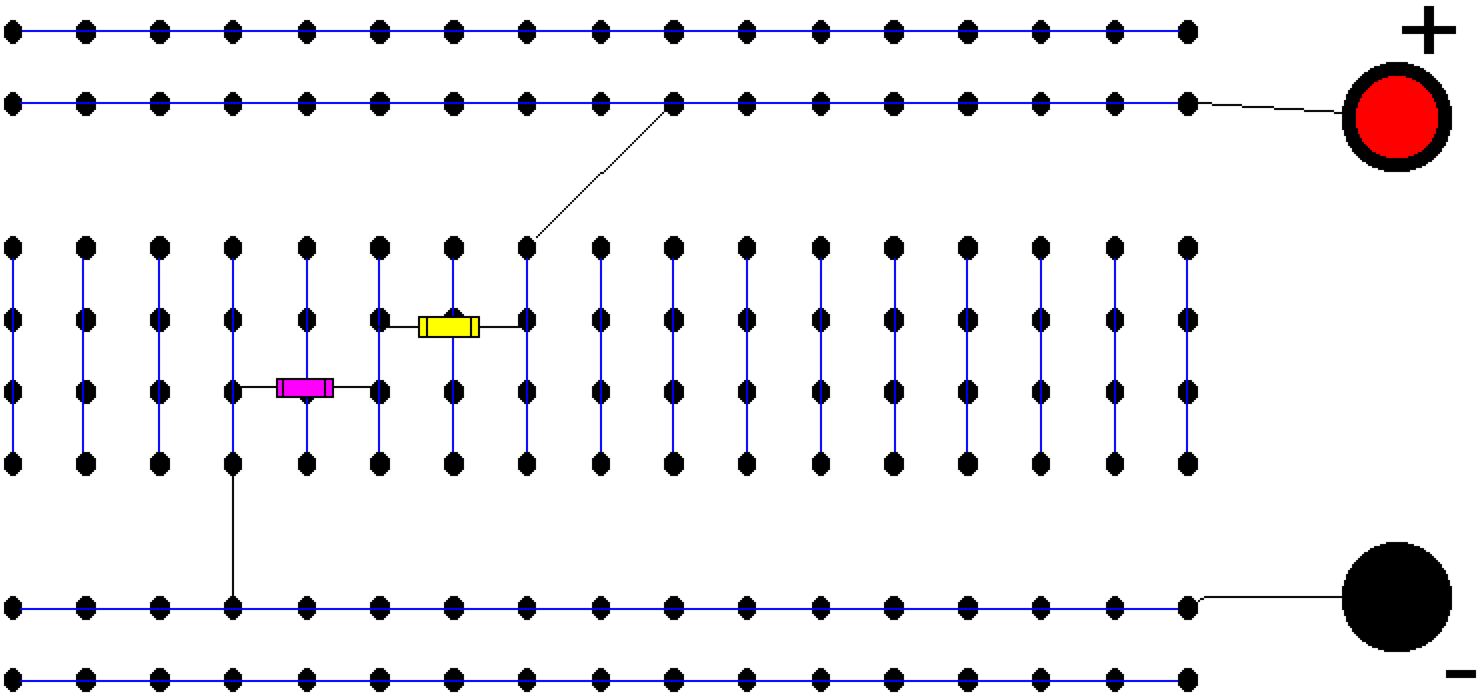




Note: Black lead of scope channel is ALWAYS ground

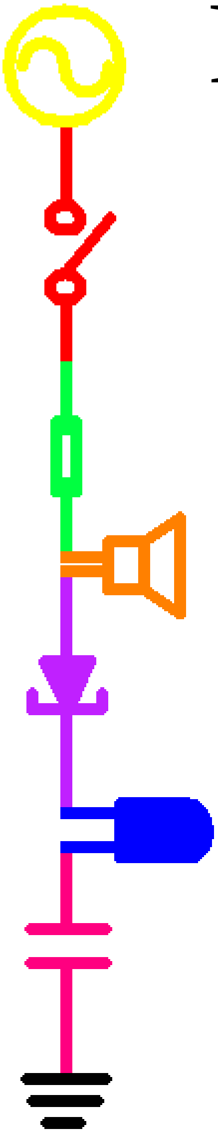


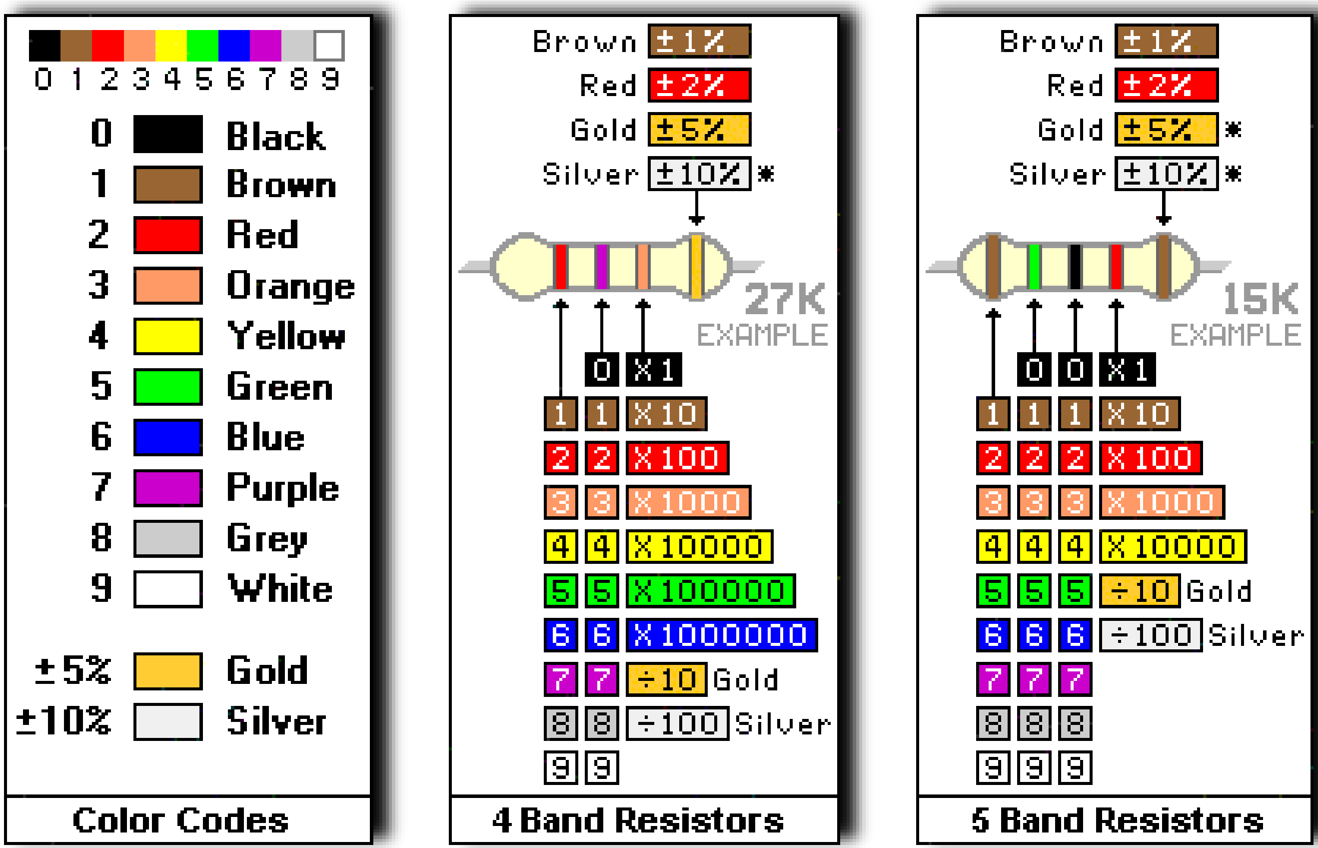
Protoboards



Note: Banana connectors are not connected internally to the holes in the board.

Reading Resistors

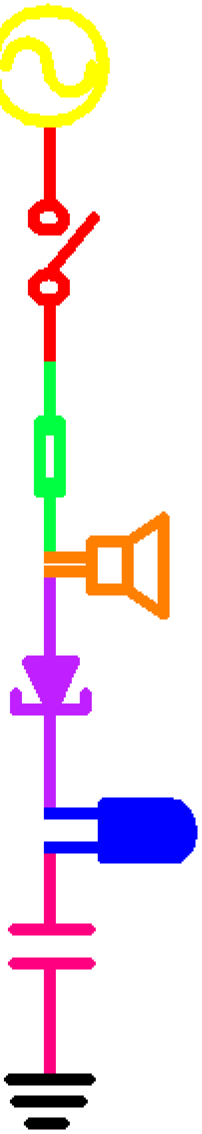


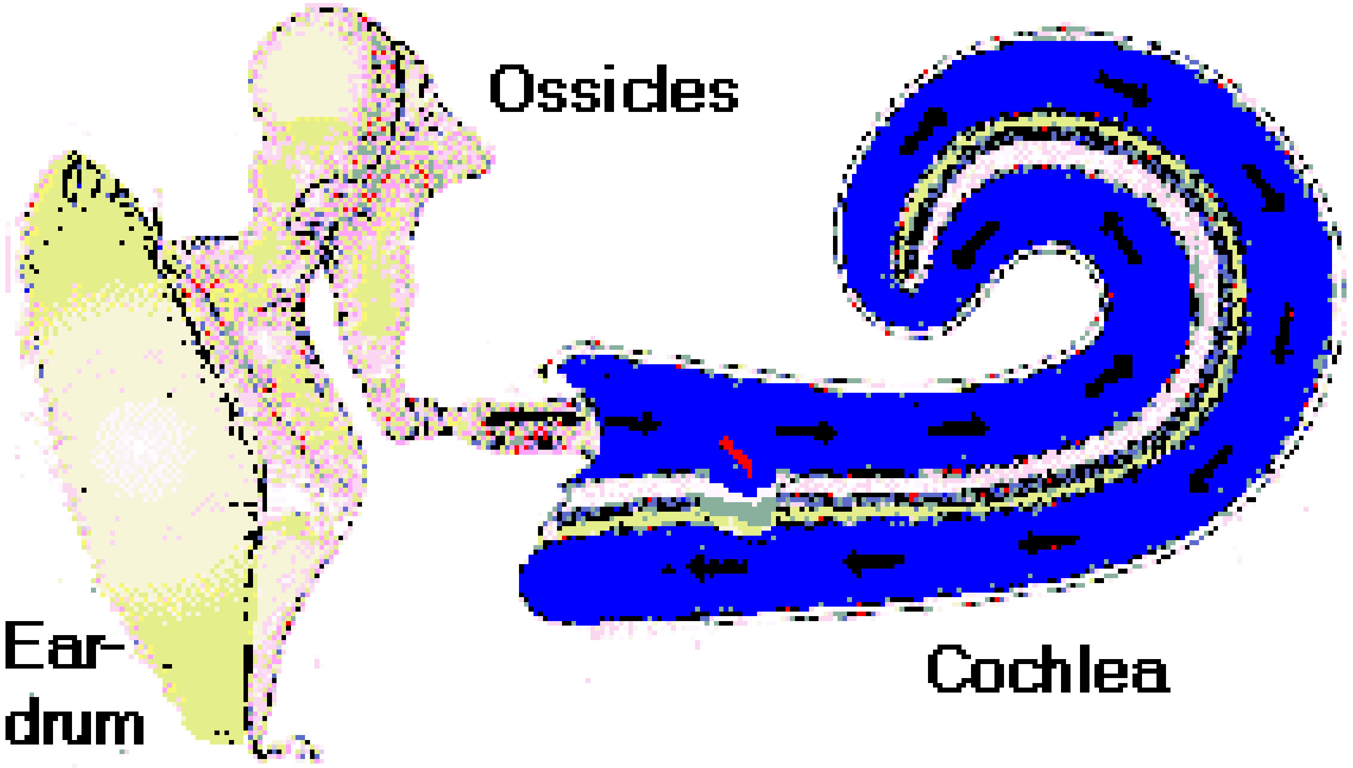


Bands: XYZT Resistance = $XY \times 10^{Z} \pm T\% \, \Omega$

http://www.dannyg.com/javascript/res/resload.htm

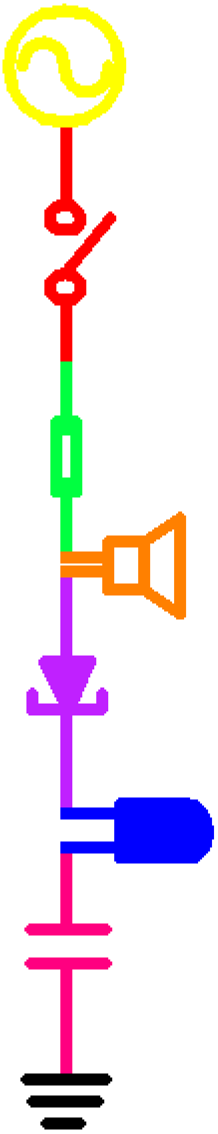
How Ears Work





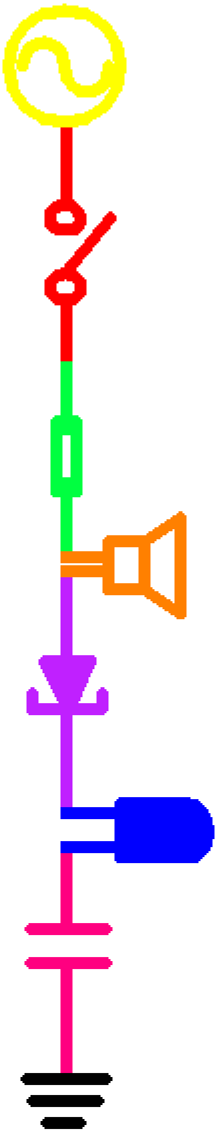
Pitch = frequency Amplitude = loudness
Some pitches sound louder to your ears.

http://members.aol.com/tonyjeffs/text/dia.htm



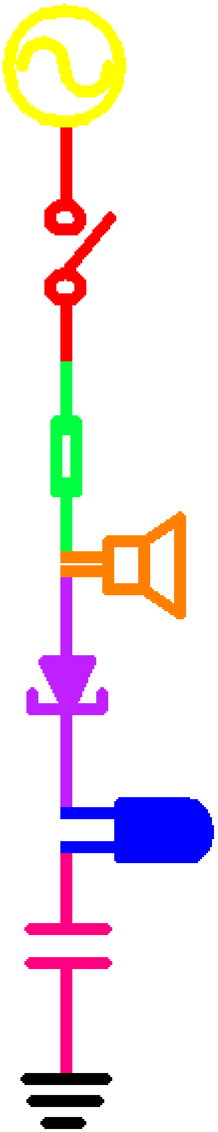
Part A – Do the lab now

- Use your kit if you purchased one, purchase one if you haven't
- Some of Part A can be done without the kit, just with the IOBoard
- If you don't have a kit
  - Make sure that you have the software loaded and that the IOBoard is working
  - We have some spare protoboards and speakers
  - There will be time during the next 2 classes to catch up
- Next class we start Part B of Experiment 1
- Any questions?

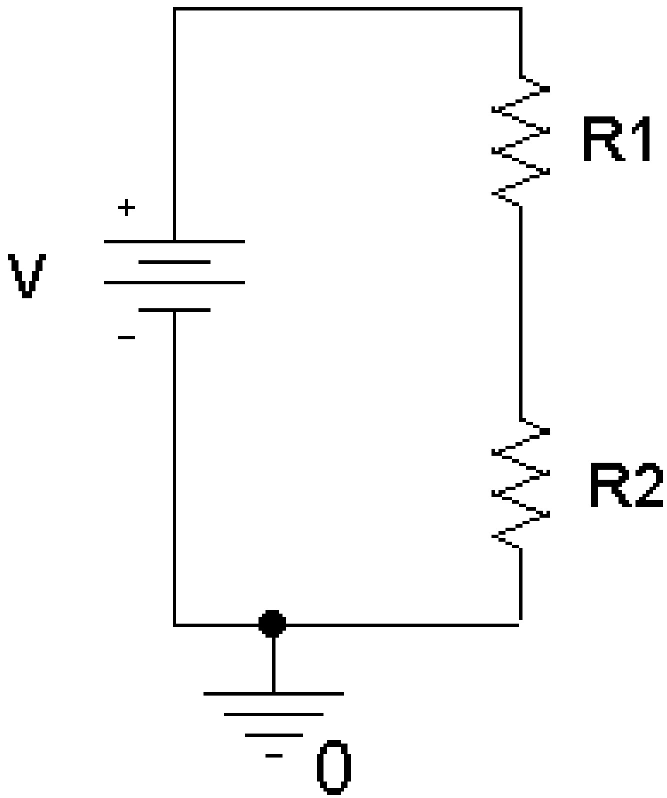


Part B

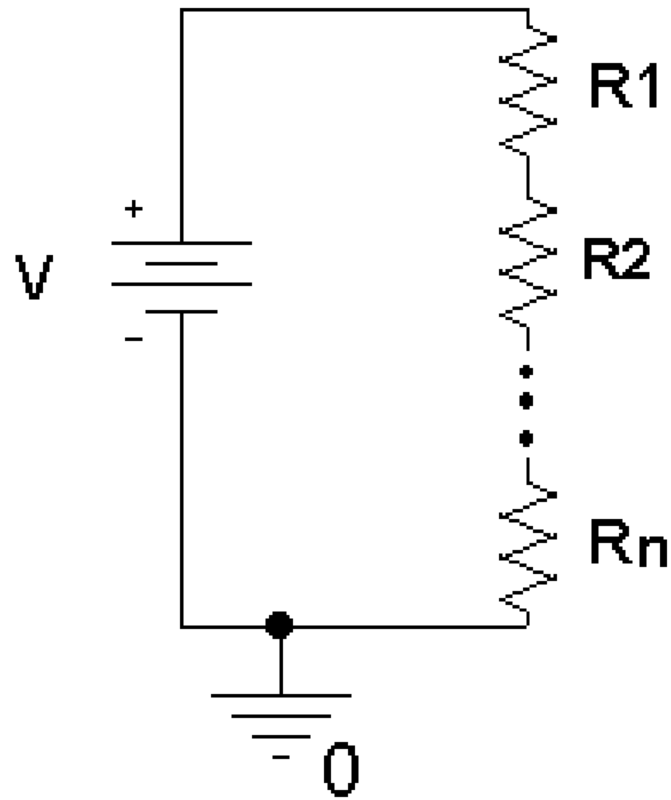
- Resistors
- Voltage Dividers
- Impedance
- Capacitors and Inductors
- Equipment Impedances
- Circuit Analysis
- Agilent Intuilink Software



Combining Resistors in Series

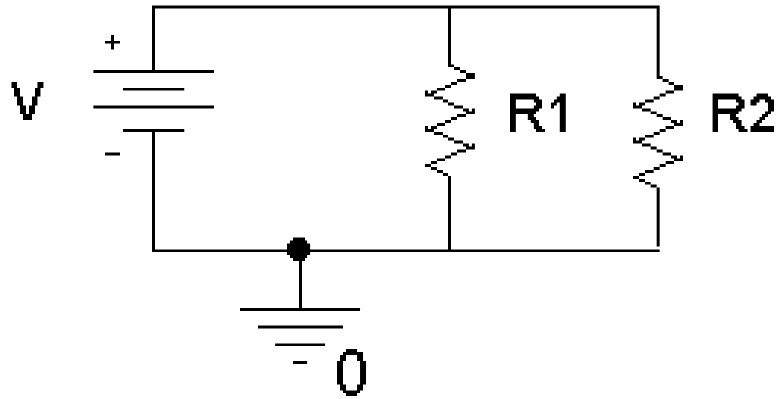


$$RT = R1 + R2$$



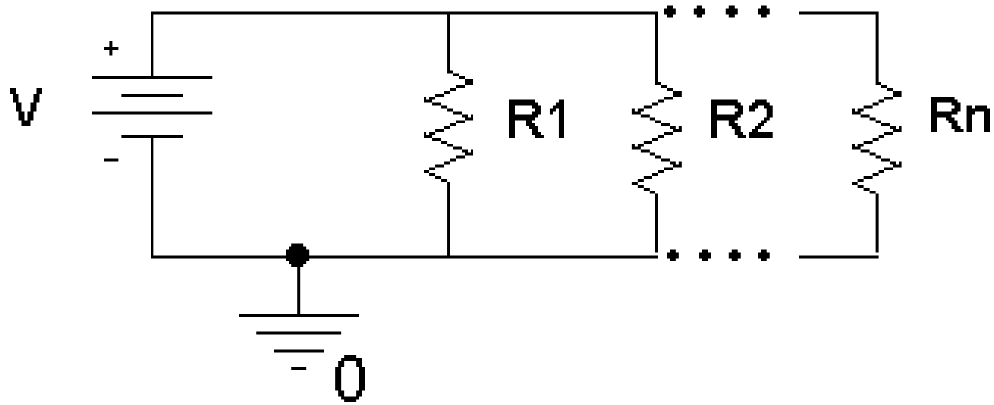
$$RT = R1 + R2 + ... + Rn$$

Combining Resistors in Parallel



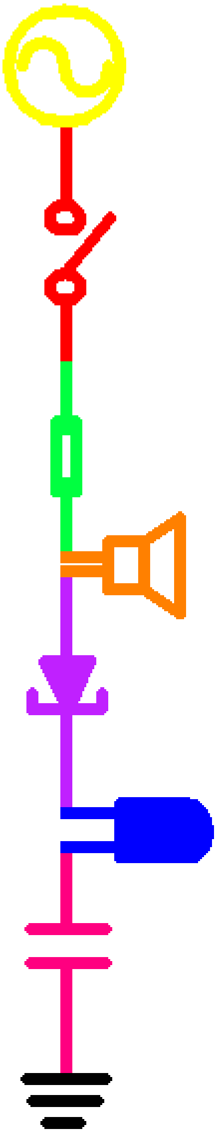
$$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2}$$

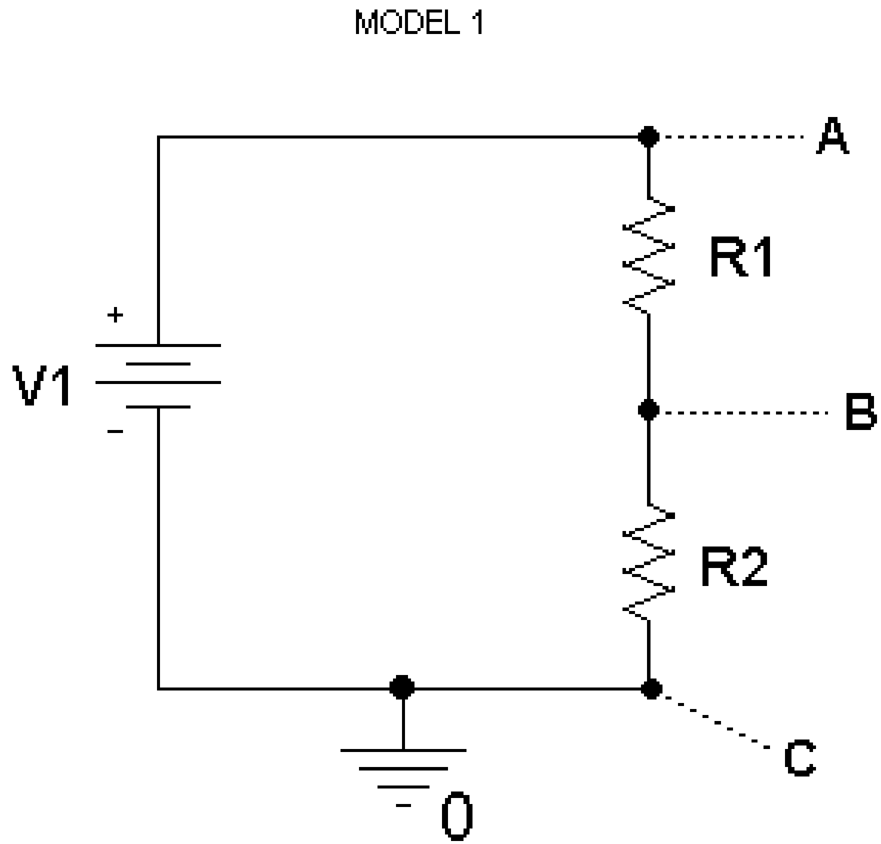
$$RT = \frac{R1 \cdot R2}{R1 + R2}$$

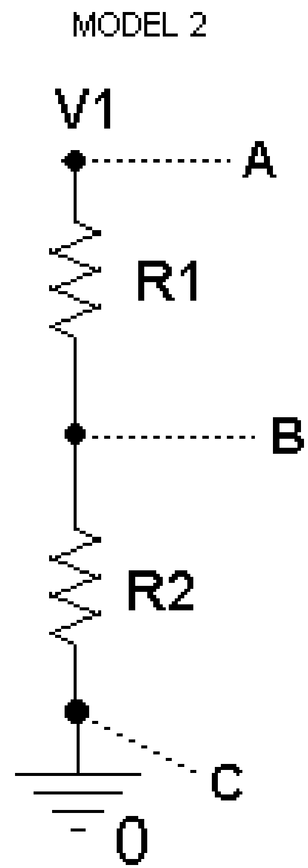


$$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \cdots + \frac{1}{Rn}$$

Measuring Voltage





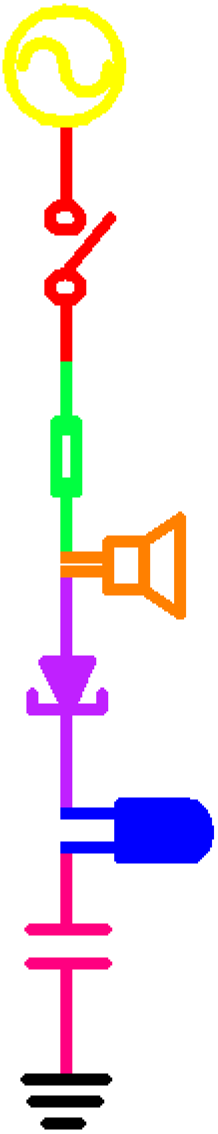


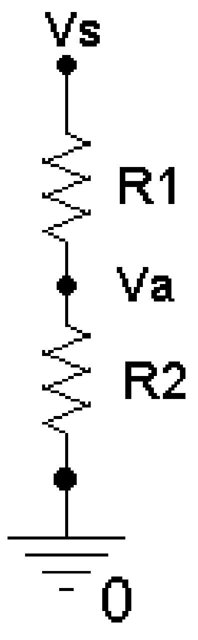
Total Voltage: $V1 = V_{R1} + V_{R2}$

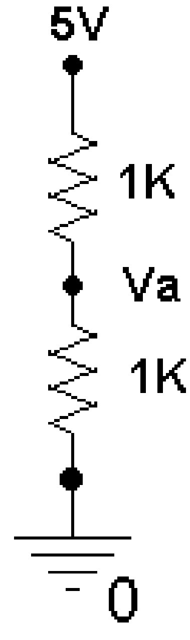
Voltage across resistors: $V_{R1} = V_A - V_B \quad V_{R2} = V_B - V_C$

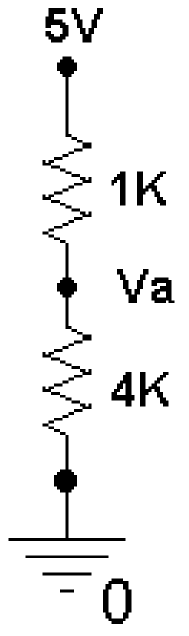
Voltage at points wrt GND: $V_A = V1 \quad V_B = V_{R2} \quad V_C = 0$

Voltage Dividers









$$Va = \frac{R2}{R1+R2} Vs$$

$$V_{R2} = Va$$

$$V_{R1} = \frac{R1}{R1+R2} Vs$$

$$Va = \frac{1K}{1K+1K} 5V$$

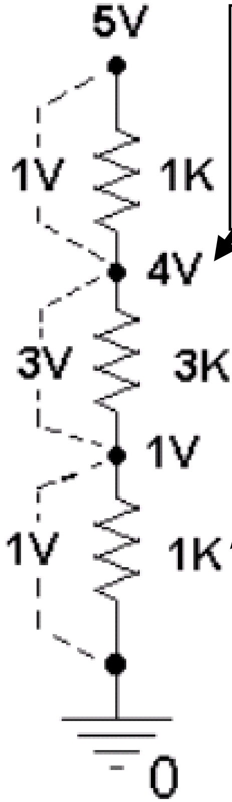
$$Va = 2.5V$$

$$Va = \frac{4K}{1K+4K} 5V$$

$$Va = 4V$$

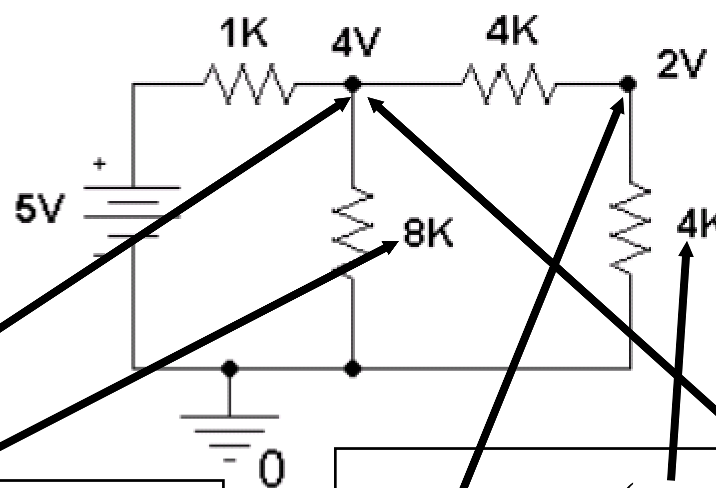
The voltage is divided up in a manner that is proportional to the resistances of the resistors in a series circuit.

More on Voltage Dividers



$$4V = \frac{(3K+1K)}{1K+3K+1K}(5V)$$

Always add up resistors relative to ground to get the voltage at a point.

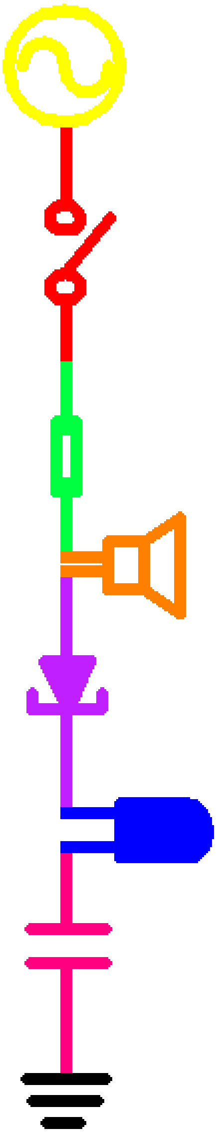


$$4V \neq \frac{(8K)}{1K+8K}(5V)$$

You cannot use a voltage divider on a non-series circuit.

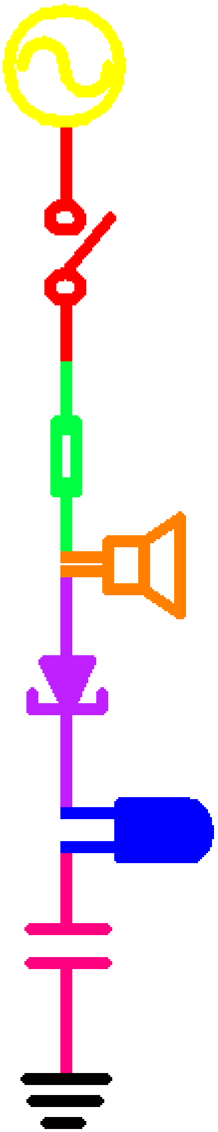
$$2V = \frac{(4K)}{4K+4K}(4V)$$

You can use a voltage divider on a series portion of a circuit.



Impedance vs. Resistance

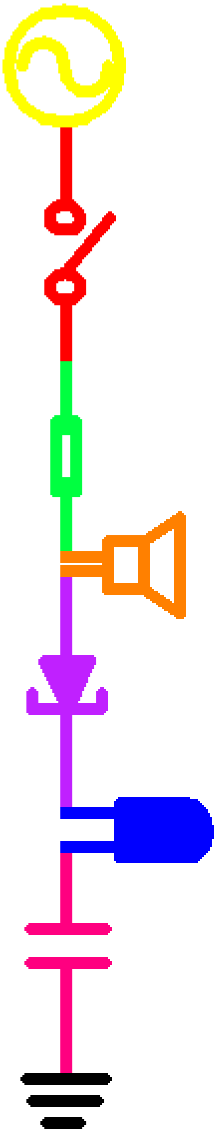
- Resistance is a property of a material that causes a reduction in the rate of flow of electrons.
- Impedance is the reduction in the rate of flow of electrons caused by the material (resistance) AND other the properties of the component involved (reactance).
- Resistors have no reactance. So the impedance of a resistor is equal to its resistance only.
- Reactance varies with the frequency of the input. Resistance remains the same at all frequencies.
- Both impedance and resistance are measured in ohms.

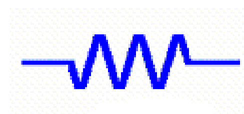


Impedance

- Definition: A general measure of how a component or group of components pushes against the current flowing through it.
- Impedance = resistance + reactance
- Impedance is used to refer to the behavior of circuits with resistors, capacitors and other components.
- When we consider components in a theoretical circuit diagram, the impedance of inductors and capacitors is their reactance only. Any resistance is modeled separately as a resistor. So theoretical capacitors and inductors have impedance, but no resistance.

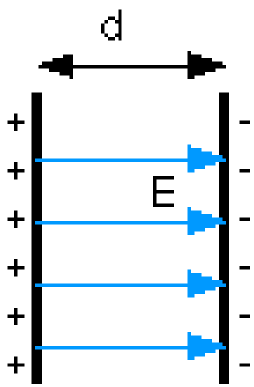
Comparison of Components



	resistor	capacitor	inductor
symbol	R		
equation	$V = IR$		
icon			
series	$R_T = R_1 + R_2$		
parallel	$R_T^{-1} = R_1^{-1} + R_2^{-1}$		
low freq	R		
high freq	R		

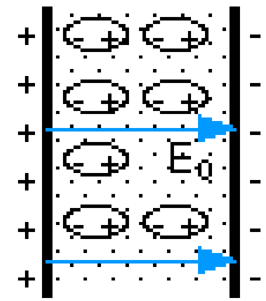
Capacitors

Capacitors consist of two plates with a dielectric material in-between. When a potential difference is placed across the plates, a charge builds up until it is large enough to cause a discharge across the plates through the material.

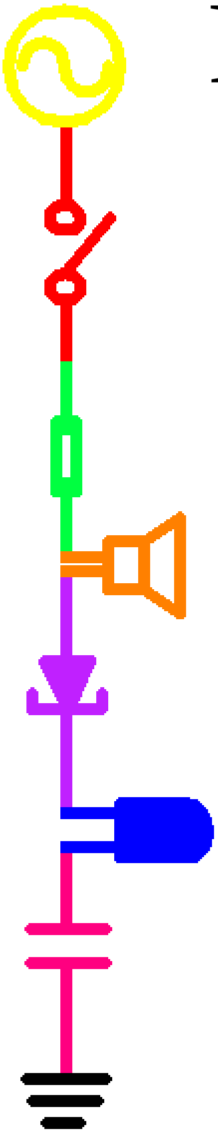


A parallel-plate capacitor with no dielectric between the plates, resulting in a large electric field.

The charge is the same in both cases.

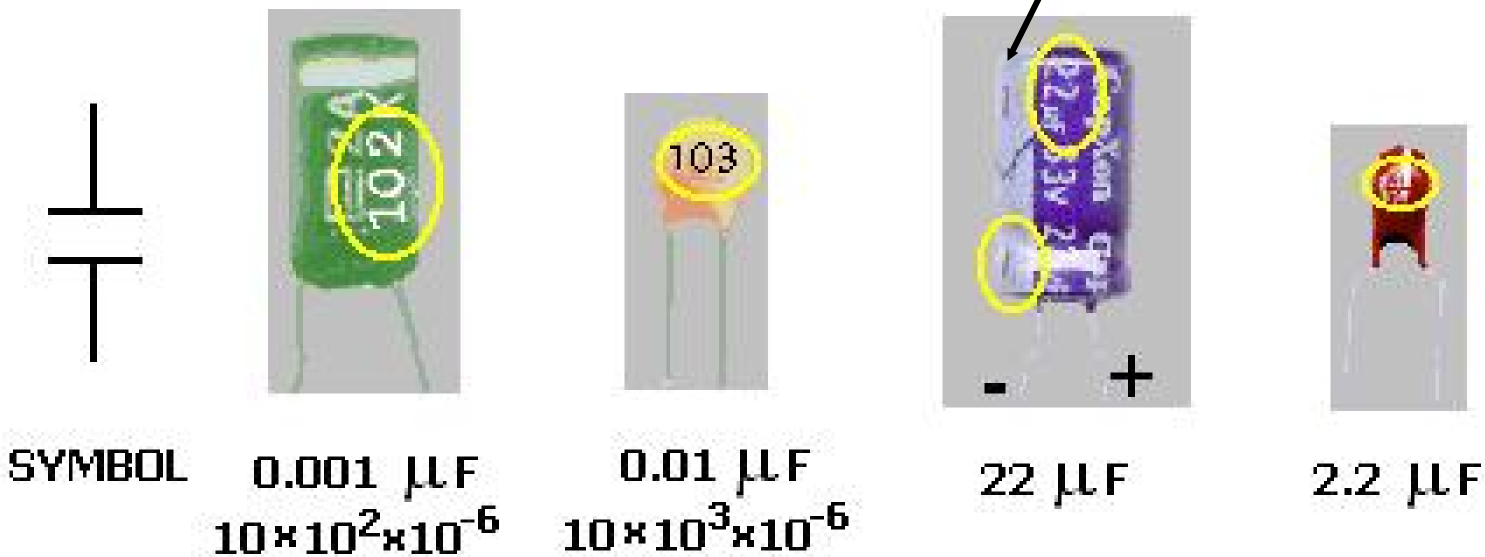


A parallel-plate capacitor with a dielectric. The electric field is reduced between the plates because the dielectric material is polarized, producing an opposing field.



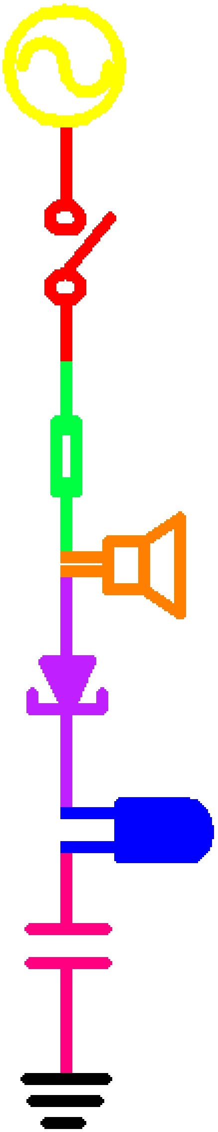
Reading Capacitors

- towards ground

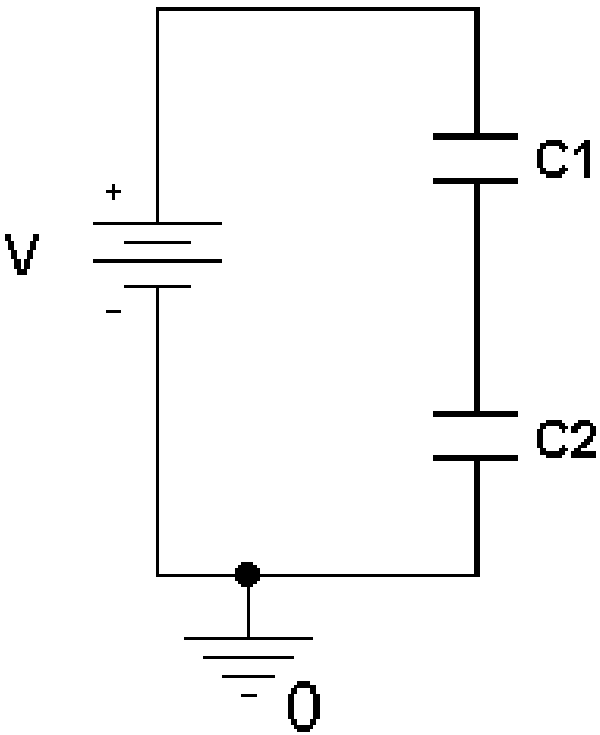


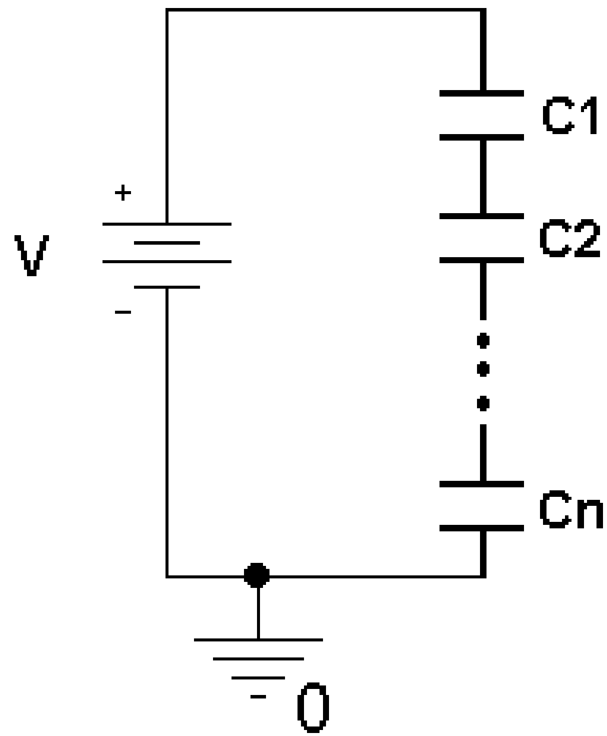
Larger capacitors have the number of microfarads written on them directly. Smaller capacitors use a code based on the number of picofarads. We generally use microfarads, so…

$$XYZ = XY * 10^{Z} * 10^{-6}\ \mu F$$



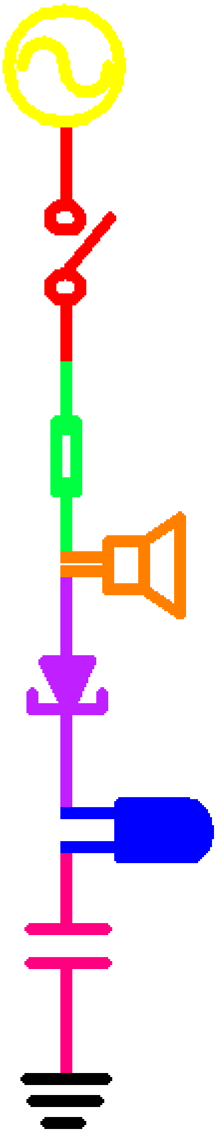
Capacitors in Series



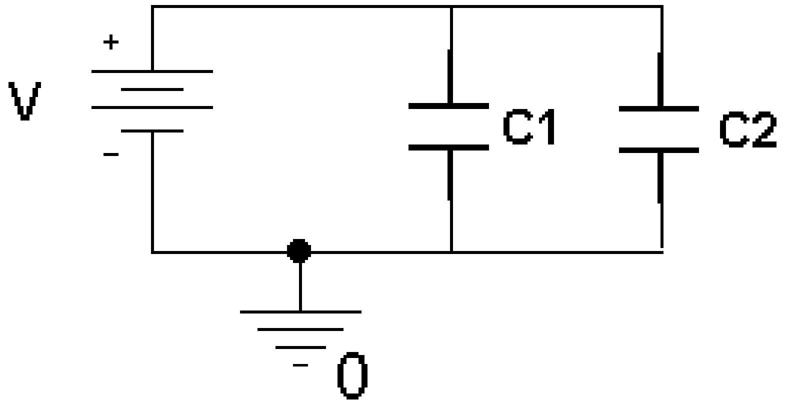


$$\frac{1}{CT} = \frac{1}{C1} + \frac{1}{C2} \qquad CT = \frac{C1 \cdot C2}{C1 + C2}$$

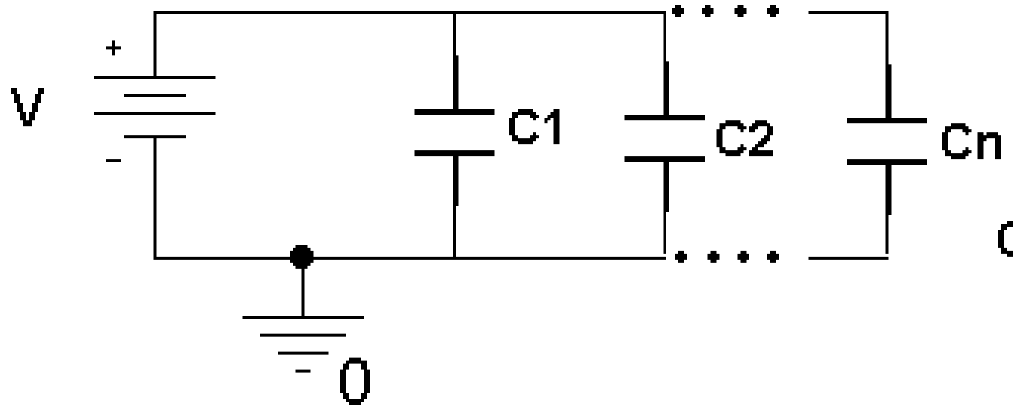
$$\frac{1}{CT} = \frac{1}{C1} + \frac{1}{C2} + \cdot \cdot \cdot + \frac{1}{Cn}$$



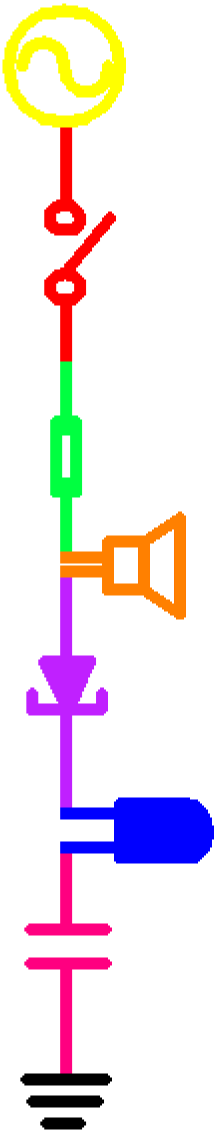
Capacitors in Parallel



CT = C1 + C2



CT = C1 + C2 + • • • + Cn



Understanding Capacitor Behavior

$$I_C = C\frac{dV_C}{dt}$$

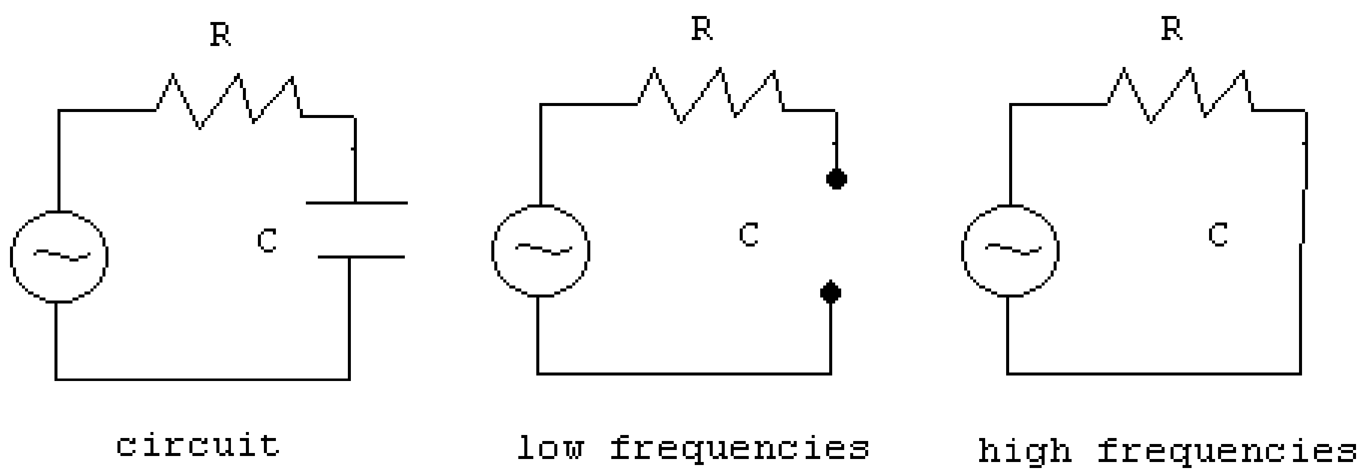
General Equation

$$I_C = C\frac{V_1 - V_0}{t_1 - t_0}$$

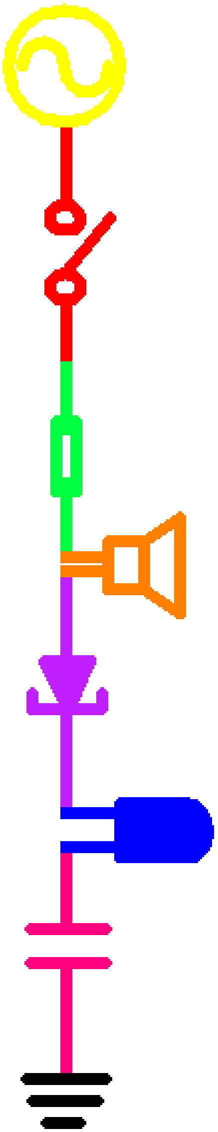
If voltage change
is linear.

Capacitor Impedance

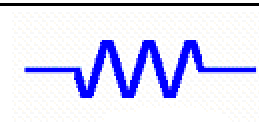
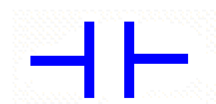
frequency	frequency approaches	impedance approaches	looks like	called
low	-->0	-->infinity	---● ●----	open circuit
high	-->infinity	-->0	-------------	short



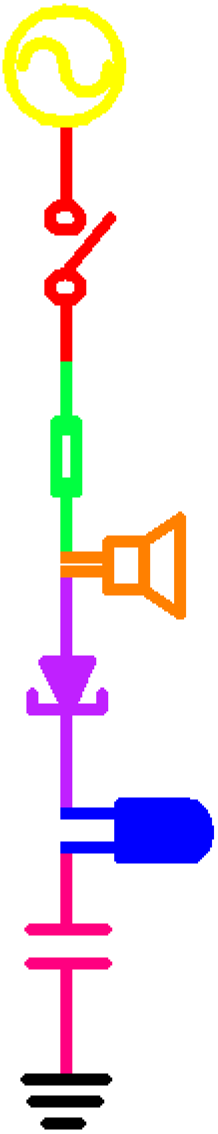
Note: Real capacitors have effectively no resistance, so impedance is reactance for all capacitors.

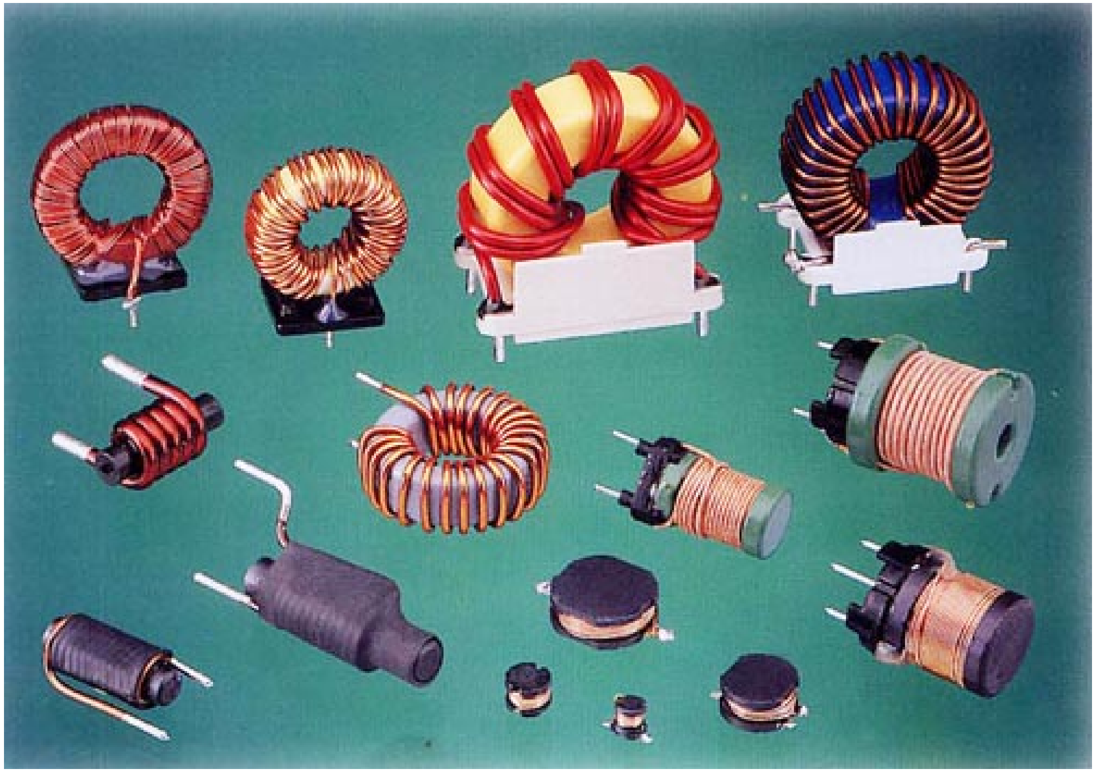


Comparison of Components

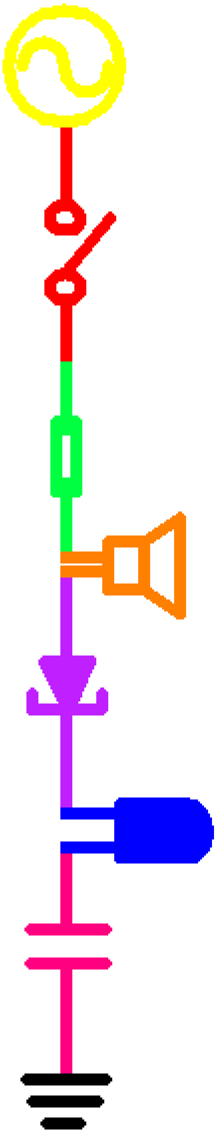
	resistor	capacitor	inductor
symbol	R	C	
equation	$V_R = I_R R$	$I_C = C\frac{dV_C}{dt}$	
icon			
series	$R_T = R_1 + R_2$	$C_T^{-1} = C_1^{-1} + C_2^{-1}$	
parallel	$R_T^{-1} = R_1^{-1} + R_2^{-1}$	$C_T = C_1 + C_2$	
low freq	R	*open circuit*	
high freq	R	*short circuit*	

Inductors



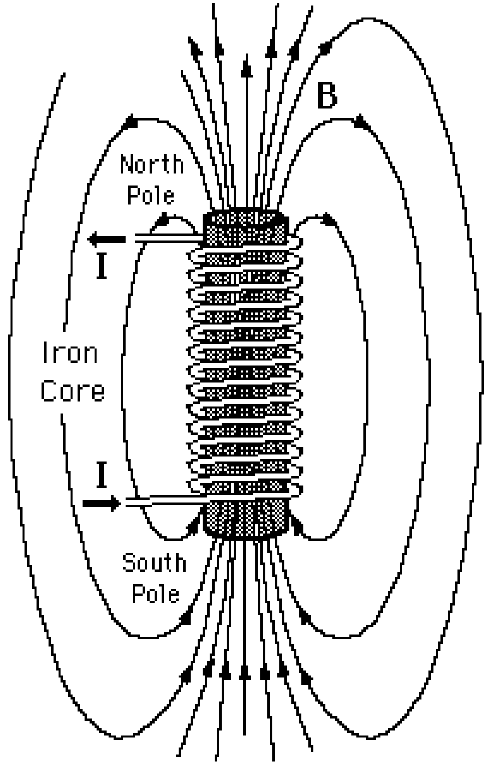


- An inductor is a coil of wire through which a current is passed. The current can be either AC or DC.

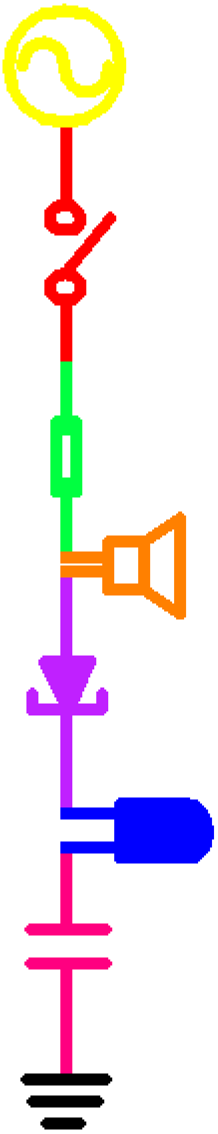


Inductors

$$V_L = L\frac{dI_L}{dt}$$



- This generates a magnetic field, which induces a voltage proportional to the rate of change of the current.



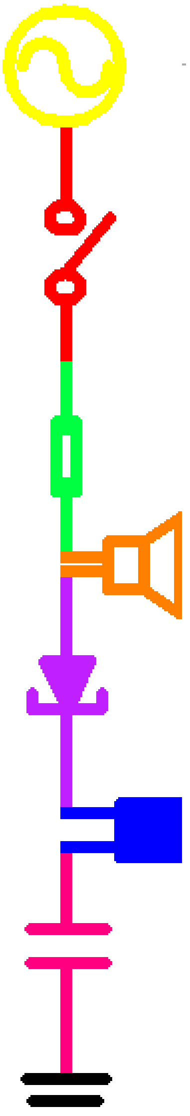
Combining Inductors

- Inductances add like resistances
- Series

$$L = L_1 + L_2 + \ldots + L_N$$

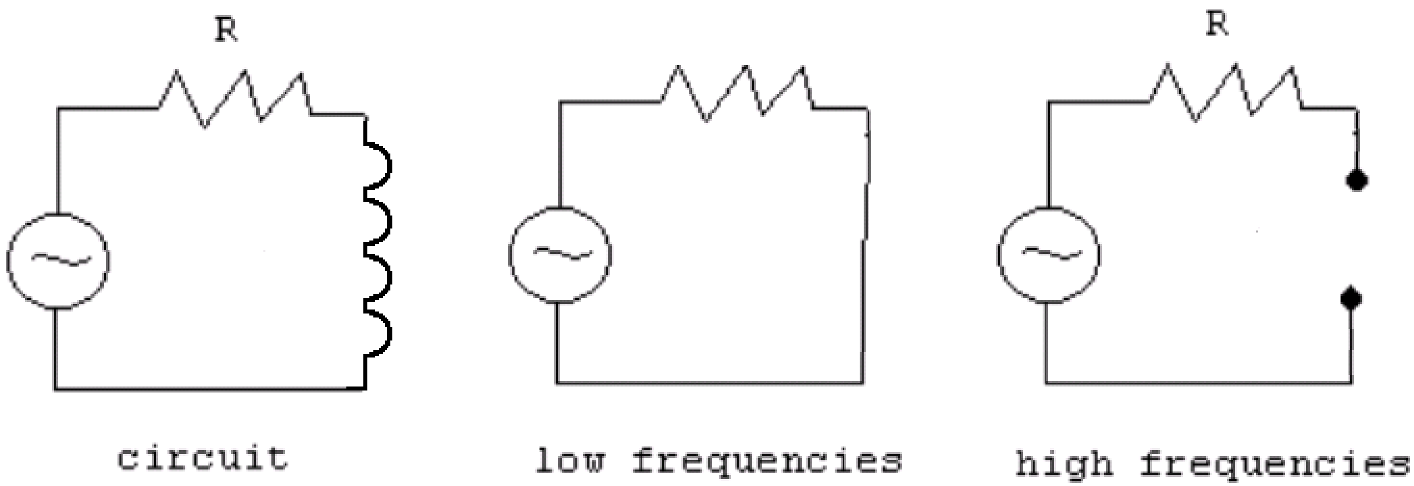
- Parallel

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots + \frac{1}{L_N}$$



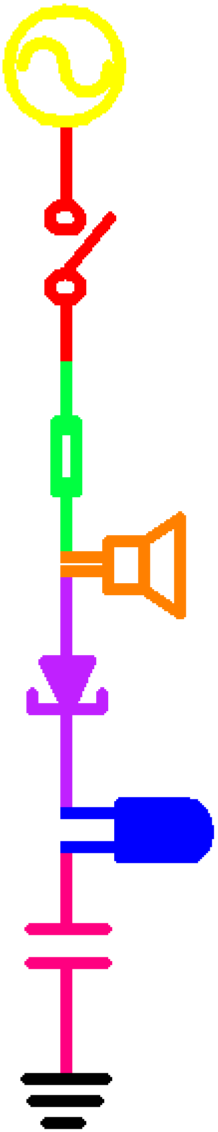
Inductor Impedance

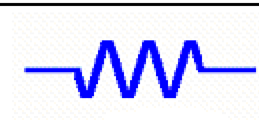
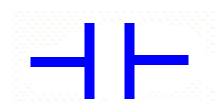
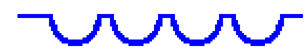
frequency	frequency approaches	impedance approaches	looks like	called
low	-->0	-->0	-------------	short
high	-->infinity	-->infinity	---● ●----	open circuit

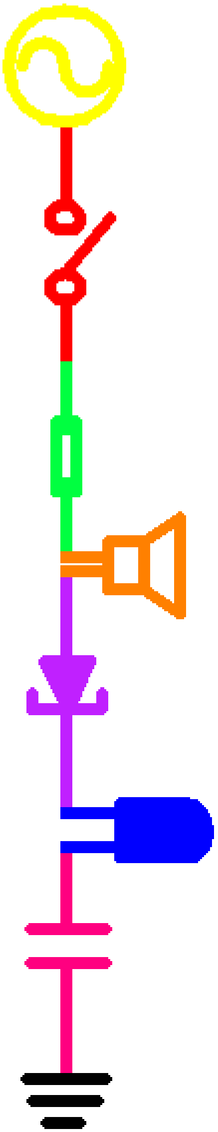


Note: Real inductors always have a small resistance (that is not shown in these circuits). The impedance of the theoretical inductor shown is only its reactance.

Comparison of Components



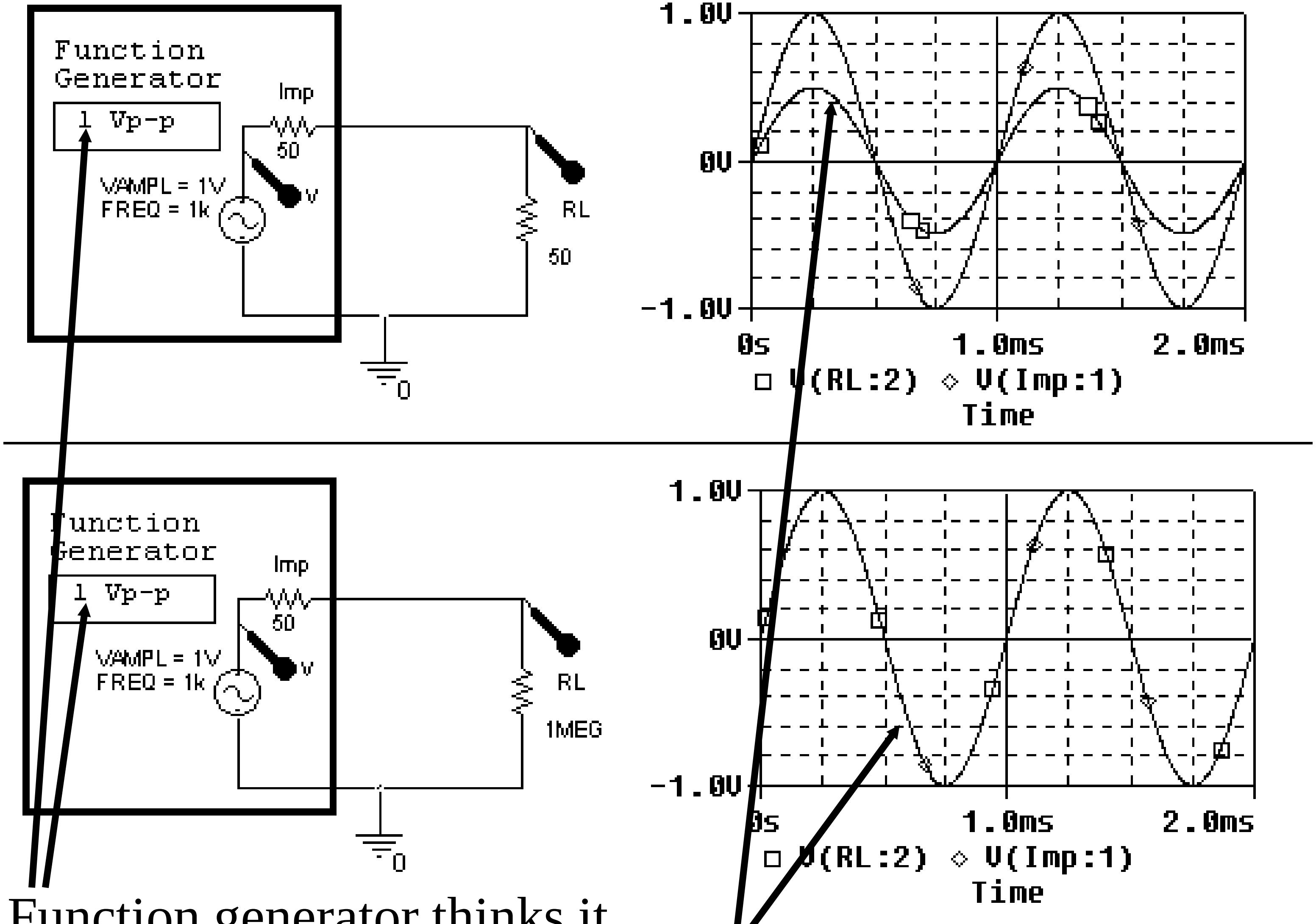
	resistor	capacitor	inductor
symbol	R	C	L
equation	$V_R = I_R R$	$I_C = C\frac{dV_C}{dt}$	$V_L = L\frac{dI_L}{dt}$
icon			
series	$R_T = R_1 + R_2$	$C_T^{-1} = C_1^{-1} + C_2^{-1}$	$L_T = L_1 + L_2$
parallel	$R_T^{-1} = R_1^{-1} + R_2^{-1}$	$C_T = C_1 + C_2$	$L_T^{-1} = L_1^{-1} + L_2^{-1}$
low freq	R	*open circuit*	*short circuit*
high freq	R	*short circuit*	*open circuit*



Equipment Impedances

- Each measuring device changes the circuit when you use it.
- The impedance of the device helps you understand how much.
- Device Impedances
  - Function Generator: 50 ohms
  - ‘Scope: 1Meg ohms
  - DMM (DC voltage): 10Meg ohms
  - DMM (AC voltage): 1Meg ohms
  - DMM (DC current): 5 ohms (negligible)

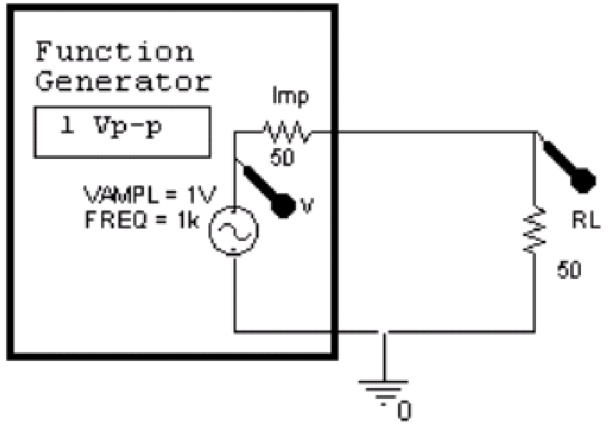
Effect of Impedance on Circuit



Function generator thinks it is putting out the same thing.

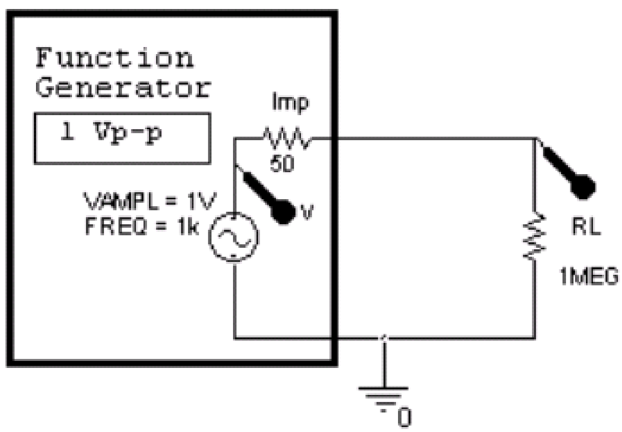
Output is clearly different.

Effect of Impedance on Circuit



$$V_{out} = \frac{50}{50+50}\left(V_{in}\right)$$

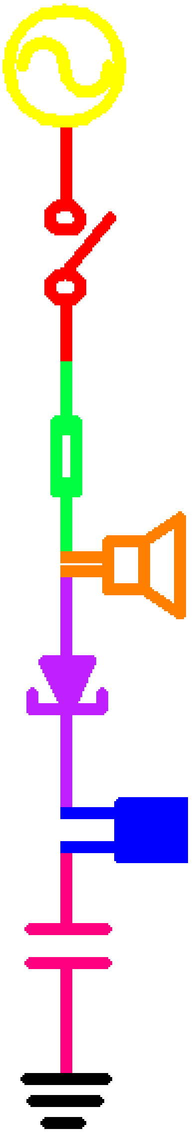
$$V_{out} = \frac{V_{in}}{2}$$



$$V_{out} = \frac{1\times10^{6}}{1\times10^{6}+50}\left(V_{in}\right)$$

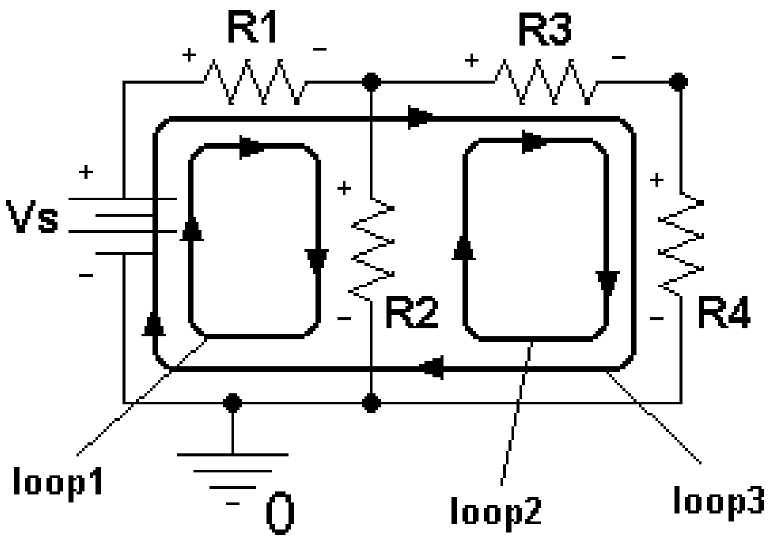
$$V_{out} \approx V_{in}$$

The IOBoard function generator has an output impedance of much less than 50Ω, so we can ignore it. Our battery however is a different story, as you will see in the experiment.



Kirchoff’s Laws

KVL



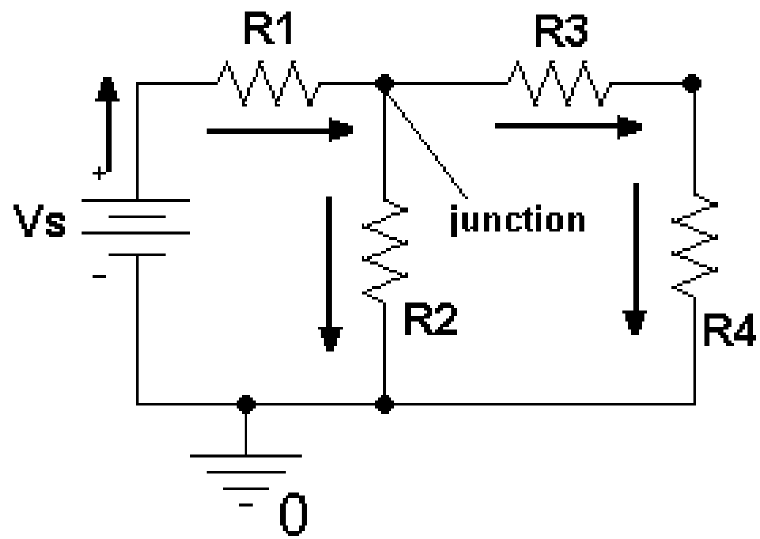
loop1: $V_s - V_{R1} - V_{R2} = 0$

loop2: $V_{R2} - V_{R3} - V_{R4} = 0$

loop3: $V_s - V_{R1} - V_{R3} - V_{R4} = 0$

sum of voltages in any loop is zero

KCL



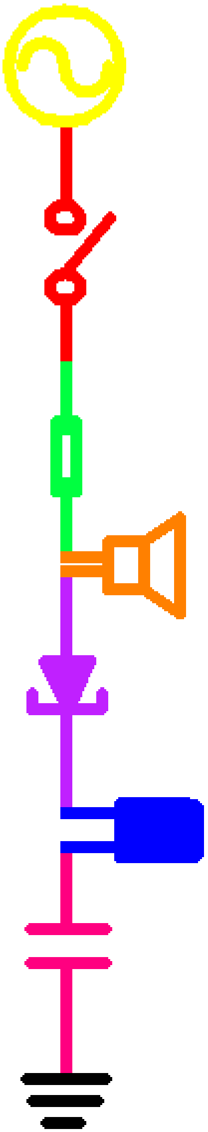
junction: $I_{R1} = I_{R2} + I_{R3}$

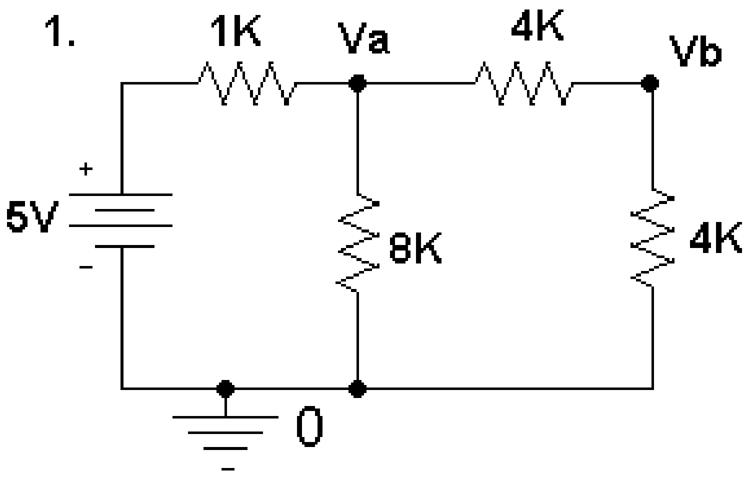
also: $I_S = I_{R1}$

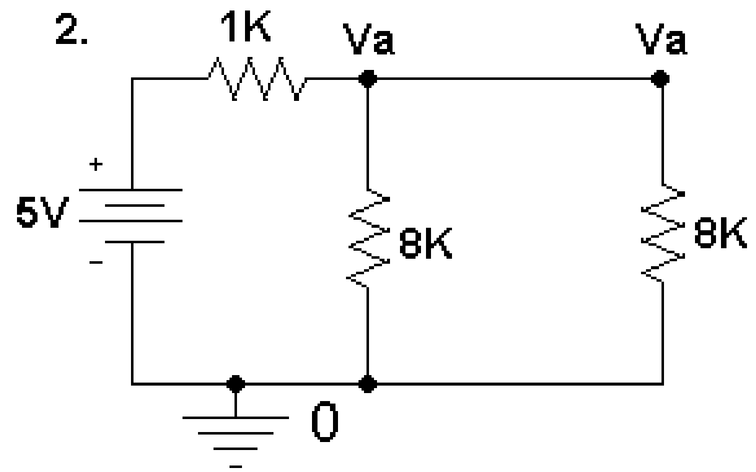
$I_{R3} = I_{R4}$

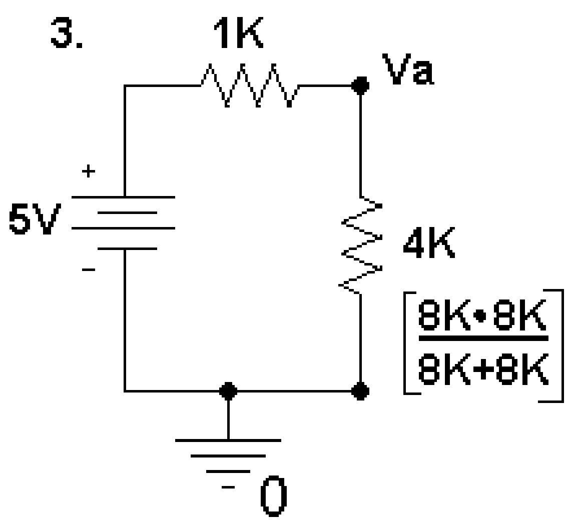
sum of currents entering a junction is the same as the sum of the currents leaving a junction

Circuit Analysis (Combination Method)









Solution

volt.div.(3.)

$$Va = \frac{4K}{1K+4K} 5V = 4V$$

$$V_{R1} = 5V - Va = 1V$$

$$I_{R1} = \frac{V_{R1}}{1K} = 1mA$$

$$V_{R2} = Va = 4V$$

$$I_{R2} = \frac{V_{R2}}{8K} = 0.5mA$$

volt.div (1.)

$$Vb = \frac{4K}{4K+4K} Va = 2V$$

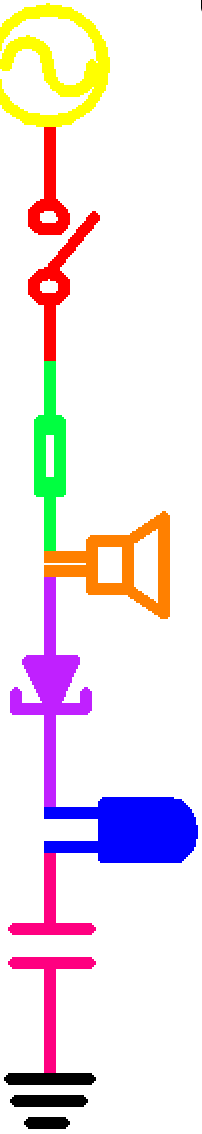
$$V_{R4} = Vb = 2V$$

$$I_{R4} = \frac{V_{R4}}{4K} = 0.5mA$$

$$V_{R3} = Va - Vb = 2V$$

$$I_{R3} = I_{R4} = 0.5mA$$

Useful Aside: SI Suffixes



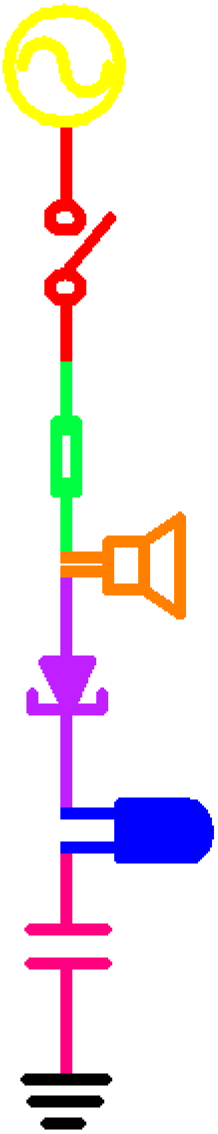
pico	p	10^{-12}
nano	n	10^{-9}
micro	µ (u)	10^{-6}
milli	m	10^{-3}
Kilo	k	10^{3}
Mega	M (Meg)	10^{6}
Giga	G	10^{9}
Tera	T	10^{12}

$$n = \frac{1}{G} \qquad G = \frac{1}{n}$$

$$\mu = \frac{1}{M} \qquad M = \frac{1}{\mu}$$

$$m = \frac{1}{k} \qquad k = \frac{1}{m}$$

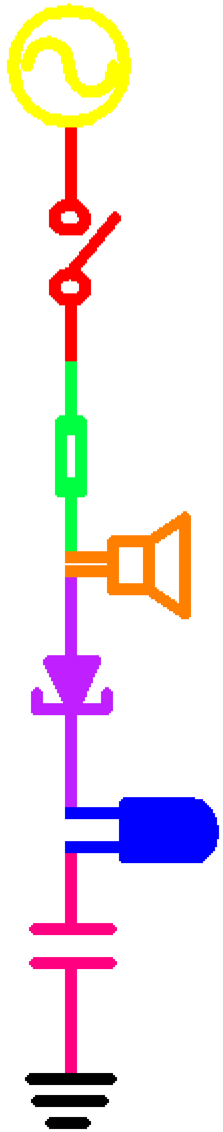
$$ex.\ \frac{1}{10k} = \frac{1}{10}\frac{1}{k} = 0.1m$$

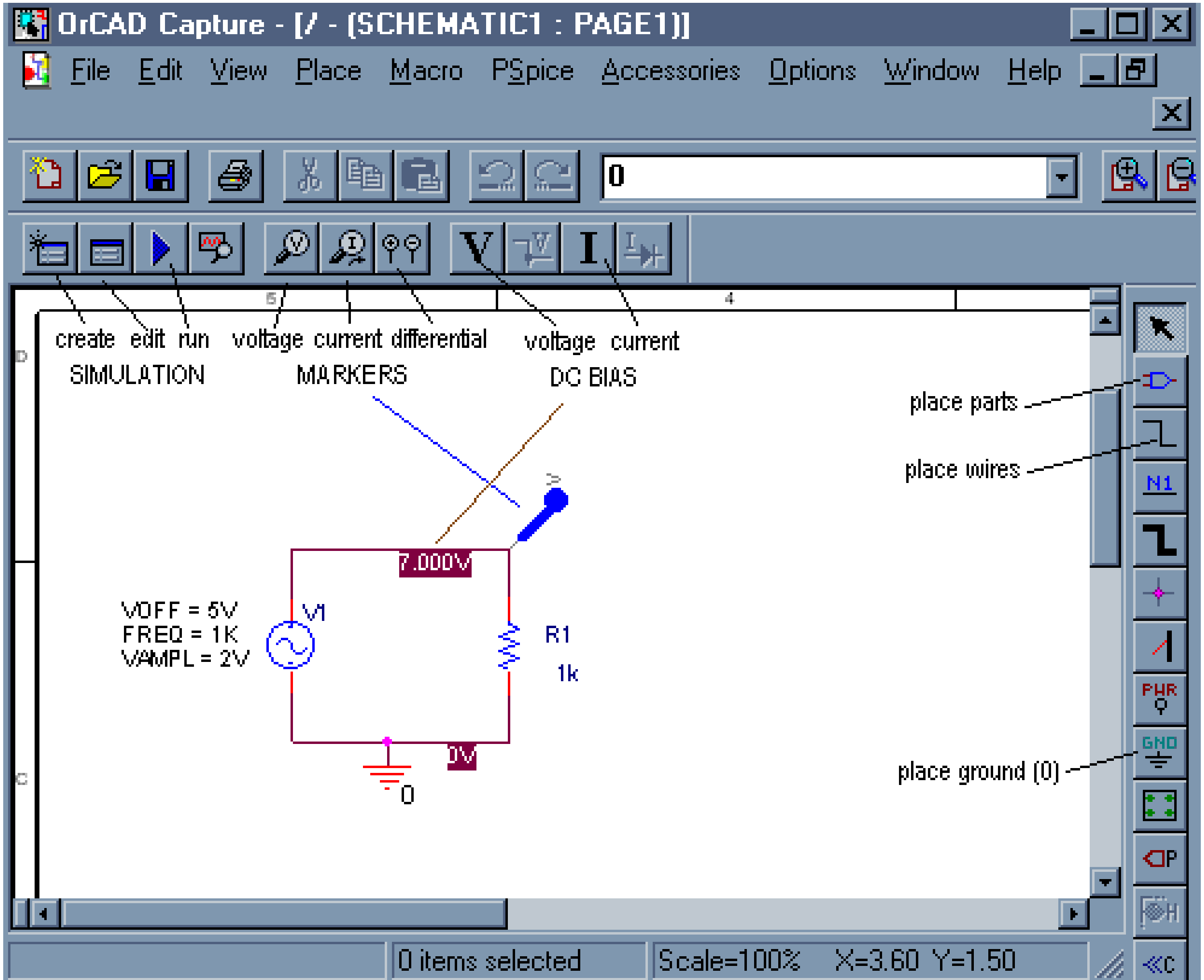


Part C

- Capture
  - Create circuits visually
  - Set up simulation parameters
- PSpice
  - Analyzes circuit
  - Displays results

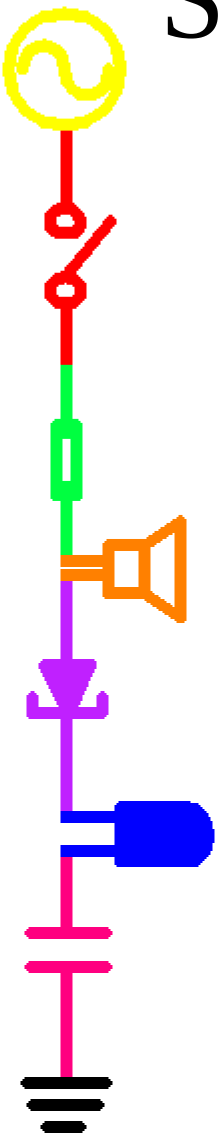
Capture

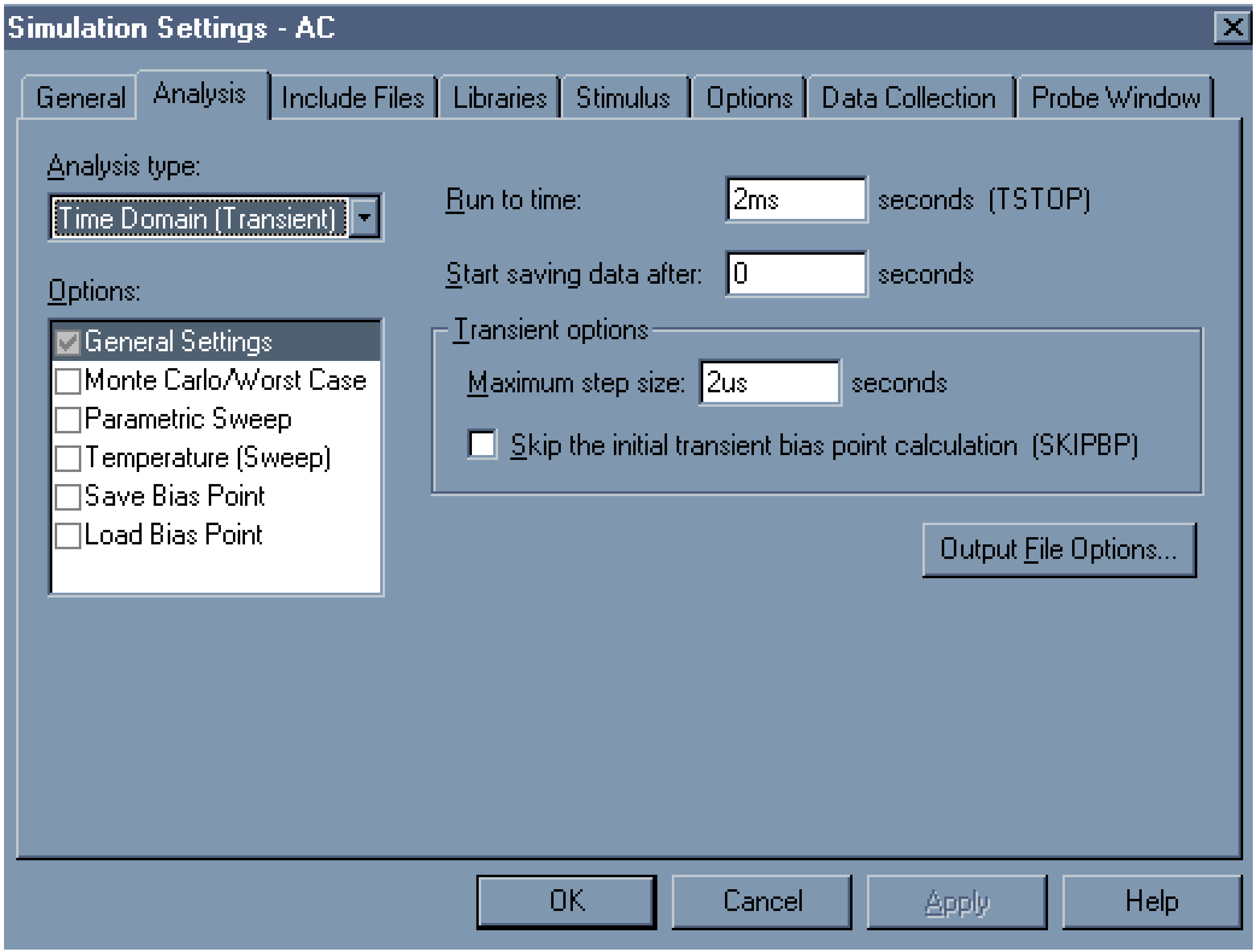



OrCAD Capture - [/ - (SCHEMATIC1 : PAGE1)]
File Edit View Place Macro PSpice Accessories Options Window Help
create edit run
SIMULATION
voltage current differential
MARKERS
voltage current
DC BIAS
place parts
place wires
place ground (0)
7.000V
VOFF = 5V
FREQ = 1K
VAMPL = 2V
V1
R1
1k
0V
0
0 items selected
Scale=100%
X=3.60 Y=1.50

Simulations

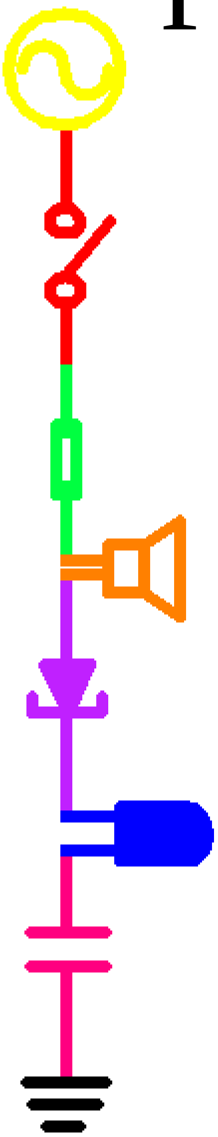
$$run\,to\,time \approx \frac{\#\,cycles}{freq} \qquad step\ size \approx \frac{run\,to\,time}{1000}$$

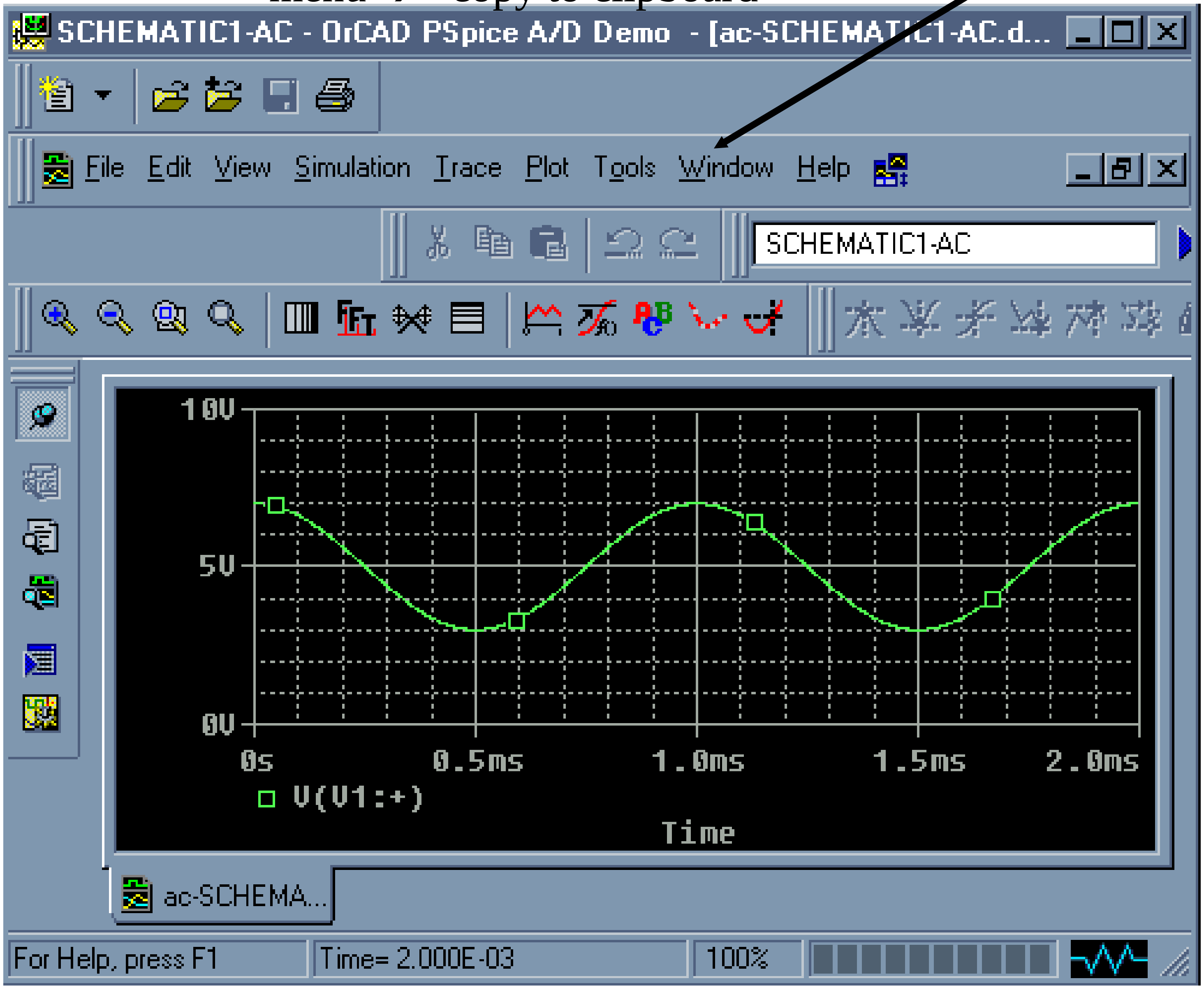




PSpice

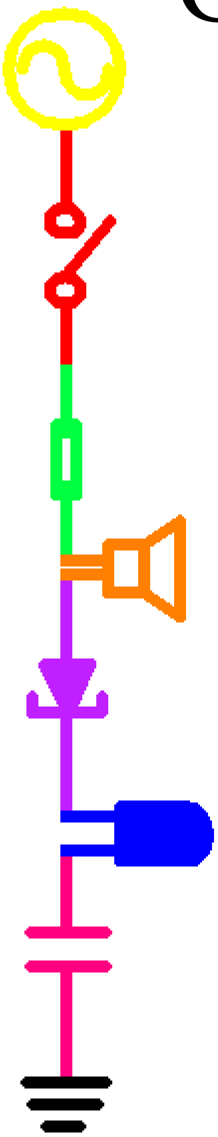
Note: To get copy of trace into word use Window menu → ”copy to clipboard”

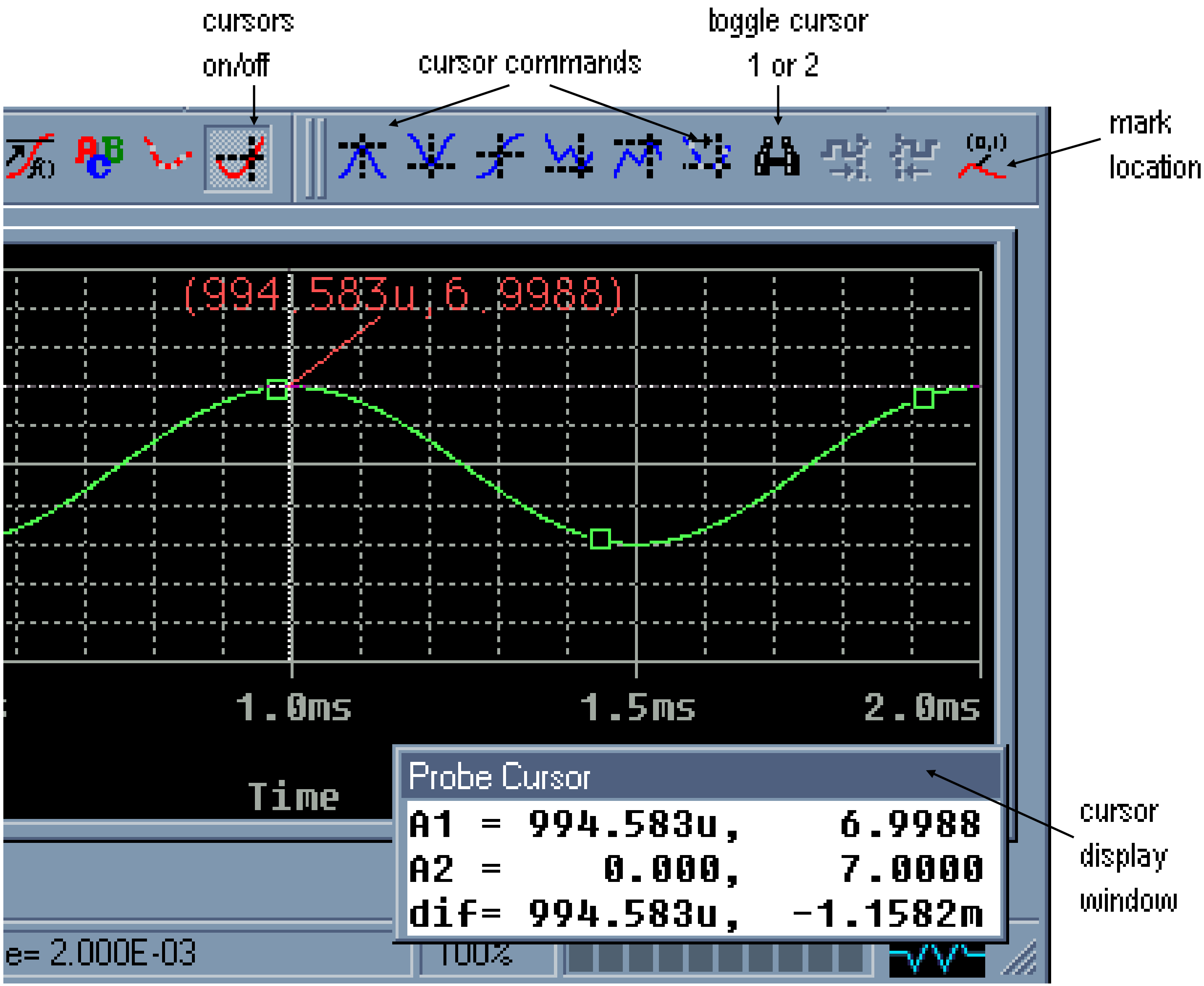




Cursors

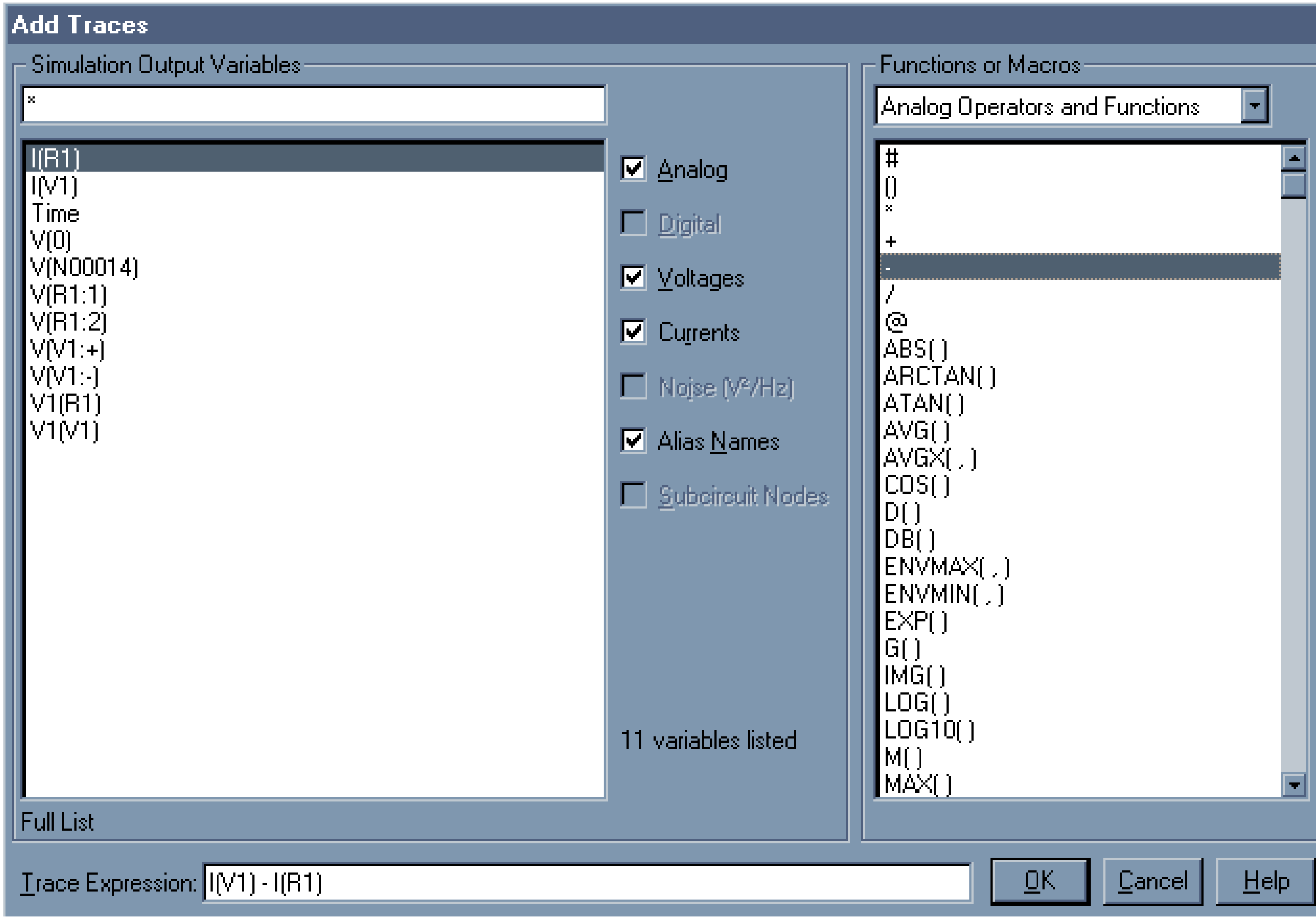
Note: You can drag the left mouse button to move one cursor and the right mouse button to move the other.

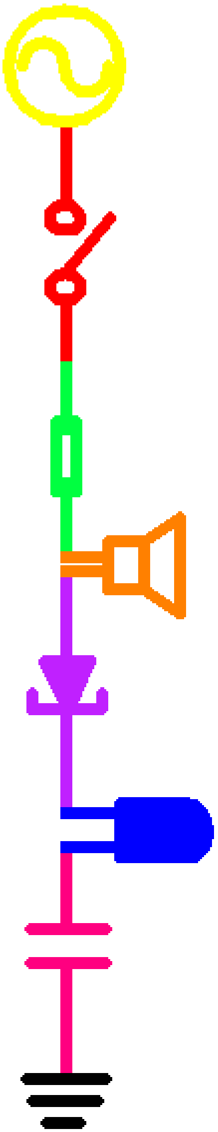




Adding Traces

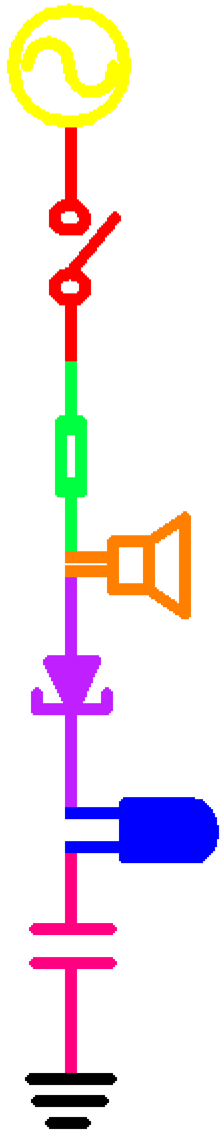
Note: To add a trace use Trace menu → "Add Trace"



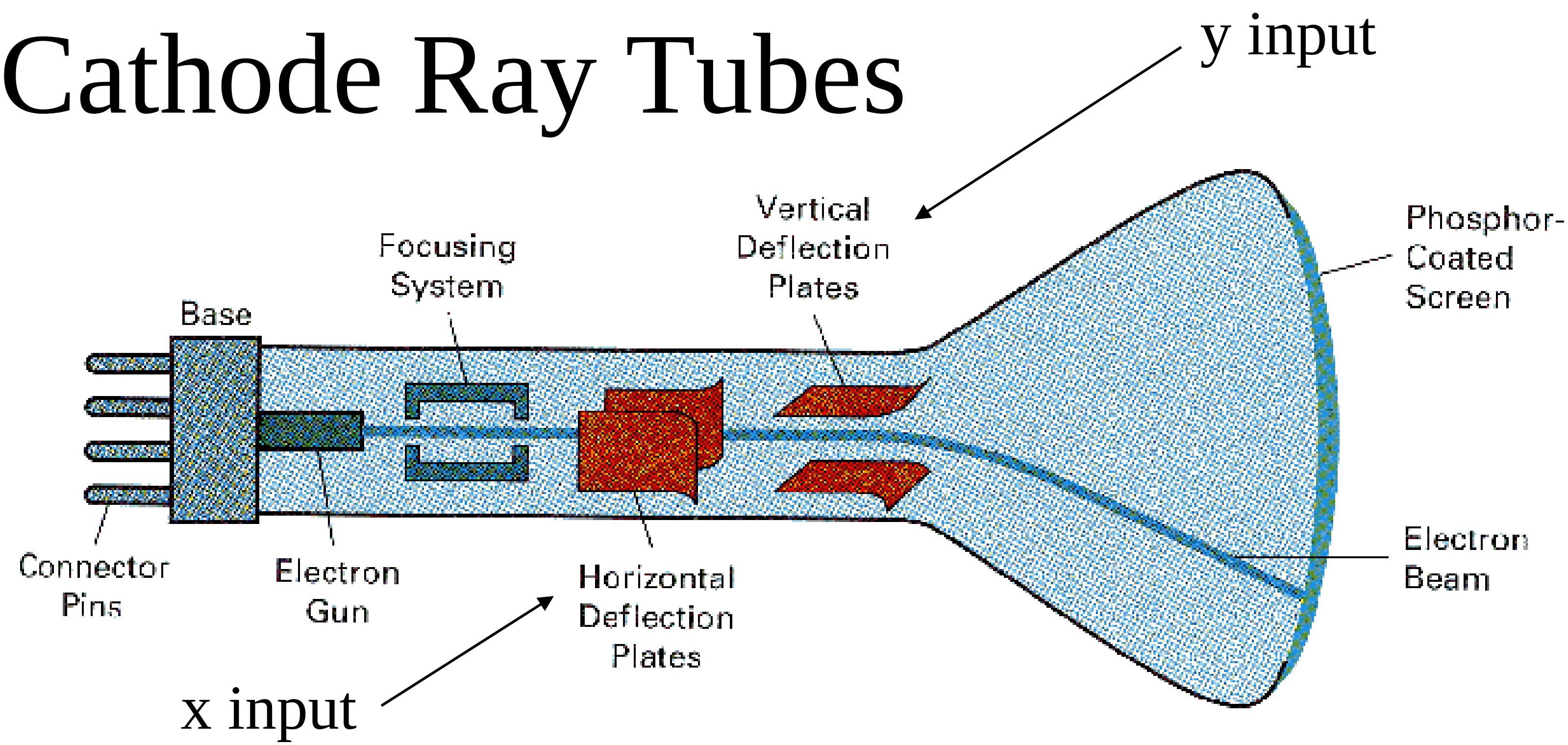


Part D

- Oscilloscopes
- Lissajous Figures



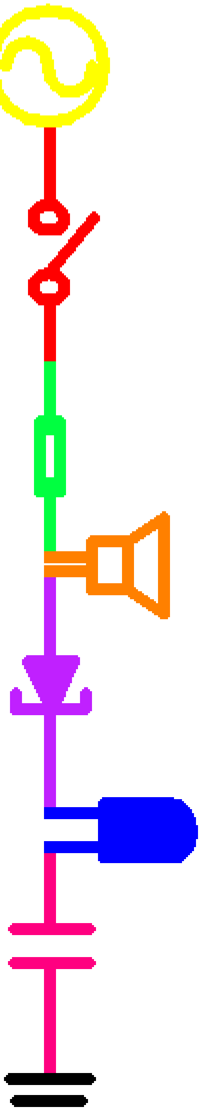
Cathode Ray Tubes



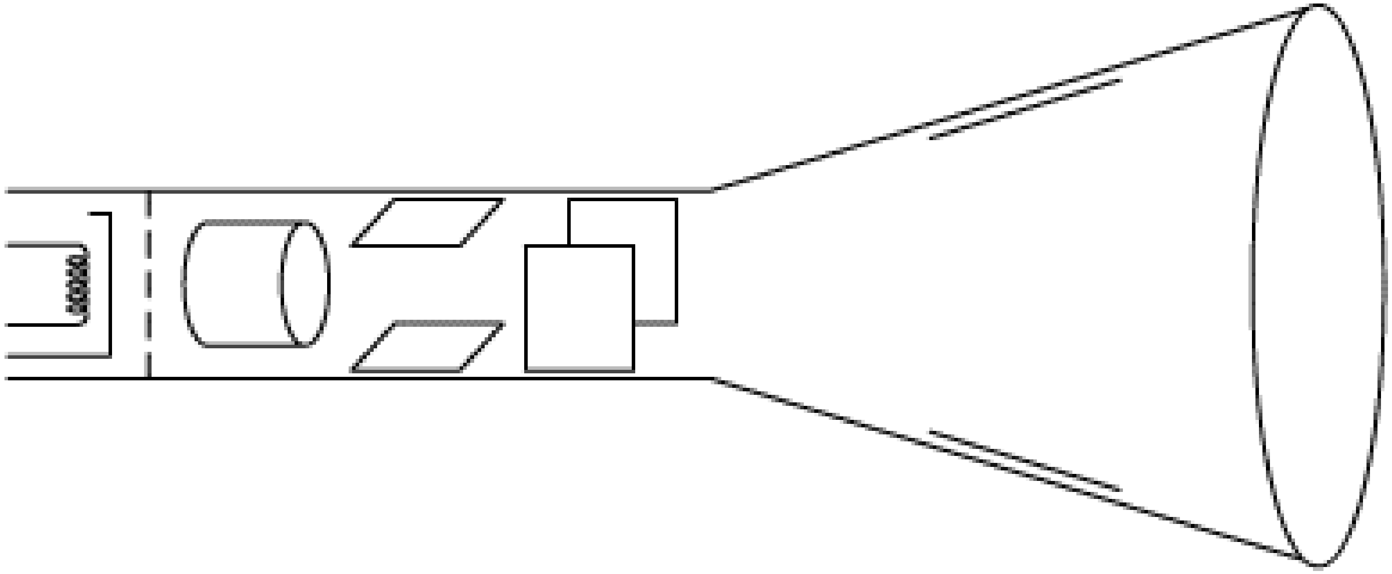
Variation in potential difference (voltage) placed on plates causes electron beam to bend different amounts.

"Sweep" refers to refreshing repeatedly at a fixed rate.

http://www.chem.uiuc.edu/clcwebsite/video/Cath.avi

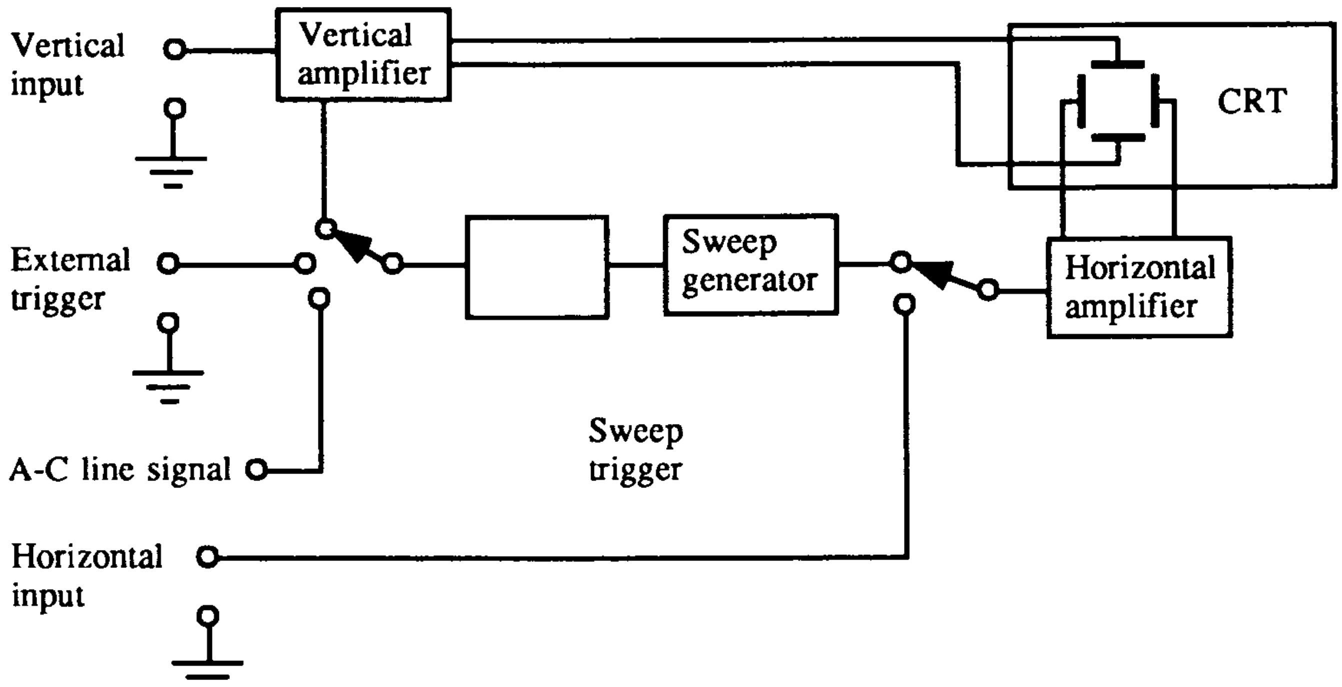


Cathode Ray Tube Animation



http://webclass.cqu.edu.au/Units/81120_FOCT_Hardware/Study_Material/Study_Guide/chap2/toc.html

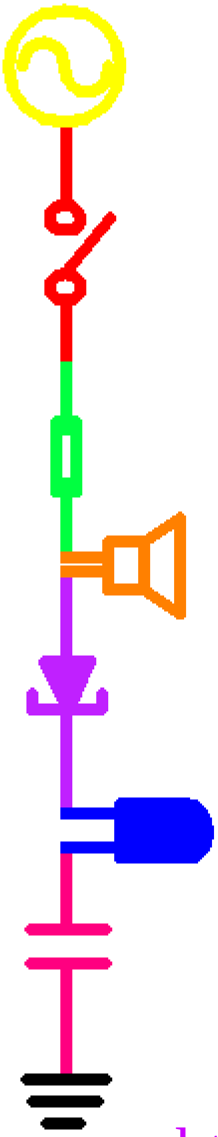
Oscilloscopes

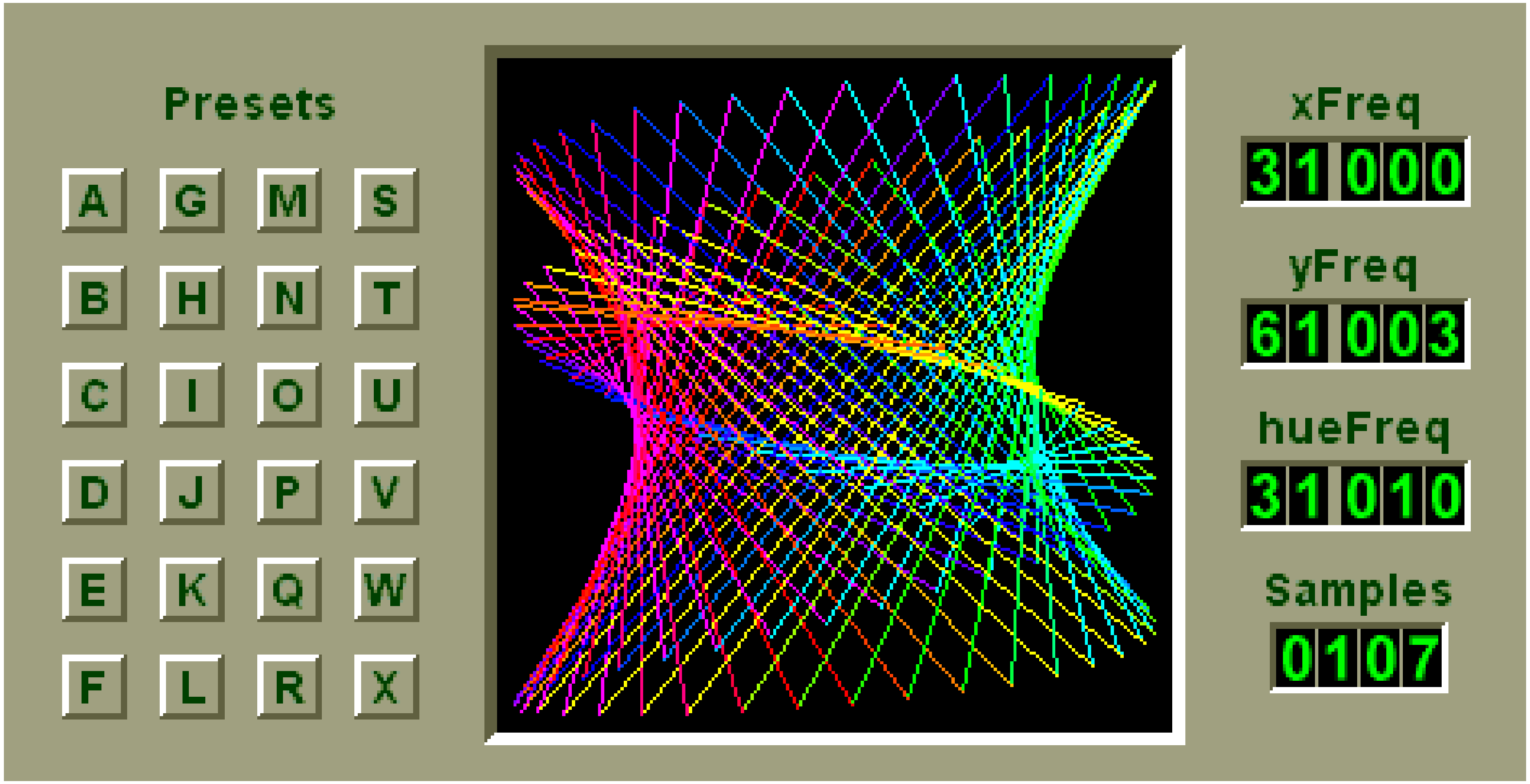


Horizontal sweeps at a constant rate. Vertical plates are attached to an external voltage, the signal you attach to the scope.

http://boson.physics.sc.edu/~hoskins/Demos/CathodeRay.html

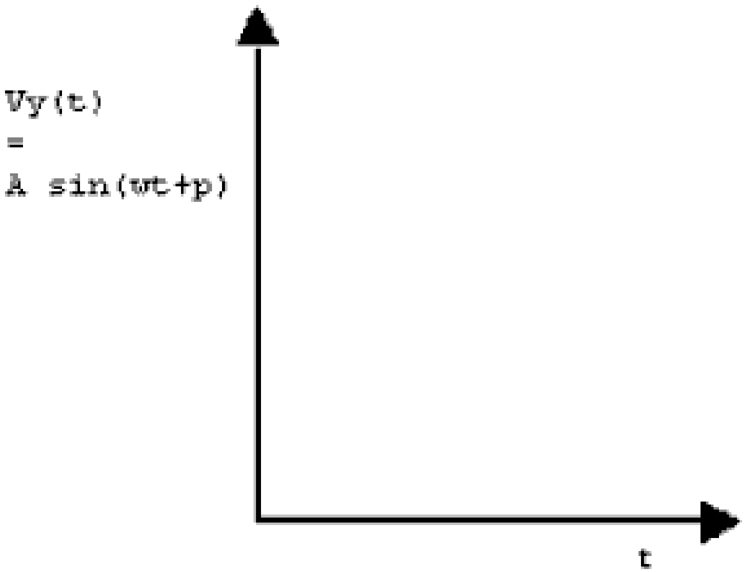
Lissajous Figures



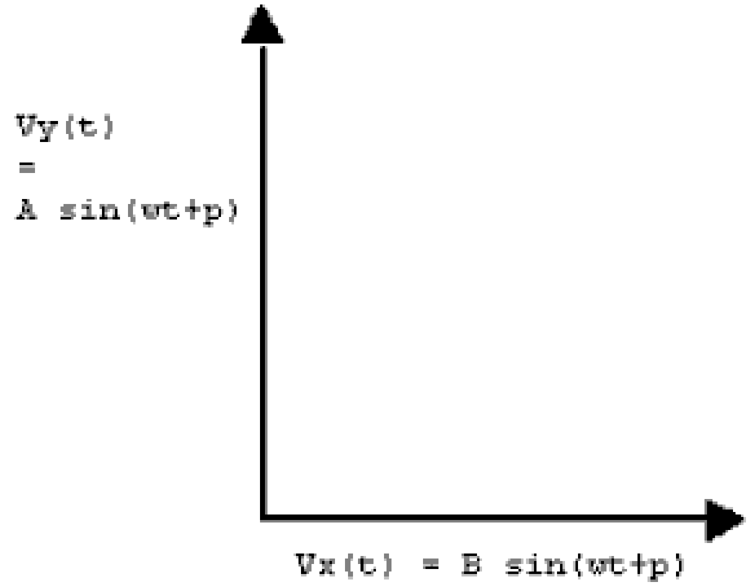


http://encyclozine.com/Science/Mathematics/Graphs/Lissajous/

Lissajous Figures



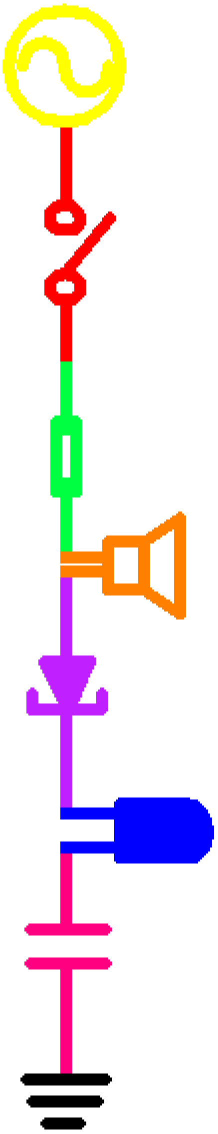
Normal operation of 'scope

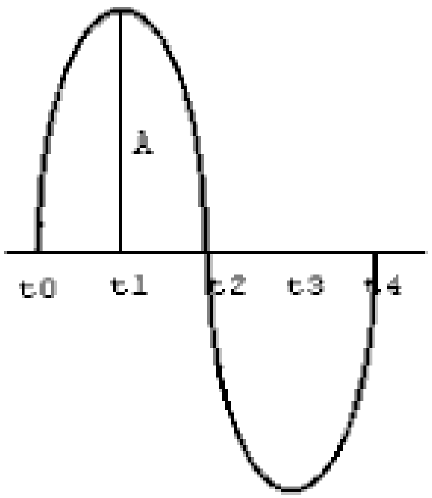


Generating Lissajous figures

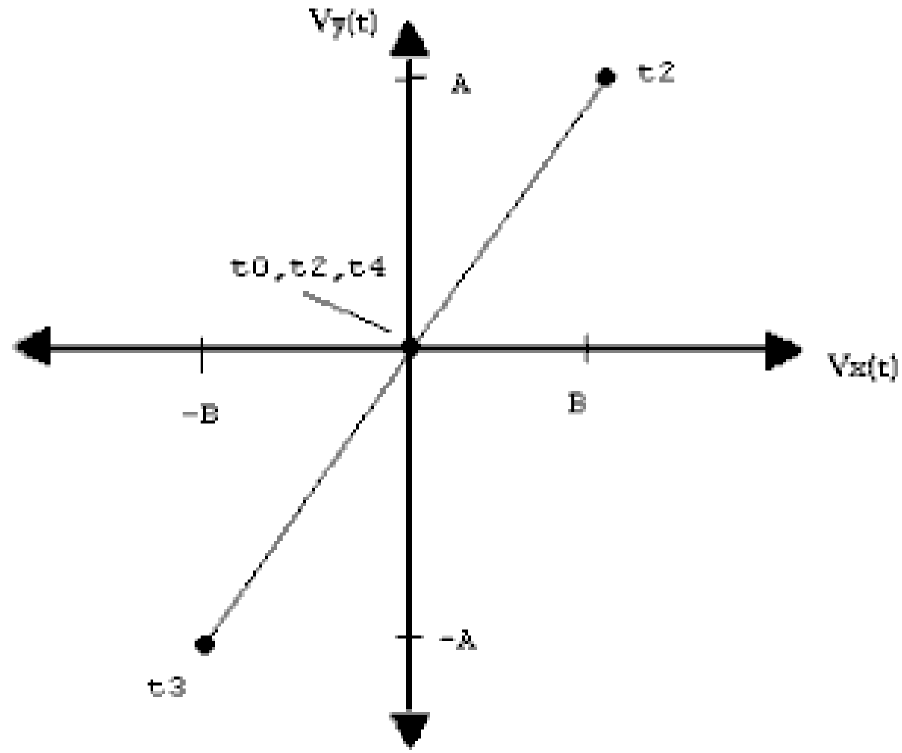
Normally the scope will plot a voltage signal with respect to time. In a Lissajous figure, two voltage signals are plotted against each other.

Lissajous Example 1

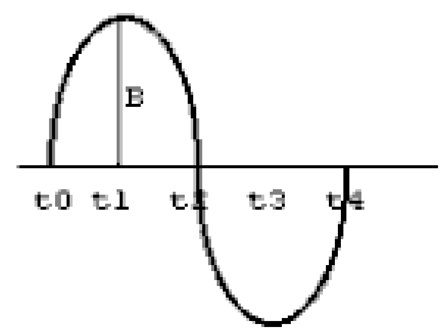




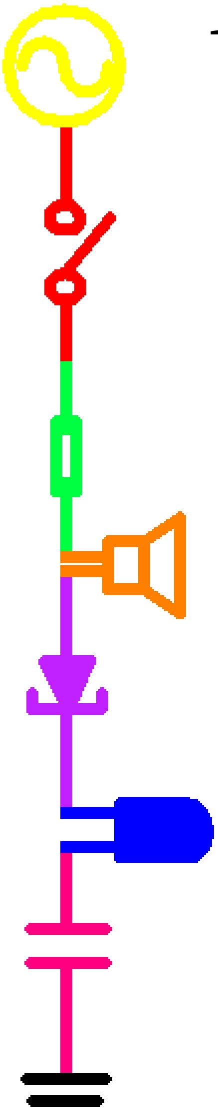
Vy(t) = A sin(wt+0)

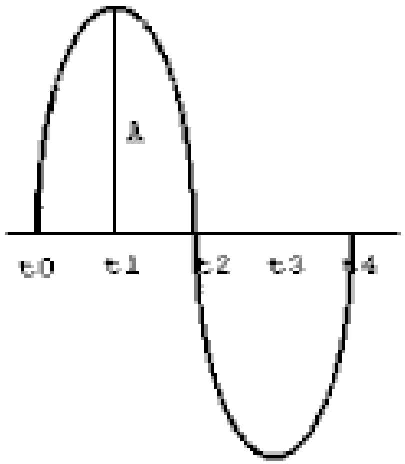


time	x	y
t0	0	0
t1	B	A
t2	0	0
t3	-B	-A
t4	0	0

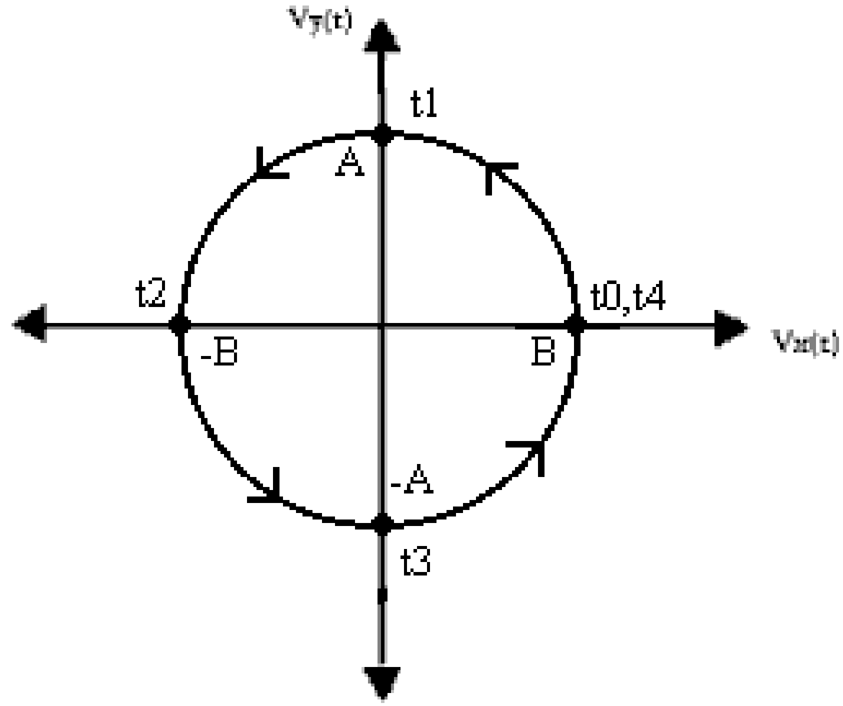


Lissajous Example 2



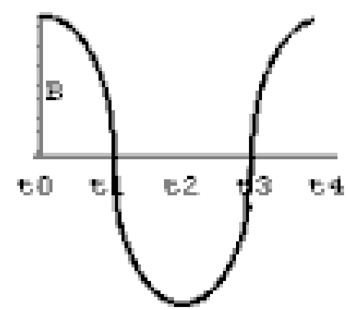


Vy(t) = A sin(wt+0)



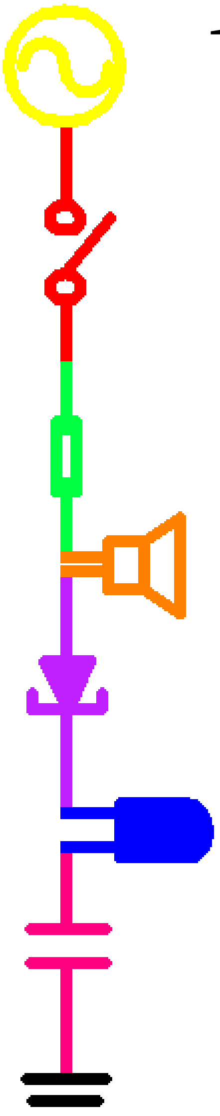
time	x	y
t0	B	0
t1	0	A
t2	-B	0
t3	0	-A
t4	B	0

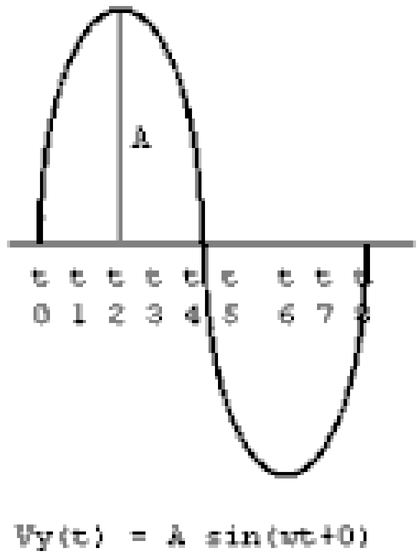
Circle iff A=B



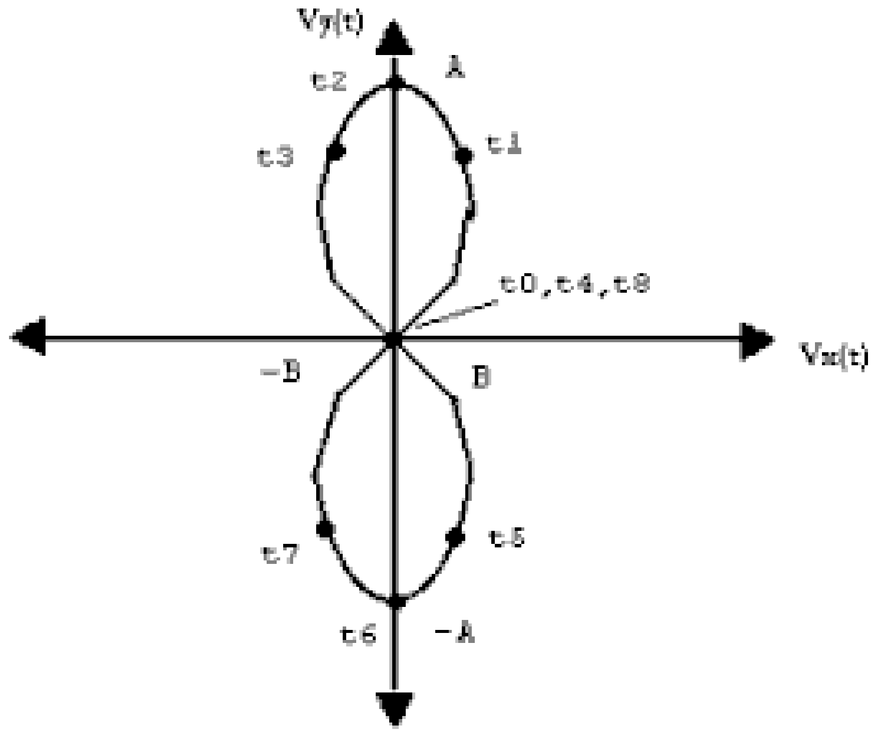
Vx(t) = B sin(wt+pi/2)

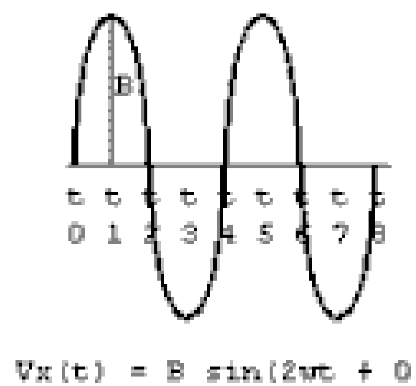
Lissajous Example 3





time	x	y
t0	0	0
t1	B	.7A
t2	0	A
t3	-B	.7A
t4	0	0
t5	B	-.7A
t6	0	-A
t7	-B	-.7A
t8	0	0





More Figures