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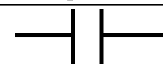
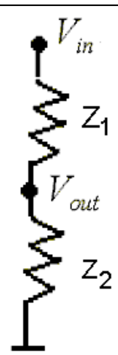
components	Resistors	Capacitors	Inductors
symbol	 **R**	 **C**	 **L**
general equation	$V_R = I_R R$	$I_C = C\frac{dV_C}{dt}$	$V_L = L\frac{dI_L}{dt}$
combining in series	$R_T = R_1 + R_2 + \ldots + R_n$	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$	$L_T = L_1 + L_2 + \ldots + L_n$
combining in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$	$C_T = C_1 + C_2 + \ldots + C_n$	$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}$
impedance	$Z_R = R$	$Z_C = \frac{1}{j\omega C} \sim \frac{1}{f}$	$Z_L = j\omega L \sim f$
frequency→0	R	open circuit	short circuit
frequency→∞	R	short circuit	open circuit
Stored Energy		$W_C = \frac{1}{2}CV^2$	$W_L = \frac{1}{2}LI^2$

Laws and Rules		
Ohm's Law	V = IR	
Kirchoff's Voltage Law	Sum of voltages in a loop is zero.	
Kirchoff's Current Law	Sum of currents entering junction equals the sum of currents leaving junction.	
Reading Resistors	XYZ = XY x 10^Z ohms	black-brown-R-O-Y-G-B-V-grey-white 0 1 2 3 4 5 6 7 8 9
Reading Capacitors	XYZ = XY x 10^Z picofarads = XY x $10^{(Z-6)}$ microfarads	
suffixes	k (10^3) Meg(10^6) G(10^9) T(10^{12})	m(10^{-3}) μ(10^{-6}) n(10^{-9}) p(10^{-12})
	<u>parallel combination shortcut</u> $R_{12} = \frac{R_1 R_2}{R_1 + R_2}$	<u>Power Equation</u> $P = VI = I^2 R = \frac{V^2}{R}$

Voltage Dividers	**Sine Waves**



$$V_{out} = \left(\frac{Z_2}{Z_1 + Z_2}\right)V_{in}$$

$$V_1 = \left(\frac{Z_1}{Z_1 + Z_2}\right)V_{in}$$

$$V_2 = \left(\frac{Z_2}{Z_1 + Z_2}\right)V_{in}$$

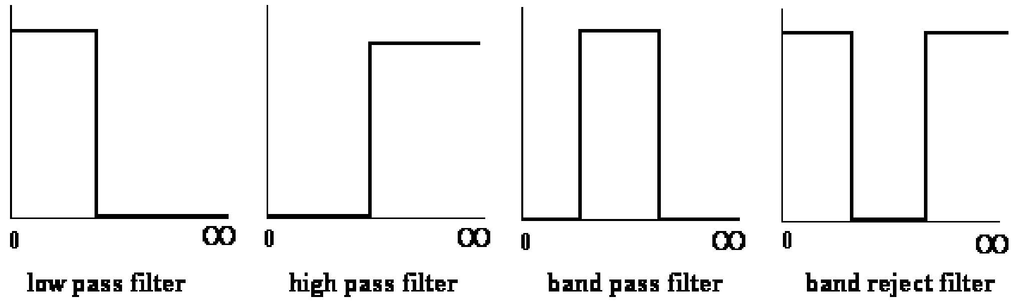
$$v(t) = A\sin(\omega t + \phi) + V_{DC}$$

$$\omega = 2\pi f \qquad f = \frac{1}{T}$$

$$\phi = -\omega t_0 = -2\pi\frac{t_0}{T}$$

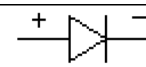
$$V_{p-p} = 2A \qquad V_{rms} = \frac{A}{\sqrt{2}}$$

Filters (Characteristic Frequency & Time Constant)		
RC Circuit (corner)	RL Circuit (corner)	RLC Circuit (resonant)
$\omega_C = \frac{1}{\tau} = \frac{1}{RC}; f_C = \frac{1}{2\pi RC}$	$\omega_C = \frac{1}{\tau} = \frac{R}{L}; f_C = \frac{R}{2\pi L}$	$\omega_0 = \frac{1}{\sqrt{LC}}; f_C = \frac{1}{2\pi\sqrt{LC}}$

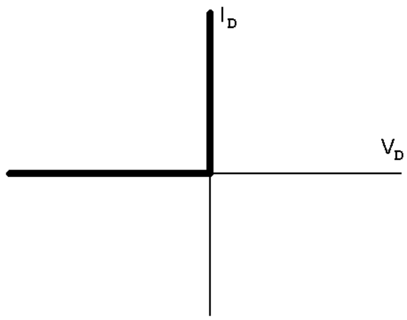


Diodes

1N914 silicon diode: $V_{on} = 0.7$ Volts

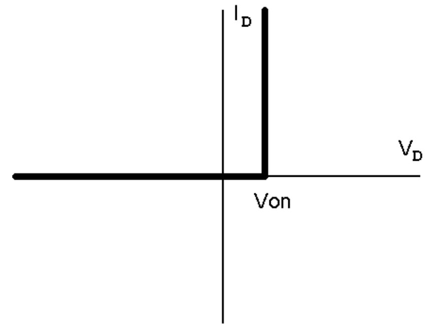


Ideal Diode



$$\begin{cases} On: & V_D = 0 \quad I_D > 0 \\ Off: & V_D < 0 \quad I_D = 0 \end{cases}$$

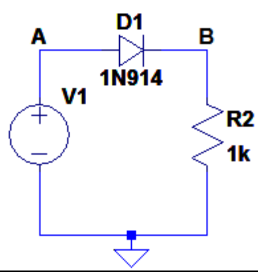
V_{on} Model

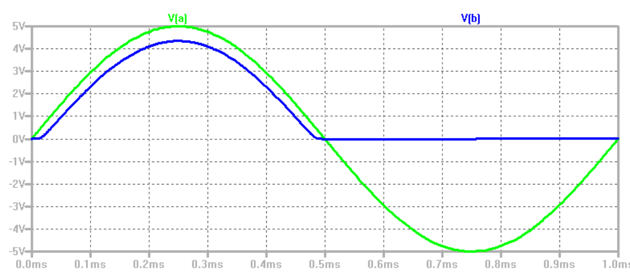


$$\begin{cases} On: & V_D = V_{on} \quad I_D > 0 \\ Off: & V_D < V_{on} \quad I_D = 0 \end{cases}$$

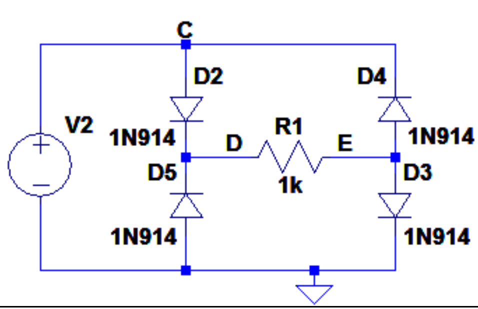
Diode Circuits

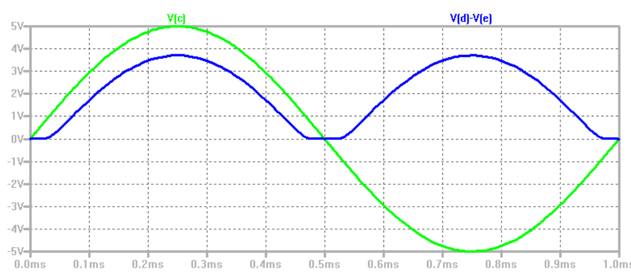
Half-Wave Rectifier





Full-Wave Rectifier





ECSE-1010 **Formula Sheet** **Quiz 1**

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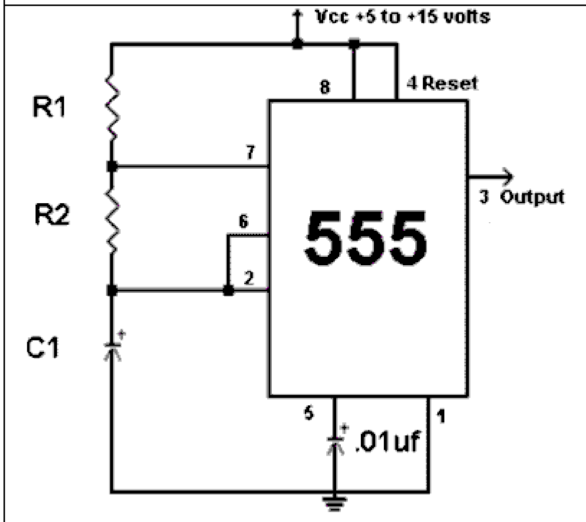
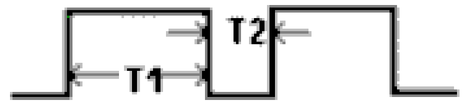
555-Timer





Charge Cycle: $T1 = 0.693(R1 + R2)C1$

$\tau 1 = (R1 + R2)C1$

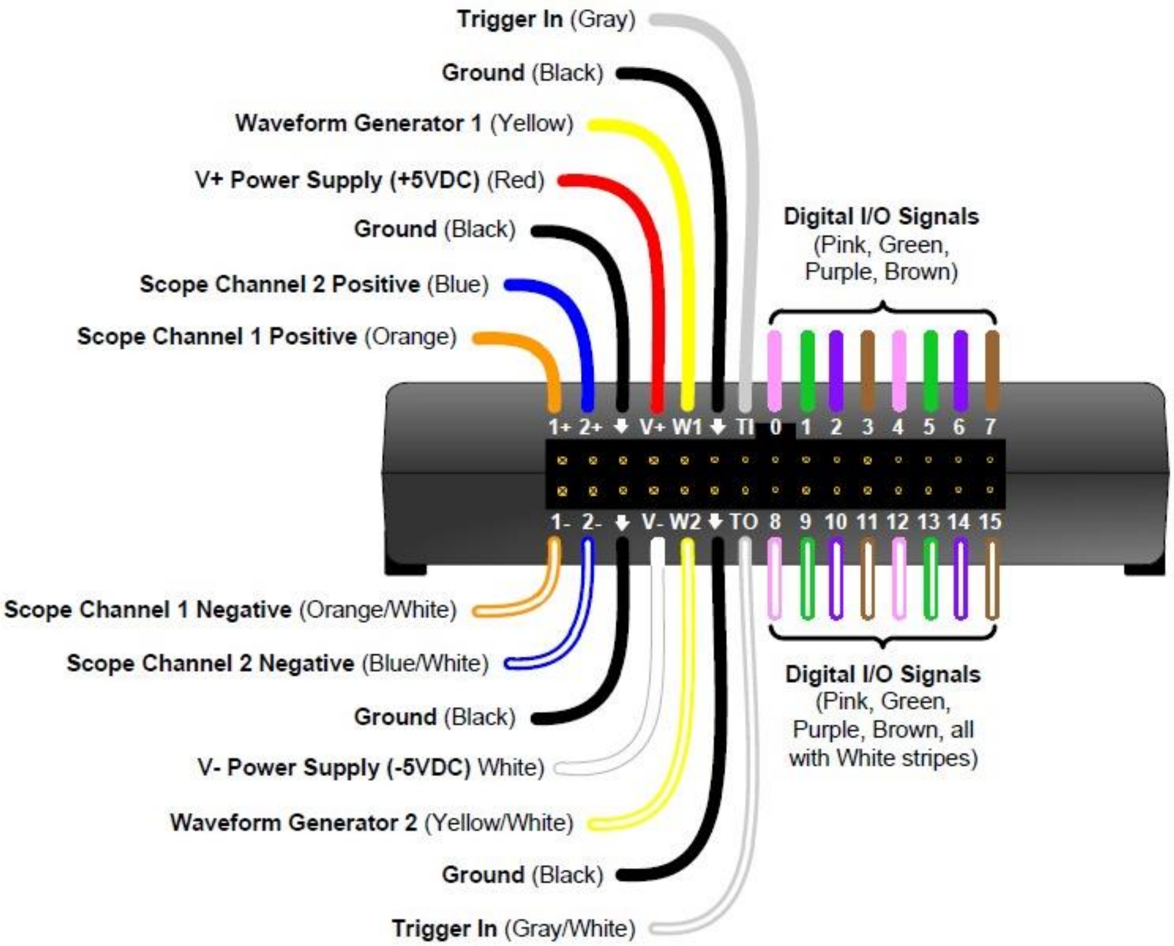
Off Time: $T2 = 0.693(R2)C1$

$\tau 2 = (R2)C1$

Frequency: $f = \dfrac{1.44}{(R1 + 2R2)C1}$

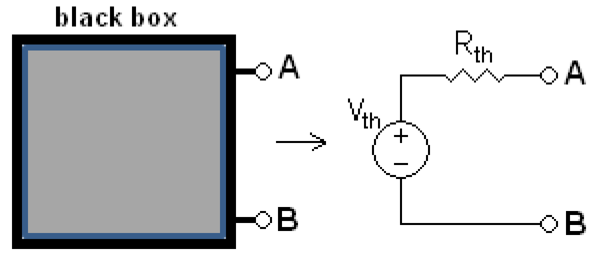
Period: $T = T1 + T2$

Duty Cycle (percentage): $D = \dfrac{T1}{T} \times 100$



Thevenin Voltage Sources

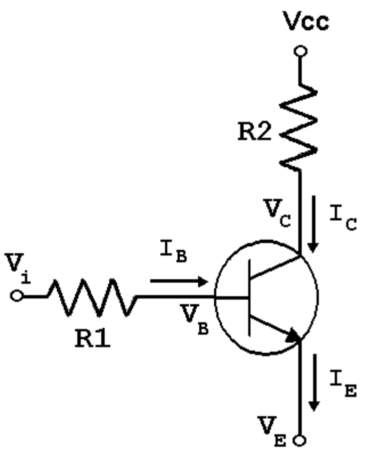
Find V_{th}	Set load between A and B to open and find V_A - V_B
Find R_{th}	Set voltage sources to shorts and find combined resistance between A and B.
	$V_L = \frac{R_L}{R_{th} + R_L} V_{th}$



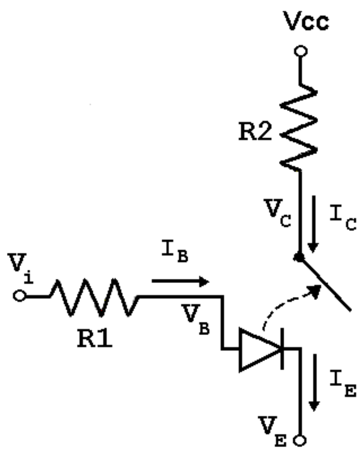
Experimental Method: Measure output voltage for open circuit (no load) or very large load to obtain V_{th}. Measure output voltage for a series of load resistances. Use the output voltage near $V_{th}/2$ to find R_{th}. Check your answer with another measurement.

Transistor as a switch

Transistor circuit



Transistor model



if $(V_i - V_E) < 0.7$
- * transistor is off
- * switch is open
- * I_C = 0 mA
- * $V_C = V_{CC}$

if $(V_i - V_E) > 0.7$
- * transistor is on
- * switch is closed
- * $I_C >> I_B$
- * $(V_B - V_E) = 0.7$
- * $V_{R1} = (V_i - (0.7 + V_E))$
- * $V_C = V_E$

Complex Polar Coordinates

Complex numbers: $z = x + jy = re^{j\theta}$ ($j = \sqrt{-1}$, 1/j = -j)

Polar to Cartesian transform: $x = r\cos\theta$, $y = r\sin\theta$

Cartesian to Polar transform: $r = \sqrt{x^2 + y^2}$ $\quad \theta = \tan^{-1}\left(\frac{y}{x}\right)$

$$\tilde{V} = \frac{x_1 + jy_1}{x_2 + jy_2} \quad \left|\tilde{V}\right| = \frac{\sqrt{x_1^{\,2} + y_1^{\,2}}}{\sqrt{x_2^{\,2} + y_2^{\,2}}} \quad \angle\tilde{V} = \tan^{-1}\left(\frac{y_1}{x_1}\right) - \tan^{-1}\left(\frac{y_2}{x_2}\right)$$

$$\tilde{V} = Ae^{j(\omega t + \phi)} = A\cos(\omega t + \phi) + jA\sin(\omega t + \phi)$$

phases	
A	0
-A	π or -π
jA	$\pi/2$
-jA	$-\pi/2$
$\tan^{-1}(1)$	$\pi/4$ or $-3\pi/4$
$\tan^{-1}(-1)$	$-\pi/4$ or $3\pi/4$
x+jy	$\tan^{-1}(y/x)$

where A is a constant

Exponential & Trig Functions

Euler's Identity $e^{j\theta} = \cos\theta + j\sin\theta$	$V(t) = V_o e^{-t/\tau}$ $\quad \tau = RC$ & $\tau = \frac{L}{R}$	$\frac{d}{dx}e^x = e^x$; $\frac{d}{dx}e^{f(x)} = f'(x)e^{f(x)}$
$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots$	$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} + \ldots$	$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} \ldots$

ECSE-1010 **Formula Sheet** **Quiz 2**

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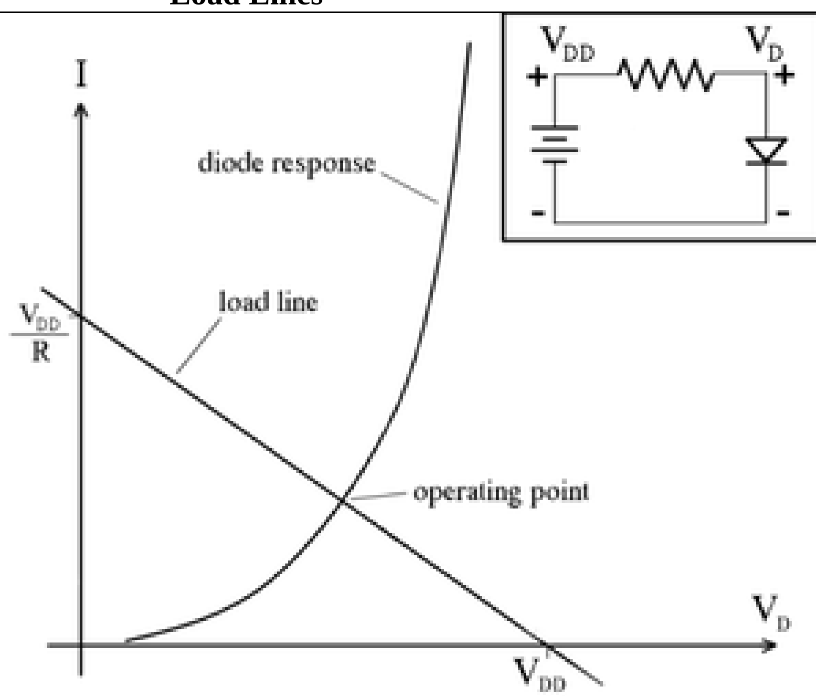
Phasor Notation & Analysis	
$V(t) = V_o \cos(\omega t + \varphi) = \mathrm{Re}\left(V_o e^{j\varphi} e^{j\omega t}\right)$	**Phasor:** $\tilde{V} = V_o e^{j\varphi}$
$V(t) = V_o e^{-\alpha t} \cos(\omega t + \varphi) = \mathrm{Re}\left(V_o e^{-\alpha t} e^{j\varphi} e^{j\omega t}\right)$	**Phasor:** $\tilde{V} = V_o e^{-\alpha t} e^{j\varphi}$

Transfer Functions		
$\tilde{V} = \tilde{I} Z$	$H(j\omega) = \dfrac{\tilde{V}_{out}}{\tilde{V}_{in}}$	$H(j\omega) = \dfrac{Z_2}{Z_1 + Z_2}$ *series circuit only*
Combining Impedances	$Z_{eq} = Z_1 + Z_2 + \ldots + Z_N$ *series*	$\dfrac{1}{Z_{eq}} = \dfrac{1}{Z_1} + \dfrac{1}{Z_2} + \ldots + \dfrac{1}{Z_N}$ *parallel*
Using Transfer Functions	$A_{out} = \lvert H \rvert \cdot A_{in}$	$\phi_{out} = \angle H + \phi_{in}$

Decibel Notation	
$dB = 10\log_{10}\left(P/P_o\right) = 20\log_{10}\left(V/V_o\right)$	$P = P_o 10^{\frac{dB}{10}}$
$dBm = 10\log_{10}\left(P/1mW\right)$	$P = (1mW)10^{\frac{dBm}{10}}$
$dBW = 10\log_{10}\left(P/1W\right)$	$P = 10^{\frac{dBW}{10}}$

Load Lines

A load line represents the I-V curve for the combination of the source and resistor. It is used to graphically determine the operating point for devices with nonlinear I-V curves like diodes and transistors.



ECSE-1010 **Crib Sheet** **Quiz 3**

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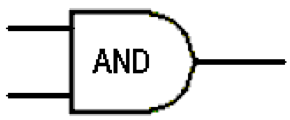
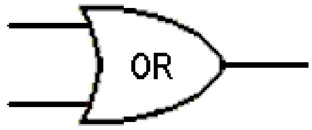
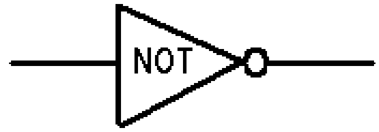
Logic Gates



A	B	$Y = A \bullet B$
0	0	0
0	1	0
1	0	0
1	1	1



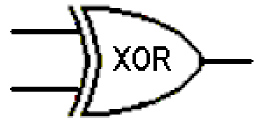
A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1



A	$Y = \overline{A}$
0	1
1	0

A	B	$Y = \overline{A \bullet B}$
0	0	1
0	1	1
1	0	1
1	1	0

A	B	$Y = \overline{A + B}$
0	0	1
0	1	0
1	0	0
1	1	0



A	B	$Y = A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

Boolean Algebra Properties

$A \bullet 0 = 0$

$A + 0 = A$

$A \bullet 1 = A$

$A + 1 = 1$

$A \bullet A = A$

$A + A = A$

$\overline{\overline{A}} = A$

$A \bullet \overline{A} = 0$

$A + \overline{A} = 1$

$A \oplus B = \overline{A} \bullet B + A \bullet \overline{B}$

$\overline{A \oplus B} = \overline{A} \bullet \overline{B} + A \bullet B$

$A \bullet B = B \bullet A$

$A + B = B + A$

$A + A \bullet B = A$

$A \bullet (A + B) = A$

$A \bullet (\overline{A} + B) = A \bullet B$

$A + \overline{A} \bullet B = A + B$

$\overline{A} + A \bullet B = \overline{A} + B$

$\overline{A} + A \bullet \overline{B} = \overline{A} + \overline{B}$

$A \bullet (B + C) = A \bullet B + A \bullet C$

$A + B \bullet C = (A + B) \bullet (A + C)$

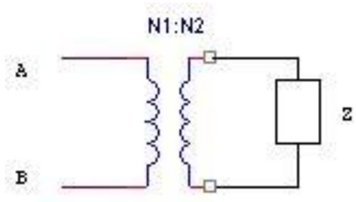
$A \bullet (B \bullet C) = (A \bullet B) \bullet C$

$A + (B + C) = (A + B) + C$

$\overline{A \bullet B} = \overline{A} + \overline{B}$

$\overline{A + B} = \overline{A} \bullet \overline{B}$

Transformers



ideal equations

$$a = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2} = \sqrt{\frac{L_2}{L_1}}$$

input impedance

$$Z_{in} = Z_{AB} = \frac{Z}{a^2}$$

ECSE-1010 **Crib Sheet** **Quiz 3**

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Op-Amp Circuits

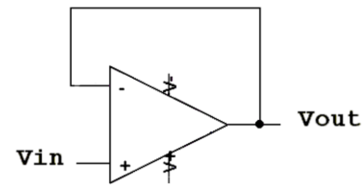
Op Amp Analysis Rules

1. $V_+ = V_-$
2. $I_+ = I_- = 0$

Op-Amp Analysis

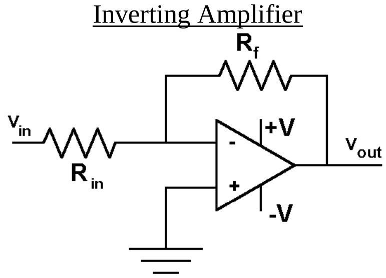
1. Remove Op-Amp
2. Draw a circuit at each input to the op-amp
3. Solve for Vout in terms of the input voltage(s).

Voltage Follower



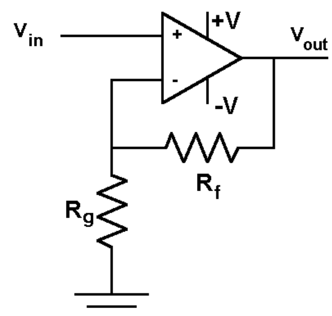
$$A_V = \frac{V_{out}}{V_{in}} = 1$$

Inverting Amplifier



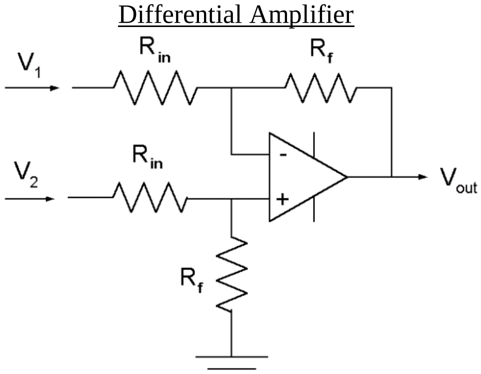
$$A_V = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

Non-Inverting Amplifier



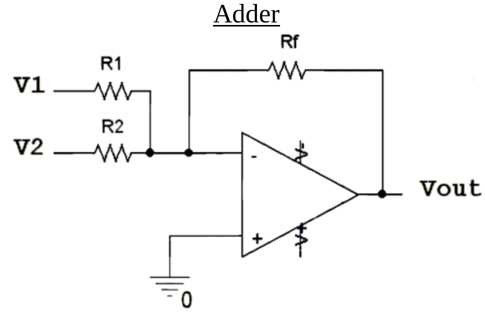
$$A_V = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_g}$$

Differential Amplifier



$$V_{out} = \frac{R_f}{R_{in}}\left(V_2 - V_1\right)$$

Adder



$$V_{out} = -\frac{R_f}{R_1}V_1 - \frac{R_f}{R_2}V_2$$