COMMON EQNS:

$I = \frac{V}{R}$, $V = IR$, $R = \frac{V}{I}$ $\qquad$ $I = \frac{P}{V}$, $P = IV$, $V = \frac{P}{I}$

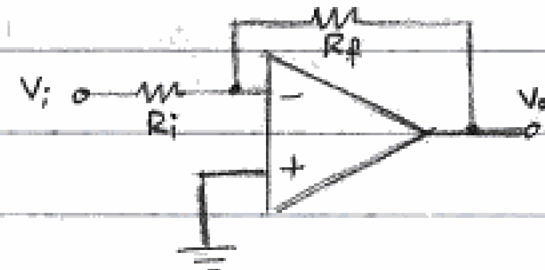
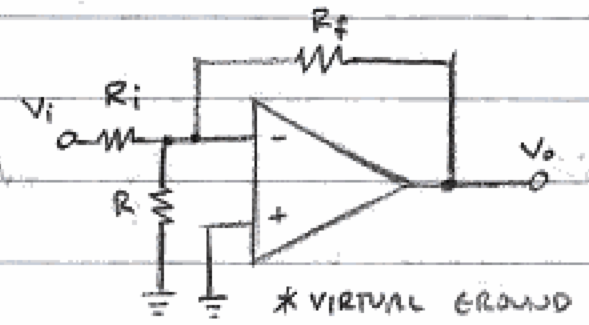
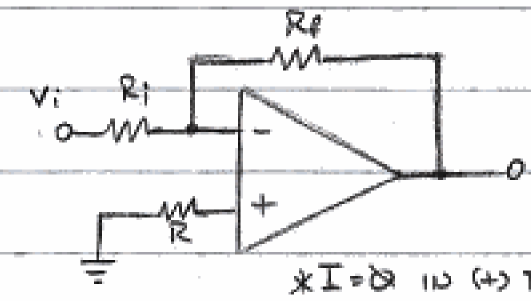
$V_o = V_i \left(\frac{R_2}{R_1 + R_2}\right)$

$V_{rms} = \frac{1}{\sqrt{2}} V$

NASH $\qquad$ ECE 3813 $\qquad$ TEST 1 NOTE SHEET

OPERATIONAL AMPLIFIERS

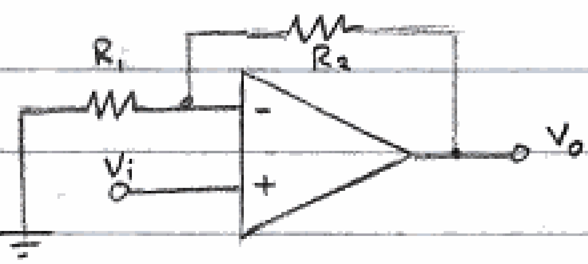
INVERTING

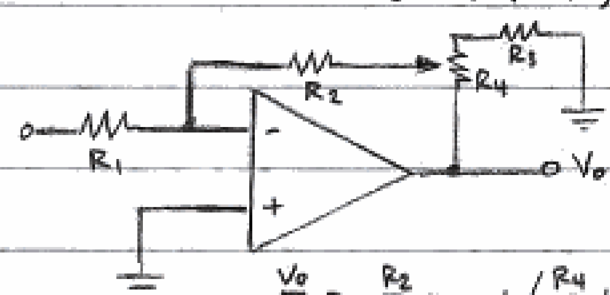
*VIRTUAL GROUND $\qquad$ *I = 0 IN (+) TERM

- $A_v = -\left(\frac{R_f}{R_i}\right)$
- $V_o = A_v V_i$

NORMAL



- $\frac{V_o}{V_i} = A_v = -\frac{R_2}{R_1}$
- $V_o = V_i\left(1 + \frac{R_2}{R_1}\right)$

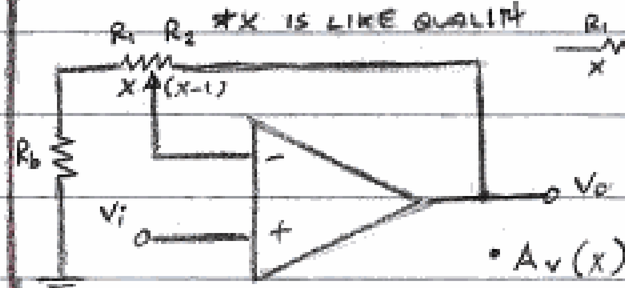


INVERTING w/ POTENTIOMETER

$\frac{V_o}{V_i} = -\frac{R_2}{R_1} = -1\left(\frac{R_4}{R_3} + \frac{R_1}{R_2} + 1\right)$

NON-INVERTING

*X IS LIKE QUALITY



$0 \le x \le 1$

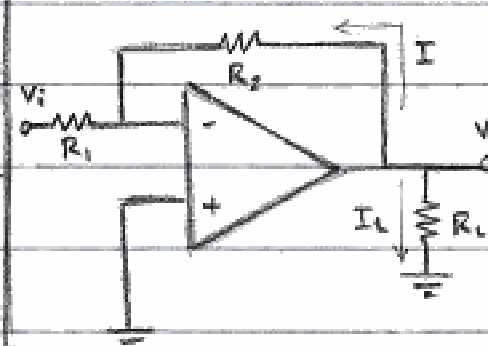
$1 \le \frac{V_o}{V_i} \le \infty$

- $A_v(x) = \frac{1}{x} = \frac{1}{R_L}$ IF NO R_b

R_m = MAX R FROM POT.

- $\frac{V_o}{V_i} = 1 + \left(\frac{(1-x)R_M}{x(R_m)+R_b}\right) = 1 + \frac{R_2}{R_1 + R_b} = A_v$

NOTABLE CONFIGURATIONS

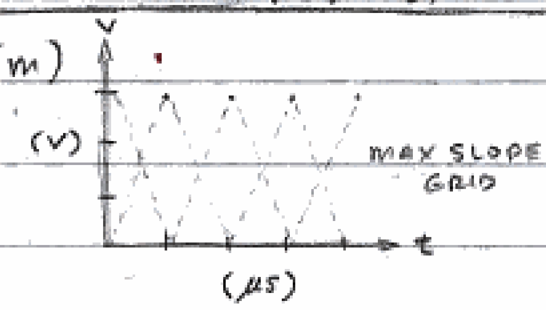


- $I_L = \frac{V_o}{R_L}$
- $V_o = -A_v(V_i)$
- $V_o = IR_2 + I_L R_L$
- $I_o = I_L + I = \frac{V_o}{R_2} + \frac{V_o}{R_L}$

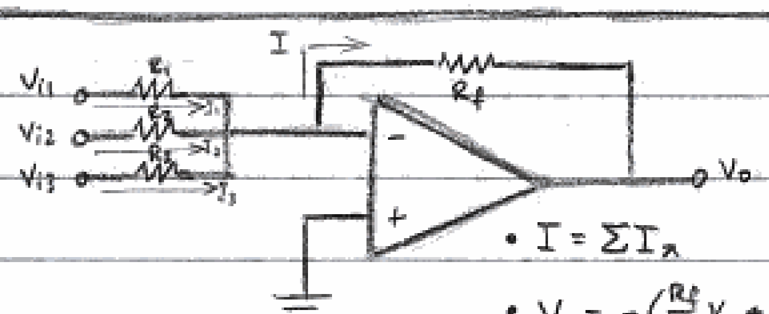
SLEW = $\frac{V}{t}$ = SLOPE (m)

$V(t) = mt$

$t_{min} = \frac{V}{m}$

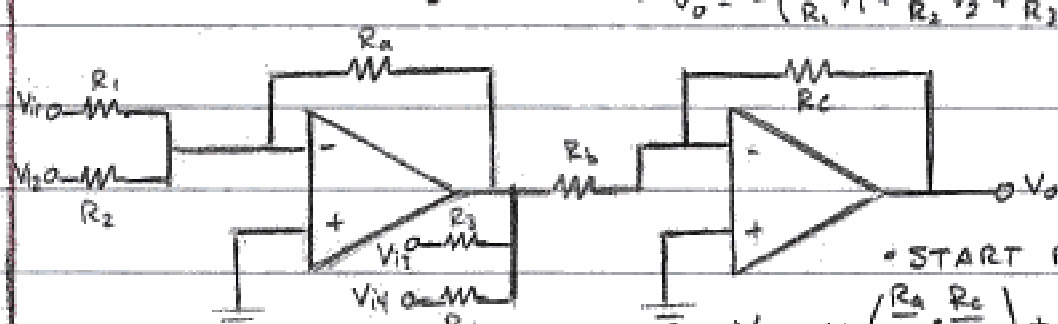


SUMMING AMPS



- R_x DETERMINES V_x (APPLIES TO BOTH CONFIGURATIONS)
- $I = \Sigma I_x$
- $V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$

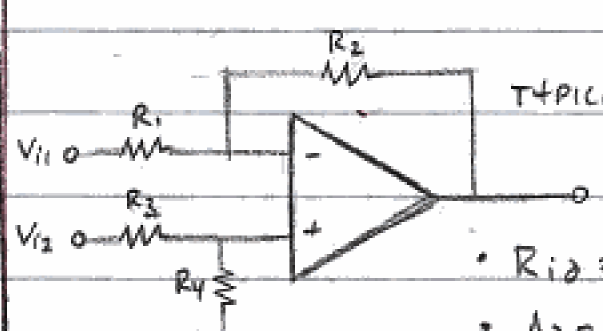
- IDEAL AMPS HAVE HIGH R_i/LOW R_o
- CLOSED-LOOP AMPS: $A_v \sim 1$
- DIFF. AMP IDEAL TO ELIM. "HUM"
- rms ONLY FOR POWER CALCULATIONS



- START BY CHOOSING $R_4 \sim 10k\Omega$
- $V_o = V_1\left(\frac{R_a}{R_1}\cdot\frac{R_c}{R_b}\right) + V_2\left(\frac{R_a}{R_2}\cdot\frac{R_c}{R_b}\right) - V_3\left(\frac{R_c}{R_3}\right) - V_4\left(\frac{R_c}{R_4}\right)$

DIFFERENCE AMP

USING SUPERPOS:
1. SET V_{i1} TO G, CALC V_{i2} → $V_{o1} = \left(-\frac{R_2}{R_1}\right)V_{i1}$
2. SET V_{i2} TO G, CALC V_{i1} → $V_{o2} = V_{i2}\left(\frac{R_2}{R_1}\right)$
3. CALC. V_{id} → $V_o = \frac{R_2}{R_1}(V_{i2} - V_{i1}) = \frac{R_2}{R_1}V_{id}$
4. CALC DIFF. GAIN → $A_d = \frac{2R_2}{R_d} = \frac{2R_4}{R_3}$



TYPICAL TO ASSUME $R_1 = R_3$ AND $R_2 = R_4$

SO $\frac{R_2}{R_1} = \frac{R_4}{R_3}$

- $R_{id} = 2R_1$ $\qquad$ *R_{id} = DIFFERENTIAL INPUT R
- $A_d = \frac{R_2}{R_1} = \frac{R_4}{R_3}$ $\qquad$ *A_d = DIFFERENTIAL GAIN, A_{cm} = COMMON MODE GAIN

~~CMRR = $\frac{A_d}{A_{cm}}$~~

- $V_o = A_d(V_i^+ - V_i^-)$ *(IDEAL, $R_1 = R_3$ & $R_2 = R_4$)

$CMRR = 20\log\left(\frac{A_d}{A_{cm}}\right)$

- $V_o = A_d(V_i^+ - V_i^-) + \frac{1}{2}A_{cm}(V_i^+ - V_i^-)$
- $V_o = \left(\frac{R_2 + R_1}{R_4 + R_3}\right)\left(\frac{R_4}{R_1}\right)V_{i2} - \left(\frac{R_2}{R_1}\right)V_{i1}$ (NON-IDEAL)

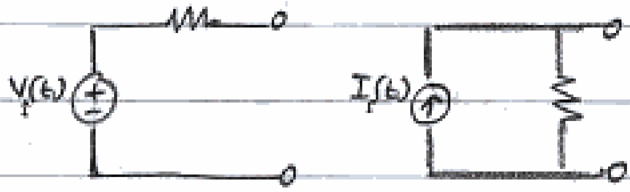
M. Nash
2010

CMRR = COMMON MODE REJECTION RATIO; MEASURES ABILITY OF AMP TO ACCURATELY CANCEL VOLTAGES

SIGNALS

THEVENIN EQUIVALENT: OPEN CIRCUIT VOLTAGE FROM A VOLTAGE SOURCE

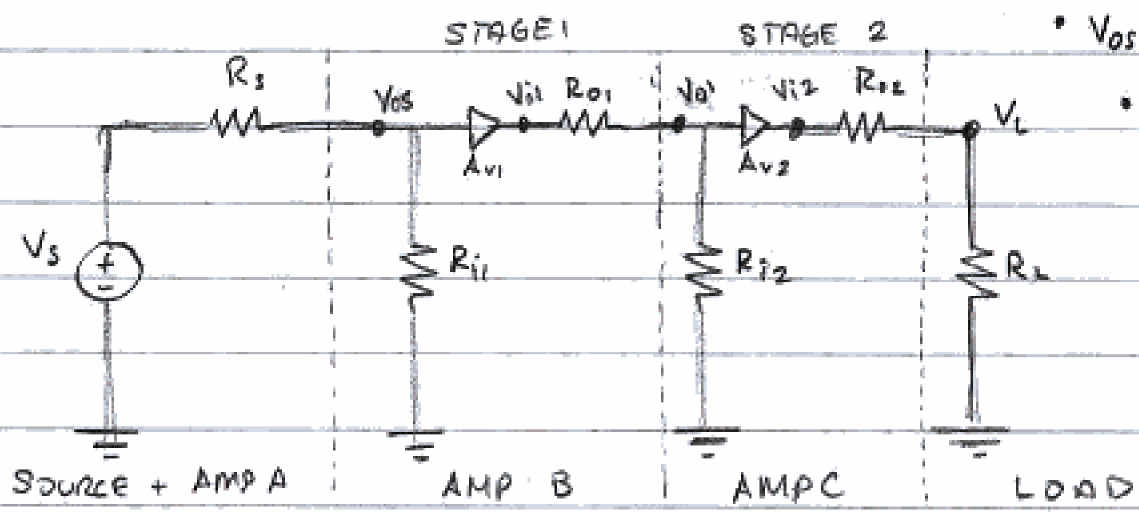
NORTON EQUIVALENT: SHORT CIRCUIT CURRENT FROM A CURRENT SOURCE



$$\left.\begin{array}{l} V_s(t) = V_{oc} \\ I_s(t) = I_{sc} \end{array}\right\} R_s = \frac{V_s}{I_s} = \text{INTERNAL RESISTANCE}$$

AMPLIFIERS:

- $P = I_{i,rms} \cdot V_{i,rms}$
- $A_v = \frac{V_o}{V_i}$ $A_p = \frac{P_o}{P_i}$, $A_I = \frac{I_o}{I_i}$ ★ OHM'S LAW MAY BE USED TO SUB $V = IR$
- $V_{rms} = \frac{1}{\sqrt{2}} V$
- $I_{rms} = \frac{1}{\sqrt{2}} I$
- $10 \log(A_p) = A_p [dB]$
- $20 \log(A_v) = A_v [dB]$
- $20 \log(A_I) = A_I [dB]$
- $10 \log(A_v[\frac{V}{V}] \cdot A_I[\frac{A}{A}]) = A_p [dB]$
- $P_i = I_{i,rms} \cdot V_{i,rms}$
- $P_o = I_{o,rms} \cdot V_{o,rms}$



- $V_{os} = V_s \left(\frac{R_{i1}}{R_{i1} + R_s} \right)$
- $V_{i1} = A_{v1} (V_{os})$
- $V_L = V_{i2} \left(\frac{R_L}{R_L + R_{o2}} \right)$
- $P_L = \frac{V_L^2}{R_L}$

★ GIVEN A SIGNAL RANGE, $V_+ = \underset{\text{ABOVE}}{V_{SUP}} - V_{RANGE}$, $V_- = \underset{\text{LOW}}{V_{SUP}} + V_{RANGE}$

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2010