Circuits Cheat Sheet

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Exam 1

- ## Amplifiers
  - Gain

$$A_v = \frac{v_O}{v_I}\left(\frac{V}{V}\right) \quad A_i = \frac{i_o}{i_I}\left(\frac{A}{A}\right) \quad A_p = \frac{p_o}{p_I} = \frac{v_O i_O}{v_I i_I}\left(\frac{W}{W}\right)$$

in dB

$$A_v \text{ or } A_i = 20 \log |A_{v \text{ or } i}|$$
$$A_p = 10 \log |A_p|$$

- Power Balance: $\quad$ ↙ dis. in amp.

$$P_{dc} + P_I = P_L + P_{loss}$$
$$\frac{P_L}{P_{dc}} \times 100 = \% \text{ efficiency}$$

- Standard Amp. (Amp. Models concept lec)

$$\frac{v_o}{v_i} = A_{vo}\left(\frac{R_L}{R_L+R_o}\right)\left(\frac{R_i}{R_s+R_i}\right)$$

- ## Ideal Op-Amps $\quad v_O = A(v_+ - v_-)$

① Draws zero input current : $i_- = i_+ = 0\,A$
② v_O is not a func. of i_O : $R_o = 0$
③ Open loop gain is inf: $v_+ = v_-$
④ Inf. Common Mode Rejection: $v_o = 0$
⑤ Inf. Bandwidth: A is not a func. of freq.

- ## Non-Ideal Op-Amps (Finite A)

inverting: $\frac{v_O}{v_I} = \frac{-R_2/R_1}{1 + \frac{1}{A}\left(1 + \frac{R_2}{R_1}\right)}$

non-inverting: $\frac{v_O}{v_I} = \frac{(1 + R_2/R_1)}{1 + \frac{1}{A}\left(1 + \frac{R_2}{R_1}\right)}$

This is the one where you make tables

★ Know how to Draw all Op-Amp Configs.

★ Know how to solve w/ Pots or dividers

- Inverting Op-Amps

$\frac{v_O}{v_I} = \frac{-R_2}{R_1} \rightarrow$ Closed Loop Gain: $G = \frac{-R_2}{R_1}$

$R_i = \frac{v_I}{i_1} = R_1$ $\quad R_o = 0$

$i_1 = \frac{v_I}{R_1}$

$i_2 = \frac{0 - v_o}{R_2}$

★ Know how to Design an Op-Amp → see ex. lec.

- Weighted Summer

$v_O = v_{O1} + v_{O2} + v_{O3}$

$v_O = -\frac{R_f}{R_1} v_1 - \frac{R_f}{R_2} v_2 - \frac{R_f}{R_3} v_3 \ldots$

$i_f = \frac{v_{Omax}}{R_f}$ (?)

- Non-Inverting Op-Amps (Rev. V.S.P.)

$R_i = \frac{v_I}{i_I \to 0} = \infty$ $\quad R_o = 0$

$G = 1 + \frac{R_2}{R_1}$

- Voltage Follower:

$R_1 = \infty$ $\quad R_2 = 0$ $\quad v_O = v_I$

- Difference Amplifier:

$v_O = v_{O1} + v_{O2}$ $\qquad$ $v_O = A_{cm} v_{Icm} + A_d v_{ID}$

$v_{O1} = \left(\frac{-R_2}{R_1}\right) v_{I1}$ $\qquad$ $v_{O2} = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3+R_4}\right) v_{I2}$

$v_{I1} = v_{ICM} - \frac{1}{2} v_{ID}$ $\qquad$ ICM = common mode

$v_{I2} = v_{Icm} + \frac{1}{2} v_{ID}$ $\qquad$ ID = differential

- Common Mode Rejection Ratio:

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

☆ if A_{cm} is zero (ideal) then CMRR = ∞.

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

$A_d = \frac{1}{2}\left(\frac{R_2}{R_1} + \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3+R_4}\right)\right)$

☆ When $A_{cm} = 0$:

$A_d = \frac{R_2}{R_1}$ $\qquad$ $R_1 = R_3$ $\qquad$ When true $A_d = \frac{R_2}{R_1}$

$R_{id} = 2R_1$ $\qquad$ $R_2 = R_4$

☆ Know how to solve when Rs have a ~~[illegible]~~ % tolerance.

- Instrumentation Amplifier

$$v_O = \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right) v_{ID}$$

w/ R_2 mismatch:

$$\hookrightarrow v_O = \frac{R_4}{R_3}\left(1 + \frac{R_{2_1} + R_{2_2}}{R_1}\right) v_{ID}$$

$$v_{ID} = v_{I2} - v_{I1}$$

$$i_1 = \frac{v_{I1} - v_{O1}}{R_2}$$

★ know how to solve w/ a pot.

$$i_2 = \frac{v_{I2} - v_{O2}}{R_2}$$

$$i_x = \frac{v_{ID}}{2R_1}$$

- IDEAL DIODES

OFF: Reverse Bias Region: $v < 0$, $i = 0$
↳ looks like an open circuit

ON: Forward Bias Region: $v > 0$, $i > 0$
↳ looks like a short circuit

→ Assume Diode state & solve to check.

★ know how to read both types of circs.

- Forward Bias Diodes

$$V_T = \frac{kT}{q}$$

$V_T = 25\ mV$ (room temp.)
$k = 8.62 \times 10^{-5}\ eV/K$
$q = 1.6 \times 10^{-19}\ C$

$$i \cong I_s \exp\left(\frac{v}{nV_T}\right)$$

$$\frac{I_2}{I_1} = \exp\left(\frac{V_2 - V_1}{V_T}\right)$$

$$V_2 - V_1 = V_T \ln\left(\frac{I_2}{I_1}\right)$$

- Modeling Diodes:

iterate: $I_D = \frac{V_{DD} - V_D}{R}$

constant drop: use ↑ w/ $V_D = 0.7$ unless told otherwise

ideal: solve w/ $V_D = 0$.

- Zener Diodes

$V_Z = V_{Z0} + I_Z r_Z$ or $V_{Z0} = V_Z - I_Z r_Z$

$$\Delta V_O = \frac{r_Z}{R + r_Z}(\Delta V_S)$$