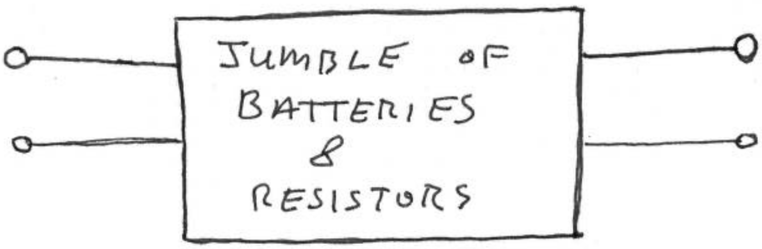
PHYS 4211 INSTRUMENTATION REVIEW

T. E. COAN

① THÉVENIN & NORTON EQUIVALENTS



ANY COLLECTION OF BATTERIES + RESISTORS THAT HAS **2** INPUTS AND **2** OUTPUTS CAN BE REPRESENTED AS A "THÉVENIN EQUIVALENT." SEE H. & H. p. 11.

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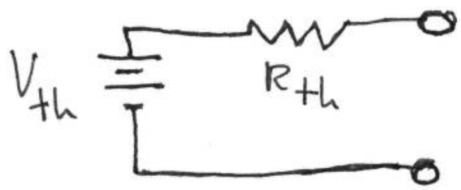

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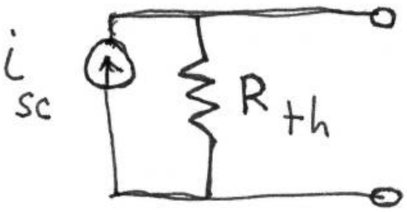


$$i_{sc} = \frac{V_{th}}{R_{th}}$$

② GENERAL OHM'S LAW

FOR COMPLEX I, V, Z:

$I = V/Z$

$V = IZ$

$Z = Z_1 + Z_2 + Z_3 + \dots$ (SERIES)

$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \dots$ (PARALLEL)

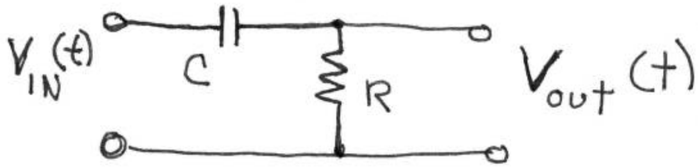
$Z_R = R$ (RESISTOR)

$Z_C = -j/\omega C$ (CAPACITOR)

$Z_L = j\omega L$ (INDUCTOR)

$j^2 = -1$

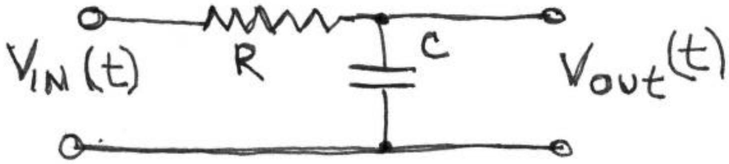
③ SIMPLE RC FILTERS



"HIGH PASS" FILTER

$$f_{3dB} = \frac{1}{2\pi RC} \qquad [f] = \text{Hz}$$

FOR $f \gg f_{3dB}$, $V_{out} \simeq V_{IN}$



"LOW PASS" FILTER

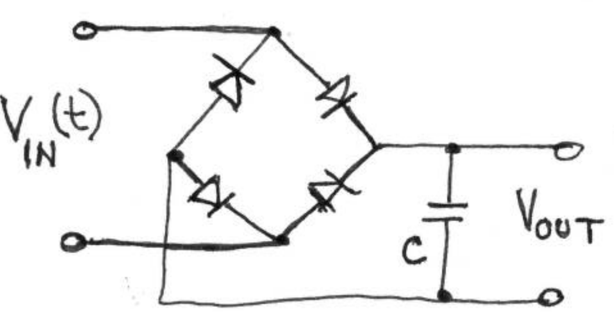
$$f_{3dB} = \frac{1}{2\pi RC}$$

FOR $f \ll f_{3dB}$, $V_{out} \simeq V_{IN}$

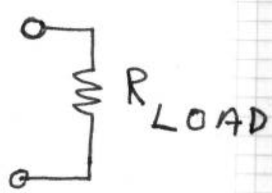
$$dB = 20 \log_{10}\left(\frac{V_{OUT}}{V_{IN}}\right)$$

V_o/V_{IN}	dB
$\frac{1}{\sqrt{2}}$	−3
1/2	−6
1/10	−20

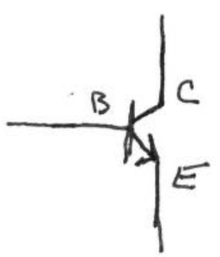
④ FULL WAVE RECTIFIER



$$\Delta V = \frac{I_{LOAD}}{2fC}$$



⑤



NPN TRANSISTOR

WHEN "ON", $V_B - V_E = 0.6$ VOLTS

$i_c = h_{fe}\, i_B \quad (h_{fe} \simeq 100)$

$i_E = (h_{fe}+1)\, i_B$

$$I_c = I_s\left\{e^{V_{BE}/V_T} - 1\right\}$$

"EBERS-MOLL" EQN

$V_T = 25$ mV

$\Delta V_{BE} = -2.1$ mV/°C

$$I_c = I_{co}\left\{\exp\left(\Delta V_{BE}/25\,(\text{mV})\right)\right\}$$

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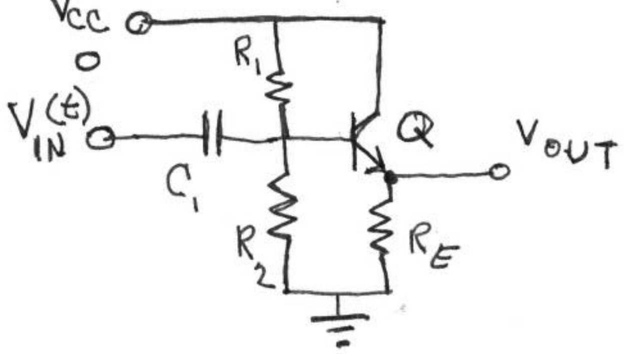
⑥ EMITTER FOLLOWER



$$Z_{IN}^{Q} \simeq (h_{fe} R_E)$$

$$Z_{IN}^{CIRCUIT} = R_{th\_bias} \| Z_{IN}^{Q} \simeq R_{th\_bias}$$

$$V_{out}(t) \simeq V_{IN}(t) - 0.6 \text{ VOLTS}$$

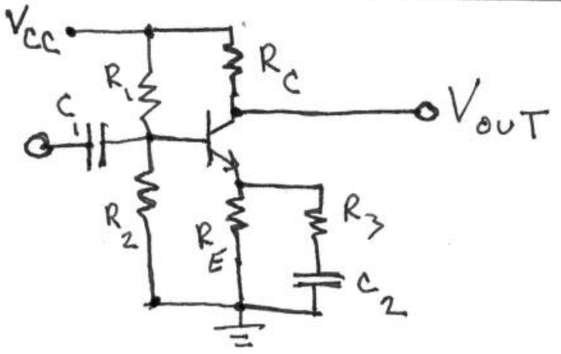
$$Z_{out} = R_E \| \frac{R_{th\_bias}}{h_{fe}} \simeq \frac{R_{th\_bias}}{h_{fe}}$$

① CHOOSE $R_{th\_bias} = R_1 \| R_2 \ll Z_{IN}^{Q}$ FOR STABLE BIASING.

② CHOOSE C_1 FROM f_{3dB}

$$C_1 = \frac{1}{2\pi f_{3dB} R_{th\_bias}}$$

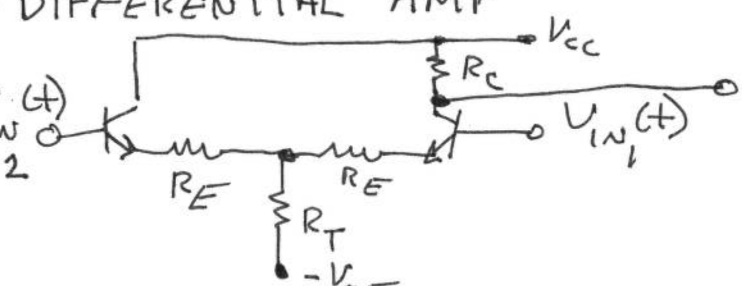
⑦ COMMON EMITTER AMP



$$G = \frac{v_{out}(t)}{V_{IN}(t)} = \frac{-R_C}{R_E'} ; \quad R_E' = R_E^{EFFECTIVE}$$

SEE LAB MANUAL. P. 115

⑧ DIFFERENTIAL AMP



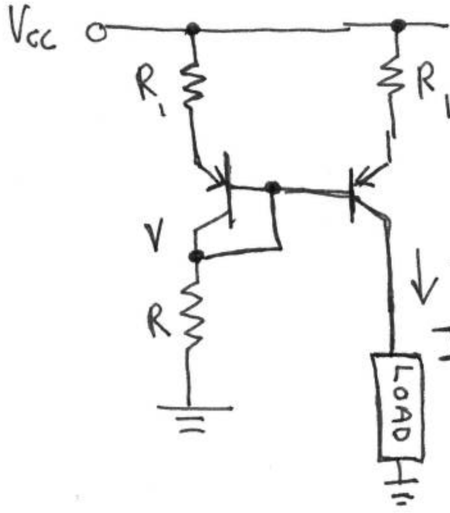
$$G_{DIFF} \equiv \frac{V_{out}}{v_1(t) - v_2(t)} = \frac{R_C}{2(R_E + r_e)}$$

$$G_{CM} \equiv \frac{V_{out}}{V_{com}} = \frac{-R_C}{2R_T + R_E + r_e}$$

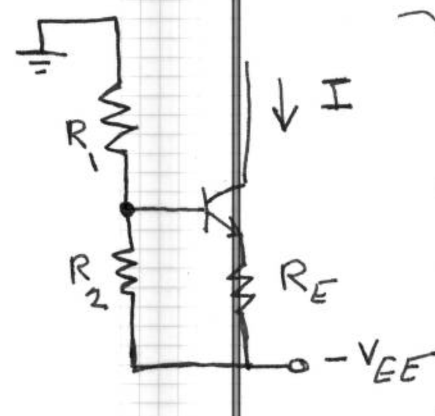
$$CMRR \equiv G_{DIFF}/G_{CM} = R_T/R_C$$

$$V_1(t) \simeq v_1(t) + V_{com}$$
$$V_2(t) = v_2(t) + V_{com}$$

9 CURRENT MIRRORS



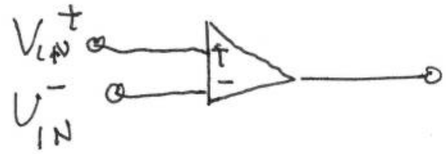
$$I = \frac{V_{cc} - 0.6}{R_1 + R}$$



USEFUL FOR R_T IN DIFF. AMP

OP-AMPS

① VERY USEFUL + VERSATILE DEVICE.



$V^{OUT} = A\,(V_{IN}^{+} - V_{IN}^{-})$

A ↳ "open-loop" GAIN $\gg 1$.

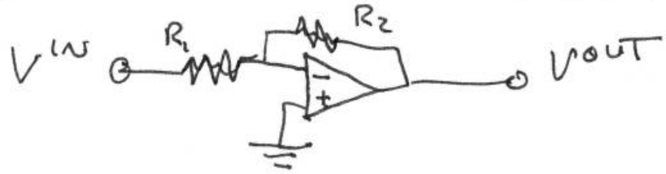
"GOLDEN RULES"

① OP-AMP INPUTS (INVERTING (−) & NON-INVERTING (+)) DRAW NO INPUT CURRENT.

② w/ "NEGATIVE FEEDBACK", V^{OUT} TRYS TO MAKE $\Delta V_{IN} = V^{+} - V^{-}$ EQUAL <u>ZERO</u>.

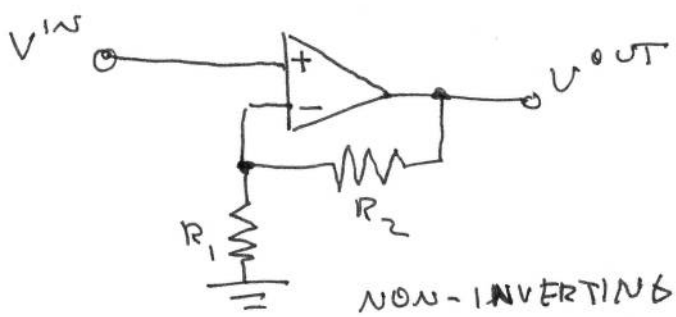
<u>CAVEAT</u>: RULES ① & ② WORK ONLY IF <u>OP-AMP</u> <u>NOT</u> <u>SATURATED</u>.

② STANDARD CONFIGURATIONS w/ <u>NEGATIVE</u> FEEDBACK.



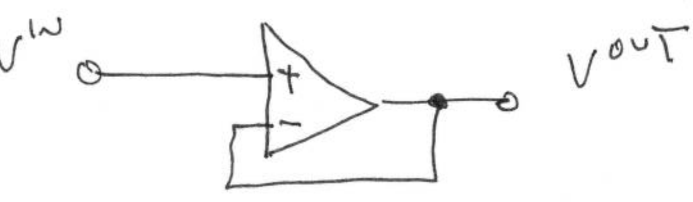
INVERTING AMP

$V^{OUT} = \underbrace{-\left(\frac{R_2}{R_1}\right)}_{\text{GAIN}} V_{IN}$



NON-INVERTING AMP

$V^{OUT} = \underbrace{\left(1 + \frac{R_2}{R_1}\right)}_{\text{GAIN}} V^{IN}$



FOLLOWER

$V^{OUT} = V^{IN}$, $G = 1$

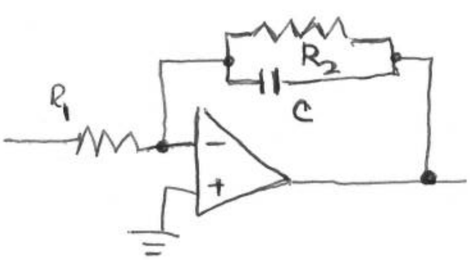
$Z^{IN} \gg 1$

OP-AMPS

③ OP-AMP "REALITIES" & CAVEATS.

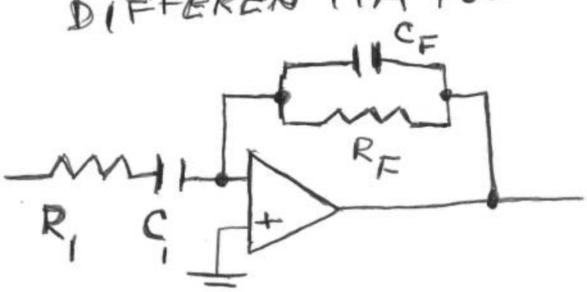
- GOLDEN RULES WORK ONLY IF OP-AMP <u>NOT</u> SATURATED, THIS MEANS $V^{OUT} < V^{OUT}_{max}$ ($\simeq V_{CC}$)
- FEEDBACK MUST BE <u>NEGATIVE</u>.
- THERE MUST BE FEEDBACK AT DC ($f=0$), OTHERWISE OP-AMP WILL SATURATE.
- RESPECT $(V^{+}_{IN} - V^{-}_{IN})$ INPUT VOLTAGE LIMITS.

OP-AMP INTEGRATOR:



$$V_{OUT} = -\frac{1}{R_1 C}\int V_{IN}\, dt + \text{CONST}$$

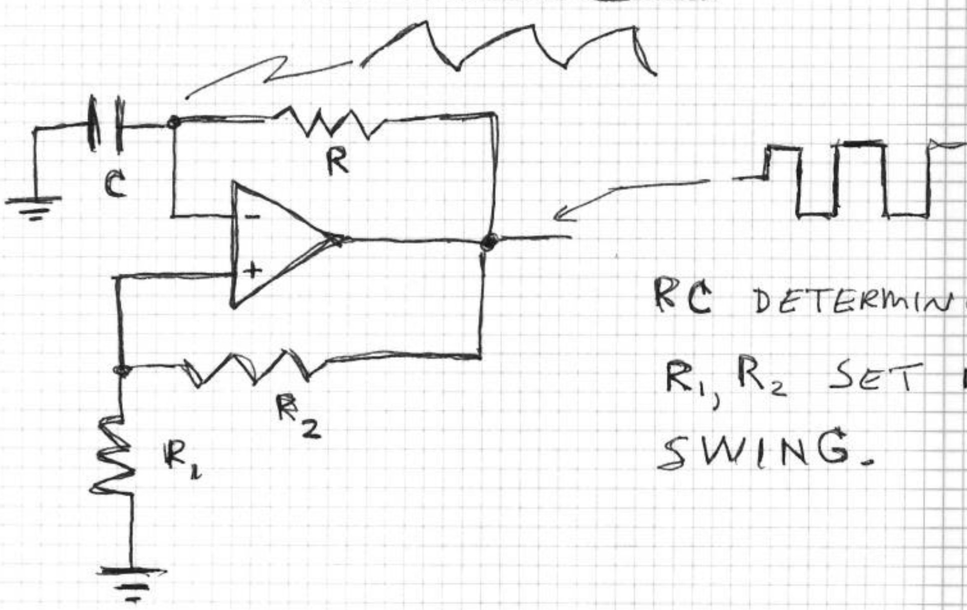
DIFFERENTIATOR



$$V_{OUT} = -R_F C_1 \frac{dV_{IN}}{dt}$$

PAY ATTENTION TO WHAT R'S AND WHAT C'S APPEAR IN THE FORMULAE.

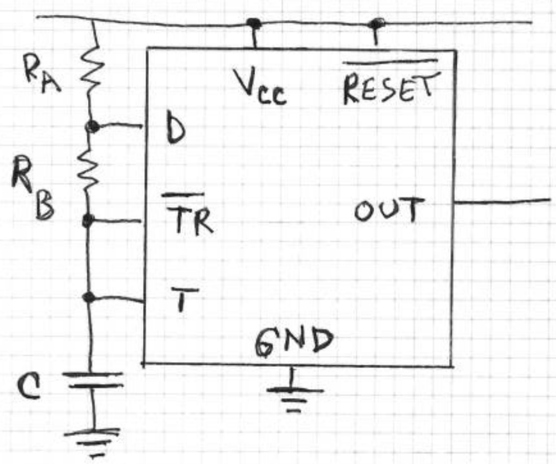
OSCILLATORS



RC DETERMINE PERIOD

R_1, R_2 SET MIN/MAX OF OUTPUT SWING.

555 OSCILLATOR



$$T = \ln 2 \left(R_A + 2 R_B\right) C$$