Semiconductor

P type	n-type
III	
B	N
Al	P
Ga	As
In	Sb

Built-in potential barrier

$$V_{bi} - \frac{KT}{e} \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

↓

V_T - Thermal Voltage

$n_i = 1.5 \times 10^{10}$ cm^{10} cm^{-3} for silicon at room temperature.

$$i_D = I_S \left(e^{\frac{V_D}{V_T}} - 1\right) \simeq I_S e^{\frac{V_D}{V_T}}$$

↓

Reverse-bias saturation current

Half-Wave Rectifier

$V_{dc} = \frac{V_m}{\pi}$ $V_{rms} = \frac{V_m}{2}$

$$\eta = \frac{\frac{V_{avg}^2}{R_L}}{\frac{V_{rms}^2}{R_L}} = 40.53\%$$

$$\text{Form Factor} = \frac{V_{rms}}{V_{avg}} = 1.57$$

Ripple factor $(\gamma) = 1.21$ or 121%
(Ideal - zero)

Full-Wave Rectifier

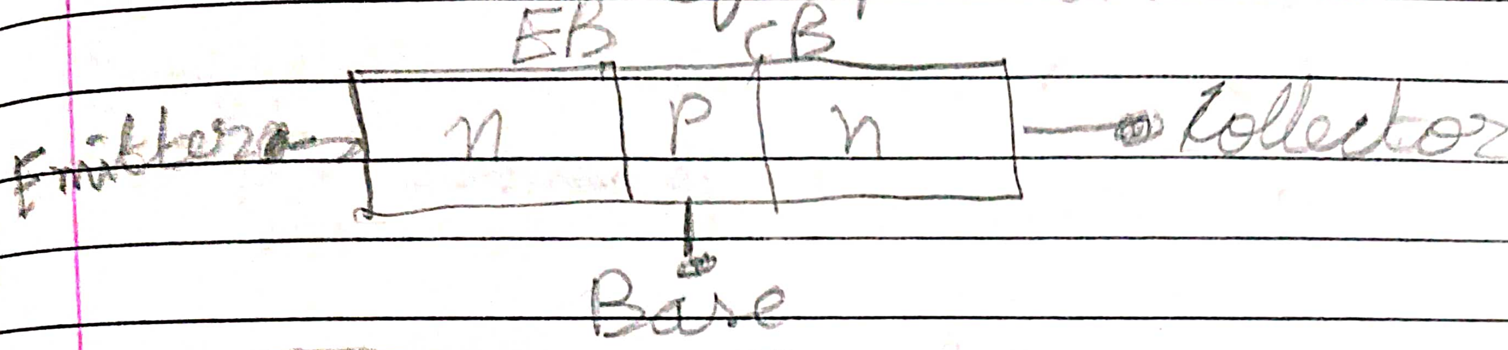
$V_{dc} = \frac{2V_m}{\pi}$ $V_{rms} = \frac{V_m}{\sqrt{2}}$ $(\gamma) = 0.482$

Form Factor $= 1.11$

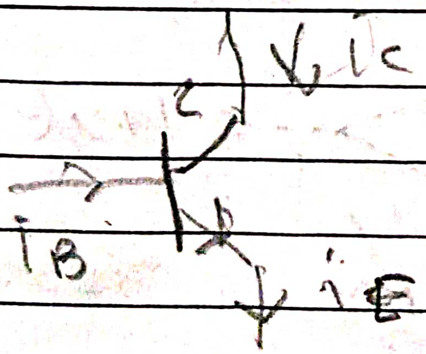
$$V_{pf} = \text{Peak factor} = \frac{V_m}{V_{rms}} = \sqrt{2}$$

BJT

Modes of Operation



EB	CB	Mode
FB	RB	Active
FB	FB	Saturation
RB	RB	Cutoff
RB	FB	Reverse active



$V_{BE} = 0.7$

NPN Transistor

$I_E = I_C + I_B$

$I_C = \alpha I_E \quad I_C = \beta I_B$

mobility $\mu_n > \mu_p$

Operational Amplifier

Ideal characteristics

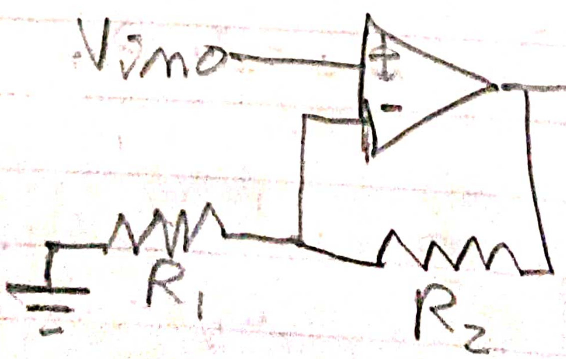
$A_{OL} = \infty$ $\quad R_0 = 0$ $\quad V_0 = 0$ if $V^+ = V^- = 0$

$R_i = \infty$ $\quad BW = \infty$

$$CMRR = \frac{A_{V\,diff}}{A_{CM}}$$

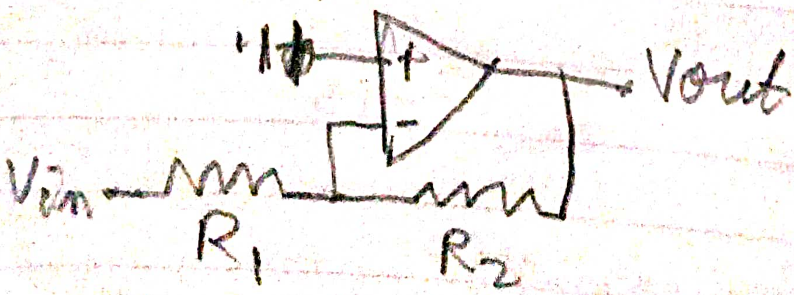
$$\text{Slew Rate} = \frac{\Delta V_{out}}{\Delta t}$$

Non inverting OP-amp



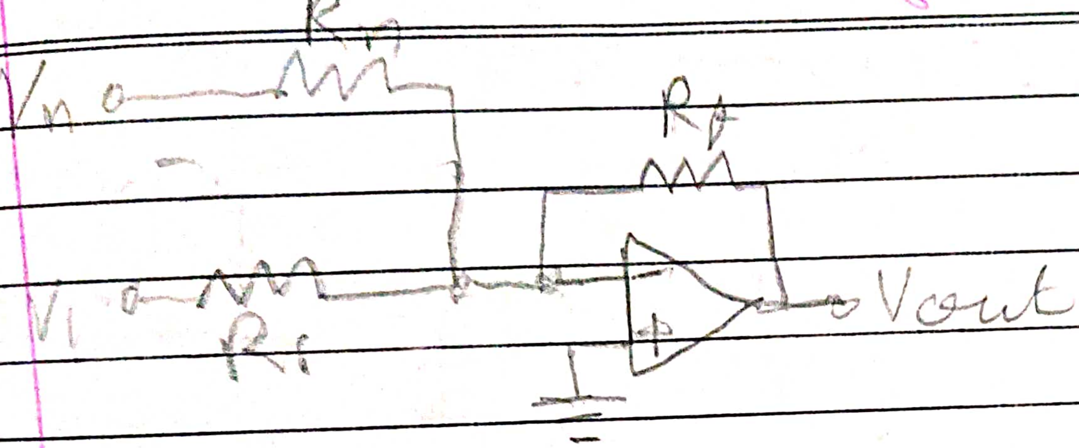
$$V_{out} = V_i\left(1 + \frac{R_2}{R_1}\right)$$

Inverting OpAmp



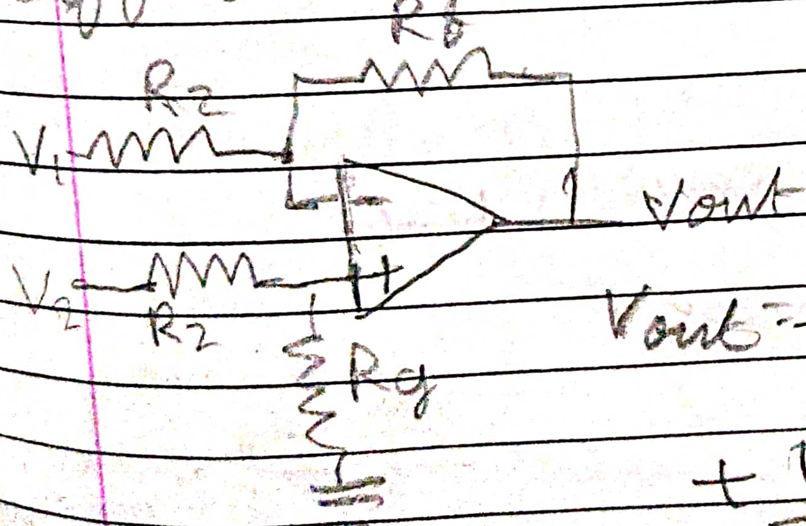
$$V_{out} = V_{in}\left(-\frac{R_2}{R_1}\right)$$

Inverting Summing Amplifier



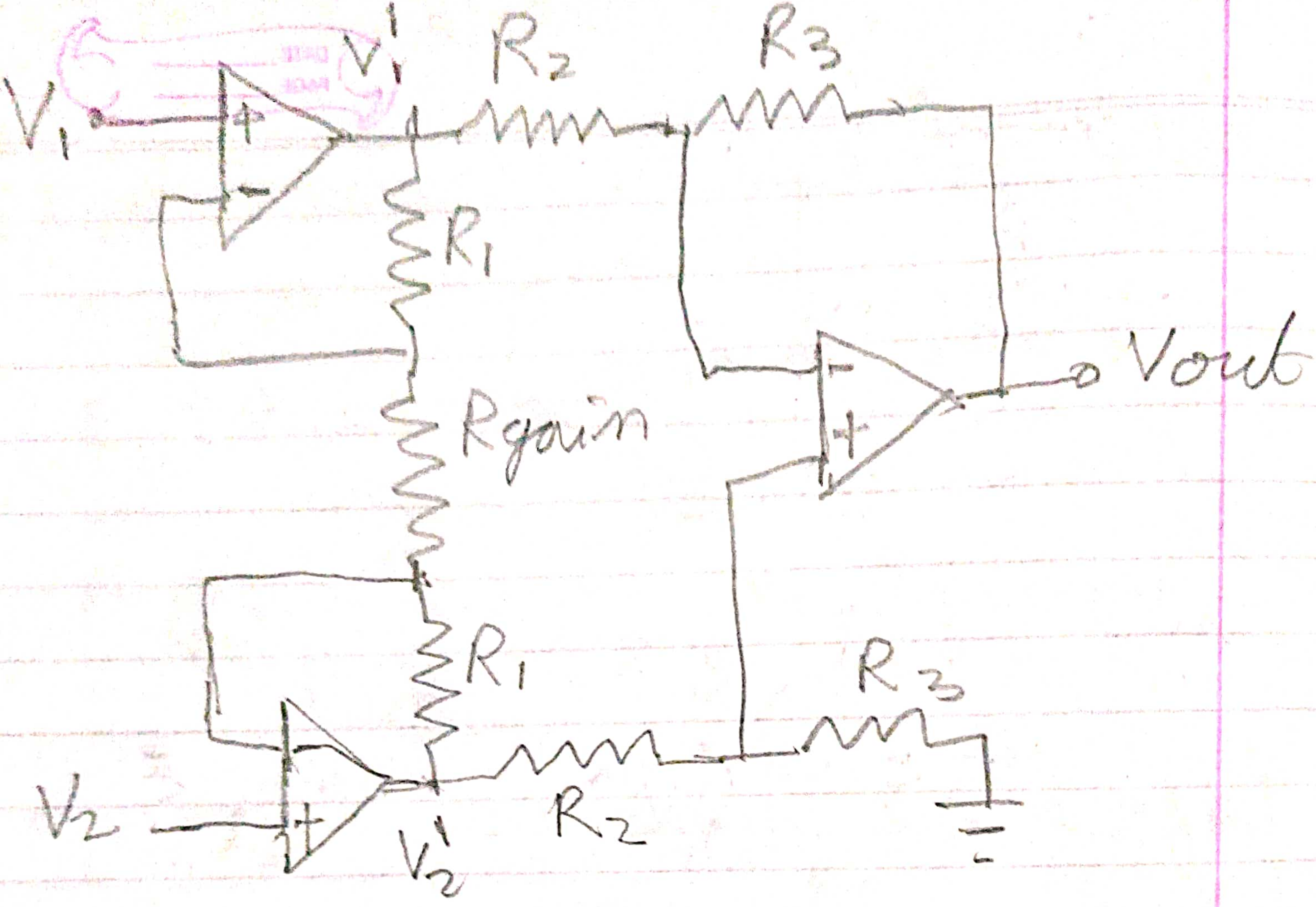
$$V_{out} = -\left(\frac{R_f}{R_1} + \frac{R_f}{R_n}\right) V_{in}$$

Difference amplifier



$$V_{out} = -V_1 \frac{R_f}{R_2} + \frac{V_2 R_g}{R_2 + R_g}\left(1 + \frac{R_f}{R_2}\right)$$

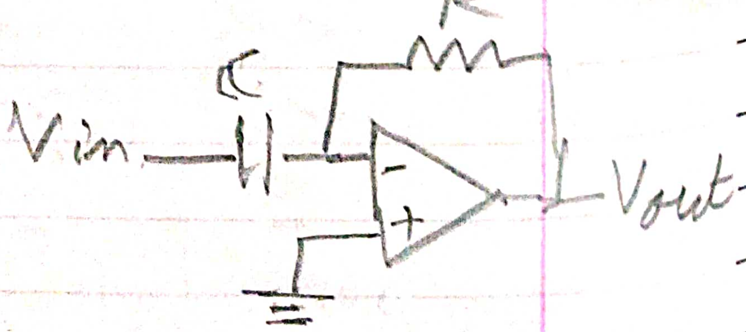
Instrumentation amplifier



$$V_{out} = \left(1 + \frac{2R_1}{R_{gain}}\right)\left(\frac{R_3}{R_2}\right)[V_2 - V_1]$$

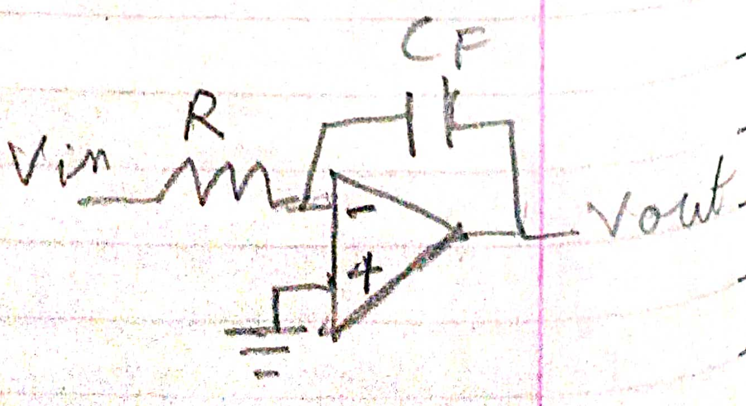
Differentiator

$$V_o = -R_F C \frac{dv_i}{dt}$$

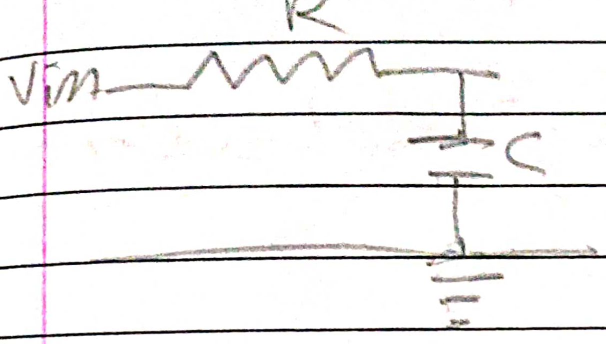


Integrator

$$V_o = \frac{-1}{R_f C}\int_0^t v_i(t)\,dt$$



Low Pass ~~Active~~ Filters



$$V_{out} = \frac{X_C}{X_C + R} V_{in}$$

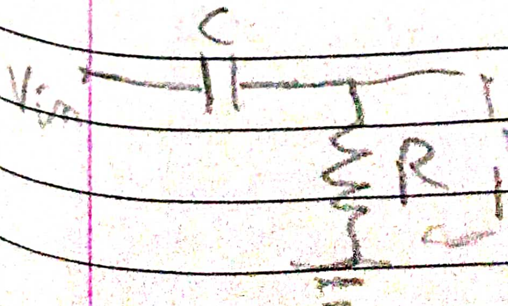
$$\phi = -\tan(\omega CR)$$
$$= -\tan\left(\frac{\omega}{\omega_c}\right) = -\tan\left(\frac{f}{f_c}\right)$$

$$f_c = \frac{1}{2\pi RC}$$

2nd orde

$$f_c = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

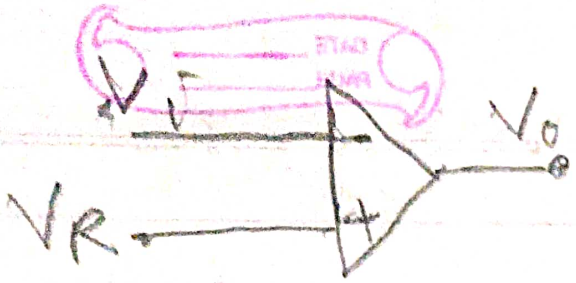
High Pass Filter



$$V_{out} = \frac{R}{X_C + R}$$

$$\phi = \tan\left(\frac{1}{\omega RC}\right) = \tan\left(\frac{\omega_c}{\omega}\right)$$
$$= \tan\left(\frac{f_c}{f}\right)$$

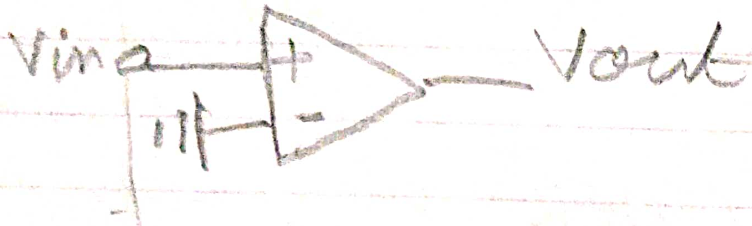
Inverting Comparator



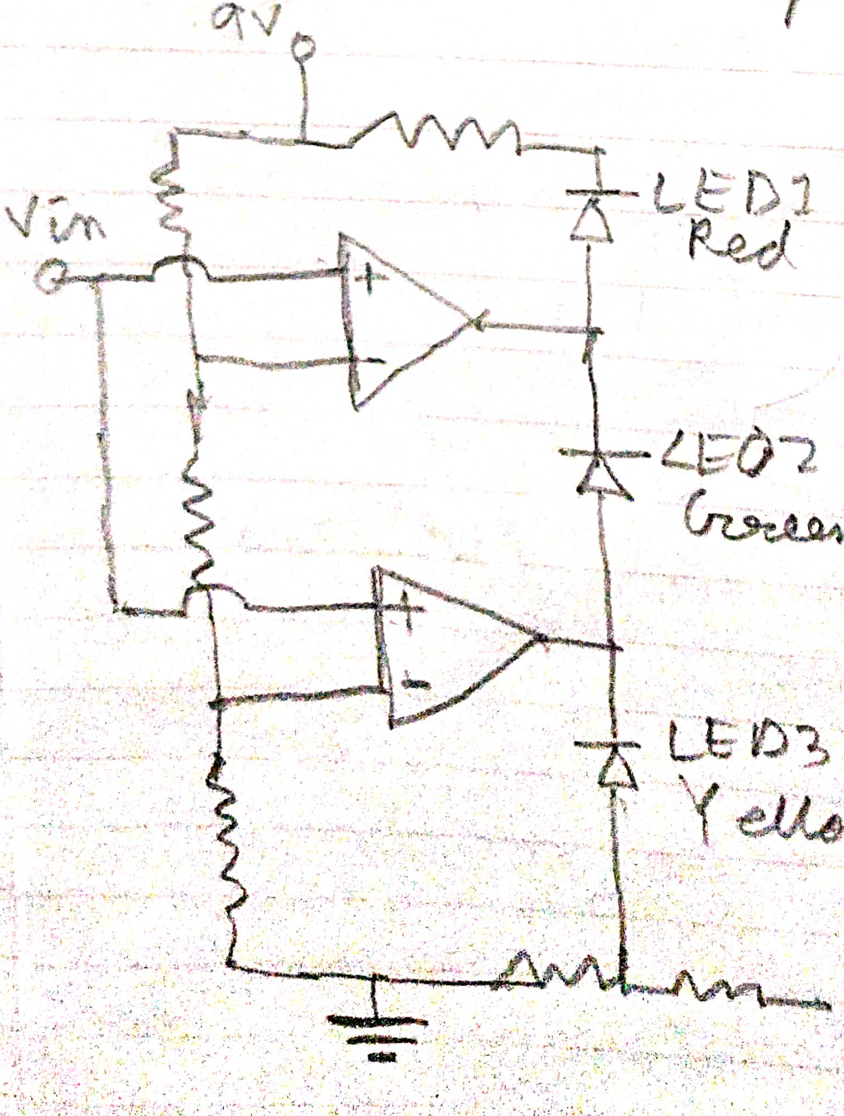
$V_o = -V_{sat}$ $\quad V_i > V_R$

$V_o = V_{sat}$ $\quad V_i < V_R$

Zero crossing detector



3-level comparator with LED



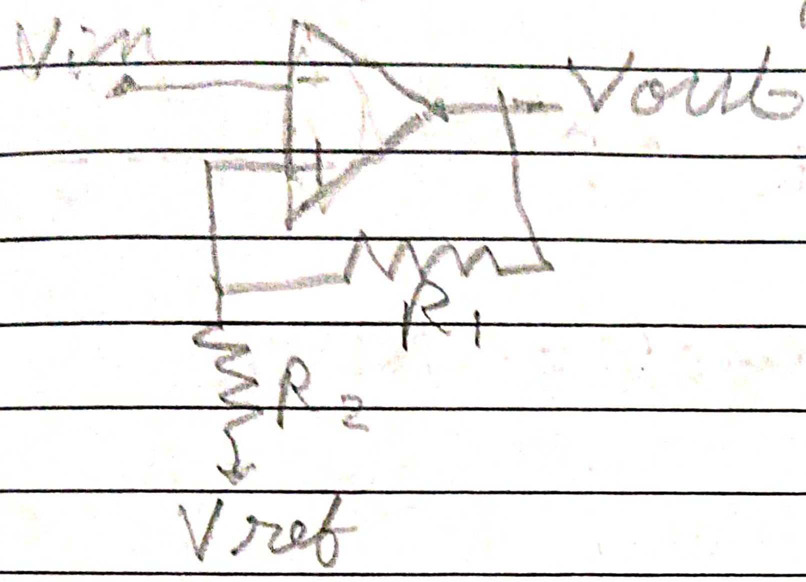
Glow condition

$V_{in} > 6$

$3 < V_{in} < 6$

$V_{in} < 3$

Regenerative comparator (Schmitt trigger)



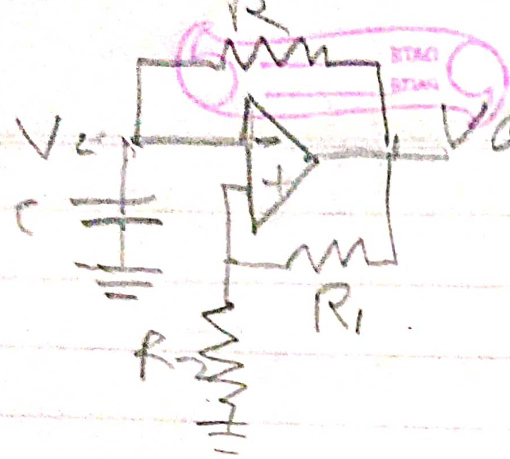
$V_{out} = +V_{sat}$

$$V^+ = \frac{R_1}{R_1+R_2} V_{ref} + \frac{R_2 V_{sat}}{R_1+R_2}$$

$V_{out} = -V_{sat}$

$$V^+ = \frac{R_1 V_{ref}}{R_1+R_2} - \frac{R_2 V_{sat}}{R_1+R_2}$$

Astable multivibrator



$$\beta = \frac{R_2}{R_1 + R_2}$$

Duty cycle = 50% not sure

$$T = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)$$

$$\text{Duty cycle} = \frac{R_1 + R_2}{R_1 + 2R_2}$$

using 555 Timer

$t_{High} = 0.693 \times C (R_1 + R_2)$

$t_{Low} = 0.693 \times C \times R_2$

① stable state

Monostable

$$T = RC \ln\left(\frac{1 + V_D/V_{sat}}{1-\beta}\right)$$

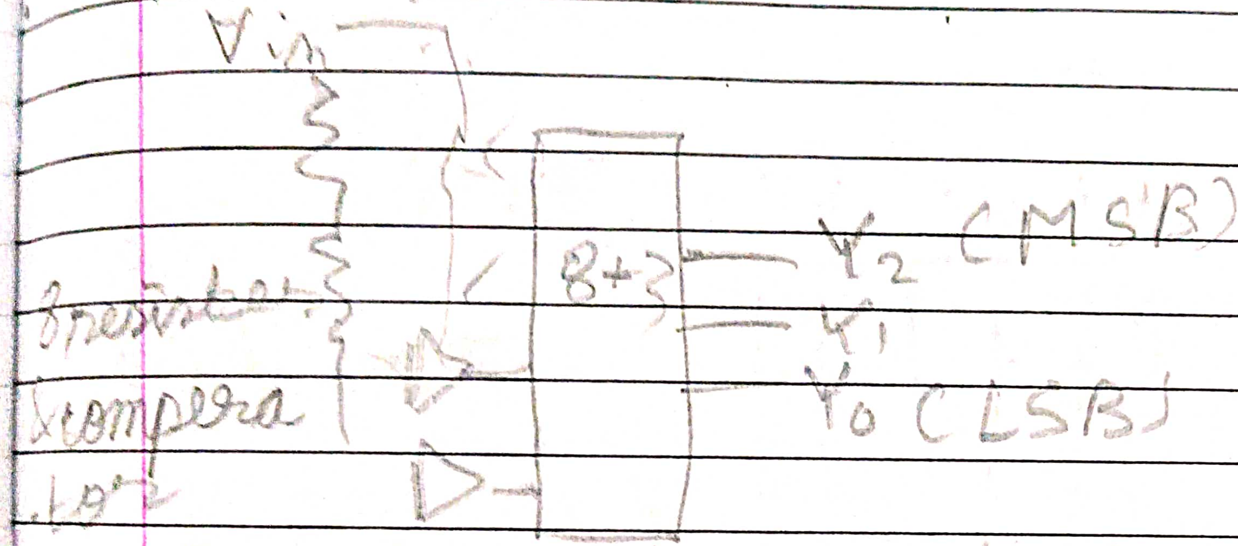
$T = 1.1 RC$

1 stable state
555 Timer

$* \; V_C = V_f + (V_i - V_f) e^{-t/RC}$

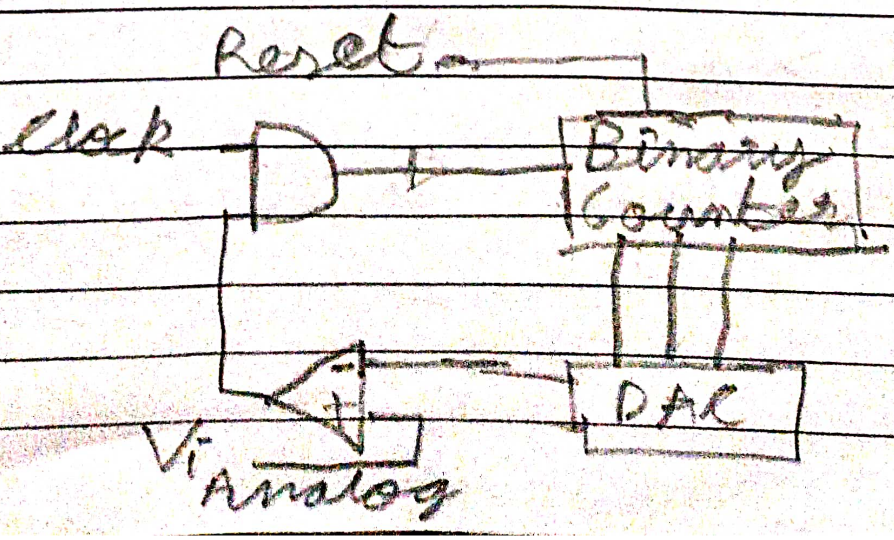
~~3 bit ADC~~

Flash / Parallel ADC



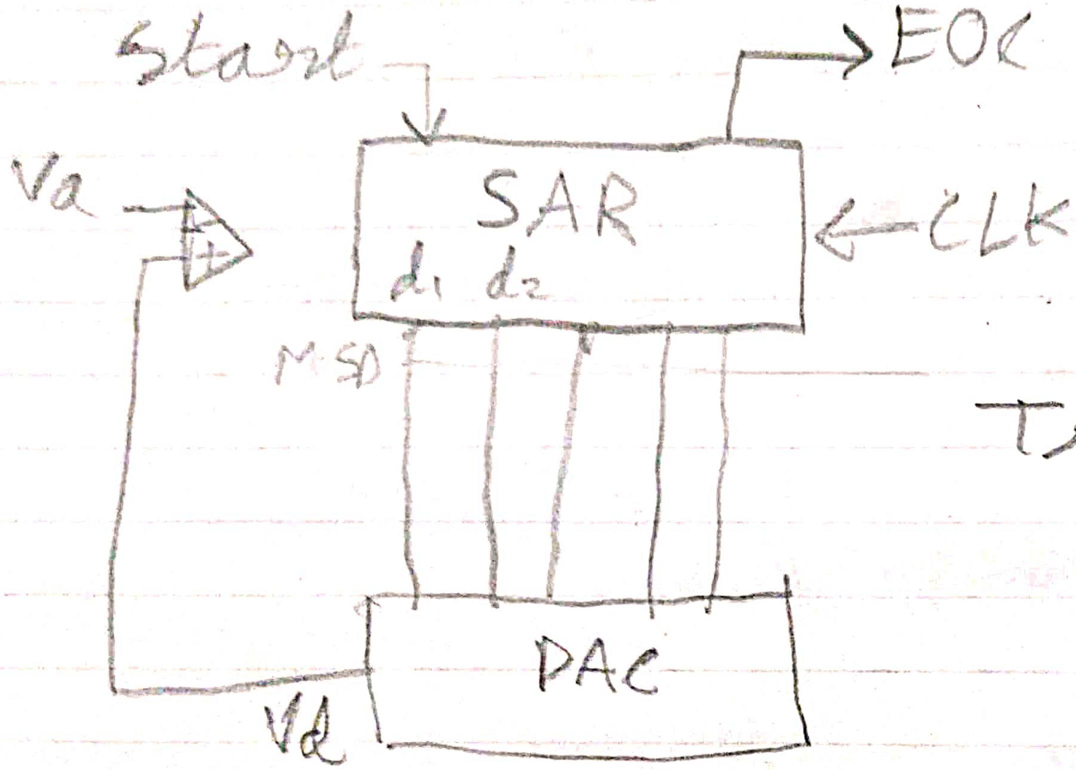
Counter type ADC

- Reset (initially set counter to zero)
- Clock - signal generator
- DAC



SA ADC

- Faster than counter ADC



Trial code

- Initially $D_1, D_2, D_3, D_4 = 1000$

$V_d < V_a$

$D_2 = 1$ $D_1, D_2, D_3, D_4 = 1100$

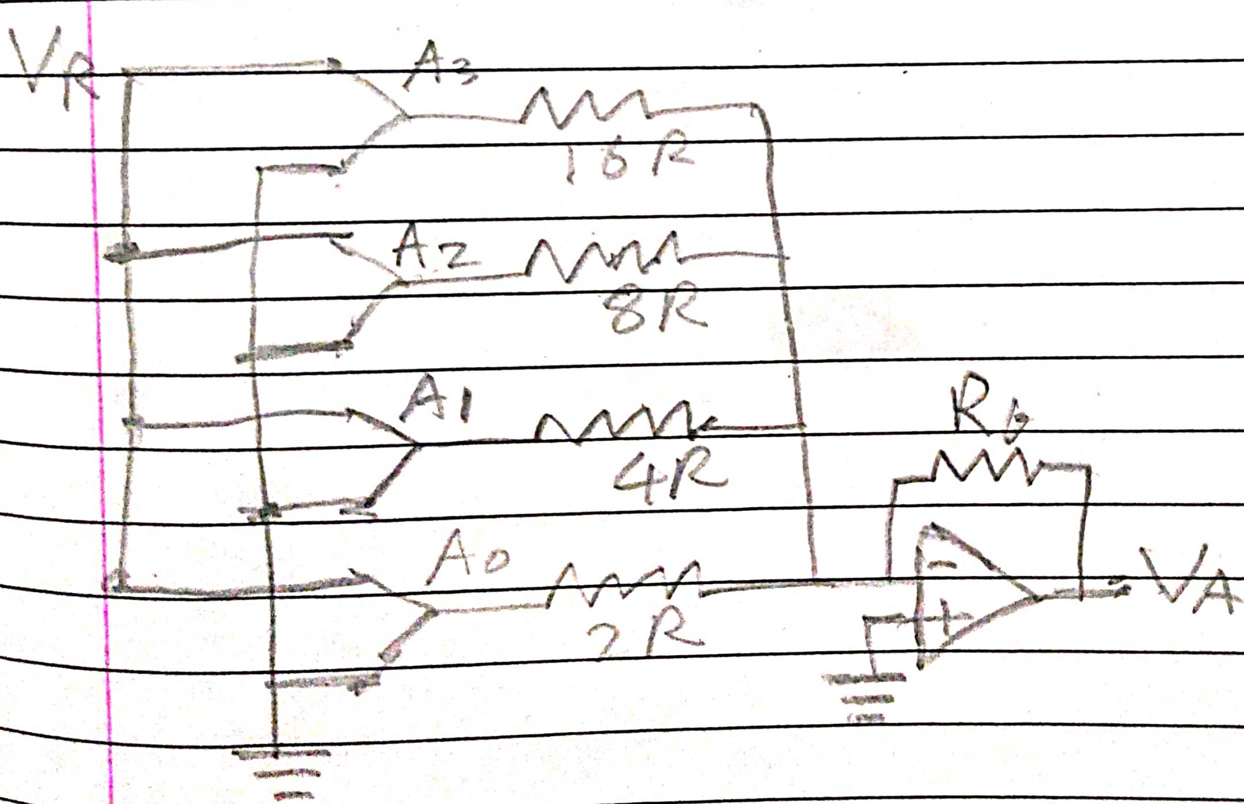
$V_d > V_a$

$D_1 = 0$ $D_2 = 1$ $D_1, D_2, D_3, D_4 = 0100$

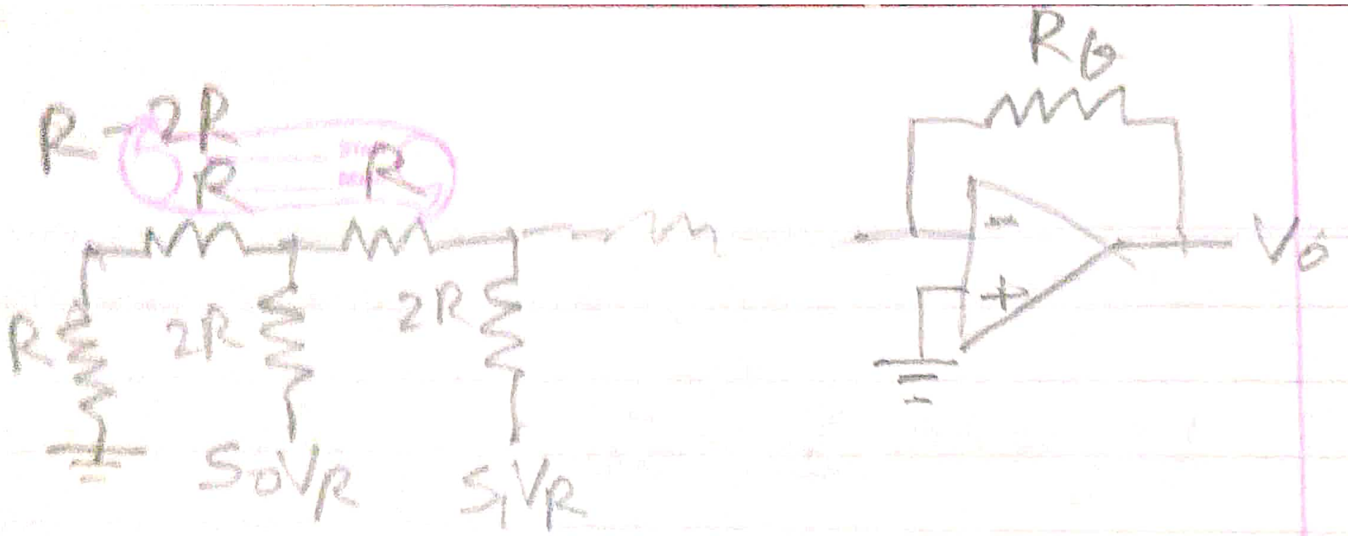
Digital to Analog converter

$$V_A = K \sum_{0}^{N-1} S_K 2^k$$

Binary Weighted DAC



$$V_0 = -\frac{R_b}{R} V_R \left[S_0 2^{-1} + S_1 2^{-2} + \dots \right]$$



$$V_o = -\frac{R_f}{R_{Th}} \frac{V_R}{2^N} \sum_{0}^{N-1} S_k 2^k$$