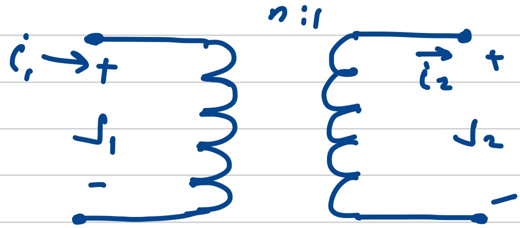
DC power supply:

Mohammed Sa'deh

1 Transformer

$$v_2 = \frac{1}{n} V_1$$

$$i_2 = n\, i_1$$



2 Rectifier

A) Half wave rectifier

$$V_{o,av} = \frac{V_m}{\pi}$$

$T = T_o$

$$i_{D,av} = \frac{V_m}{\pi R_L}$$

$f = f_o$

$$I_{FM} = \frac{V_m}{\pi R_L}$$

$$PIV = V_{RM} = -V_m$$

B) Full Wave rectifier

1 Center-tapped transformer full-wave rectifier

$T = \frac{1}{2} T_o$

$$V_{o,av} = \frac{2 V_m}{\pi}$$

$f = 2 f_o$

$$i_{o,av} = I_{FM} = \frac{2 V_m}{\pi R_L}$$

$$PIV = V_{RM} = -2 V_m$$

② Bridge full-wave rectifier

$$V_{o,av} = \frac{2V_m}{\pi}$$ $T = \frac{1}{2}T_o$

$$i_{o,av} = I_{FM} = \frac{2V_m}{\pi R_L}$$ $f = 2f_o$

$$PIV = V_{RM} = -V_m$$

③ Filter

Ripple factor $r = \frac{RMS}{\text{Average Value of output signal}} \times 100\%$

For triangular signal $RMS = \frac{\text{Peak Value}}{\sqrt{3}}$

or $RMS = \frac{\text{Peak-to-Peak Value}}{2\sqrt{3}} = \frac{V_{Lr,p-p}}{2\sqrt{3}}$

$$r = \frac{\frac{V_{Lr,p-p}}{2\sqrt{3}}}{V_{L,dc}}$$

$$V_{L,dc} = V_{L,av} = V_m - \frac{1}{2}V_{Lr,p-p}$$

for Half-wave rectifier

$$V_{Lr,p-p} = \frac{V_m}{f_o RC}$$

$$\Rightarrow r = \frac{1}{\sqrt{3}(2f_o RC - 1)} \times 100\%$$

for full-wave rectifier

$$V_{Lr,p-p} = \frac{V_m}{2f_o RC}$$

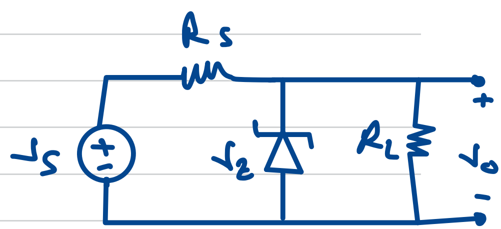
$$\Rightarrow r = \frac{1}{\sqrt{3}(4f_o RC - 1)} \times 100\%$$

4 Regulator with Zener diode:

Zener in the Break down region:

$$I_{Z(min)} < I_Z < I_{Z(max)}$$

Design for R_s



$$\frac{V_{s(max)} - V_Z}{I_{L(min)} + I_{Z(max)}} \leq R_s \leq \frac{V_{s(min)} - V_Z}{I_{L(max)} + I_{Z(min)}}$$

AC Small Signal analysis for diodes

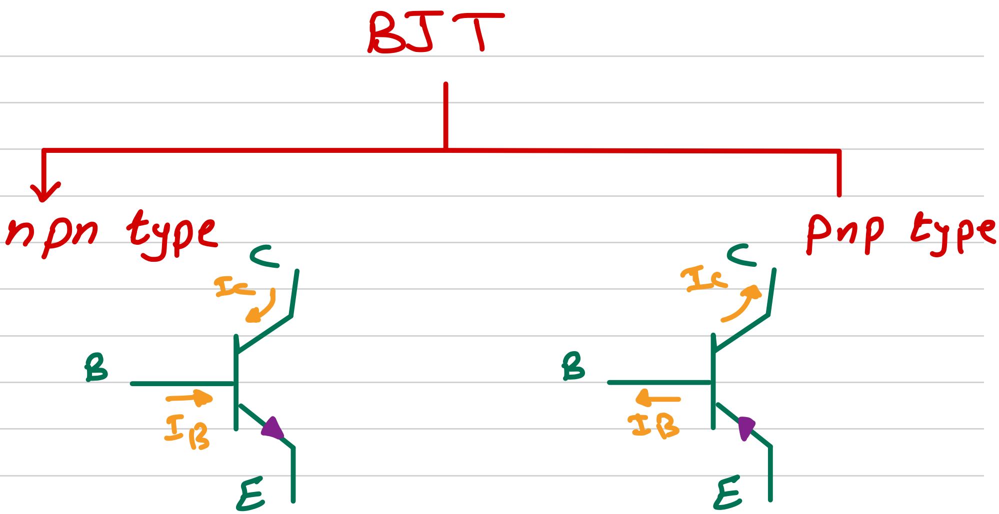
$$i_D(t) = I_{DQ} + i_d(t)$$

↑ DC component ↑ AC component

$$v_D(t) = V_{DQ} + v_d(t)$$

↑ DC component ↑ AC component

$$v_d = \frac{i_d}{r_d} \quad , \quad r_d = \frac{V_T}{I_{DQ}} \quad ; \quad V_T = 25.69\, mV$$



In active region

$$I_C = \alpha I_E$$

$$I_C = \beta I_B$$

$$I_E = I_C + I_B = (\beta+1) I_B$$

$$\beta = \frac{\alpha}{1-\alpha} \quad ; \quad \alpha = \frac{\beta}{\beta+1}$$

for npn $\longrightarrow$ $V_{BE} = 0.7$ Volt.
for pnp $\longrightarrow$ $V_{BE} = -0.7$ Volt.

to verify that BJT in active region

for npn $\rightarrow$ $V_{CE} > V_{CE,sat} = 0.2$ Volt
for pnp $\rightarrow$ $V_{CE} < V_{CE,sat} = -0.2$ Volt

In Cutoff region

$$I_C = I_B = I_E = 0$$

In Saturation region

For npn : $V_{CE} = V_{CE,sat} = 0.2$ Volt
$V_{BE} = 0.8$ Volt.

For pnp : $V_{CE} = V_{CE,sat} = -0.2$ Volt
$V_{BE} = -0.8$ Volt.

to verify that BJT in saturation region

$$I_{B(min)} = \frac{I_{C,sat}}{\beta}$$

$I_B > I_{B(min)}$ BJT in Saturation region

$I_B < I_{B(min)}$ BJT in active region

AC Small Signal analysis

$h_{fe} = \beta$, $h_{ie} = \frac{V_T}{I_B}$; $V_T = 25.69\,mV$

$h_{fb} = \alpha$, $h_{ib} = \frac{V_T}{I_E}$

OP-Amp

$i(+) = i(-) = 0$

① Linear region

→ there is negative feedback.

$V_d = V(+) - V(-) = 0$

1) Inverting Amplifier $V_o = -\frac{R_F}{R_i} V_s$

2) Inverting Adder $V_o = -\left(\frac{R_F}{R_1} V_1 + \frac{R_F}{R_2} V_2 + \frac{R_F}{R_3} V_3\right)$

3) Non-Inverting Amplifier $V_o = \left(1 + \frac{R_F}{R_i}\right) V(+)$

4) Subtraction $V_o = \left(\left(1 + \frac{R_F}{R_i}\right) V(+) - \frac{R_F}{R_i} V_2\right)$

5) Instrumentation Amplifier $V_o = \left(1 + \frac{2}{a}\right)(V_1 - V_2)$

② Non-Linear (comparator)

→ there is neither negative nor positive feedback.

When $V_d > 0 \rightarrow V(+) > V(-) \rightarrow V_o = +V_{sat}$

When $V_d < 0 \rightarrow V(+) < V(-) \rightarrow V_o = -V_{sat}$

③ Schmitt trigger

→ there is positive feedback

find V_{UT} and V_{LT} by assume:

1) $V_o = +V_{sat} \rightarrow V_d > 0$

2) $V_o = -V_{sat} \rightarrow V_d < 0$

Voltage Regulator

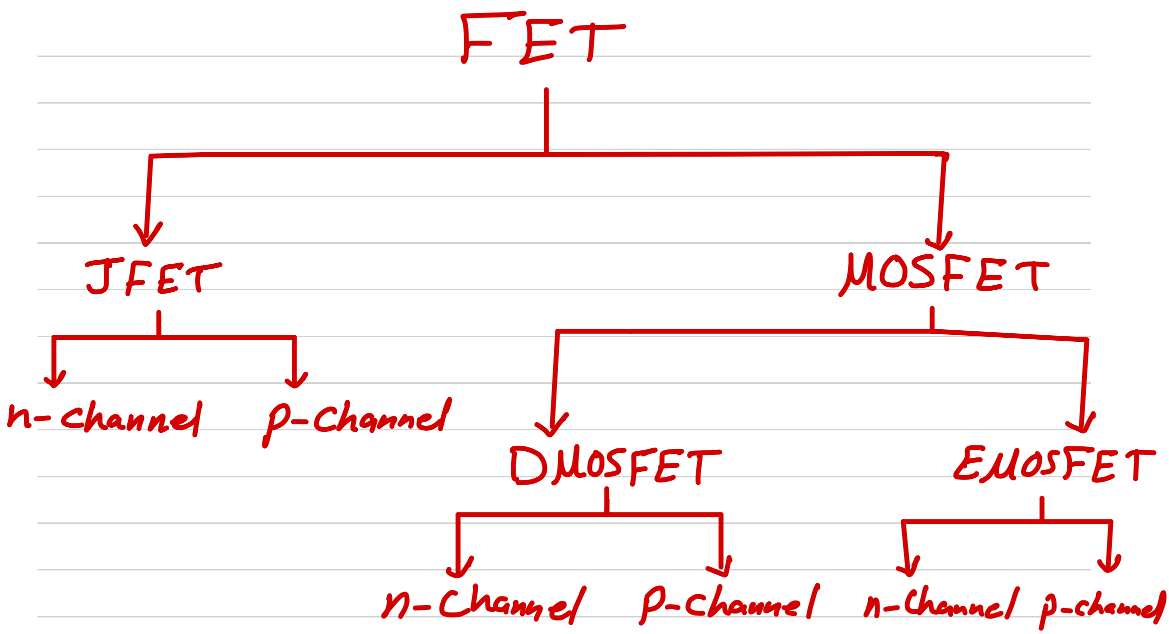
1) Simple Discrete Regulator

$$V_o = \left(1 + \frac{R_1}{R_2}\right) V_Z$$

For current limiting $R_{SC} = \dfrac{0.7}{I_{L(max)}}$

2) IC Regulator

$$V_o = V_{REG}\left(1 + \frac{R_2}{R_1}\right) + R_2 I_Q$$

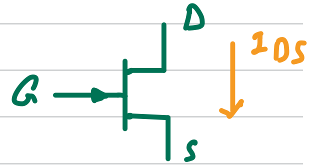


1 JFET

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \qquad I_{DS} \leq I_{DSS}$$

A) n-channel

V_P , V_{GS} negative



Pinch off region →
- $V_P < V_{GS} \leq 0$
- $|V_{DS}| > |V_P| - |V_{GS}|$

B) P-channel

V_P , V_{GS} positive

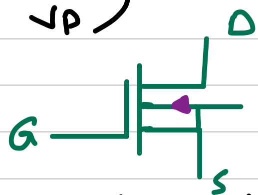
Pinch off region →
- $0 \leq V_{GS} < V_P$
- $|V_{DS}| > |V_P| - |V_{GS}|$

2) DMOSFET

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

A) n-channel

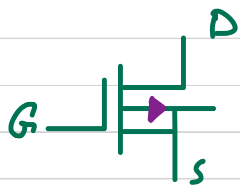
V_P negative



Pinch off regio
- → $V_{GS} > V_P$
- → $V_{DS} > V_{GS} - V_P$

B) P-Channel

V_P positive

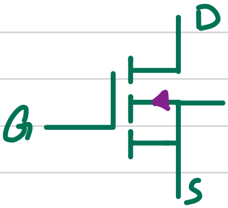


pinch off region
- → $V_{GS} < V_P$
- → $V_{DS} < V_{GS} - V_P$

3) EMOSFET

$$I_{DS} = K_n(V_{GS} - V_T)^2$$

A) n-Channel

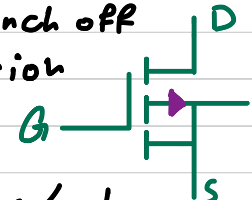


in pinch off region

$V_{GS} > V_T$ positive

B) P-channel

in pinch off region



$V_{GS} < V_T$ negative

For both: $|V_{DS}| > |V_{GS} - V_T|$

AC Small Signal analysis:

⇒ For JFET and DMOSFET

$$g_m = \frac{-2 I_{DSS}}{V_P}\left(1 - \frac{V_{GS}}{V_P}\right)$$

⇒ For EMOSFET

$$g_m = 2 K_n (V_{GS} - V_T)$$

$$g_m = 2\sqrt{K_n I_{DS}}$$

Drain equivalent Circuit:

- What's in the Drain Stay the same
- What's in the Source multiply By $(\mu + 1)$
- V_g multiply By μ. ← عكس الاشارة

Source equivalent Circuit.

- What's in the Source Stay the same.
- What's in the Drain divide By $(\mu + 1)$
- V_g multiply B $\frac{\mu}{\mu + 1}$

$$\mu = g_m r_{ds}$$

$$* \; K_n = \frac{I_{D(on)}}{(V_{GS(on)} - V_{GS(Th)})^2}$$