5.1 CASCADED SYSTEM

Let A_{V1}, A_{V2}, A_{V3} and so on are the voltage gains of each stage **under loaded conditions.** That is A_{V1} is determined with the input impedance to A_{V2} acting as the load on A_{V1}. For A_{V2}, A_{V1} will determine the signal strength and source impedance at the input to A_{V2}.

Total gain of the system is,

$$\boxed{A_{V_T} = A_{V_1} . A_{V_2} . A_{V_3} \ldots\ldots} \quad \ldots\ldots(1)$$

and the total current gain is given by

$$\boxed{A_{i_T} = -A_{V_T} \frac{Z_{i_1}}{R_L}} \quad \ldots\ldots\ldots\ldots(2)$$

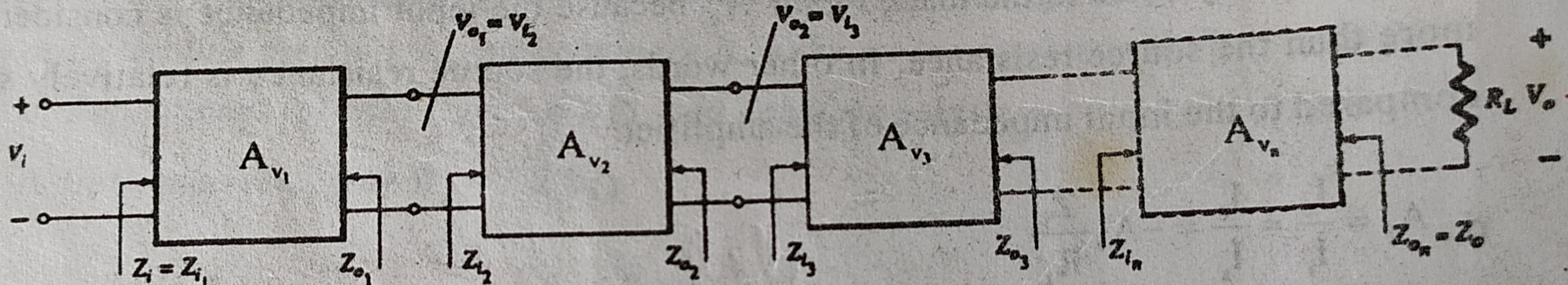


Fig.5.1 Cascaded system

5.3 Darlington Connection

A very popular connection of two bipolar junction transistors for operation as one "superbeta" transistor is the Darlington connection shown in Fig.5.7. The main feature of the Darlington connection is that the composite transistor acts as a single unit with a current gain that is the product of the current gains of the individual transistors. If the connection is made using two separate transistors having current gains of β_1 and β_2, the Darlington connection provides a current gain of

$$\boxed{\beta_D = \beta_1\beta_2} \qquad \text{.........(1)}$$

If the two transistors are matched so that $\beta_1 = \beta_2 = \beta$, the Darlington connection provides a current gain of

$$\beta_D = \beta^2 \qquad \text{.........(2)}$$

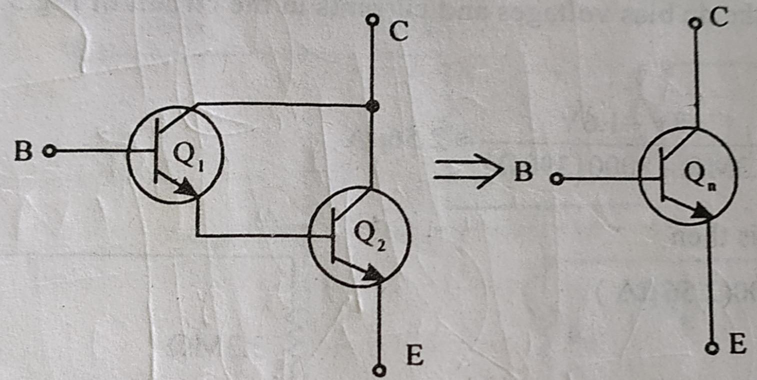


Fig.5.6 Darlington combination

A Darlington transistor connection provides a transistor having a very large current gain, typically a few thousand.

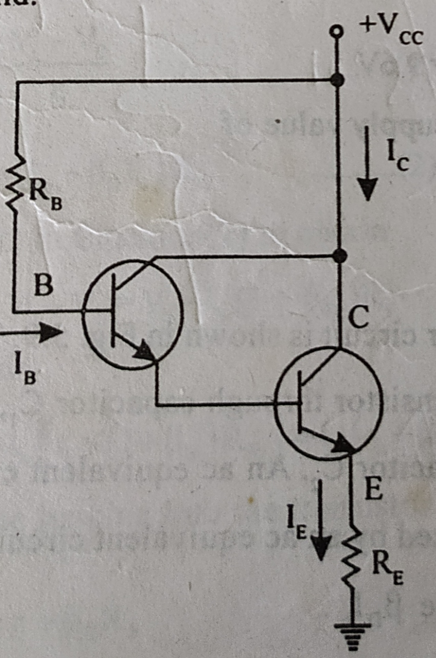


Fig.5.7 Basic Darlington bias circuit

Current Mirror Circuits

A current mirror circuit provides a constant current, and is used primarily in integrated circuits. The constant current is obtained from an output current, which is the reflection or mirror of a constant current developed on one side of the circuit. The circuit is particularly suited to IC manufacture since the circuit requires that the transistors used have identical base-emitter voltage drops and identical values of beta - results best achieved when transistors are formed at the same time in IC manufacture. In fig.5.13 the current I_x set by transistor Q_1 and resistor R_x is mirrored in the current I through transistor Q_2.

The current I_x and I can be obtained using the circuit currens listed in fig. 5.14. We assume that the emitter current (I_E) for both transistors is the same (Q_1 and Q_2 being fabricated near each other on the same chip). The two transistor base currents are then approximately,

$$I_B = \frac{I_E}{\beta+1} \approx \frac{I_E}{\beta}.$$

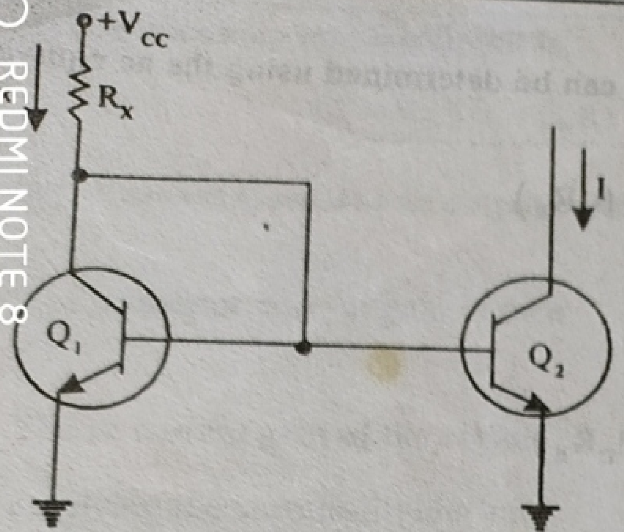


Fig.5.13 Current mirror circuit

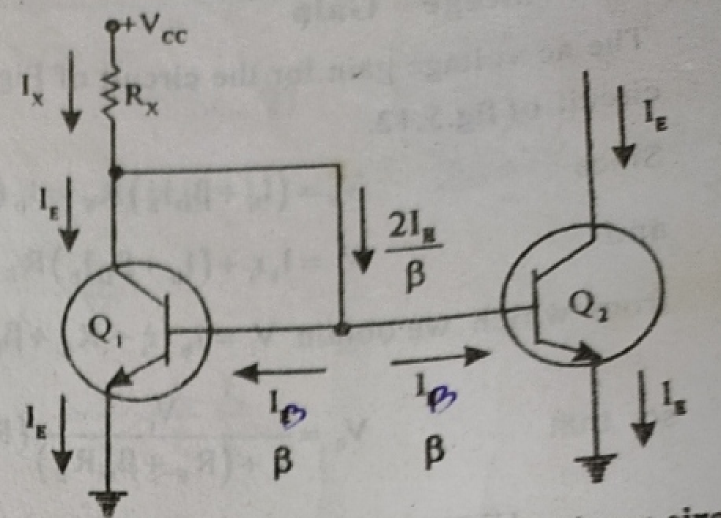


Fig.5.14 Circuit currents for current mirror circuit.

The collector current of each transistor is then $I_C \approx I_E$

Finally, the current I_x through resistor R_x is

$$I_x = I_E + \frac{2I_E}{\beta} = \frac{\beta I_E}{\beta} + \frac{2I_E}{\beta} = \frac{\beta+2}{\beta} I_E \approx I_E$$

In summary, the constant current provided at the collector of Q_2 mirrors that of Q_1.

Since $$I_x = \frac{V_{CC} - V_{BE}}{R_x} \qquad \text{..........(1)}$$

the current I_x set by V_{CC} and R_x is mirrored in the current into the collector of Q_2.

Transistor Q_1 is referred to as a diode - connected transistor because the base and the collector are shorted together.

10/09/20 AEC Thursday

Transconductance →

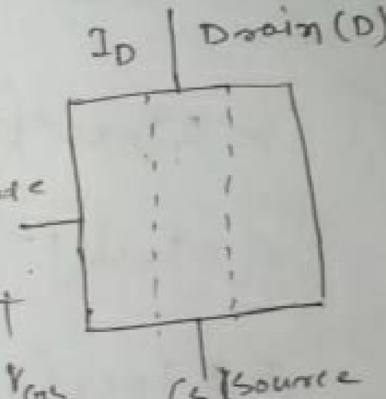
Resistance (It is the opposition offered by the conductor)

$$(\delta) = \frac{1}{R} = \frac{I}{V}$$

Friday 11/09/20

Small signal analysis of FET →

"When an a.c supply is connected to a transistor that phenomenon is called as small signal analysis".



$$\text{Impedance}, Z = \frac{\Delta V_{GS}}{\Delta I_D}$$

$$\text{Transconductance (} \cancel{\text{co}} \text{) conductance} = \frac{1}{Z} = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$\text{Transconductance}, = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$\Rightarrow g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$\boxed{\Delta = \frac{\partial}{\partial x} a_x + \frac{\partial}{\partial y} a_y + \frac{\partial}{\partial z} a_z}$$

$$\boxed{g_m = \frac{\partial I_D}{\partial V_{GS}}}$$

According to Schockley eqn.

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

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

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

$$= I_{DSS} \frac{\partial \left(1 - \frac{V_{gs}}{V_P}\right)^2}{\partial \left(1 - \frac{V_{gs}}{V_P}\right)} \times \frac{\partial}{\partial V_{gs}} \left(1 - \frac{V_{gs}}{V_P}\right)$$

$$= I_{DSS} \times 2 \times \left(1 - \frac{V_{gs}}{V_P}\right) \times \left\{ \frac{\partial}{\partial V_{gs}}(1) - \frac{\partial}{\partial V_{g}}\left(\frac{V_{gs}}{V_P}\right) \right\}$$

$$= 2 I_{DSS} \times \left(1 - \frac{V_{gs}}{V_P}\right) \times \left\{ 0 - \frac{\partial \left(\frac{V_{gs}}{V_P}\right)}{\partial V_{gs}} \right\}$$

$$\cancel{= 2 I_{DSS} \times \left(1 - \frac{V_{gs}}{V_P}\right)}$$

$$= 2 I_{DSS}\left(1 - \frac{V_{gs}}{V_P}\right) \left\{ -\frac{1}{V_P} \frac{\partial V_{gs}}{\partial V_{gs}} \right\} \quad (\because V_P = \text{const.})$$

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

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

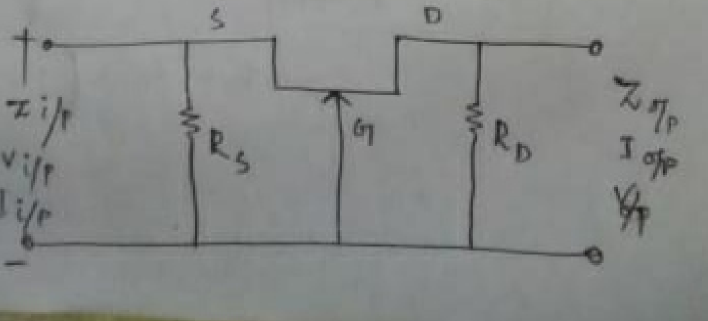
This is the expression for transconductance for FET.

$$\Rightarrow \boxed{g_m = g_{mo}\left(1 - \frac{V_{gs}}{V_P}\right)} \quad \left(\because g_{mo} = \frac{2 I_{DSS}}{|V_P|}\right)$$

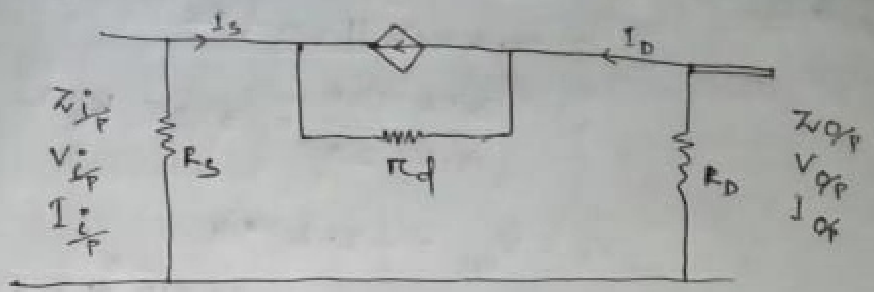
saturday
12/09/20

AEC

π model for common gate configuration (FET) →



The equivalent rd model will be -



$Z_i = R_S \parallel \frac{1}{g_m}$

$I_i = I_s$

$V_i = V_{GS}$

$Z_o = R_D \parallel r_d$

$I_o = I_D$

$V_o = I_o \times R_D$

$V_o = I_D \times R_D$

current gain $A_i = \frac{I_o}{I_i} = \frac{I_D}{I_s}$

voltage gain, $A_v = \frac{V_o}{V_i} = \frac{I_D R_D}{V_{GS}}$ or $g_m \times R_D$

(prob-01)

given, $I_D = 2.03$ mA.

$V_{GS} = -2.2$ volt

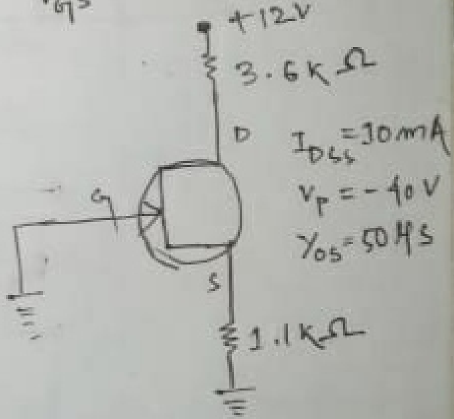
$R_D = 3.6\ k\Omega = 3.6 \times 10^3$

$R_S = 1.1\ k\Omega = 1.1 \times 10^3$

a) find g_m

b) find r_d

c) find Z_i, Z_o, A_i, A_v



$Sol^n \rightarrow$ (b) $r_d = \frac{1}{Y_{os}}$

$r_d = \frac{1}{50 \times 10^{-6}\ S} = 20{,}000\ \Omega$

$\Rightarrow r_d = 20\ K\Omega$

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

$= \frac{2 \times 10 \times 10^{-3}}{|-4|}\left\{1 - \frac{(-2.2)}{-4}\right\}$

$= 5 \times 10^{-3}\left(\frac{1.8}{4}\right)$

$= 2.25 \times 10^{-3}\ S$

$g_m = 2.25\ mS$

(c) $Z_i = R_S \parallel \frac{1}{g_m} = \frac{R_S \times \frac{1}{g_m}}{R_S + \frac{1}{g_m}}$

$= \frac{R_S/g_m}{\frac{R_S g_m + 1}{g_m}}$

$= \frac{R_S}{R_S g_m + 1} =$

15/09/20 Tuesday

$Z_o = R_D \parallel r_d$

$= 3.6\,K\Omega \parallel 20\,K\Omega$

$= \frac{3.6 \times 20}{3.6 + 20} = 3.05\,K\Omega$

$V_i = V_{gs} = -2.2$ Volt

$V_o = I_D \times R_D = 2.03 \times 10^{-3} \times 3.6 \times 10^{3}$

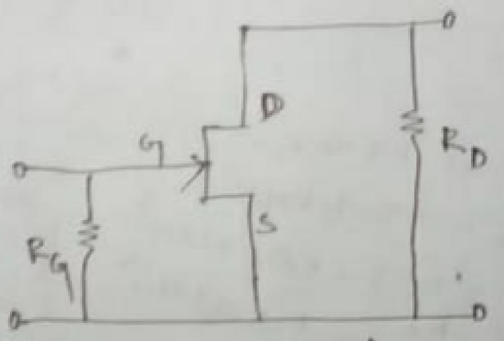
$V_o = 7.308$ Volt

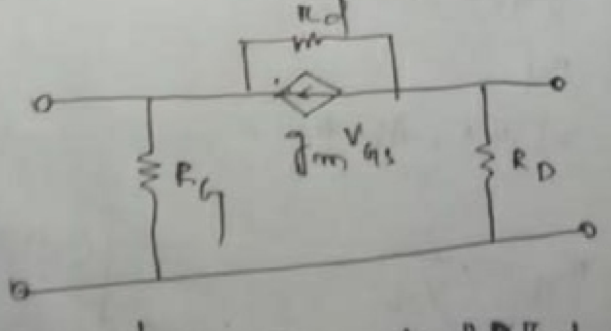
$A_v = \frac{V_o}{V_i} = \frac{7.308}{-2.2} = -3.32$

$I_i = I_s = 2.03$, $I_o = I_D = 2.03\,mA$

$A_i = \frac{I_o}{I_i} \simeq 1$

r_d model for common source configuration FET

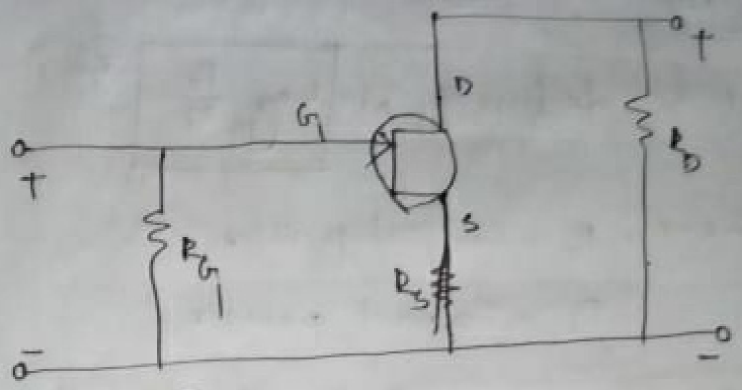


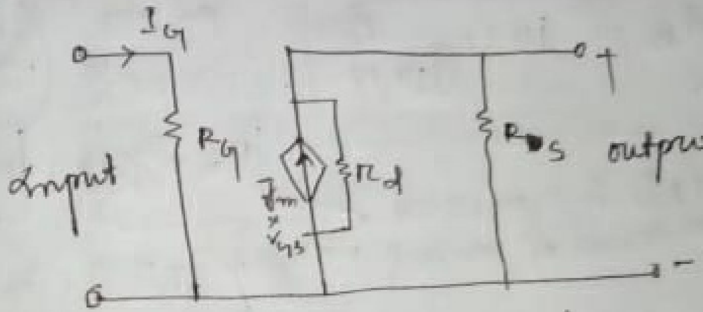


$Z_i = R_G \parallel \frac{1}{g_m}$, $Z_o = R_D \parallel r_d$,

$I_i = I_G$, $I_o = I_D$, $V_i = -V_{GS}$, $V_o = I_D R_D$

r_d Model for common drain configuration of FET →





$Z_i = R_G$, $Z_0 = r_d \| R_S \| \frac{1}{g_m}$

$I_i = I_G$, $I_0 = -I_D = -g_m \times V_{GS}$

$V_i = I_G R_G = V_{GS}$, $V_0 = I_D \times Z_0$

$A_i = \frac{-g_m V_{GS}}{I_G}$, $A_v = \frac{I_D Z_0}{I_G R_G}$

friday
18/09/20

Low frequency analysis of BJT & FET →

$a = b^x$

$x = \log_b a$

$\Rightarrow x = \log_{10} a$

$\log_{10} 1 = 0$

$\log_{10} 10 = 1$

$\log_{10} 100 = 2$

$\log_{10} \frac{a}{b} = \log_{10} a - \log_{10} b$

$\log_{10} (ab) = \log_{10} a + \log_{10} b$