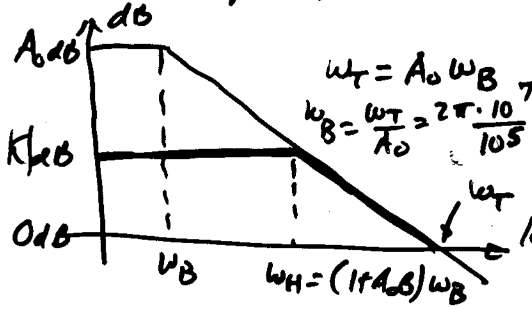
Op Amp Frequency Response - Summary

$$\frac{V_{out}(s)}{V_{in}(s)} = A_v(s) = K\left(\frac{1}{\frac{s}{\omega_B(1+A_0\beta)}+1}\right); \quad K = \frac{A_0}{1+A_0\beta} \text{ for NInv.}, \quad K = \left(-\frac{R_2}{R_1}\right)\frac{A_0}{1+A_0\beta} \text{ for Inv.}$$

$\omega_H = \omega_B(1+A_0\beta)$ ← −3dB frequency

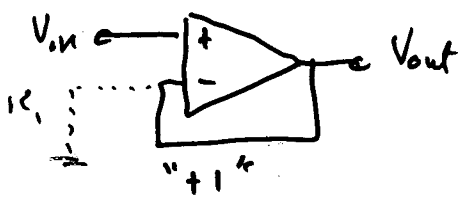
Example



$\omega_T = A_0\omega_B$

$\omega_B = \frac{\omega_T}{A_0} = \frac{2\pi \cdot 10^7}{10^5}$

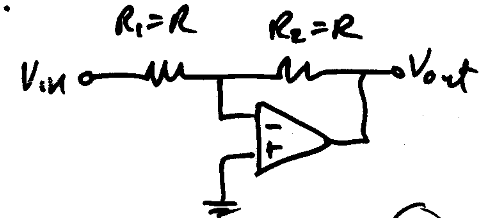
1.) An op amp with $A_0 = 100\,dB$, and $f_T = 10\,MHz$ is used to build a voltage amplifier having a gain of +1 and a gain of −1. Find ω_H.



$\beta = \frac{R_1}{R_1+R_2} = \frac{\infty}{\infty + 0} = 1$

$\therefore \omega_H = 200\pi(1 + 10^5 \cdot 1)$

$\simeq 2\pi \times 10^7 \rightarrow$ **10 MHz**



$\beta = \frac{R_1}{R_1+R_2} = \frac{R}{R+R} = \frac{1}{2}$

$\omega_H = 200\pi(1 + 10^5 \cdot \frac{1}{2}) \simeq \pi \times 10^7$

$f_H \cong 5\,MHz$

2.) Repeat 1.) but let the amplifiers have a gain of $\pm 100\,\frac{V}{V}$

$\beta = \frac{R_1}{R_1+R_2} = \frac{R_1}{R_1 + 99R_1} = \frac{1}{100}$

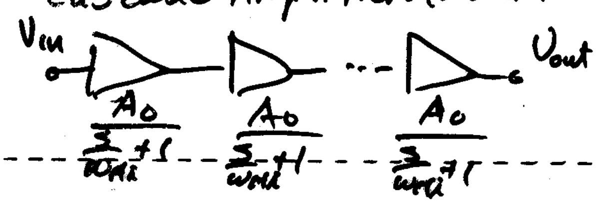
$\omega_H = 200\pi\left(1 + \frac{10^5}{10^2}\right)$

$\simeq 2\pi \times 10^5 \rightarrow$ **100kHz**

$\beta = \frac{R_1}{R_1+R_2} = \frac{R_1}{R_1 + 100R_1} = \frac{1}{101}$

$\omega_H = 200\pi\left(1 + \frac{10^5}{101}\right) \Rightarrow$ **99kHz**

N-Cascade Amplifiers (Identical)



$$\frac{V_{out}}{V_{in}} = \left(\frac{A_0}{\frac{s}{\omega_{Hi}}+1}\right)^n$$

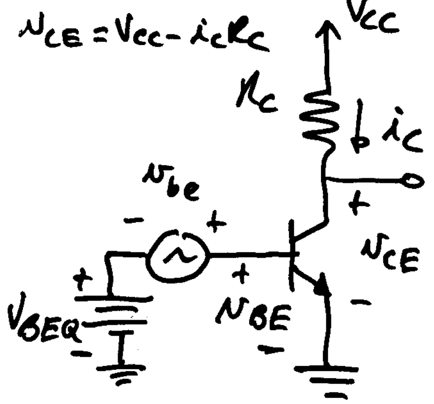
$$\boxed{\omega_H = \omega_{Hi}\sqrt{2^{1/n} - 1}}$$

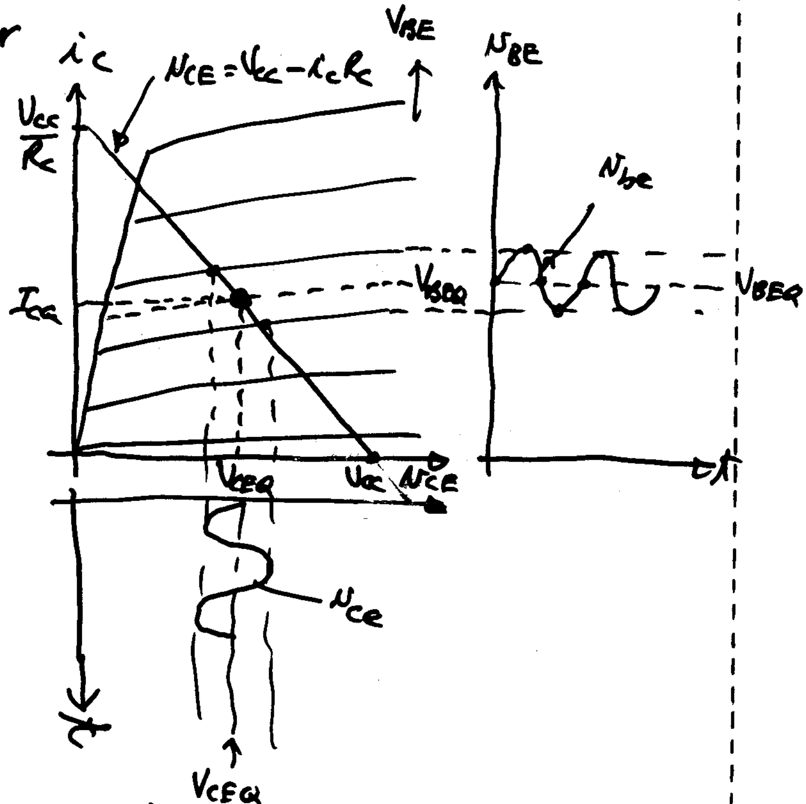
For $n = 3$, $\omega_H = 0.51\,\omega_{Hi}$

CHAPTER 13 - TRANSISTOR AMPLIFIERS

1.) BJT Amplifier

$v_{CE} = V_{CC} - i_C R_C$





Mathematically -

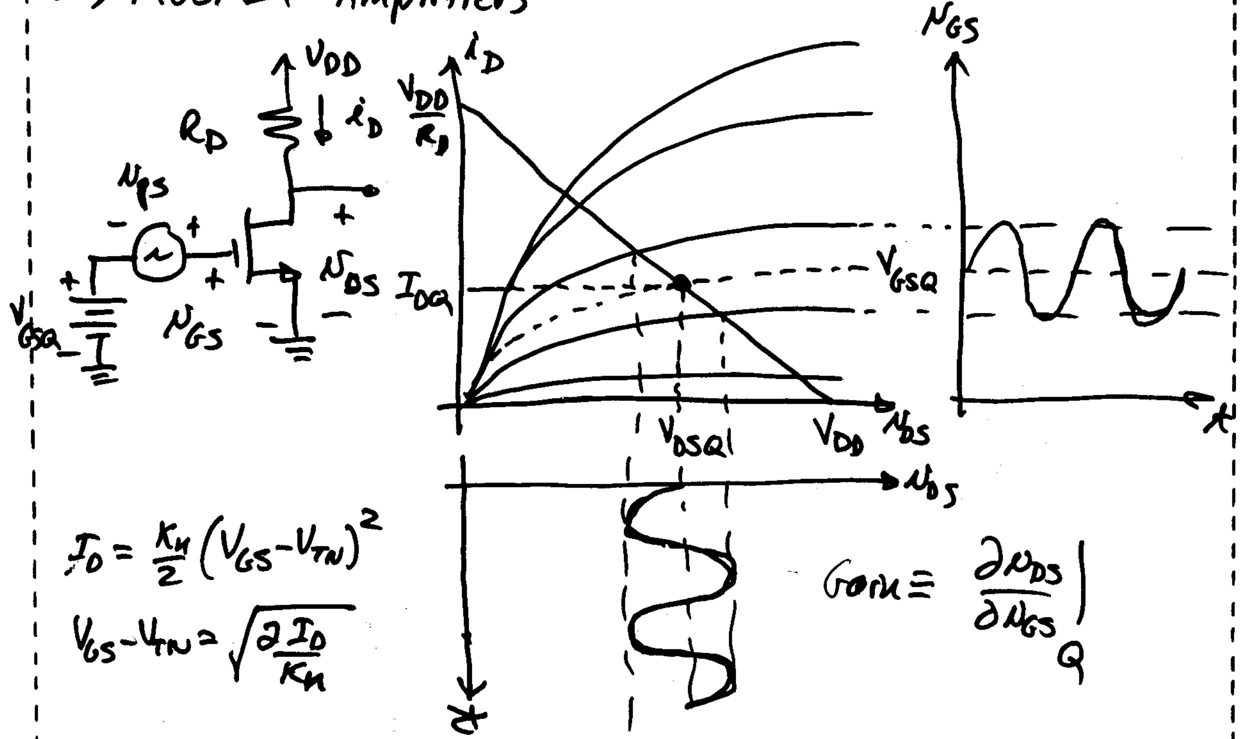
$$v_{CE} = V_{CC} - i_C R_C = V_{CC} - R_C\left[I_S \exp\left(\frac{v_{BE}}{V_T}\right)\right]$$

$$\left.\frac{\partial v_{CE}}{\partial v_{BE}}\right|_Q = \text{gain} = -\frac{R_C I_S}{V_T}\exp\left(\frac{V_{BEQ}}{V_T}\right) = -\frac{R_C}{V_T} I_{CQ}$$

Suppose, $R_C = 10K$, $I_{CQ} = 1mA$ & $V_T = 25mV$

$$\left.\frac{\partial v_{CE}}{\partial v_{BE}}\right|_Q = \text{Voltage gain} = -\frac{10^4 \cdot 10^{-3}}{25\times 10^{-3}} = -\frac{10{,}000}{25} = -400 \, V/V$$

2.) MOSFET Amplifiers



$I_D = \frac{K_n}{2}(V_{GS} - V_{TN})^2$

$V_{GS} - V_{TN} = \sqrt{\frac{2 I_D}{K_n}}$

Gain $\equiv \left.\frac{\partial v_{DS}}{\partial v_{GS}}\right|_Q$

$v_{DS} \cong V_{DD} - R_D\left[\frac{K_n}{2}(v_{GS} - V_{TN})^2\right]$ ← Assumes $v_{DS} > v_{GS} - V_{TN}$

$\left.\frac{\partial v_{DS}}{\partial v_{GS}}\right|_Q = -R_D K_n (V_{GSQ} - V_{TN}) = -R_D K_N \sqrt{\frac{2 I_{DQ}}{K_n}} = -R_D \sqrt{K_n I_{DQ} 2}$

Assume $K_n = 250 \frac{\mu A}{V^2}$, $I_D = 1mA$, and $R_D = 10K$

Voltage gain $= \left.\frac{\partial v_{DS}}{\partial v_{GS}}\right|_Q = -10^4 \sqrt{250 \cdot 2000} \times 10^{-6}$

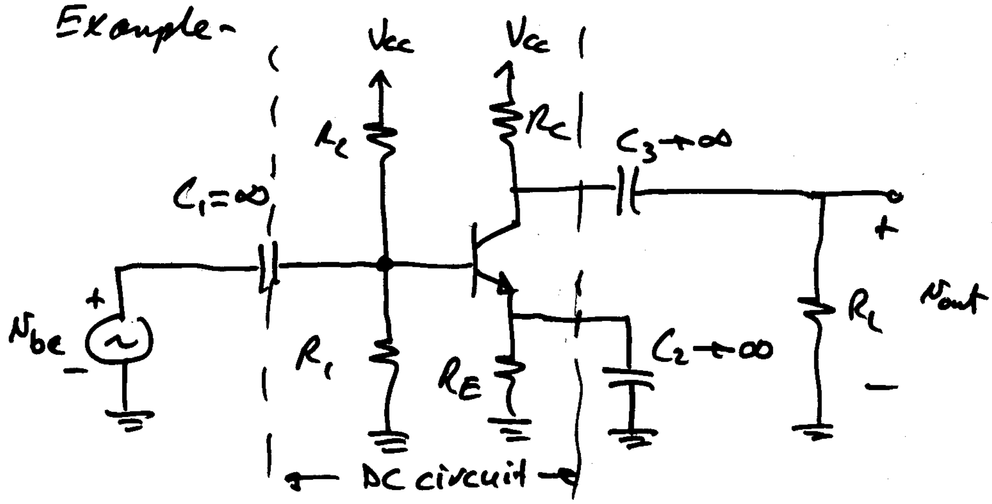
$= \underline{\underline{-7.07 \ \frac{V}{V}}}$

MOSFET gain << BJT gain

3) Coupling and Bypass Capacitors

How do you separate ac and dc signals?

Example -



C_1 & C_3 are coupling capacitors

C_2 is a bypass capacitor

On p. 560 → 586 (AC ckt. & DC ckt.)