AE_LECTURE6_ANALYSIS OF CASCODE AMPLIFIER.*

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Abstract

AE_lecture6 deals with midfrequency and high frequency analysis of CASCODE Amplifier.

AE LECTURE 6 Analysis of CASCODE AMPLIFIER

CASCODE AMPLIFIER- This is a form of composite transistor where CE and CB have been cascaded. By using the composite form we achieve best of both the circuit configurations namely we get a moderate input impedance and high voltage gain of CE configuration and almost near unilaterality , very large output impedance , large output voltage swing limited by BV_{CBO} and much larger Band Width of CB configuration. Because of near unilaterality on account of near zero reverse transmission factor, this CASCODE is very suitable RF Amplifier applications. This configuration is also suitable for constant current drive as required in generating SAW TOOTH WAVEFORM.

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Figure 1. The Circuit Schematic of Cascode Amplifier with self-biasing.



This CASCODE configuration has a self biasing for Q point stabilization. Both Transistors are in forward active mode. Q_1 is connected in CE configuration under signal condition and Q_2 is in CB configuration under signal condition.

 C_1 provides the ground to Q_2 under signal condition.

 C_2 is the coupling capacitor and C_3 provides the by-pass capacitor of emitter resistance. INCREMENTAL MODEL



Figure 2. Midfrequency Incremental model of the Cascode Amplifier with BJT not replaced by its incremental model.

Effectively we obtain CE configuration followed by CB configuration hence we call it CE-CB cascade. Overall Reverse transmission factor= h_{re} . h_{rb}

$$\left(\frac{r_{\pi}}{r_{\mu}}\right) \times \left(\frac{r_{x}}{r_{c}}\right)$$

Figure 3

 $= 10^{-4} \times 10^{-5} = 10^{-9} =$ this provides the near-unilaterality property to CASCODE configuration making it suitable for RF applications.

Overall $R_{out}=1/h_{ob}=2M$

=

Overall $R_{in} = h_{ie} = r_x + r_\pi = (100 + 2.6 k\Omega)$

Frequency response of CB \gg Frequency response of CE

CE configuration faces a load which is $R_{\rm in}$ of CB which is r_e . Hence Miller Muliplication factor is only 1+1 hence Miller Capacitance is much lower thereby boosting the frequency response of CASCODE configuration.

INCREMENTAL MODEL



Figure 3. The incremental model of Cascode Amplifier with CE BJT being replaced by Hybrid-pi Model and CB BJT being replaced by T-Model. This is high frequency Model.

 $R_{s}{=}1k\Omega,\,\beta_{fo}{=}100,\,r_{x}{=}0.1k,\,C_{\mu}{=}2pF,\,R_{L}{=}2k,\,g_{m}{=}40mS,\,r_{\pi}{=}2.5k,\,C_{\pi}{=}100pF$

$$g_m = \frac{I_c}{V_T} = \frac{1}{25} = 40mS; I_c = g_m V_T = 25mV \times 40mS = 1mA$$



$$\mathbf{r}_{\pi} = \frac{\beta_o}{g_m} = \frac{\beta_o \times V_T}{I_C} = \frac{100 \times 25mV}{1mA} = 2.5k$$



$$r_{e} = \frac{V_{T}}{I_{E}} = 25\Omega; \alpha_{fo} = 0.99; \beta_{fo} = \frac{\alpha_{fo}}{1 - \alpha_{fo}} = \frac{0.99}{1 - 0.99} = 99 \sim 100$$



$$C_{\pi} = 100 pF = C_{e}; C_{\mu} = C_{bo} = 2 pF$$

$$\omega_{T} = \left(\frac{g_{m}}{C_{\pi} + C_{\mu}}\right) = \frac{0.04}{102 \times 10^{-12}} \frac{rad}{sec} = \frac{0.04}{102} \times 10^{12} \frac{rad}{sec}$$



$$\omega_T = \frac{040000}{102} \times 10^6 \frac{rad}{sec} = 400M \frac{rad}{sec}$$



$$f_T = \frac{400}{2\pi} MHz = 63.66 MHz$$

AT MID FREQUENCIES



Figure 4. Midfrequency incremental model of CASCODE AMPLIFIER.

Figure 12

$$v_2 = -R_L(\alpha_f i_s); i_s = \frac{v_1}{r_s};$$



$$v_1 = -r_e(100i_1)$$

Figure 14

$$i_1 = \frac{v_s}{R_s + r_x + r_\pi} = \frac{v_s}{1k + 0.1k + 2.5k} = \left(\frac{v_s}{3.6k}\right)$$

$$\therefore v_1 = -(100) \left(\frac{v_s}{3.6k}\right) (25\Omega)$$



$$\left(\frac{v_1}{v_s}\right) = A_{vo1} = \frac{-(100)(25)}{3600} = \frac{-2500}{3600} = -0.715$$



$$v_2 = -(\alpha_f)(R_L)\left(-\frac{v_1}{r_s}\right)$$



$$\therefore \frac{v_2}{v_1} = \frac{(\alpha_f)(R_L)}{r_e} = \frac{(0.99)(2000)}{25} = 79.2$$



$$A_{vo2} = 79.2$$

$$\therefore A_{vo} = -(0.715)(79.2) = -56.6$$

$$A_{vo} = \frac{-\beta_o R_L}{R_S + r_x + r_\pi} = \frac{-(100)R_L}{(3600)}$$

Midband gain of cascade ~ a single stage CE amplifier with a load resistance of 2k. BW calculations The midband gain of CE stage =-g_mr_e=-1 Therefore Miller Capacitance=C_µ[1-(-1)]=2C_µ Therefore total input Capacitance=C_π+C_µ (1-A_V)=100+8=108pF There is very little Miller Multiplication of C_µ. R_{eq} of C_M (Miller Capacitance) is =

$$r_{\pi} ||(R_{s} + r_{x}) = (2.5k)||(1.1k) = \frac{(2.5)(1.1)}{(2.5+1.1)} = 0.763k$$

$$\tau_{10} = C_M R_s = (108 pF \times 0.763 k) = 82.5 ns$$

$$\therefore \omega_h = \frac{1}{82.5ns} = 0.0121 \frac{Grad}{sec}$$



$$f_h(for \ CE) = \frac{12.1}{2\pi} MHz = 1.93 MHz$$

The BW of common base is much larger.

$$\omega_h(for CB) = \frac{1}{\tau_1 + \tau_2} = \frac{1}{C_s r_s + C_{bo} R_L}$$



$$=\frac{1}{100\times10^{-12}\times25+4\times10^{-12}\times2000}$$



Figure 29

$$=\frac{1}{10.5 \times 10^{-9}}$$

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Figure 30
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 $=rac{1}{1.05 imes 10^{-8}}$



$$= 95.2M \frac{rad}{sec}$$

Figure 32

$$f_h(CB) = 15MHz$$

$Overall \ BW \ of \ Cascode{=}1.93 Mhz$

Exact analysis gives the same result.

$$A_{V}(s) = \frac{-k\left[s - (0.2 + j0.98)\frac{Grad}{sec}\right]\left[s - (0.2 - j0.98)\frac{Grad}{sec}\right]}{\left[s + 0.0124\frac{Grad}{sec}\right]\left[s + 0.1\frac{Grad}{sec}\right]\left[s + 0.4\frac{Grad}{sec}\right]\left[s + 3.26\frac{Grad}{sec}\right]}$$

Figure 34

Four poles because there are $C_{\mu}, C_{e}, C_{\pi}, C_{bo}$.

There are two zeroes which are complex conjugate.

If CB stage was replaced by 2k to obtain the same gain the Miller Multiplication would have increased and BW fallen to 491 kHz.

$$\tau = (r_{\pi_1} | | R_s + r_x) [C_{\pi} + C_{\mu} (1 + g_m R_L)] = 324 nsec$$

Figure 35

 $\omega_{h} = \frac{1}{324} \frac{Grad}{sec}$

Figure 36

 $f_h = 491 \, kHz$

(1)Large gain x BW or large GBP

(2) Output Voltage swing is limited by BV_{CBO} and not BV_{CEO} .

Applications:-

(1) Wide band video amplifier (TV & FM Radio)

(2) Wide Band Amplifier used in RF communication,

(3)Near ideal current sources and in high gain amplifiers.

(4) Current Amplification factor is increased $(\beta_{fo} + 1)$.

(5)Used in high performance differential amplifers which is the building block of op amps. This enables very high gain & high CMRR.

(6) We can realize near ideal current sources.

(7) Much higher B.W.