# 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 uni-laterality 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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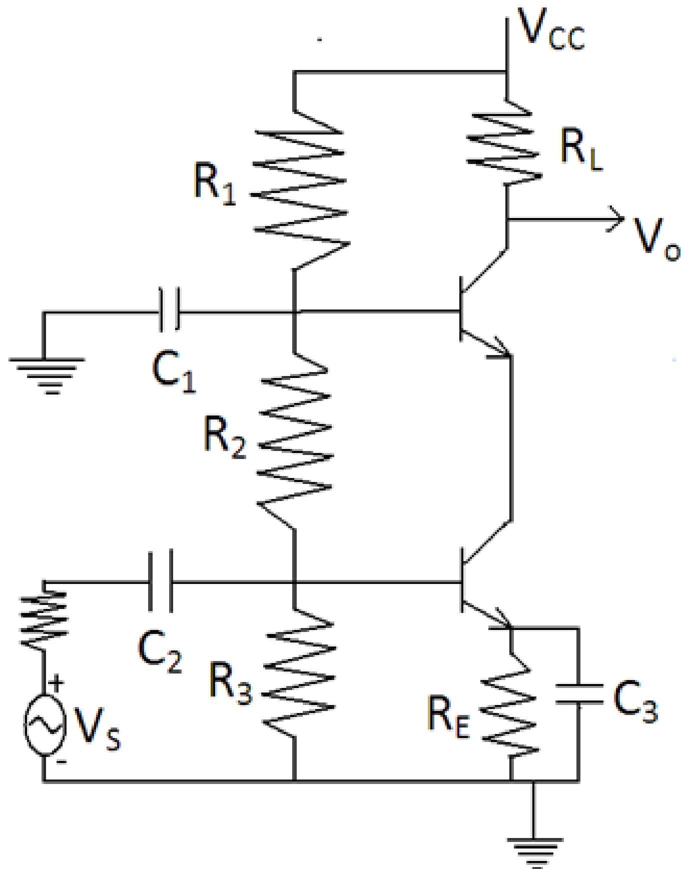


Figure 1.The Circuit Schematic of Cascode Amplifier with self-biasing.

**Figure 1**

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

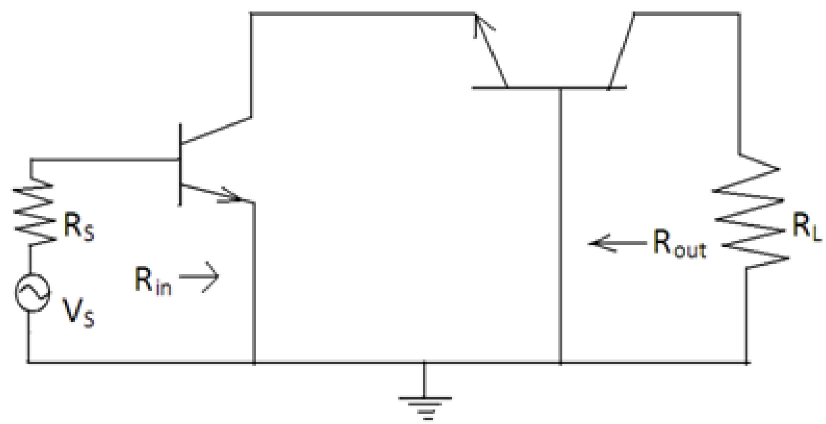


Figure 2. Midfrequency Incremental model of the Cascode Amplifier with BJT not replaced by its incremental model.

**Figure 2**

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

Frequency response of CB$\gg$ Frequency response of CE

CE configuration faces a load which is $R_{in}$ 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

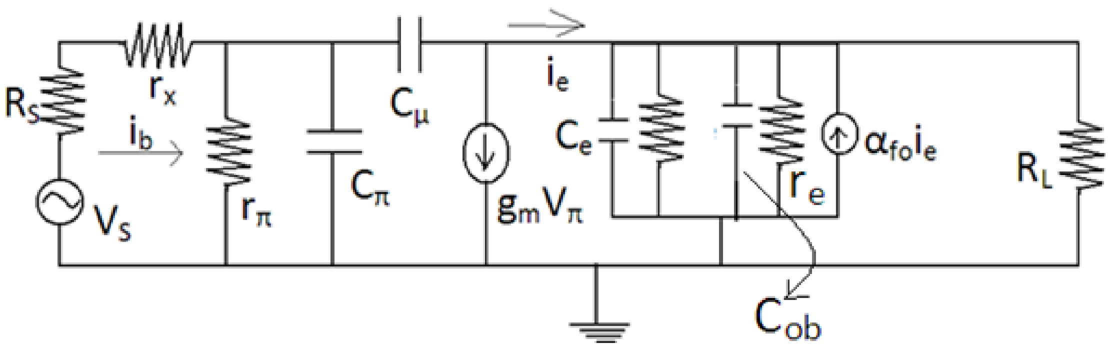


Figure 3. The incremental model of Cascode Amplifier with CE BJT being replaced by Hybrid-pi Model and CB BJT being replaced by T-Model. This is high frequency Model.

**Figure 4**

$R_s$=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

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

**Figure 5**

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

**Figure 6**

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$$r_e = \frac{V_T}{I_E} = 25\Omega; \alpha_{fo} = 0.99; \beta_{fo} = \frac{\alpha_{fo}}{1-\alpha_{fo}} = \frac{0.99}{1-0.99} = 99\sim100$$

**Figure 7**

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

**Figure 8**

$$\omega_T = \left(\frac{g_m}{C_\pi + C_\mu}\right) = \frac{0.04}{102\times10^{-12}}\frac{rad}{sec} = \frac{0.04}{102}\times10^{12}\frac{rad}{sec}$$

**Figure 9**

$$\omega_T = \frac{040000}{102}\times10^{6}\frac{rad}{sec} = 400M\frac{rad}{sec}$$

**Figure 10**

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

**Figure 11**

AT MID FREQUENCIES

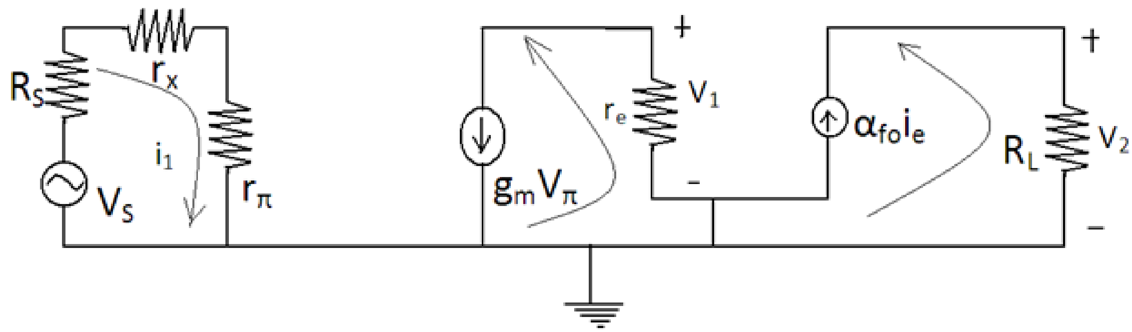


Figure 4. Midfrequency incremental model of CASCODE AMPLIFIER.

**Figure 12**

$$v_2 = -R_L(\alpha_f i_e); i_e = \frac{v_1}{r_e};$$

**Figure 13**

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

**Figure 14**

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

**Figure 15**

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

**Figure 16**

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

**Figure 17**

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

**Figure 18**

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

**Figure 19**

$$\therefore A_{vo2} = 79.2$$

**Figure 20**

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

**Figure 21**

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

**Figure 22**

Midband gain of cascade ∼ a single stage CE amplifier with a load resistance of 2k.
BW calculations
The midband gain of CE stage =-$g_m r_e$=-1
Therefore Miller Capacitance=$C_\mu$[1-(-1)]=2$C_\mu$
Therefore total input Capacitance=$C_\pi$+$C_\mu$ (1-$A_V$)=100+8=108pF
There is very little Miller Multiplication of $C_\mu$.
$R_{eq}$ of $C_M$ (Miller Capacitance) is =

$$r_\pi||(R_S + r_x) = (2.5k)||(1.1k) = \frac{(2.5)(1.1)}{(2.5+1.1)} = 0.763k$$

**Figure 23**

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

**Figure 24**

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

**Figure 25**

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

**Figure 26**

The BW of common base is much larger.

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

**Figure 27**

$$= \frac{1}{100 \times 10^{-12} \times 25 + 4 \times 10^{-12} \times 2000}$$

**Figure 28**

$$= \frac{1}{2.5 \times 10^{-9} + 8 \times 10^{-9}}$$

**Figure 29**

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

**Figure 30**

$$= \frac{1}{1.05 \times 10^{-8}}$$

**Figure 31**

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

**Figure 32**

$$f_h(CB) = 15MHz$$

**Figure 33**

Overall BW of Cascode=1.93Mhz
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.

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

**Figure 35**

$$\omega_h = \frac{1}{324}\frac{Grad}{sec}$$

**Figure 36**

$f_h$=491kHz
(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.