LECTURE 230 – 741 FREQUENCY RESPONSE
(READING: GHLM – 537-544)

Objective
The objective of this presentation is:
1.) Illustrate the frequency analysis of a complex amplifier
2.) Examine both dominant and non-dominant poles

Outline
• Analysis of the high frequency response
• -3dB frequency
• Slew rate
• Summary

HIGH FREQUENCY RESPONSE OF THE 741 OP AMP
Simplified Schematic of the 741 Op Amp with Idealized Biasing
AC Schematic of the High-Frequency Gain Path of the 741

![AC Schematic of the High-Frequency Gain Path of the 741](image)

AC Calculations:

\[ R_{p1} = R_{o1} = 6.8\, \text{M}\Omega, \quad R_9 = 50\, \text{k}\Omega, \quad R_8 = 100\, \Omega, \text{ and } R_{p2} = r_{o13B} \]

Calculation of the –3dB Frequency

Use the open-circuit time constant approach on \( C_c \).

\[ R_{oc} = r_{o17T} || r_{o13B}; \quad r_{o17} = \frac{V_{AN}}{I_{C17}} = 130\, \text{V} / 550\, \mu\text{A} = 236.4\, \text{k}\Omega, \quad r_{o17T} = r_{o17}(1 + g_{m17}R_8) = 732.3\, \text{k}\Omega \]

\[ r_{o13B} = \frac{V_{AP}}{I_{C13B}} = 50\, \text{V} / 550\, \mu\text{A} = 90.9\, \text{k}\Omega \]

\[ R_{oc} = 732.3\, \text{k}\Omega || 90.9\, \text{k}\Omega = 80.8\, \text{k}\Omega \]

\[ G_{mc} = 6.39\, \text{mA/V} \]
Calculation of the –3dB Frequency - Continued

Using the previous results of the open-circuit time constant gives,

\[ R_{co} = R_{ic} + R_{oc} + G_{mc}R_{ic}R_{oc} = [1.95+0.0808 + (6.39)(80.8)(1950)]M\Omega = 1.007x10^9\Omega \]

\[ C_cR_{co} = 30pF\cdot1.007x10^9\Omega = 0.0302\text{seconds} \Rightarrow f_{-3dB} = \frac{1}{2\pi C_cR_{co}} = 5.27\text{Hz} \]

An alternate approach:
Use Miller’s theorem to reflect \( C_c \) to the input of the Darlington second stage.

\[ C_{eq} = (1 + A_{v2}) C_c = 545 C_c = 16.4\text{nF} \quad R_{Load1} = R_{ic} = 1.95\text{M}\Omega \]

\[ f_{dom} = \frac{1}{2\pi R_{Load1} C_{eq}} = 4.97\text{ Hz} \]

\[ GB = A_{v1}A_{v2}f_{dom} = (565)(544.3)(4.97\text{Hz}) = 1.53\text{MHz} \]

Nondominant Poles of the 741

Many of the nondominant poles are difficult to calculate, however the following is an example one that is relatively easy. Consider the pole caused by \( C_{\pi4} \) in the circuit shown.

We will ignore the frequency of Q2 because it is npn and has a much higher \( f_T \).

From previous work we calculated that \( g_{m2} = g_{m4} = 0.46\text{mA/V} \). Assuming that \( C_{je} = 0.6\text{pF} \) and \( \tau_F = 25\text{ns} \) for the lateral pnp gives,

\[ C_{b4} = \tau_Fg_{m4} = 25\times10^{-9}\cdot0.46\times10^{-3} = 10.75\text{pF} \Rightarrow C_{\pi4} = C_{b4} + C_{je} = 11.35\text{pF} \]

The open-circuit time resistance seen from \( C_{\pi4} \) is

\[ R_{\pi04} = \frac{1}{2g_{m2}} = 1087\Omega \Rightarrow \text{Nondominant pole} = \frac{1}{2\pi C_{\pi4}R_{\pi04}} = 12.9\text{MHz} \]

(Computer results show a pole at –15 MHz)
Nondominant Poles – Continued

Another pole exists at the output of the second stage.

We have calculated previously that $R_{oc} = 80.8\, \text{k}\Omega$.

The value of $C_{p2}$ is approximately, $C_{jc23} + C_{cs17} \approx 1\, \text{pF}$

Another nondominant pole $= \frac{1}{2\pi C_{p2} R_{oc}} = 1.97\, \text{MHz}$

(This is the second pole of Millers compensation)

Slew Rate for the 741 Op Amp

The current available to charge and discharge the compensation capacitor $C_c$ is $2I_C4 = 19\, \mu\text{A}$. Therefore the slew rate is

$$SR = \frac{2I_C4}{C_c} = \frac{2(9.5\, \mu\text{A})}{30\, \text{pF}} = 0.64\, \text{V/\muS}$$
SUMMARY

- The –3dB frequency of a complex amplifier is reasonably easy to calculate
- Calculation of higher-order poles is more difficult
- Slew rate for the 741 op amp is slightly less than 1V/µs