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

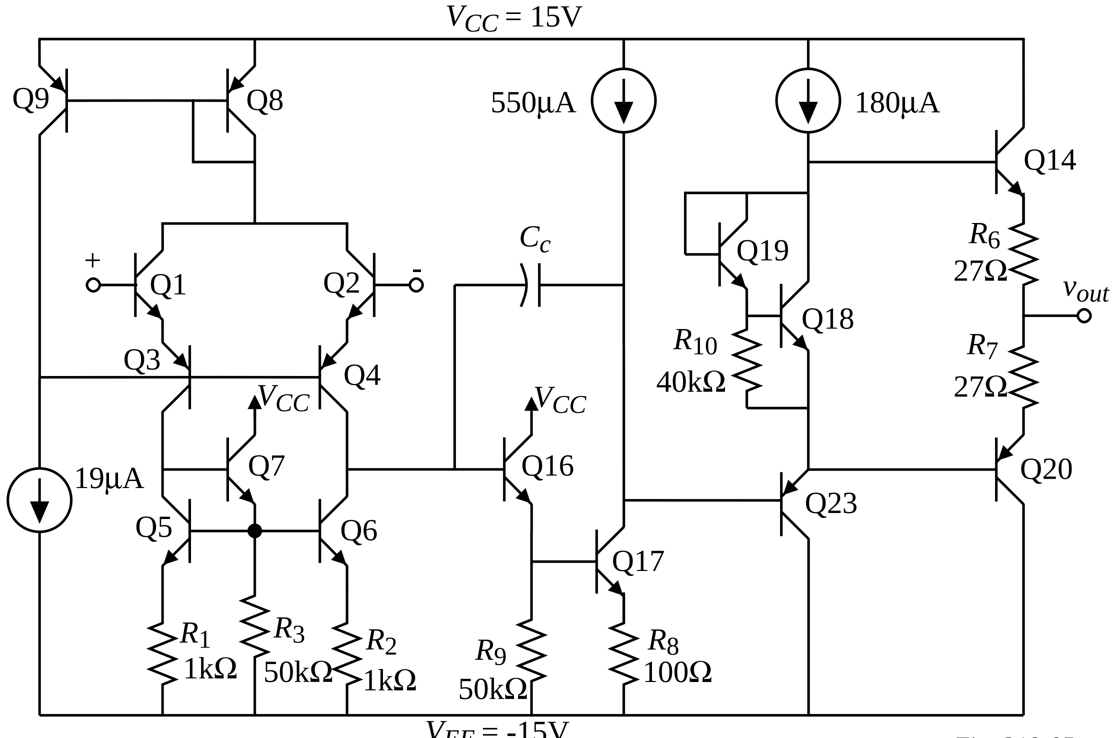

Fig. 210-05

AC Schematic of the High-Frequency Gain Path of the 741

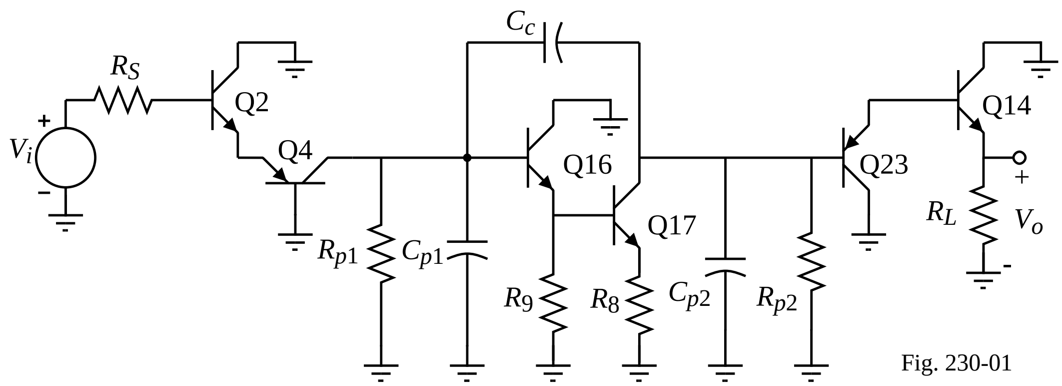

Fig. 230-01

AC Calculations:

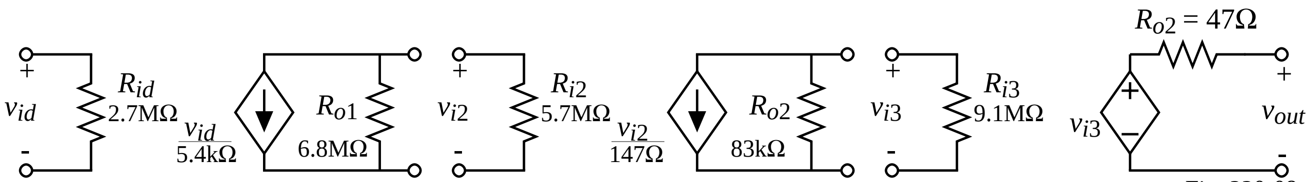

Fig. 220-08

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

Calculation of the –3dB Frequency

Use the open-circuit time constant approach on C_c.

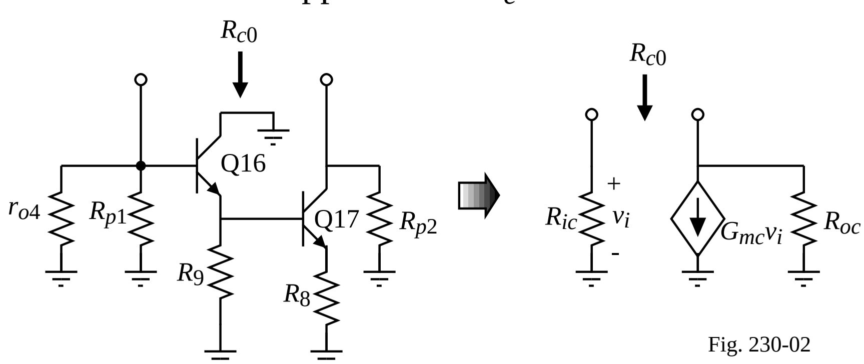

Fig. 230-02

$R_{ic} = r_{o4}||R_{p1}||R_{i2}$: $r_{o4} = \dfrac{V_{AP}}{I_{C4}} = 5.26\text{M}\Omega$, $R_{i2} = r_{\pi 16} + (\beta_N + 1)(R_9||R_{eq1}) = 5.72\text{M}\Omega$

$\therefore$ $R_{ic} = 5.26\text{M}\Omega||6.8\text{M}\Omega||5.72\text{M}\Omega = 1.95\text{M}\Omega$

$R_{oc} = r_{o17T}||r_{o13B}$:

$r_{o17} = V_{AN}/I_{C17} = 130\text{V}/550\mu\text{A} = 236.4\text{k}\Omega$, $r_{o17T} = r_{o17}(1+g_{m17}R_8) = 732.3\text{k}\Omega$

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

$\therefore$ $R_{oc} = 732.3\text{k}\Omega||90.9\text{k}\Omega = 80.8\text{k}\Omega$

$G_{mc} = 6.39\text{mA/V}$

Calculation of the –3dB Frequency - Continued

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

$$R_{co} = R_{ic} + R_{oc} + G_{mc}R_{ic}R_{oc} = [1.95+0.0808 + (6.39)(80.8)(1950)]\text{M}\Omega = 1.007\text{x}10^9\Omega$$

$$\therefore \quad C_cR_{co} = 30\text{pF}\cdot 1.007\text{x}10^9\Omega = 0.0302\text{seconds} \Rightarrow \quad f_{-3\text{dB}} = \frac{1}{2\pi C_cR_{co}} = 5.27\text{Hz}$$

An alternate approach:

Use Miller's theorem to reflect C_c to the input of the Darlington second stage.

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

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

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

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 $C_{\pi 4}$ in the circuit shown.

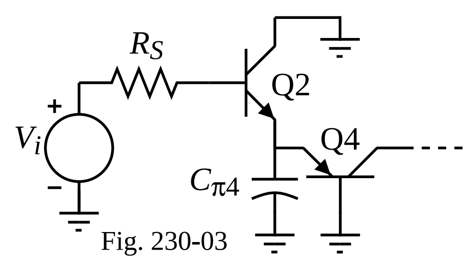

Fig. 230-03

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} = 0.6pF and τ_F = 25ns for the lateral pnp gives,

$$C_{b4} = \tau_F g_{m4} = 25\text{x}10^{-9}\cdot 0.46\text{x}10^{-3} = 10.75\text{pF} \Rightarrow \quad C_{\pi 4} = C_{b4} + C_{je} = 11.35\text{pF}$$

The open-circuit time resistance seen from $C_{\pi 4}$ is

$$R_{\pi 04} = \frac{1}{2g_{m2}} = 1087\Omega \qquad \Rightarrow \quad \text{Nondominant pole} = \frac{1}{2\pi C_{\pi 4}R_{\pi 04}} = 12.9\text{MHz}$$

(Computer results show a pole at –15MHz)

Nondominant Poles – Continued

Another pole exists at the output of the second stage.

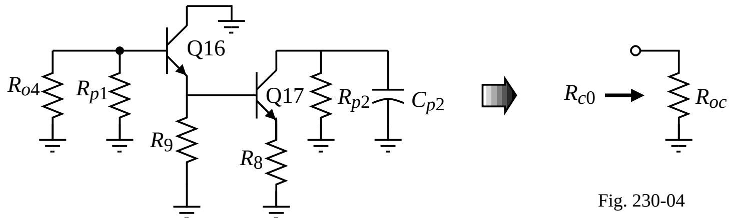

Fig. 230-04

We have calculated previously that R_{oc} = 80.8kΩ.

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

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

(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 $2I_{C4}$ = 19µA. Therefore the slew rate is

$$SR = \frac{2I_{C4}}{C_c} = \frac{2(9.5\mu\text{A})}{30\text{pF}} = 0.64\text{V}/\mu\text{S}$$

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

