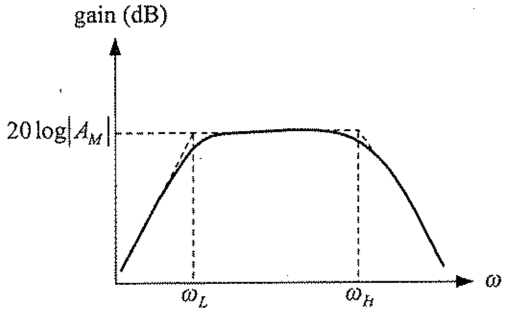
7-1 頻率響應分析方法

轉移函數與 Bode Plot

範例 1

The magnitude response of a capacitively coupled amplifier is shown in Fig.. Explain the reason for the magnitude decreasing at low and high frequencies.



[91中山通訊所（甲乙）]

【解析】

放大器外部耦合或旁路電容（大電容）造成低頻衰減，電晶體元件內部小電容造成高頻衰減。

範例 2

Find the midband gain in dB and bandwidth in Hz for the amplifier described by $A(S)=\dfrac{2.5\times10^{7}(S+2\times10^{5})}{(S+10^{5})(S+5\times10^{5})}$. What type of amplifier is this?

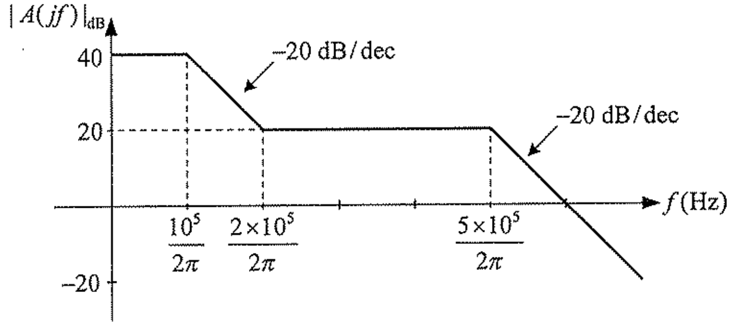
[97成大微電子／電機（甲乙丁戊）／電通（丙丁）所]

【解析】

將轉移函數標準化可得

$$A(jf)=\frac{100(1+\dfrac{j2\pi f}{2\times10^{5}})}{(1+\dfrac{j2\pi f}{10^{5}})(1+\dfrac{j2\pi f}{5\times10^{5}})}$$

則大小波德圖爲



由圖可知，中頻增益爲40 dB，頻寬約爲

$$f_H = \frac{1}{2\pi\sqrt{(\frac{1}{10^5})^2 + (\frac{1}{5\times10^5})^2 - 2(\frac{1}{2\times10^5})^2}} = 21.658\ (\text{KHz})$$

此爲低通放大器。

範例 3

For the transfer function:

$$A_v(S) = \frac{8\times10^{13} S(S+20)}{(S+30)(S+400)(S+10000)(S+100000)}$$

(1)please write down the poles and zeros.

(2)please state which pole is the dominant low frequency pole and which frequency is the dominant high frequency pole.

(3)please sketch the Bode magnitude plot. [95成大奈米科技暨微系統所]

【解析】

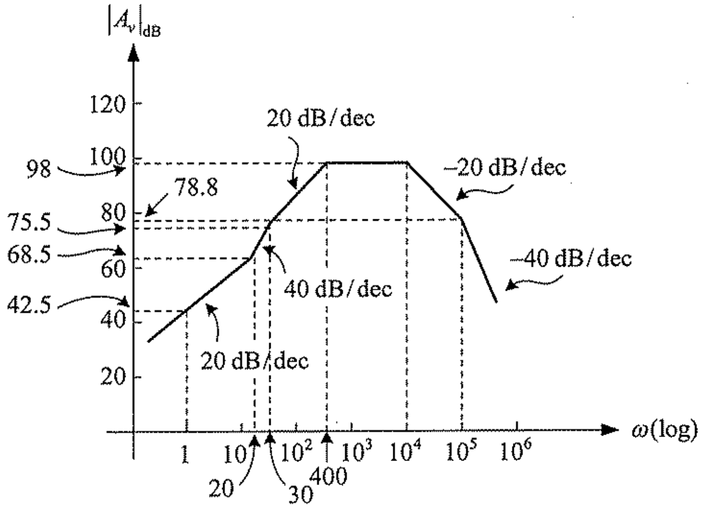
(1)zeros： $z_1 = 0$ (rad/sec)， $z_2 = -20$ (rad/sec)， $z_3 = z_4 = \infty$ (rad/sec)

poles： $p_1 = -30$ (rad/sec)， $p_2 = -400$ (rad/sec)， $p_3 = -10^4$ (rad/sec)，

$p_4 = -10^5$ (rad/sec)

(2)&(3)將轉移函數表爲波德圖標準式可得

$$A_v(S) = \frac{\frac{400}{3} S(1+\frac{S}{20})}{(1+\frac{S}{30})(1+\frac{S}{400})(1+\frac{S}{10^4})(1+\frac{S}{10^5})}$$



由主極點近似法可知

$$f_L = \frac{400}{2\pi} = 63.66 \ \ (\text{Hz})$$

$$f_H = \frac{10^4}{2\pi} = 1.59 \ \ (\text{KHz})$$

極點頻率、零點頻率與 3 dB 頻率求法

範例 4

The high-frequency response of an amplifier is characterized by 2 zeros at $S=\infty$ and 2 poles frequency at ω_{p1} and ω_{p2}. For $\omega_{p2}=k\omega_{p1}$, find the value of k that results in the exact value of ω_H being $0.9\omega_{p1}$.

[97海洋固態電子所]

【解析】

由於

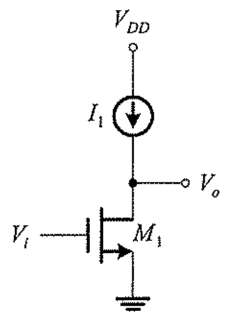
$$\frac{1}{\omega_H}=\frac{1}{\omega_{p1}}+\frac{1}{\omega_{p2}} \Rightarrow \frac{1}{0.9\omega_{p1}}=\frac{1}{\omega_{p1}}+\frac{1}{k\omega_{p1}}$$

可得 $k=9$

範例 5

右圖電路是一個Common-Source Amplifier with Active Load。電晶體M_1及電流源I_1具有相同的Output Resistance，r_o。令V_i訊號源的輸出阻抗為0，則此放大器的transfer function可寫成：

$$A_v(S)=\frac{V_o(S)}{V_i(S)}=A_M\frac{1-S/\omega_z}{1+S/\omega_p}$$



求：

(1) A_M。

(2) ω_z。

(3) ω_p之公式，以g_m、r_o、C_{gs}、C_{gd}表示。 [95交大電子所]

【解析】

由輸出端之節點方程式：$(SC_{gd}+2/r_o)V_o(S)=(SC_{gd}-g_m)V_i(S)$，可得

$$\frac{V_o(S)}{V_i(S)}=A_M\frac{1-S/\omega_z}{1+S/\omega_p}$$

(1) $$A_M=-g_m(r_o//r_o)=-\frac{1}{2}g_m r_o\text{(V/V)}$$

(2)由輸出端列節點方程式

$$V_o(\frac{1}{r_o}+\frac{1}{r_o}+SC_{gd})=(SC_{gd}-g_m)V_{gs}$$

令V_o爲零且$S=z$，可得

$$z=\frac{g_m}{C_{gd}}$$

因此

$$\omega_z=|z|=\frac{g_m}{C_{gd}}\ \text{(rad/sec)}$$

(3) $$\omega_p=\frac{1}{\tau}=\frac{2}{C_{gd}r_o}$$

範例 6

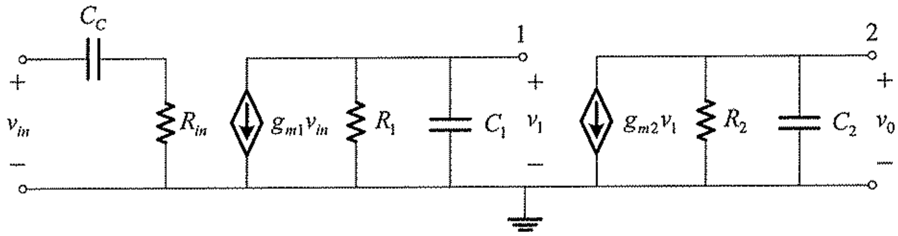
The small-signal equivalent circuit of a two-stage amplifier is shown in the Fig., where $R_{in} = 1\,\text{M}\Omega$, $C_C = 1\,\mu\text{F}$, $g_{m1} = 100\,\mu\text{A/V}^2$, $g_{m2} = 125\,\mu\text{A/V}^2$, $R_1 = 200\,\text{K}\Omega$, $R_2 = 250\,\text{K}\Omega$, $C_1 = 0.5\,\text{pF}$ and $C_2 = 2.5\,\text{pF}$.

(1)Determine the midband gain (in dB).

(2)If a compensation capacitor (2 pF) is added between nodes 1 and 2, estimate the dominant pole frequency (in Hz).

(3)Roughly sketch the magnitude response of the amplifier gain (v_o / v_{in}) after compensation, and indicate the –3 dB frequencies (in Hz) in your plot.

(4)Find the zero results from the compensation capacitor. Is the zero located in the right-half or the left-half plane?



[95大同電機所]

【解析】

(1)中頻分析：C_C short，C_1、C_2 open

$$A_M = \frac{V_o}{V_{in}} = \frac{V_1}{V_{in}}\frac{V_o}{V_1} = (-g_{m1}R_1)(-g_{m2}R_2) = 625$$

因此

$$A_M(\text{dB}) = 20\log|A_M| = 56\,(\text{dB})$$

(2)由於

$$\frac{V_o}{V_1} = -g_{m2}R_2 = -31.25 \triangleq K$$

所以