University of Diyala
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Electronics II : 3ed Year - 2015/2016
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❖ *LOW-FREQUENCY RESPONSE - BJT AMPLIFIER WITH RL*

The analysis of this section will employ the loaded (R_L) voltage-divider BJT bias configuration introduced. For the network of Fig. 2, the capacitors C_S, C_G, and C_E will determine the low-frequency response. We will now examine the impact of each independently in the order listed.

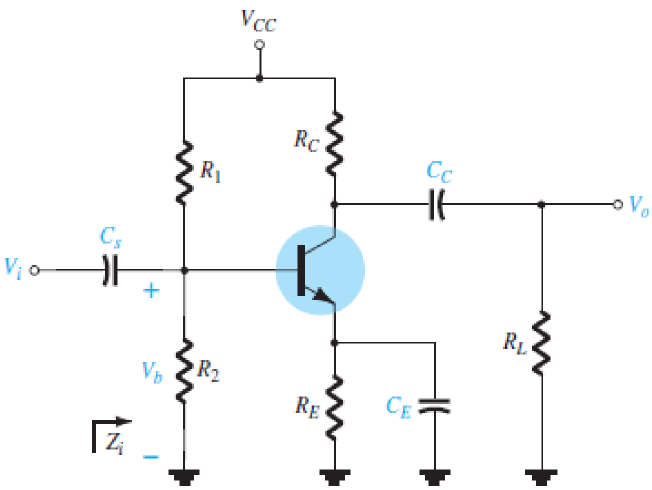


Fig. 1

Loaded BJT amplifier with capacitors that affect the low- frequency response.

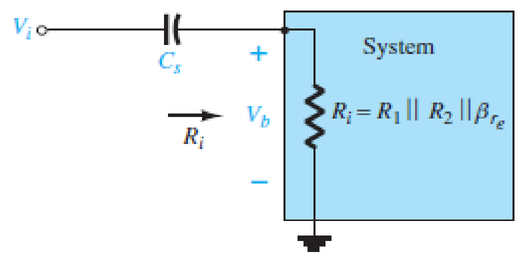


Fig. 2

Determining the effect of C_S on the low-frequency response.

➢ ***C_S*** Because C_S is normally connected between the applied source and the active device, the general form of the RC configuration is established by the network of Fig. 2.

$$R_i = R_1 // R_2 //\beta r_e$$

The cutoff frequency defined by C_S is:

$$f_{L_s} = \frac{1}{2\pi R_i C_s}$$

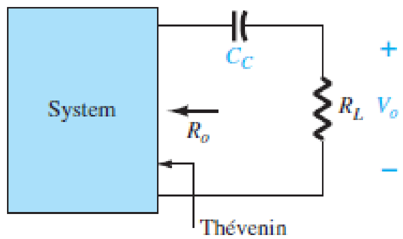


Fig. 3

Determining the effect of Cc on the low-frequency response.

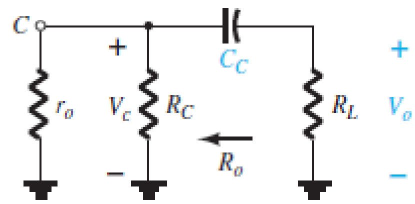


Fig. 4

Localized ac equivalent for C_C with Vi = 0V.

- ***Cc*** Because the coupling capacitor is normally connected between the output of the active device and the applied load, the *RC* configuration that determines the low-cutoff frequency due to *Cc* appears in Fig. 3. the cutoff frequency due to *Cc* is determined by:

$$f_{L_C} = \frac{1}{2\pi(R_o + R_L)C_C} \qquad R_o = R_C \| r_o$$

- $\boldsymbol{C_E}$ The cutoff frequency due to C_E can be determined using the following equation:

$$f_{L_E} = \frac{1}{2\pi R_e C_E} \qquad R_e = R_E \| \left(\frac{R_1 \| R_2}{\beta} + r_e\right)$$

The gain for the network determined by:

$$A_v = \frac{V_o}{V_i} = \frac{-R_C \| R_L}{r_e}$$

❖ *IMPACT OF R_S ON THE BJT LOW-FREQUENCY RESPONSE*

In this section we will investigate the impact of the source resistance on the various cutoff frequencies. In Fig. 5.

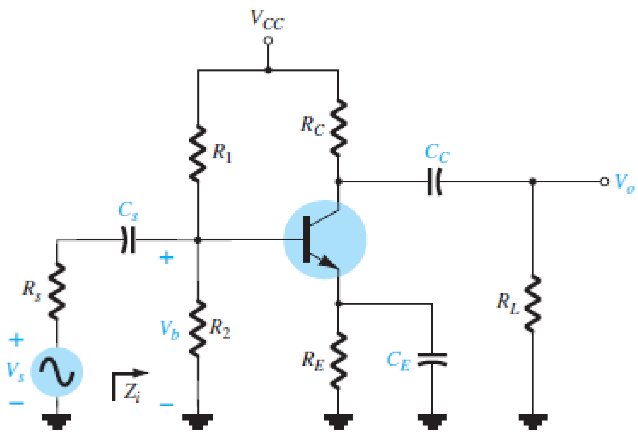


Fig. 5

Determining the effect of R_S on the low-frequency response of a BJT amplifier.

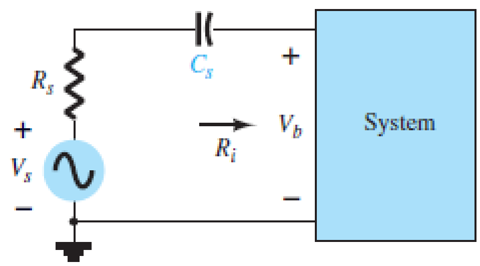


Fig. 6

Determining the effect of C_S on the low- frequency response.

➢ ***C_S*** The equivalent circuit at the input is now as shown in Fig. 6, with *Ri* continuing to be equal to $R_1 \| R_2 \| \beta r_e$. Doing so would result in the following Equation for the cutoff frequency:

$$f_{L_s} = \frac{1}{2\pi(R_i + R_s)C_s}$$

so that

$$A_{v_{\text{mid}}} = \frac{\mathbf{V}_b}{\mathbf{V}_s} = \frac{R_i}{R_i + R_s}$$

And

$$A_{v_s} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \cdot \frac{V_b}{V_s}$$

➢ ***Cc*** For the coupling capacitor *Cc*, we find that the derivation of the equation for the cutoff frequency remains the same. That is,

$$f_{L_C} = \frac{1}{2\pi(R_o + R_L)C_C}$$

➢ $\boldsymbol{C_E}$ For the same capacitor, we find that R_S will affect the resistance level substituted into the cutoff equation so that,

$$f_{L_E} = \frac{1}{2\pi R_e C_E}$$

with

$$R_e = R_E \| \left(\frac{R'_s}{\beta} + r_e\right) \text{ and } R'_s = R_s \| R_1 \| R_2$$

❖ *LOW-FREQUENCY RESPONSE-FET AMPLIFIER*

The analysis of the FET amplifier in the low-frequency region will be quite similar to that of the BJT amplifier. There are again three capacitors of primary concern as appearing in the network of Fig.7: $\boldsymbol{C_G}$, $\boldsymbol{C_C}$, and $\boldsymbol{C_S}$.

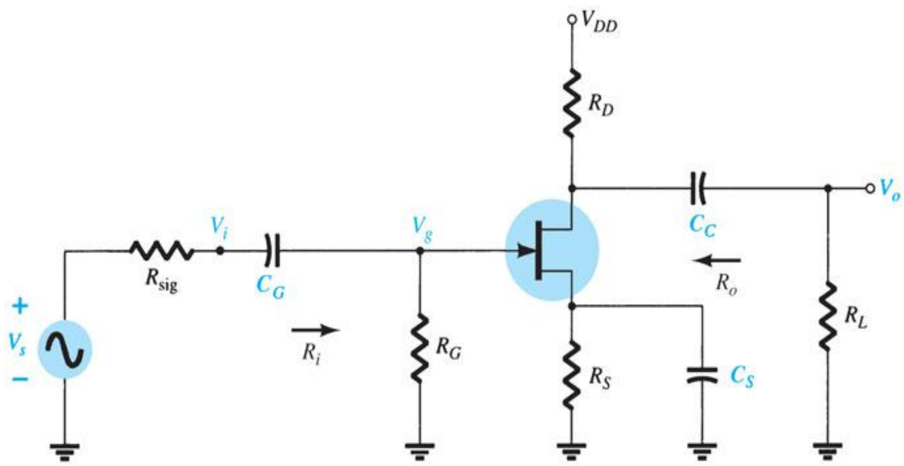


Fig.7

Capacitive elements that affect the low-frequency response of a JFET amplifier.

➢ $\boldsymbol{C_G}$ For the coupling capacitor between the source and the active device, the ac equivalent network is as shown in Fig.8. The cutoff frequency determined by C_G is:

$$f_{L_G} = \frac{1}{2\pi(R_{sig} + R_i)C_G}$$

$$R_i = R_G$$

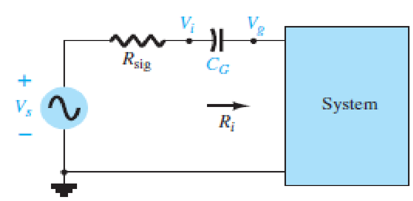


Fig.8

Determining the effect of C_G on the low-frequency response

- ***Cc*** For the coupling capacitor between the active device and the load the network of Fig. 9. The resulting cutoff frequency is:

$$f_{L_C} = \frac{1}{2\pi(R_o + R_L)C_C}$$

$$R_o = R_D \| r_d$$

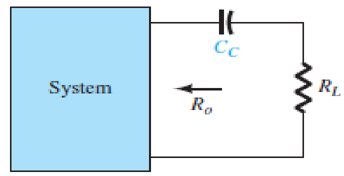


Fig.9
Determining the effect of C_C on the low-frequency response.

- ***C_S*** For the source capacitor C_S, the resistance level of importance is defined by Fig. 10.The cutoff frequency is defined by:

$$f_{L_S} = \frac{1}{2\pi R_{eq} C_S}$$

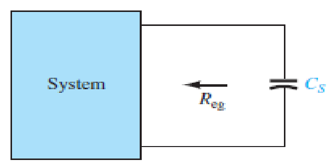


Fig.10
Determining the effect of on low-frequency response.

For Fig.7, the resulting value of is

$$R_{eq} = \frac{R_S}{1 + R_S(1 + g_m r_d)/(r_d + R_D \| R_L)}$$

which for $r_d = \infty\ \Omega$, becomes $R_{eq} = R_S \| \frac{1}{g_m}$

The midband gain of the system is determined by:

$$A_{v_{mid}} = \frac{V_o}{V_i} = -g_m(R_D \| R_L)$$

❖ *HIGH-FREQUENCY RESPONSE-BJT AMPLIFIER*

In Fig. 11, the various parasitic capacitances (C_{be} , C_{bc} , C_{ce}) of the transistor are included with the wiring capacitances (C_{Wi} , C_{Wo}) introduced during construction. The high-frequency equivalent model for the network of Fig. 11 appears in Fig. 12. Note the absence of the capacitors C_S, C_C, and C_E, which are all assumed to be in the short-circuit state at these frequencies.

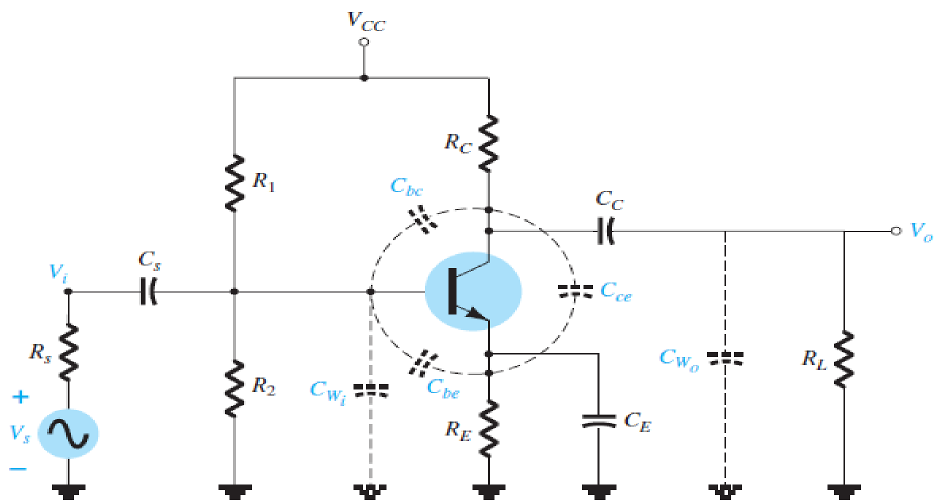


Fig.11
Network of Fig.11 with the capacitors that affect the high-frequency response.

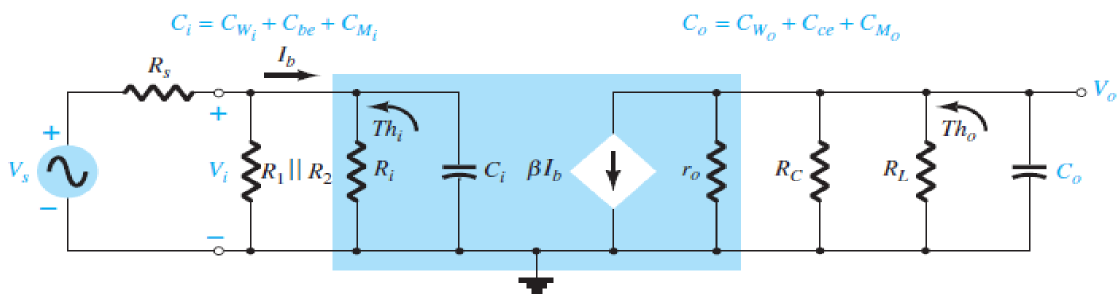


Fig.12
High-frequency ac equivalent model for the network of Fig. 11

Determining the Thevenin equivalent circuit for the input and output networks of Fig.12 results in the configurations of Fig.13 For the input network, the - 3dB frequency is defined by:

$$f_{H_i} = \frac{1}{2\pi R_{\mathrm{Th}_i} C_i}$$

With

$$R_{\mathrm{Th}_i} = R_s \| R_1 \| R_2 \| \beta r_e$$

And

$$C_i = C_{W_i} + C_{be} + C_{M_i} = C_{W_i} + C_{be} + (1 - A_v)C_{bc}$$

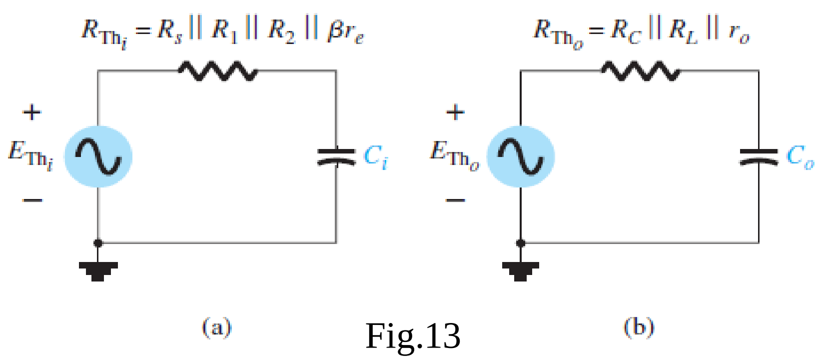


Fig.13

Thevenin circuits for the input and output networks of the network of Fig.12

For the output network

$$f_{H_o} = \frac{1}{2\pi R_{\mathrm{Th}_o} C_o}$$

With

$$R_{\mathrm{Th}_o} = R_C \| R_L \| r_o$$

And
$$C_o = C_{W_o} + C_{ce} + C_{M_o}$$

or
$$C_o = C_{W_o} + C_{ce} + (1 - 1/A_v)C_{bc}$$

For Ay large (typical): $1 \gg 1/A_v$

And
$$C_o \cong C_{W_o} + C_{ce} + C_{bc}$$

❖ *HIGH-FREQUENCY RESPONSE-FET AMPLIFIER*

The analysis of the high-frequency response of the FET amplifier will proceed in a very similar manner to that encountered for the BJT amplifier. As shown in Fig.14, there are interelectrode and wiring capacitances that will determine the high-frequency characteristics of the amplifier.

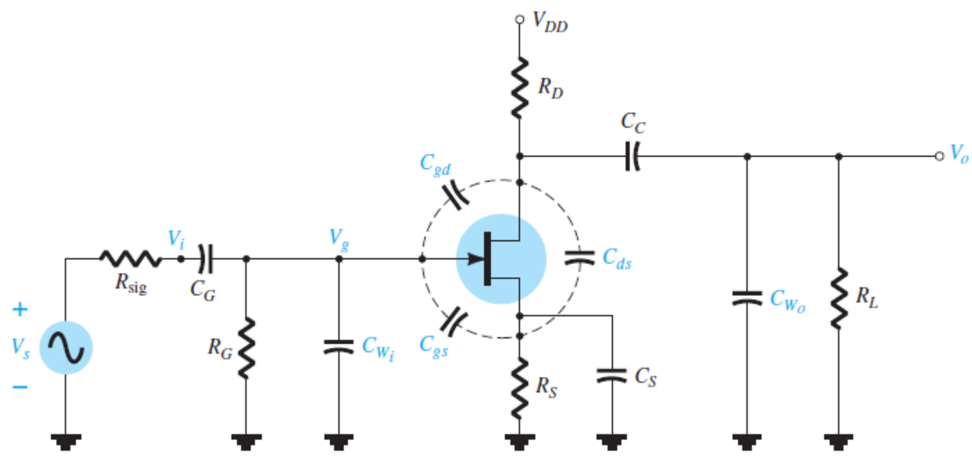


Fig.14
Capacitive elements that affect the high-frequency response

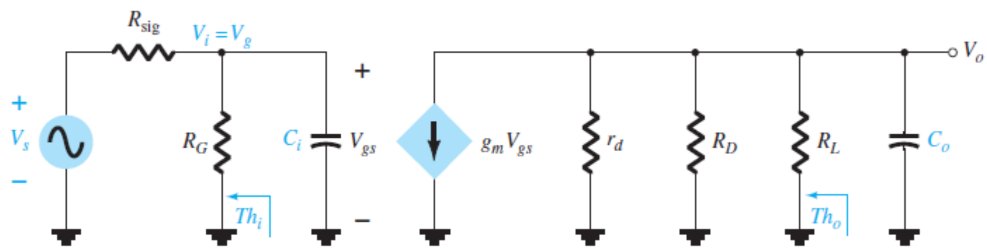


Fig.15

High-frequency ac equivalent circuit for Fig.14.

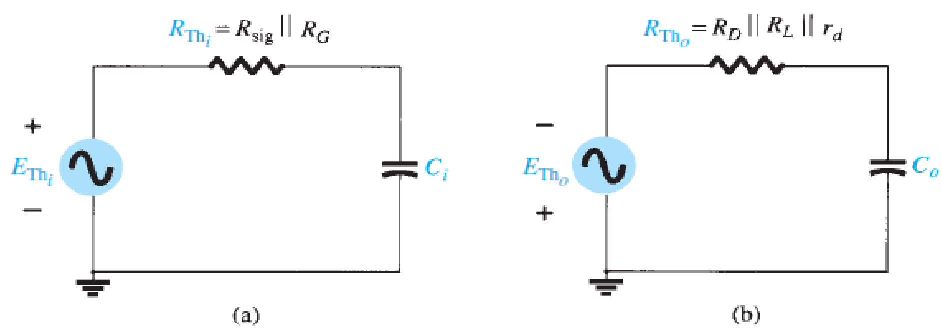


Fig.16

The Thevenin equivalent circuits for: (a) the input circuit and (b) the output circuit.

The cutoff frequencies defined by the input and output circuits can be obtained by first finding the Thevenin equivalent circuits for each section as shown in Fig.16. For the input circuit.

$$f_{H_i} = \frac{1}{2\pi R_{Th_i} C_i}$$

And

$$R_{Th_i} = R_{sig} \| R_G$$

With $$C_i = C_{W_i} + C_{gs} + C_{M_i}$$

And $$C_{M_i} = (1 - A_v)C_{gd}$$

For the output circuit,

$$f_{H_o} = \frac{1}{2\pi R_{\mathrm{Th}_o} C_o}$$

With $$R_{\mathrm{Th}_o} = R_D \| R_L \| r_d$$

And $$C_o = C_{W_o} + C_{ds} + C_{M_o}$$

And $$C_{M_o} = \left(1 - \frac{1}{A_v}\right)C_{gd}$$

❖ *MULTISTAGE FREQUENCY EFFECTS*

Most of a cascaded amplifier stages are used to obtain either voltage gain or a current gain. However, in most cascaded amplifiers, ultimately the power gain is important. If a voltage gain is required, we can calculate the total gain by using the equation for voltage gain of one stage. Thus, the voltage gain for stage l is:

$$A_{v1} = \frac{V_{o1}}{V_{in1}}$$

In addition, the voltage gain for stage 2 is:

$$A_{v2} = \frac{V_{o2}}{V_{in2}}$$

The gain for additional stages can be written in a similar manner. Then, the total amplifier voltage gain A_{total} for n-cascaded stages is:

$$\frac{V_{o1}}{V_{in1}} \times \frac{V_{o2}}{V_{o1}} \times \frac{V_{o3}}{V_{o2}} \times . \quad . \quad . \frac{V_{o(n-1)}}{V_{on}} = \frac{V_{o(n-1)}}{V_{in1}}$$

$$A_{total} = A_1 \times A_2 \times A_3 \times . \quad . \quad . \times A_n$$

Setting the magnitude of this result equal to 1/√2 (-3 dB level) results in

$$\frac{1}{\sqrt{[1 + (f_L/f_L')^2]^n}} = \frac{1}{\sqrt{2}}$$

so that
$$\left[1+\left(\frac{f_L}{f'_L}\right)^2\right]^n = 2$$

and
$$1+\left(\frac{f_L}{f'_L}\right)^2 = 2^{1/n}$$

With the result that

$$f'_L = \frac{f_L}{\sqrt{2^{1/n}-1}}$$

In a similar manner, it can be shown that for the high-frequency region,

$$f'_H = \left(\sqrt{2^{1/n}-1}\right)f_H$$

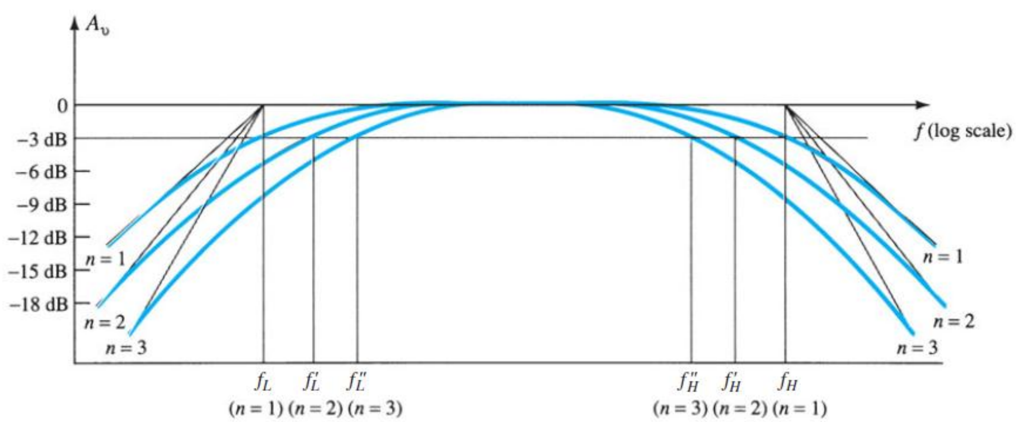


Fig.17

Effect of an increased number of stages on the cutoff frequencies and the bandwidth.

Example (1): Determine the cutoff frequencies for the network of fig.1. using the following parameters : C_S = 10μf , C_E = 20μf , C_C = 1μf , R_1 = 40kΩ , R_2 = 10kΩ , R_E = 2kΩ , R_C = 4kΩ , R_L = 2.2kΩ , β = 100 , V_{CC} = 20v , r_o = ∞Ω ?

Solution: The dc base voltage is determined by:

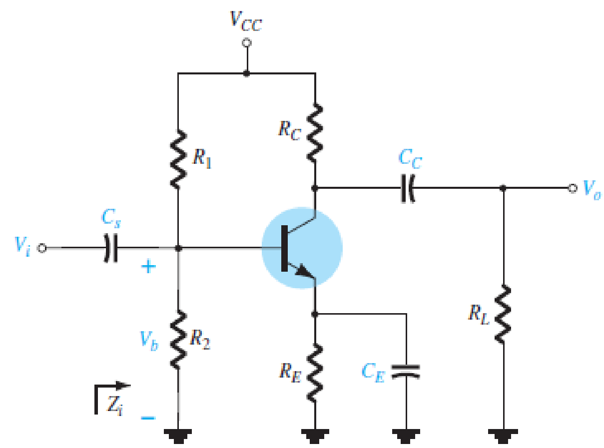


Fig.1

$$V_B = \frac{R_2 V_{cc}}{R_1 + R_2} = \frac{10k\Omega(20v)}{10k\Omega + 40k\Omega} = \frac{200v}{50} = 4v$$

$$I_E = \frac{V_E}{R_E} = \frac{4v - 0.7v}{2k\Omega} = \frac{3.3v}{2k\Omega} = 1.65mA$$

$$r_e = \frac{26mV}{1.65mA} \cong 15.76\Omega$$

$$\beta r_e = 100(15.76\Omega) = 1576\Omega = 1.576k\Omega$$

The Midband Gain of the system is determined by:

$$A_v = \frac{V_o}{V_i} = \frac{-R_c \| R_L}{r_e} = -\frac{(4k\Omega)\|(2.2k\Omega)}{15.76\Omega} = \cong -90$$

For $\boldsymbol{C_s}$

$$R_i = R_1 \| R_2 \| \beta r_e = 40k\Omega \| 10k\Omega \| 1.576k\Omega \cong 1.32k\Omega$$

$$f_{LS} = \frac{1}{2\pi R_i C_s} = \frac{1}{(6.28)(1.32k\Omega)(10\mu f)} \cong 12.06 \text{ Hz}$$

For $\boldsymbol{C_c}$

$$f_{Lc} = \frac{1}{2\pi(R_o + R_L)C_c}\ , \qquad R_o = R_c \| r_o \cong\ R_c$$

$$= \frac{1}{(6.28)(4k\Omega + 2.2k\Omega)(1\mu f)} \cong 25.68 \text{ Hz}$$

For $\boldsymbol{C_E}$

$$R_e = R_E \| \left(\frac{R_1 \| R_2}{\beta} + r_e \right)$$

$$= 2k\Omega \| \left(\frac{40k\Omega \| 10k\Omega}{100} + 15.76\Omega \right)$$

$$= \ 2k\Omega \| \left(\frac{8k\Omega}{100} + 15.76\Omega \right)$$

$$= 2k\Omega \| (80\Omega + 15.76\Omega)$$

$$= 2k\Omega \| 95.76\Omega$$

$$= 91.38\Omega$$

$$f_{LE} = \frac{1}{2\pi R_e C_E} = \frac{1}{(6.28)(91.38\Omega)(20\mu f)} \cong 87.13 \text{ Hz}$$

Since $f_{LE} >> f_{LC}$ or f_{LS} the bypass capacitor C_E is determining the lower cutoff frequency of the amplifier.

Example (2): Determine the cutoff frequencies for the network of fig.2. using the following parameters : $C_S = 10\mu f$, $C_E = 20\mu f$, $C_C = 1\mu f$, $R_S = 1k\Omega$, $R_1 = 40k\Omega$, $R_2 = 10k\Omega$, $R_E = 2k\Omega$, $R_C = 4k\Omega$, $R_L = 2.2k\Omega$, $\beta = 100$, $V_{CC} = 20v$, $r_o = \infty\Omega$?

Solution: The dc base voltage is determined by:

$$V_B = \frac{R_2 V_{cc}}{R_1 + R_2} = \frac{10k\Omega(20v)}{10k\Omega + 40k\Omega} = \frac{200v}{50} = 4v$$

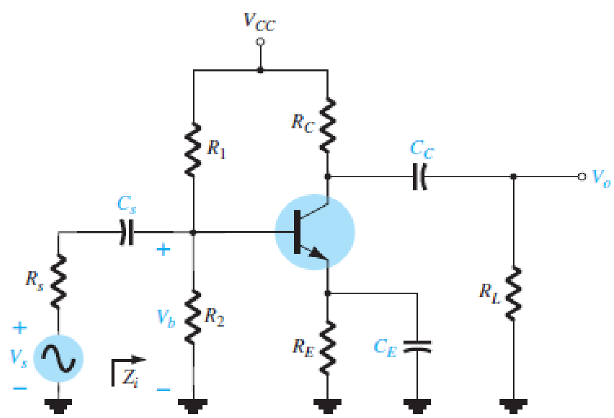


Fig.2

$$I_E = \frac{V_E}{R_E} = \frac{4v - 0.7v}{2k\Omega} = \frac{3.3v}{2k\Omega} = 1.65mA$$

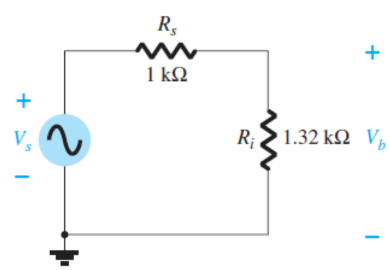
$$r_e = \frac{26mV}{1.65mA} \cong 15.76\Omega$$

$$\beta r_e = 100(15.76\Omega) = 1576\Omega = 1.576k\Omega$$

The Midband Gain of the system is determined by:

$$A_v = \frac{V_o}{V_i} = \frac{-R_c \| R_L}{r_e} = -\frac{(4k\Omega)\|(2.2k\Omega)}{15.76\Omega} =\cong -90$$

$$R_i = R_1 \| R_2 \| \beta r_e = 40k\Omega \| 10k\Omega \| 1.576k\Omega \cong 1.32k\Omega$$



$$V_b = \frac{R_i V_s}{R_i + R_s}$$

$$\frac{V_b}{V_s} = \frac{R_i}{R_i + R_s} = \frac{1.32k\Omega}{1.32k\Omega + 1k\Omega} = 0.569$$

$$A_{vs} = \frac{V_o}{V_s} = \frac{V_o}{V_i} * \frac{V_b}{V_s} = (-90)(0.569) = -51.21$$

For $\boldsymbol{C_s}$

$$f_{LS} = \frac{1}{2\pi(R_s + R_i)C_s} = \frac{1}{(6.28)(1k\Omega + 1.32k\Omega)(10\mu f)} \cong 6.86 \text{ Hz}$$

For $\boldsymbol{C_c}$

$$f_{Lc} = \frac{1}{2\pi(R_o + R_L)C_c}\ , \qquad R_o = R_c \| r_o \cong\ R_c = \frac{1}{(6.28)(4k\Omega + 2.2k\Omega)(1\mu f)} \cong 25.68 \text{ Hz}$$

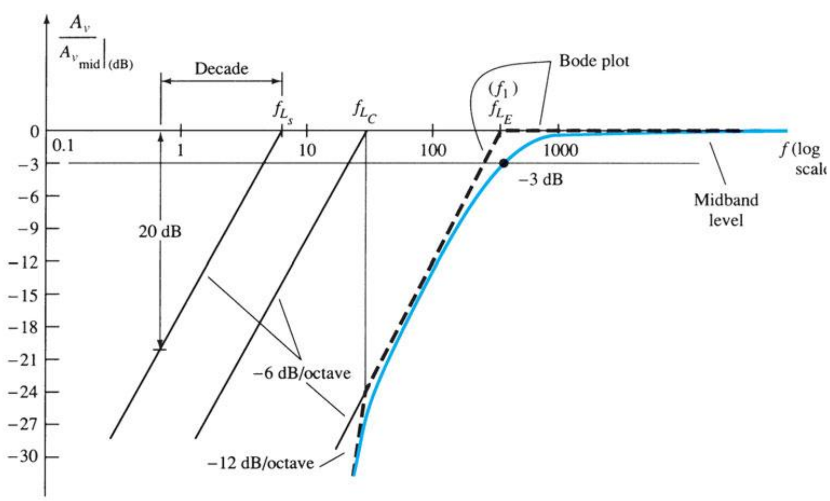
For $\boldsymbol{C_E}$

$$R'_s = R_s \| R_1 \| R_2 = 1k\Omega \| 40k\Omega \| 10k\Omega \cong 0.889k\Omega$$

$$R_e = R_E \| \left(\frac{R'_s}{\beta} + r_e \right)$$

$$= 2k\Omega \| \left(\frac{0.889k\Omega}{100} + 15.76\Omega \right) = 2k\Omega \| (8.89\Omega + 15.76\Omega) = 2k\Omega \| (24.65\Omega) \cong 24.35\Omega$$

$$f_{LE} = \frac{1}{2\pi R_e C_E} = \frac{1}{(6.28)(24.35\Omega)(20\mu f)} \cong 327 \text{ Hz}$$



Example (3): Determine the cutoff frequencies for the network of fig.3. using the following parameters : C_S = 2µf , C_G = 0.01µf , C_C = 0.5µf , R_{Sig} = 10kΩ, R_G = 1MΩ , R_D = 4.7kΩ , R_S = 1kΩ , R_L = 2.2kΩ , I_{DSS} = 8mA , V_d = -4v , $r_d = \infty\Omega$, V_{DD} =20v,V_{GSQ} = -2v?

Solution: The dc base voltage is determined by:

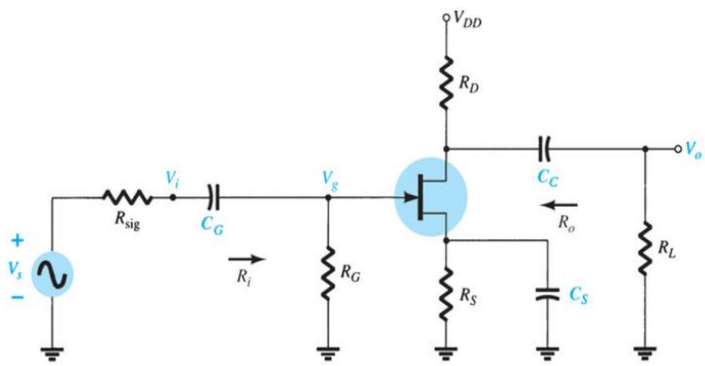


Fig.3

$$g_{m0} = \frac{2I_{DSS}}{|V_P|} = \frac{2(8mA)}{4V} = 4mS$$

$$g_m = g_{m0}\left(1 - \frac{V_{GSQ}}{V_P}\right)$$

$$g_m = 4mS\left(1 - \frac{-2v}{-4v}\right) = 2mS$$

For $\mathbf{C_G}$

$$f_{LG} = \frac{1}{2\pi(R_{sig} + R_i)C_G} = \frac{1}{(6.28)(10k\Omega + 1M\Omega)(0.01\mu f)} \cong 15.8 \text{ Hz}$$

For $\mathbf{C_c}$

$$f_{Lc} = \frac{1}{2\pi(R_o + R_L)C_C} = \frac{1}{(6.28)(4.7k\Omega + 2.2k\Omega)(0.5\mu f)} \cong 46.13 \text{ Hz}$$

For **C**$_S$

$$R_{eq} = R_S \left\| \frac{1}{g_m} = 1k\Omega \right\| \frac{1}{2mS} = 1k\Omega \| 0.5k\Omega = 333.33\Omega$$

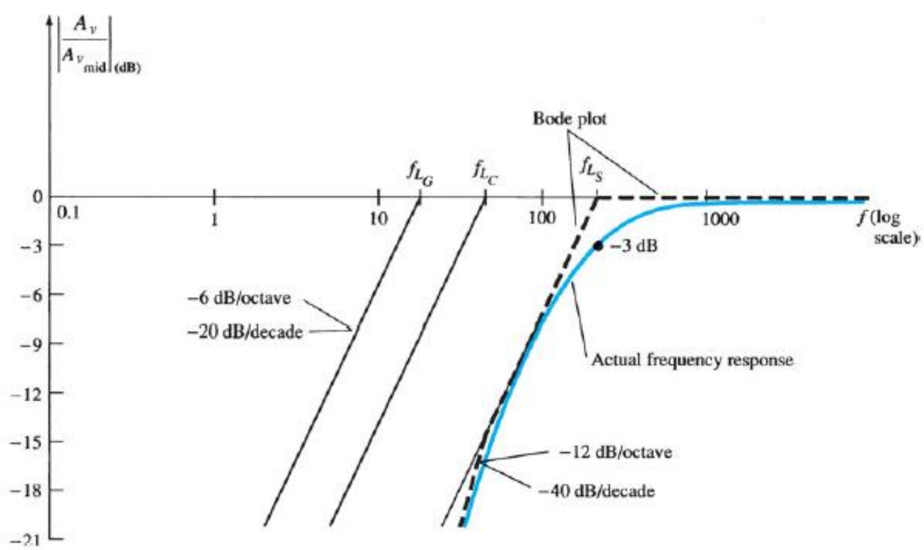
$$f_{LS} = \frac{1}{2\pi R_{eq} C_s} = \frac{1}{(6.28)(333.33\Omega)(2\mu f)} = 238.73 \text{ Hz}$$

Because f_{LS} is the largest of the three cutoff frequencies, it defines the low-cutoff frequency for the network of Fig.3.

The Midband Gain of the system is determined by:

$$A_{Vmid} = \frac{V_O}{V_i} = -g_m(R_D \| R_L) = (-2mS)(4.7k\Omega \| 2.2k\Omega)$$

$$= -(2mS)(1.4k\Omega) \cong -3$$



Example (4): Determine the high-cutoff frequencies for the network of fig.4. using the following parameters : C_S = 10µf , C_E = 20µf , C_C = 1µf , R_S = 1kΩ, R_1 = 40kΩ , R_2 = 10kΩ , R_E = 2kΩ , R_C = 4kΩ , R_L = 2.2kΩ , β = 100 , V_{CC} = 20v , r_o = ∞Ω, C_{be} = 36pf, C_{bc} = 4pf, C_{ce} = 1pf, C_{Wi} = 6pf, C_{Wo} = 8pf ?

Solution: The dc base voltage is determined by:

$$V_B = \frac{R_2V_{cc}}{R_1+R_2} = \frac{10k\Omega(20v)}{10k\Omega+40k\Omega} = \frac{200v}{50} = 4v$$

$$I_E = \frac{V_E}{R_E} = \frac{4v-0.7v}{2k\Omega} = \frac{3.3v}{2k\Omega} = 1.65mA$$

$$r_e = \frac{26mV}{1.65mA} \cong 15.76\Omega$$

$$\beta r_e = 100(15.76\Omega) = 1576\Omega = 1.576k\Omega$$

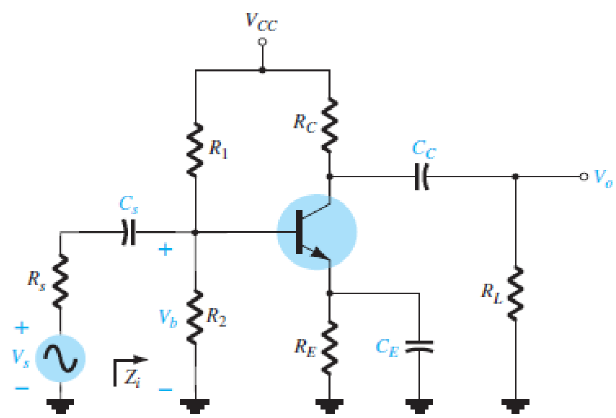


Fig.4

The Midband Gain of the system is determined by:

$$A_v = \frac{V_o}{V_i} = \frac{-R_c\|R_L}{r_e} = -\frac{(4k\Omega)\|(2.2k\Omega)}{15.76\Omega} =\cong -90$$

$$R_{Thi} = R_s\|R_1\|R_2\|\beta r_e = 1k\Omega\|40k\Omega\|10k\Omega\|576k\Omega \cong 0.57k\Omega$$

With $C_i = C_{wi} + C_{be} + C_{Mi}$, $C_{Mi} = (1- A_v)\, C_{bc}$

$C_i = C_{wi} + C_{be} + (1- A_v)\, C_{bc}$

= 6pf + 36pf + [1 - (-90)] 4pf

= 406pf

$$f_{Hi} = \frac{1}{2\pi R_{Thi} C_i} = \frac{1}{(6.28)(0.57k\Omega)(406pf)} = 687.73\ k\text{Hz}$$

$$R_{Tho} = R_c \| R_L = 4k\Omega \| 2.2k\Omega = 1.419k\Omega$$

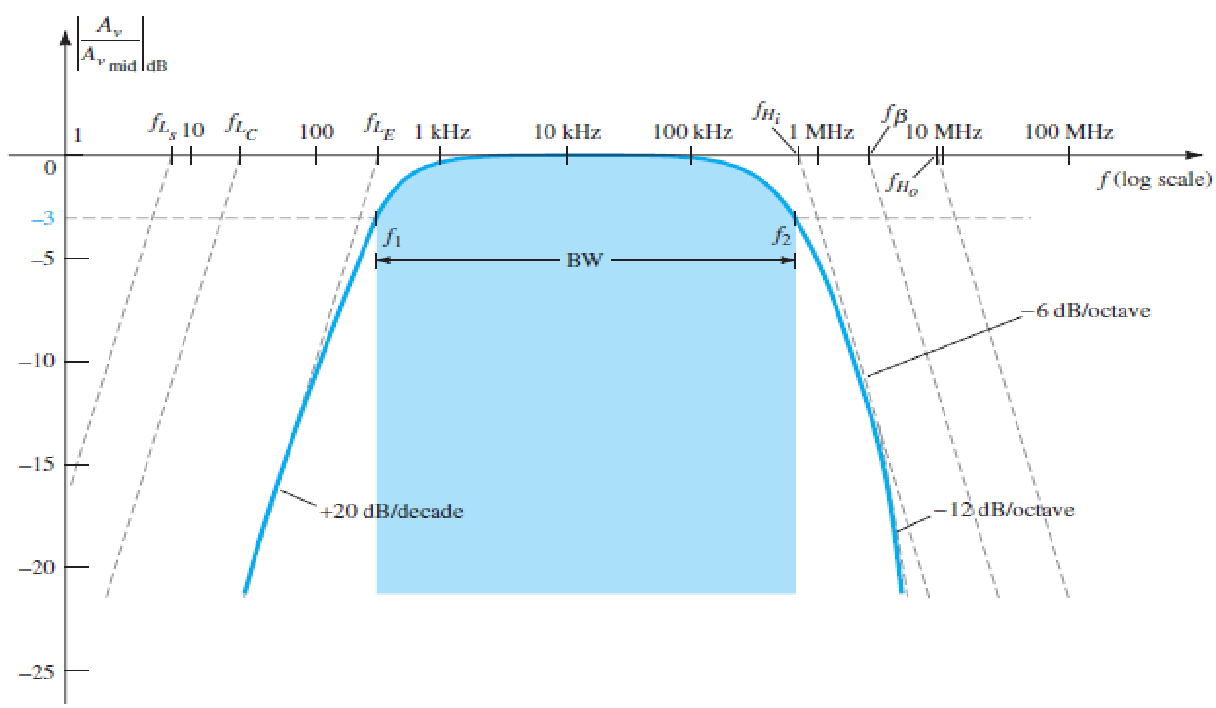
With $C_o = C_{wo} + C_{ce} + C_{Mo}$, $C_{Mo} = (1 - 1/A_v)\, C_{bc}$

$C_o = C_{wo} + C_{ce} + (1 - 1/A_v)\, C_{bc}$

$= 8pf + 1pf + [1 - 1/(-90)]\, 4pf$

$= 13.04pf$

$$f_{Ho} = \frac{1}{2\pi R_{Tho} C_o} = \frac{1}{(6.28)(1.419k\Omega)(13.04pf)} = 8.6\ M\text{Hz}$$



Example (5): Determine the high-cutoff frequencies for the network of fig.5. using the following parameters : C_S = 2µf , C_G = 0.01µf , C_C = 0.5µf , R_{Sig} = 10kΩ, R_G = 1MΩ , R_D = 4.7kΩ , R_S = 1kΩ , R_L = 2.2kΩ , I_{DSS} = 8mA , V_d = -4v , r_d = ∞Ω, V_{DD} =20v,V_{GSQ} = -2v, C_{gd} = 2pf, C_{gs} = 4pf, C_{ds} = 0.5pf, C_{Wi} = 5pf, C_{Wo} = 6pf ?

Solution: The dc base voltage is determined by:

$$g_{m0} = \frac{2I_{DSS}}{|V_P|} = \frac{2(8mA)}{4V} = 4mS$$

$$g_m = g_{m0}\left(1 - \frac{V_{GSQ}}{V_P}\right)$$

$$g_m = 4mS\left(1 - \frac{-2v}{-4v}\right) = 2mS$$

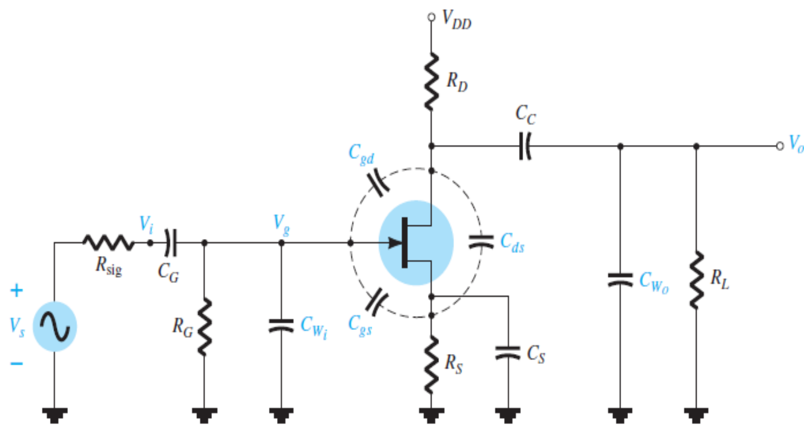


Fig.5

The Midband Gain of the system is determined by:

$$A_{Vmid} = \frac{V_O}{V_i} = -g_m(R_D \| R_L) = (-2mS)(4.7k\Omega \| 2.2k\Omega)$$

$$= -(2mS)(1.4k\Omega) \cong -3$$

$$R_{Thi} = R_{sig} \| R_G = 10k\Omega \| 1M\Omega = 9.9k\Omega$$

With $C_i = C_{wi} + C_{gs} + C_{Mi}$, $C_{Mi} = (1- A_v)\, C_{gd}$

$C_i = C_{wi} + C_{gs} + (1- A_v)\, C_{gd}$

= 5pf + 4pf + (1+ 3) 2pf

= 9pf + 8pf = 17pf

$$f_{Hi} = \frac{1}{2\pi R_{Thi} C_i} = \frac{1}{(6.28)(9.9k\Omega)(17pf)} = 945.67\ k\text{Hz}$$

$$R_{Tho} = R_D \| R_L = 4.7k\Omega \| 2.2k\Omega \cong 1.5k\Omega$$

With $C_o = C_{wo} + C_{ds} + C_{Mo}$, $C_{Mo} = (1 - 1/A_v)\, C_{gd}$

$C_o = C_{wo} + C_{ds} + (1 - 1/A_v)\, C_{gd}$

$= 6pf + 0.5pf + [\, 1 - 1/(-3)\,]\, 2pf$

$= 9.17pf$

$$f_{Ho} = \frac{1}{2\pi R_{Tho} C_o} = \frac{1}{(6.28)(1.5k\Omega)(9.17pf)} = 11.57\ M\text{Hz}$$

H.W :- For the network of Fig .1. determine :

a - r_e .
b - $A_{vmid} = V_o / V_i$.
c - Z_i .
d - f_{LS} , f_{LC} , f_{LE} .
e – Sketch the low- frequency response for the amplifier .

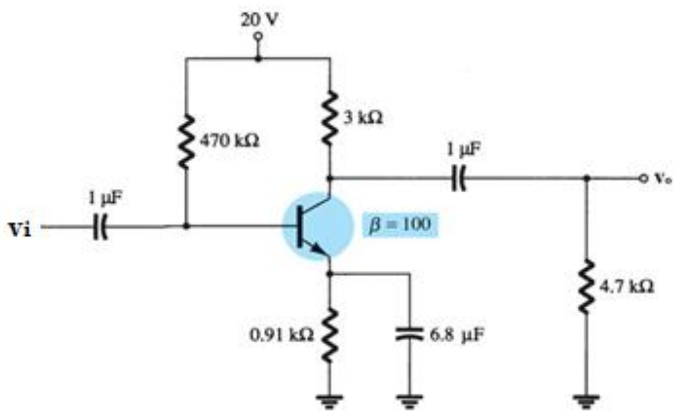


Fig .1

H.W :- For the network of Fig .2. determine :

a – g_{mo} and g_m .
b – A_v and A_{vs}.
c – f_{Hi} and f_{Ho} .
d - Sketch the high- frequency response for the amplifier .

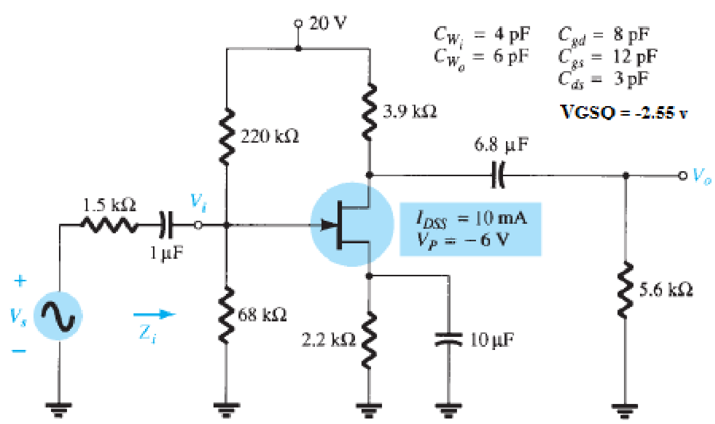


Fig .2