Frequency Response of JFET Amplifiers

Low-Frequency Response of JFET Amplifiers:

The Capacitors C_G, C_C, and C_S will determine the lower-cutoff frequency (f_L) of the common-source JFET amplifier shown in Fig. 18-1, but the results can be applied to any JFET amplifier.

For the cutoff-frequency of C_G,

$$R_{sig} + R_i = X_{C_G} \Rightarrow$$

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

where $R_i = R_G$.

For the cutoff-frequency of C_C,

$$R_L + R_o = X_{C_C} \Rightarrow$$

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

where $R_o = R_D$.

For the cutoff-frequency of C_S,

$$R_{eq} = X_{C_S} \Rightarrow$$

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

where $R_{eq} = R_S \| 1/g_m$.

The lower-cutoff frequency,

$$\boxed{f_L = Max.[\, f_{L_G}, f_{L_C}, f_{L_S} \,]}$$

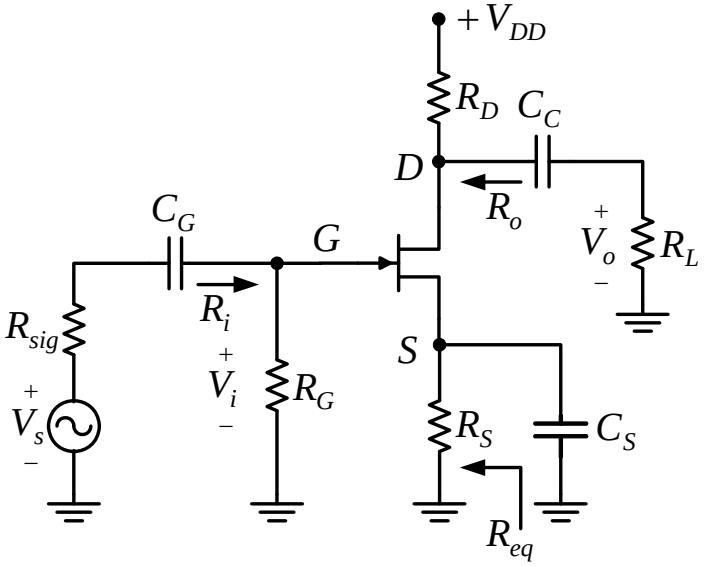

Fig. 18-1

High-Frequency Response of JFET Amplifiers:

The analysis of the high-frequency response of the JFET amplifier is similar to that encountered for the BJT amplifier. As shown in Fig. 18-2, there are interelectrode and wiring capacitances that will determine the high-frequency characteristics of the amplifier. The capacitors C_{gs} and C_{gd} typically vary from 1 to 10 pF, while the capacitance C_{ds} is usually quite a bit smaller, ranging from 0.1 to 1 pF.

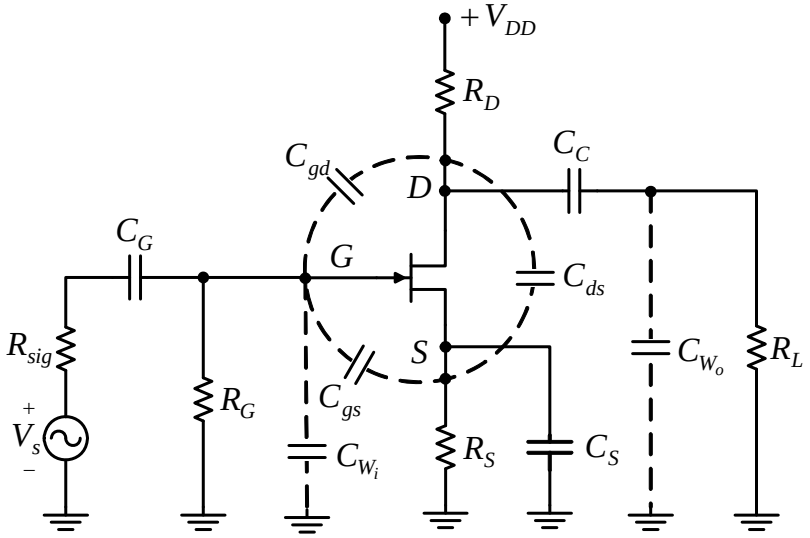

Fig. 18-2

Since the circuit of Fig. 18-2 is an inverting amplifier, a Miller effect capacitance will appear in the high-frequency ac equivalent circuit appearing in Fig. 18-3. 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. 18-3.

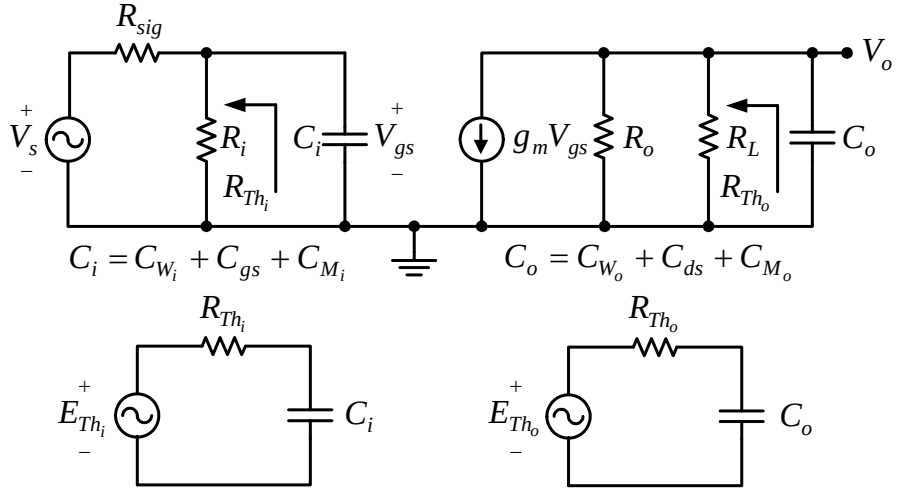

Fig. 18-3

For the input circuit,

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

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

with $C_i = C_{W_i} + C_{gs} + C_{M_i} = C_{W_i} + C_{gs} + (1 - A_v) C_{gd}$.

For the output circuit,

$$\boxed{f_{H_o} = \frac{1}{2\pi R_{Th_o} C_o}}$$

and $R_{Th_o} = R_L \| R_D$.

with $C_o = C_{W_o} + C_{ds} + C_{M_o} = C_{W_o} + C_{ds} + (1 - 1/A_v) C_{gd}$.

The higher-cutoff frequency,

$$\boxed{f_H = Min.[f_{H_i}, f_{H_o}]}$$

Example 18-1:

For the JFET amplifier circuit shown in Fig. 18-4, with the following parameters: I_{DSS} = 8 mA, V_P = −4 V, $r_d > 10R_D$, C_{gd} = 2 pF, C_{gs} = 4 pF, C_{ds} = 0.5 pF, C_{W_i} = 5 pF, and C_{W_o} = 6 pF.

a. Determine f_L, f_H, and BW.

b. Sketch the frequency response.

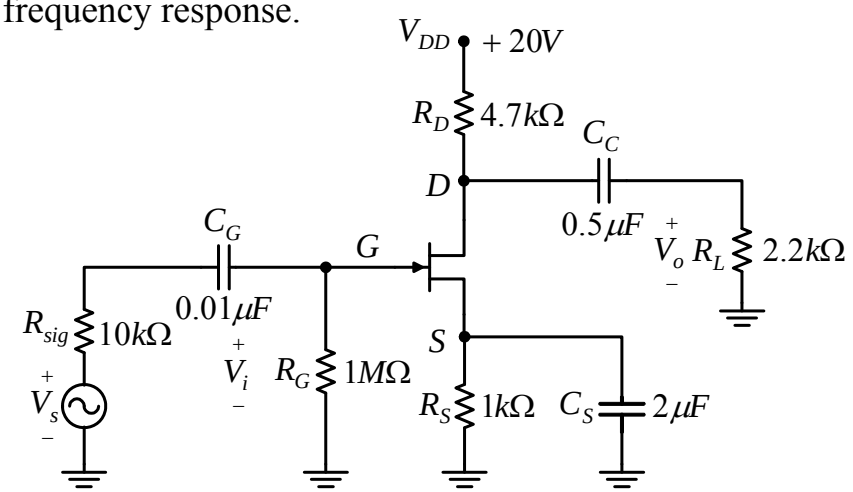

Fig. 18-4

Solution:

From dc analysis (see Fig. 18-5):

$V_{GSQ} = -2V$, and $I_{DQ} = 2mA$,

$$g_m = \frac{2I_{DSS}}{|V_P|}\left(1 - \frac{V_{GSQ}}{V_P}\right) = \frac{2(8m)}{4}\left(1 - \frac{-2}{-4}\right) = 2mS,$$

$$A_v = -g_m(R_L \| R_D) = -2m(2.2k \| 4.7k) = -3.$$

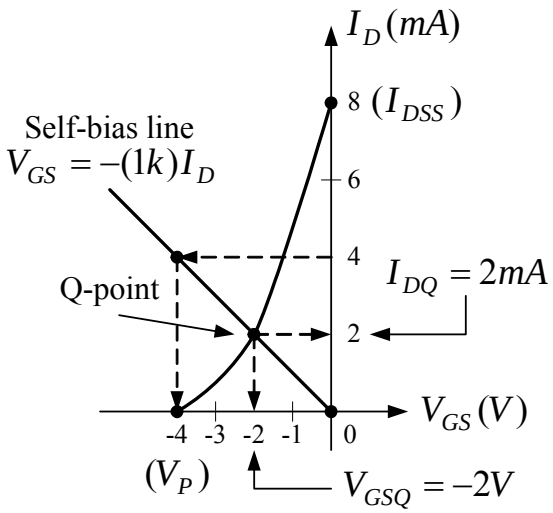

Fig. 18-5

$$f_{L_G} = \frac{1}{2\pi(R_{sig} + R_G)C_G} = \frac{1}{2\pi(10k + 1M)(0.01\mu)} \approx 16Hz,$$

$$f_{L_C} = \frac{1}{2\pi(R_L + R_D)C_C} = \frac{1}{2\pi(2.2k + 4.7k)(0.5\mu)} \approx 46Hz,$$

$$R_{eq} = R_S \| 1/g_m = 1k \| 0.5k = 333.3\Omega,$$

$$f_{L_S} = \frac{1}{2\pi R_{eq}C_S} = \frac{1}{2\pi(333.3)(2\mu)} \approx 239Hz,$$

The lower-cutoff frequency, $f_L = Max.[f_{L_G}, f_{L_C}, f_{L_S}]$

$= Max.[16,46,239] = 239Hz$.

$$R_{Th_i} = R_{sig} \| R_G = 10k \| 1M \approx 9.9k\Omega,$$

$$C_i = C_{W_i} + C_{gs} + (1 - A_v)C_{gd} = 5p + 4p + (1+3)(2p) = 17pF,$$

$$f_{H_i} = \frac{1}{2\pi R_{Th_i}C_i} = \frac{1}{2\pi(9.9k)(17p)} \approx 945.66kHz,$$

$$R_{Th_o} = R_L \| R_D = 2.2k \| 4.7k = 1.5k\Omega,$$

$$C_o = C_{W_o} + C_{ds} + (1 - 1/A_v)C_{gd} = 6p + 0.5p + (1 + 1/3)(2p) = 9.17pF,$$

$$f_{H_o} = \frac{1}{2\pi R_{Th_o}C_o} = \frac{1}{2\pi(1.5k)(9.17p)} \approx 11.57MHz,$$

The higher-cutoff frequency, $f_H = Min.[f_{H_i}, f_{H_o}]$

$= Min.[945.66k, 11.57M] = 945.66kHz$.

The bandwidth, $BW = f_H - f_L = 945.66k - 239 \approx 945.42kHz$.

The frequency response for the low- and high-frequency regions and bandwidth are shown in Fig. 18-6.

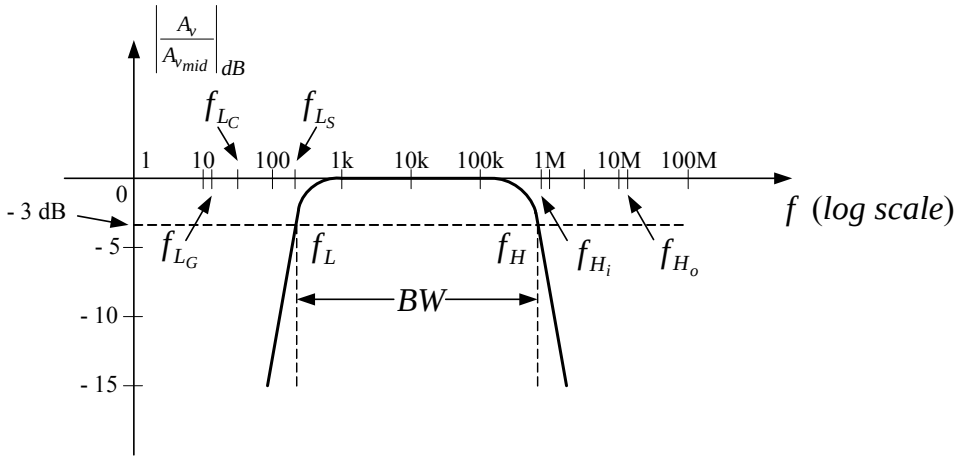

Fig. 18-6

Exercise:

For the JFET amplifier circuit of Fig. 18-7, determine the lower- and higher-cutoff frequencies and sketch the frequency response.

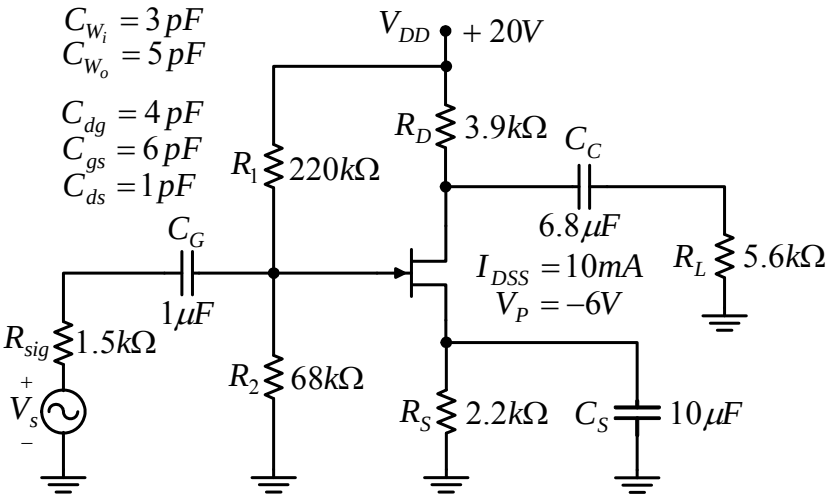

Fig. 18-7