

Analog Electronics Application

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JFET

Equations

$$g_m = y_{fs} = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$g_{m0} = \frac{2I_{DSS}}{|V_P|}$$

$$g_m = g_{m0}\left[1 - \frac{V_{GS}}{V_P}\right]$$

$$g_m = g_{m0}\sqrt{\frac{I_D}{I_{DSS}}}$$

$$r_d = \frac{1}{y_{os}} = \left.\frac{\Delta V_{DS}}{\Delta I_D}\right|_{V_{GS}=\text{constant}}$$

For JFET and depletion-type MOSFET configurations, see Tables 8.1 and 8.2.

TABLE 7.1
TABLE 8.1
TABLE 8.2



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FIXED-BIAS CONFIGURATION

EXAMPLE 8.7 The fixed-bias configuration of Example 7.1 had an operating point defined by $V_{GS_Q} = -2$ V and $I_{D_Q} = 5.625$ mA, with $I_{DSS} = 10$ mA and $V_P = -8$ V. The network is redrawn as Fig. 8.14 with an applied signal V_i. The value of y_{os} is provided as 40 μS.

a. Determine g_m.
b. Find r_d.
c. Determine Z_i.
d. Calculate Z_o.
e. Determine the voltage gain A_v.
f. Determine A_v ignoring the effects of r_d.

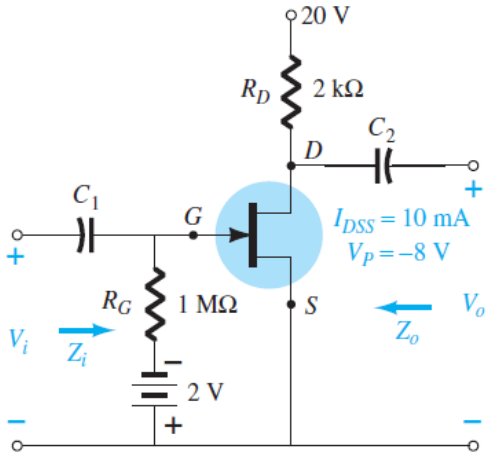
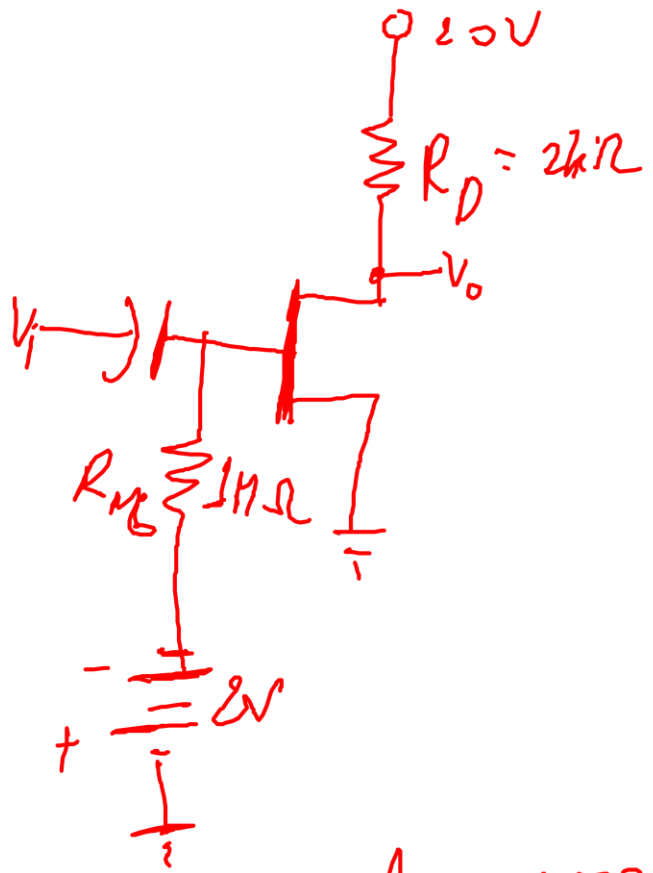


FIG. 8.14
JFET configuration for Example 8.7.

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FIXED-BIAS CONFIGURATION



$$g_m \rightarrow Y_m = \frac{2I_{DSS}}{|V_p|}\left[1 - \frac{V_{GS}}{V_p}\right]$$

$$= \frac{2.10mA}{|-8|}\left[1 - \frac{(-2V)}{(-8)}\right]$$

$$g_m = 1,875mS$$

$$r_d = \frac{1}{g_{os}} = \frac{1}{40\mu S} = 24k\Omega$$

$$A_V = -1,875.(R_D \| r_d) \qquad Z_i = R_G = 1M\Omega$$

$$= 1,875.(1.85k\Omega)$$

$$A_V = -3,49$$

$$Z_o = R_D \| r_d = \frac{R_D . r_d}{R_D + r_d} = \frac{2.10^{-3}.24.10^{-3}}{26.10^{-3}} = 1,86k\Omega$$

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FIXED-BIAS CONFIGURATION

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SELF-BIAS CONFIGURATION (Unbypassed)

EXAMPLE 8.8 The self-bias configuration of Example 7.2 has an operating point defined by $V_{GS_Q} = -2.6$ V and $I_{D_Q} = 2.6$ mA, with $I_{DSS} = 8$ mA and $V_P = -6$ V. The network is redrawn as Fig. 8.20 with an applied signal V_i. The value of g_{os} is given as 20 μS.

a. Determine g_m.
b. Find r_d.
c. Find Z_i.
d. Calculate Z_o with and without the effects of r_d. Compare the results.
e. Calculate A_v with and without the effects of r_d. Compare the results.

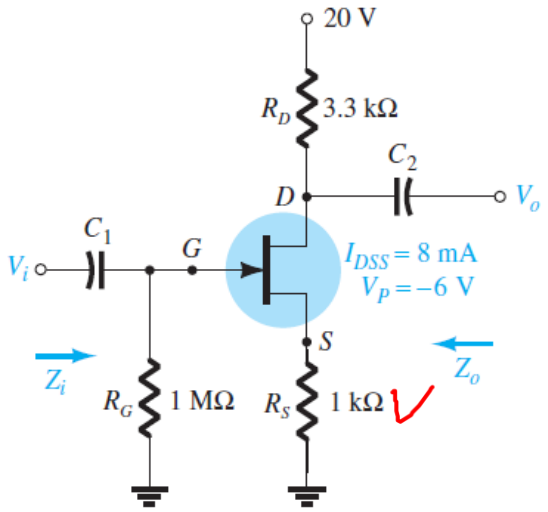


FIG. 8.20
Network for Example 8.8.

$A_v = \frac{V_o}{V_i}$

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

$= \left(\frac{2I_{DSS}}{V_P}\right)\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 2.67$ mS

$\Rightarrow 1.51$ mS $= g_m$

$r_d = \frac{1}{g_{os}} = \frac{1}{20\,\mu S} = 50\,k\Omega$

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SELF-BIAS CONFIGURATION (Bypassed And Unbypassed

$g_m = 1,51\,mS$, $r_d = 50\Omega$, $Z_i = 1\,M\Omega$

if $r_d = \infty$; $Z_o = R_D = 3,3k\Omega$

if $r_d = 50k\Omega$; $Z_i = R_D \| r_d = \frac{3,3k\Omega \cdot 50k\Omega}{53,3k\Omega} = 3,3k\Omega$

if $r_d = \infty$; $A_V = \frac{-g_m \cdot R_D}{1 + g_m \cdot R_S} = -1,98$

if $r_d = 50k\Omega$;

$$A_V = \frac{-g_m \cdot R_D}{1 + g_m \cdot R_S + \frac{R_D + R_S}{r_d}} = -1,92$$

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COMMON-GATE CONFIGURATION

EXAMPLE 8.9 Although the network of Fig. 8.27 may not initially appear to be of the common-gate variety, a close examination will reveal that it has all the characteristics of Fig. 8.24. If $V_{GS_Q} = -2.2$ V and $I_{D_Q} = 2.03$ mA:

a. Determine g_m.
b. Find r_d.
c. Calculate Z_i with and without r_d. Compare results.
d. Find Z_o with and without r_d. Compare results.
e. Determine V_o with and without r_d. Compare results.

$$A_V = \frac{V_o}{V_i}$$

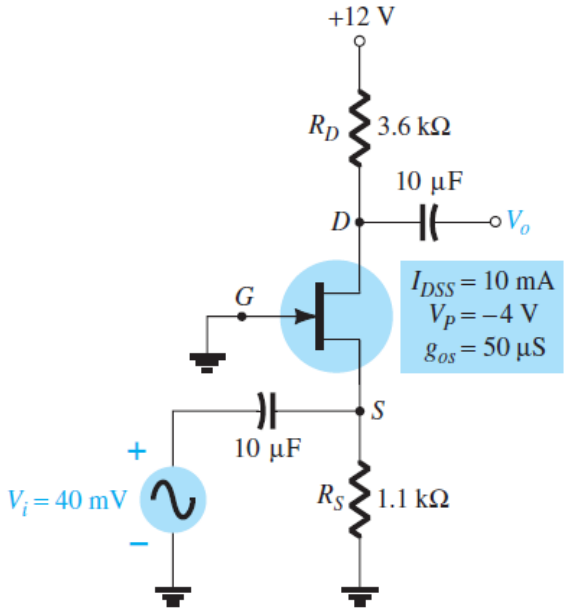
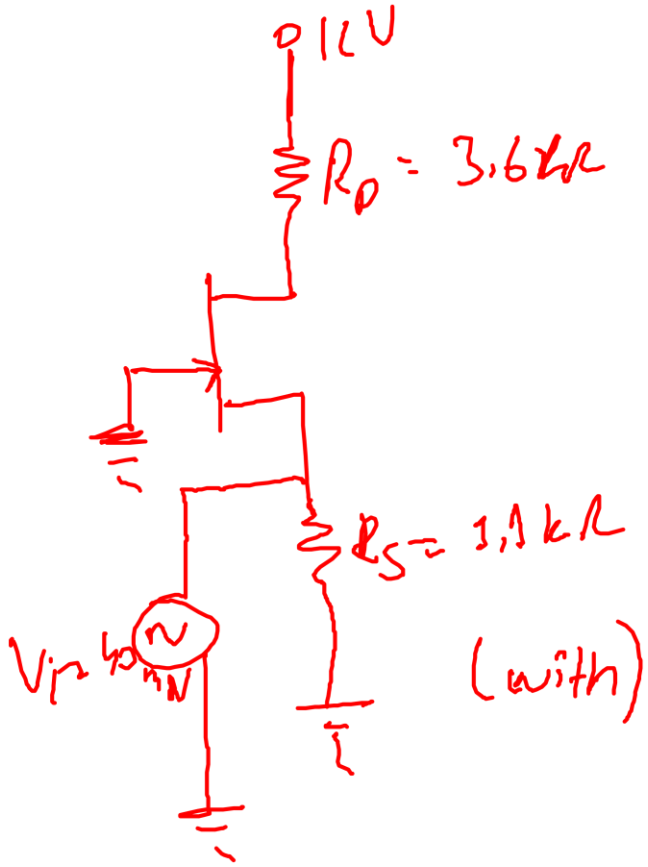


FIG. 8.27
Network for Example 8.9.

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COMMON-GATE CONFIGURATION



If $V_{GS_Q} = -2.1V$ and $I_{D_Q} = 2.03mA$

$g_{m_{max}} = 5mS$

$g_m = 2.25mS$

$r_d = 20k\Omega$

(with) $Z_i = R_S \,||\, \left[\frac{r_d + R_D}{1 + g_m \cdot r_d}\right]$

$= 1.1k\Omega \,||\, \left[\frac{20k\Omega + 3.6k\Omega}{1 + (2.25mS)20k\Omega}\right]$

$= 0.35\,k\Omega$

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COMMON-GATE CONFIGURATION

(without r_d) $Z_i = R_S \parallel \frac{1}{g_m}$

$= 1{,}1k\Omega \parallel \frac{1}{2{,}25mS} = 0{,}31k\Omega$

$V_0 = A_V \cdot V_i$

$= 7{,}02 \cdot (40mV)$

$= 280{,}8mV$

(with r_d) $Z_0 = R_D \parallel r_d = 3.6k\Omega \parallel 20k\Omega = 3{,}05k\Omega$

(without r_d) $Z_0 = R_D = 3{,}6k\Omega$

(with r_d) $A_V = \frac{\left[g_m \cdot R_D + \frac{R_D}{r_d}\right]}{\left[1 + \frac{R_D}{r_d}\right]} = \frac{\left[(2{,}25mS) \cdot (3{,}6k\Omega) + \frac{3.6k\Omega}{20k\Omega}\right]}{\left[1 + \frac{3.6}{20}\right]} = 7{,}02$

withou r_d

$A_V = g_m \cdot R_D$

$= 2{,}25 \cdot (3{,}6k\Omega)$

$= 8{,}1 \rightarrow 8{,}1 \cdot (40mV) = 324mV$

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SOURCE-FOLLOWER (COMMON-DRAIN) CONFIGURATION

EXAMPLE 8.10 A dc analysis of the source-follower network of Fig. 8.32 results in $V_{GS_Q} = -2.86$ V and $I_{D_Q} = 4.56$ mA.

a. Determine g_m.
b. Find r_d.
c. Determine Z_i.
d. Calculate Z_o with and without r_d. Compare results.
e. Determine A_v with and without r_d. Compare results.

$g_{m_0} = 8\,mS$

$g_m = 2{,}28\,mS$

$r_d = 40k\Omega$

$Z_i = R_G = 1M\Omega$

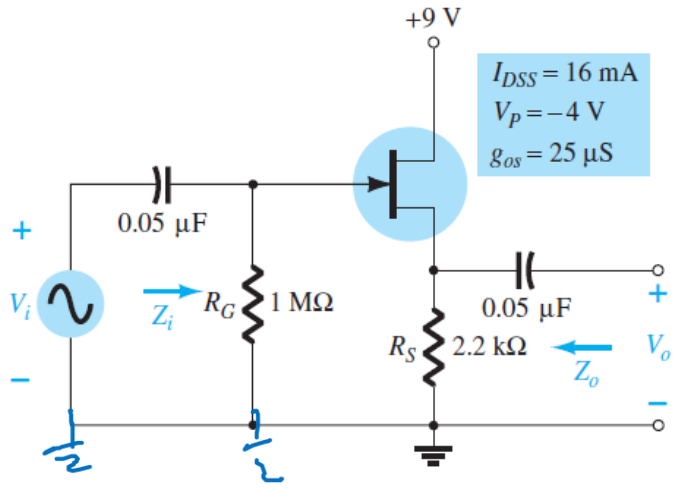


FIG. 8.32
Network to be analyzed in Example 8.10.

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SOURCE-FOLLOWER (COMMON-DRAIN) CONFIGURATION

(with r_d) $Z_o = R_D \parallel r_d \parallel 1/g_m = 47k\Omega \parallel 2.2k\Omega \parallel 438\Omega$

$= 362,52\Omega$

(without r_d) $Z_o = R_S \parallel 1/g_m = 2.2k\Omega \parallel 438,6\Omega$

$= 365,06\Omega$

(with r_d) $A_v = \dfrac{g_m (r_d \parallel R_S)}{1 + g_m (r_d \parallel R_S)} = 0,83$

(without r_d) $A_v = \dfrac{g_m \cdot R_S}{1 + g_m \cdot R_S} \cong 0,83$

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DEPLETION-TYPE MOSFETs

EXAMPLE 8.11 The network of Fig. 8.34 was analyzed as Example 7.7, resulting in $V_{GS_Q} = 0.35$ V and $I_{D_Q} = 7.6$ mA.

a. Determine g_m and compare to g_{m0}.
b. Find r_d.
c. Sketch the ac equivalent network for Fig. 8.34.
d. Find Z_i.
e. Calculate Z_o.
f. Find A_v.

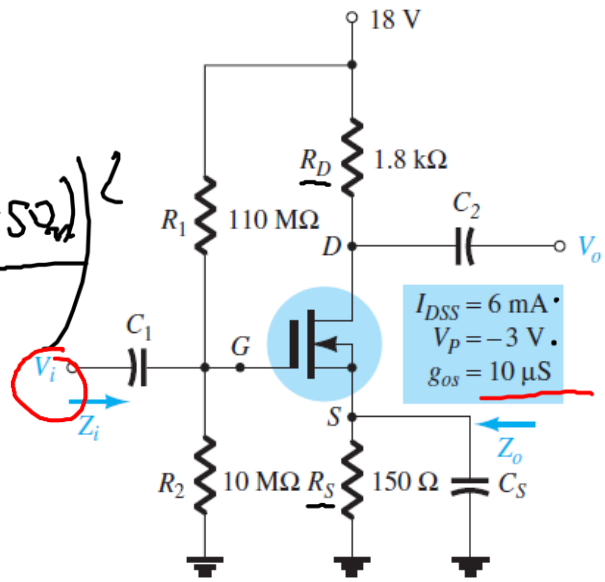


FIG. 8.34
Network for Example 8.11.

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DEPLETION-TYPE MOSFETs

$V_{GS} = 1,5V - 7,6mA \cdot (150\Omega)$

$= 0,35V$

$g_{m0} = \frac{2I_{DSS}}{|V_p|} = \frac{2(6mA)}{|-3V|} = 4mS$

In table 8.1

$g_m = g_{m0} \cdot \left(1 - \frac{V_{GS}}{V_p}\right) = 4,mS\left(1 - \frac{0,35}{-3}\right)$

$Z_i = R_1 \| R_2 = 10M\Omega \| 150M\Omega$

$= \frac{1500}{120} = 9,17M\Omega$

$r_d = \frac{1}{g_{os}} = \frac{1}{10\mu S} = 100k\Omega = 4,17mS$

$Z_o = R_D \| r_d = 18 \| 100 = 1,77k\Omega$

$A_v = -g_m (r_d \| R_D)$

$A_v = (-4,17) \cdot (1,77) = -8,05$

$A = \frac{v_o}{v_i} = -$

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DEPLETION-TYPE MOSFETs

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ENHANCEMENT-TYPE MOSFETs

EXAMPLE 8.12 The E-MOSFET of Fig. 8.40 was analyzed in Example 7.10, with the result that $k = 0.24 \times 10^{-3}$ A/V^2, $V_{GS_Q} = 6.4$ V, and $I_{D_Q} = 2.75$ mA.

a. Determine g_m.
b. Find r_d.
c. Calculate Z_i with and without r_d. Compare results.
d. Find Z_o with and without r_d. Compare results.
e. Find A_v with and without r_d. Compare results.

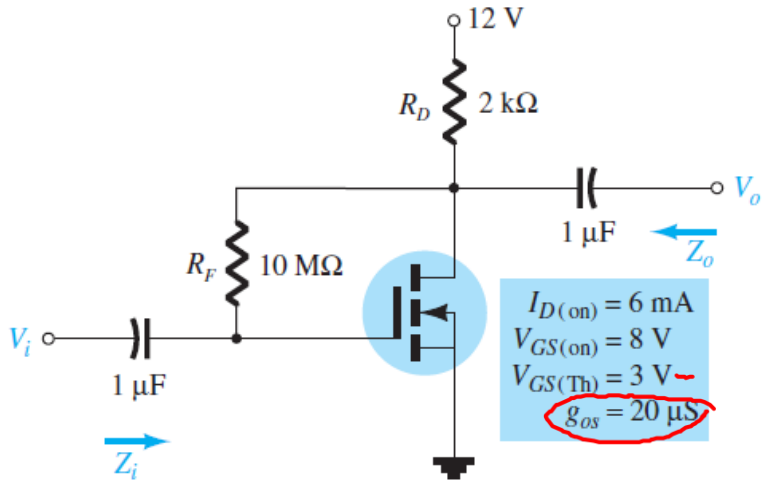


FIG. 8.40
Drain-feedback amplifier from Example 8.11.

$$g_m = 2k(V_{GS} - V_{G(Th)})$$

$$= 2.(0,24 \times 10^{-3}).(3,5)$$

$$= 1,68 \text{ mS}$$

$$r_d = \frac{1}{g_{os}} = \frac{1}{20\mu S} = 50k\Omega$$

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ENHANCEMENT-TYPE MOSFETs

Z_i (with r_d): (in table 8.1)

$$Z_i = \frac{R_f + r_d \| R_D}{1 + g_m (r_d \| R_D)} = \frac{10\,M\Omega + \overbrace{50\,k\Omega \| 2\,k\Omega}^{1.92\,k\Omega}}{1 + \underbrace{(1{,}63\,mS)\cdot(1.92\,k\Omega)}_{3.13}} = 2{,}52\,M\Omega$$

Z_i (without r_d):

$$Z_i = \frac{R_F}{1 + g_m R_D} = \frac{10\,M\Omega}{1 + (1{,}63\,mS)\cdot(2\,k\Omega)} = 2{,}53\,M\Omega$$

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ENHANCEMENT-TYPE MOSFETs

Z_o (with r_d) → (: not to be 8.1):

$$Z_o = R_F \,||\, r_d \,||\, R_D = 10\,M\Omega \,||\, 50\,k\Omega \,||\, 2\,k\Omega$$

$$59.75\,k\Omega \,||\, 2\,k\Omega$$

$$= 1.92\,k\Omega$$

Z_o (without r_d) → $Z_o = R_D = 2\,k\Omega$

A_v (with r_d): $A_v = -g_m \cdot (R_F \,||\, r_d \,||\, R_D)$

$$= -(1{,}63\,mS)(1{,}92)$$

$$= -3.21$$

A_v (without r_d)

$$A_v = -g_m \cdot R_D = (-1{,}63\,mS)(2\,k\Omega)$$

$$= -3.26$$

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DESIGNING FET AMPLIFIER NETWORKS

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DESIGNING FET AMPLIFIER NETWORKS

EXAMPLE 8.13 Design the fixed-bias network of Fig. 8.43 to have an ac gain of 10. That is, determine the value of R_D.

$A_v = 10$

$V_{GS} = 0$

$g_{m0} = \frac{2 I_{DSS}}{|V_p|} = \frac{2(10\,mA)}{|-4V|} = 5mS$

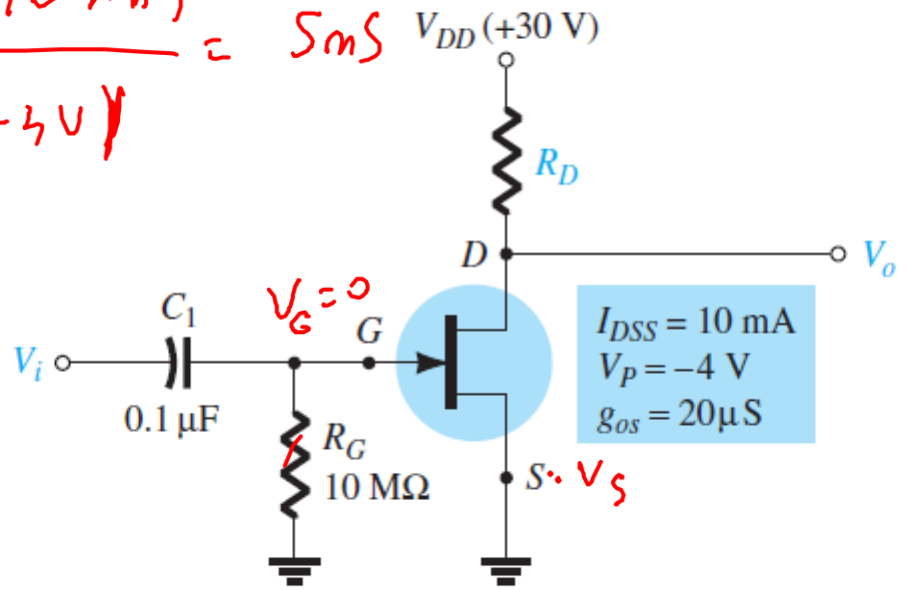


FIG. 8.43
Circuit for desired voltage gain in Example 8.13.

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DESIGNING FET AMPLIFIER NETWORKS

$A_V = -g_m (R_D \| r_d) = -g_{m0} \cdot (R_D \| r_d) = -10$

-10

$5\,mS$

$\frac{R_D \cdot 50k\Omega}{R_D + 50k\Omega} = 2k\Omega \leftarrow R_D \| r_d = 2k\Omega$

$\frac{1}{g_{os}} = \frac{1}{20\mu S} = \frac{1}{20 \cdot 10^{-6} S} = 50k\Omega$

So $R_D = 2R_D + 100k\Omega$

$4gR_{D_1} = 10$

$R_D = \underline{2{,}08\,k\Omega} \rightarrow \underline{2k\Omega (Standart)}$

$Z_o = R_D \| r_d = 2 \| 50$

$= \underline{1{,}92k\Omega}$

$Z_i = R_G = 10M\Omega$

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DESIGNING FET AMPLIFIER NETWORKS

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CASCADE CONFIGURATION

EXAMPLE 8.16 Calculate the dc bias, voltage gain, input impedance, output impedance, and resulting output voltage for the cascade amplifier shown in Fig. 8.48.

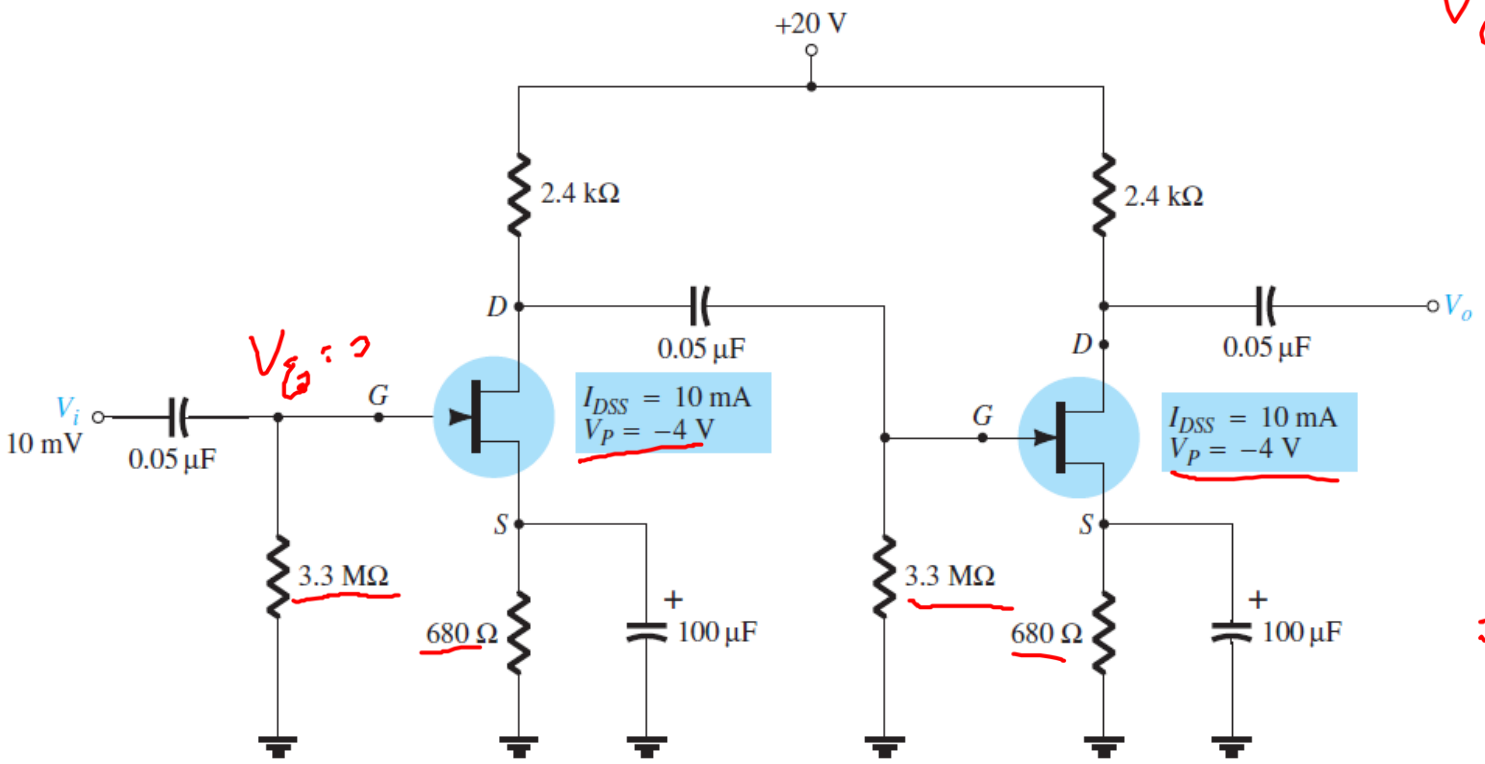


FIG. 8.48
Cascade amplifier circuit for Example 8.16.

$V_{GS} = V_G - V_S$

$V_{GS} = -I_D \cdot R_S$

$I_{DSS} \cdot \left(1 - \frac{V_{GS}}{V_P}\right)^2$

$= 10\,mA \left(1 - \frac{(-I_D \cdot R_S)}{V_P}\right)^2$

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CASCADE CONFIGURATION

$$I_D = 10 \cdot \left(1 - \frac{(I_D \cdot 180\Omega)}{(+4)}\right)^2$$

$$I_D = 10\,(1 - 170 I_D)^2$$

$$I_D = 10\,(1 - 340 I_D + 28900 I_D^2)$$

$$I_D = \frac{-b \mp \sqrt{b^2 - 4ac}}{2a}$$

$I_{D_1} = 2.8\,mA$

$I_{D_2} = 14.1\,mA$

$$V_{GS} = -2.8\,mA \cdot 680$$

$$= -1.9\,V$$

$$g_{m0} = \frac{2I_{DSS}}{|V_p|} = \frac{2.10\,mA}{|-4|} = 5\,mS$$

$$g_m = g_{m0} \cdot \left(1 - \frac{V_{GS}}{V_p}\right) = 5.10^{-3}\left(1 - \frac{(-1.9)}{-4}\right)$$

$$= 2.6\,mS$$

$$A_V = A_{V_1} \cdot A_{V_2}$$

$$= A_{V_1} = -g_m \cdot R_D = -6.24$$

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CASCADE CONFIGURATION

$A_V = A_{V_1} \cdot A_{V_2} = (-6,2) \cdot (-6,21) = 38,4$

$A_V = \frac{V_0}{V_i} \Rightarrow V_0 = A_V \cdot V_i$

$= 38,4 \cdot (1mV)$

$\simeq$ ~~40mV~~ 38,4mV

$Z_i = 33 M\Omega = R_G$

$Z_0 = R_D = 2,2k\Omega$

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Thanks

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