Figure 1-1

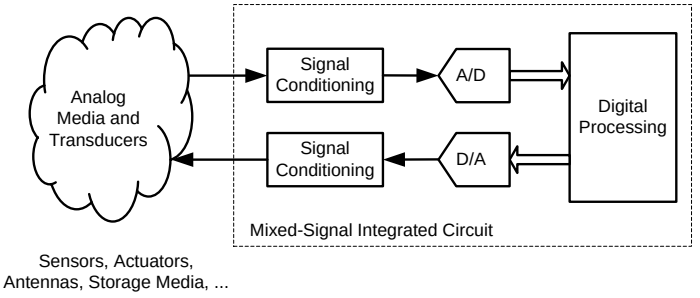


Figure 1-2

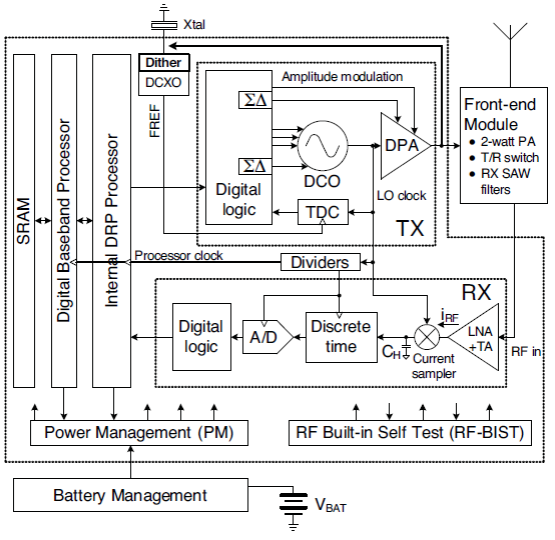


Figure 1-3

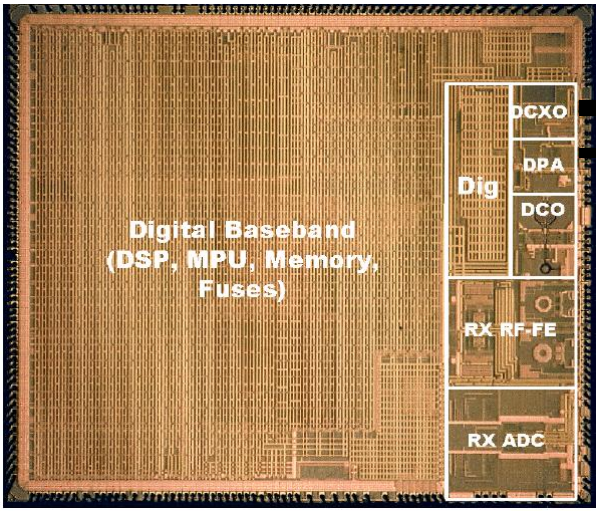


Figure 1-4

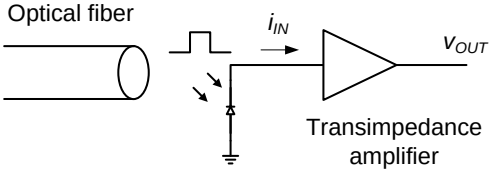


Figure 1-5

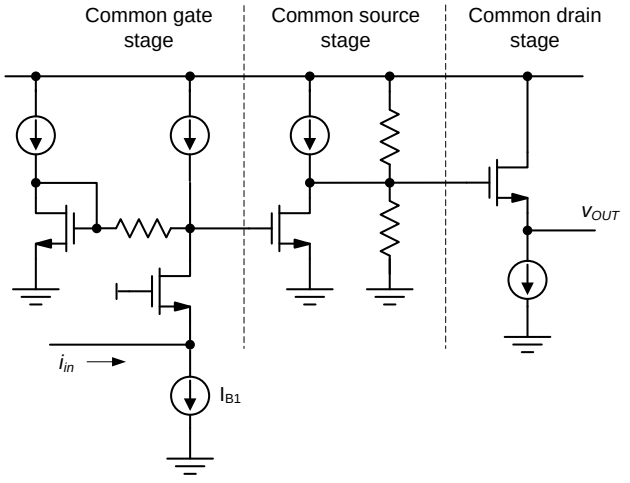
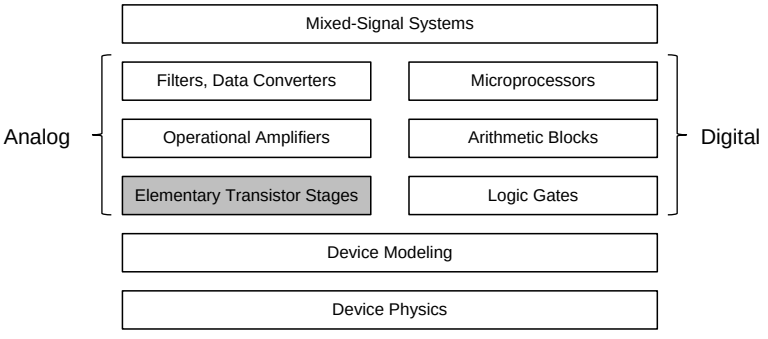


Figure 1-6



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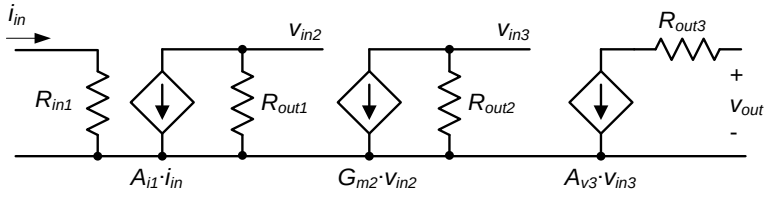


Figure 1-8

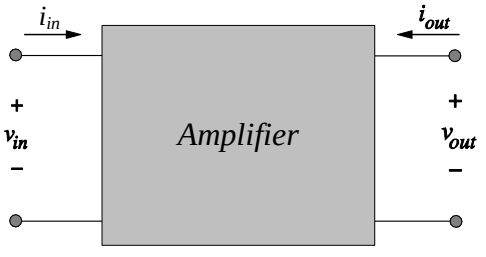
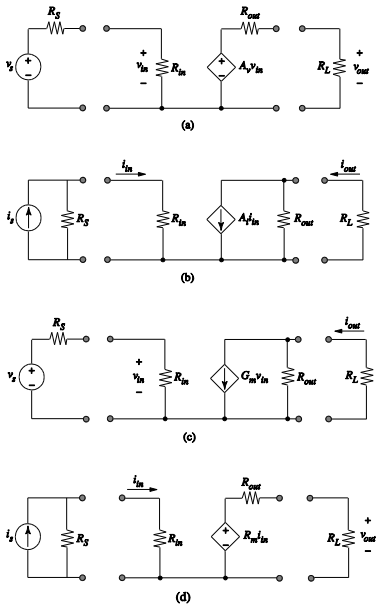


Figure 1-9



(Howe & Sodini, Figure 8.2)

Figure 1-10

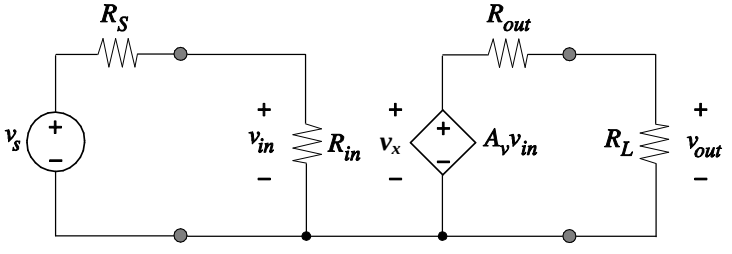
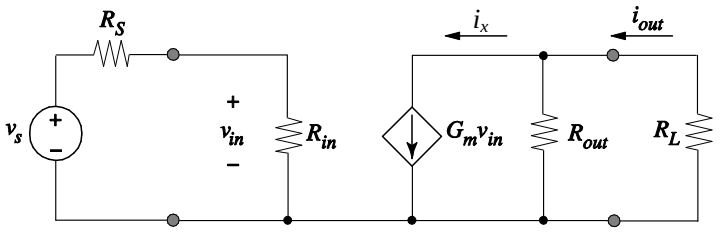
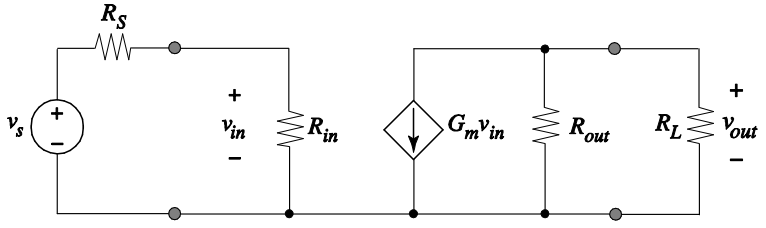


Figure Ex1-1



(Howe & Sodini, Figure 8.5)

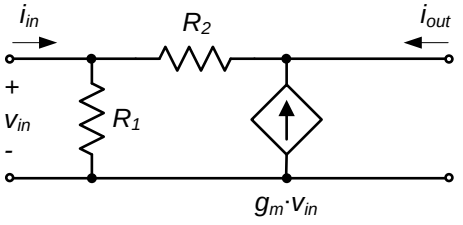
Figure 1-11



$G_m = -A_v/R_{out}$

Figure 1-12

(a)



(b)

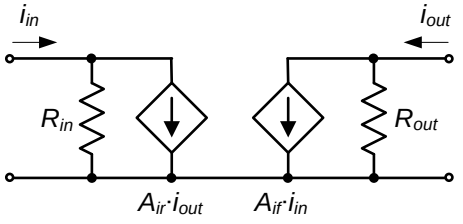
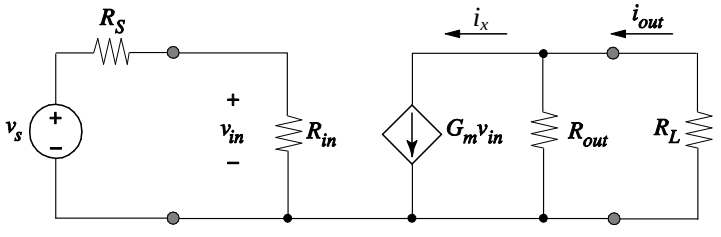
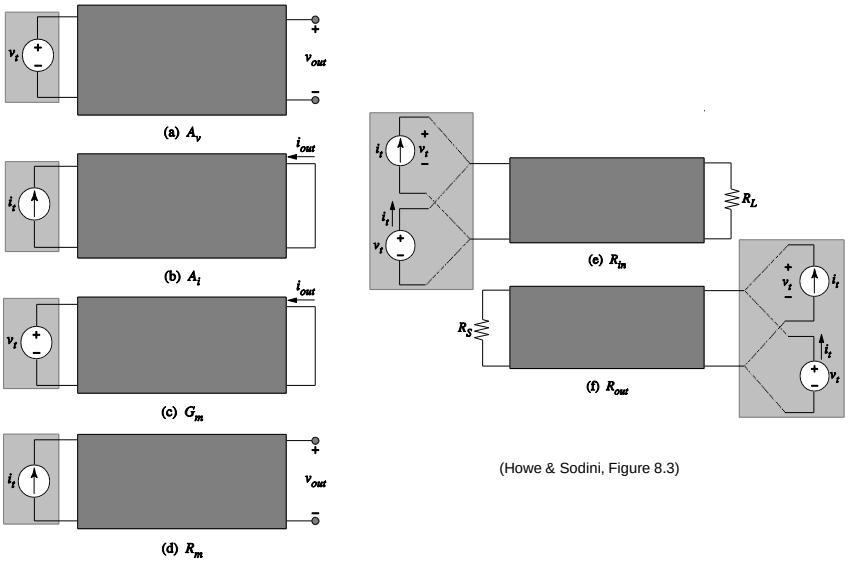


Figure Ex1-1



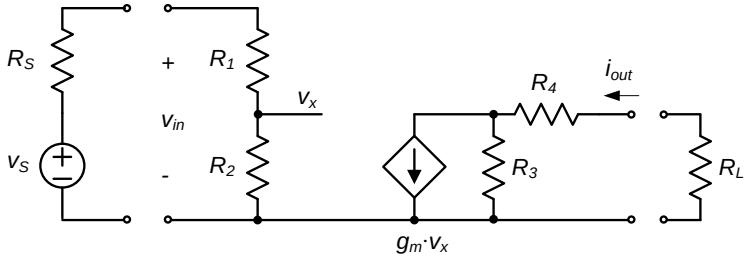
(Howe & Sodini, Figure 8.5)

Figure 1-13

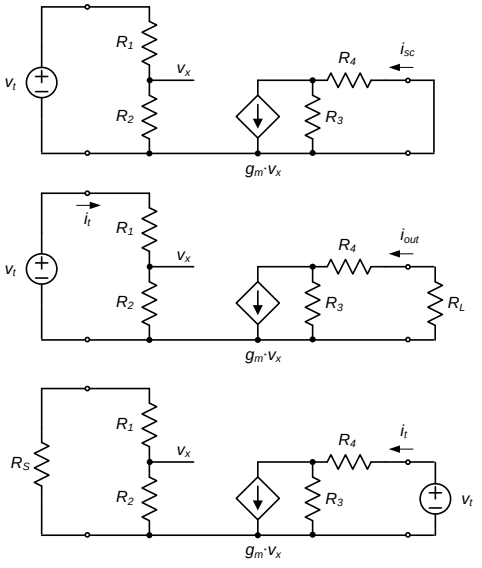


(Howe & Sodini, Figure 8.3)

Figure Ex1-2

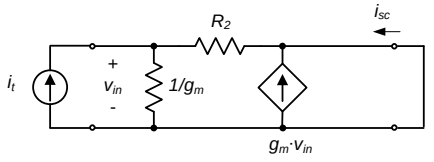


Ex1-2 (Solution)

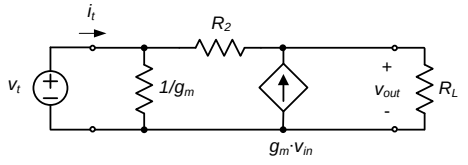


Ex1-3 (Solution)

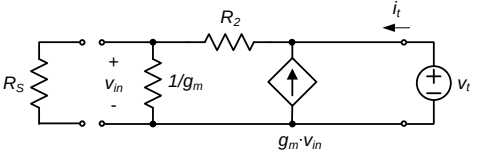
(1)



(2)

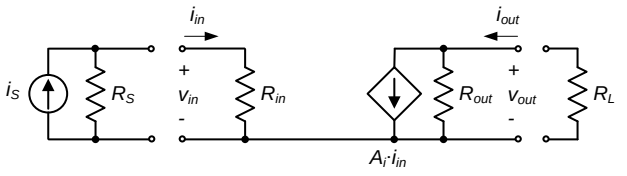


(3)



Ex1-3 (Solution)

(4)



(5)

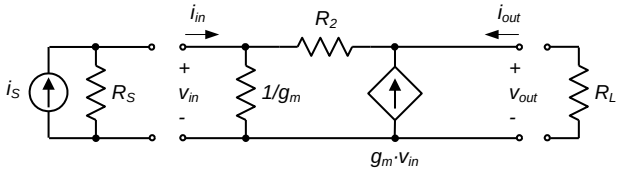


Figure 1-14

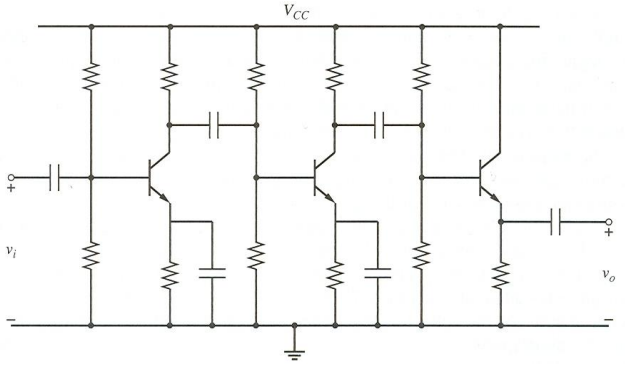


Figure P1-1

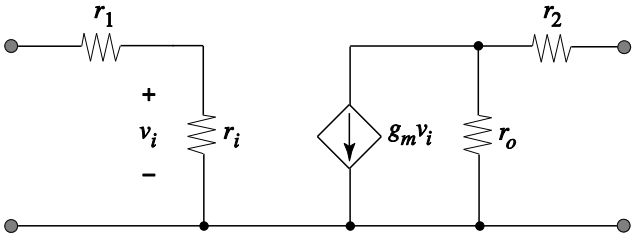


Figure P1-5

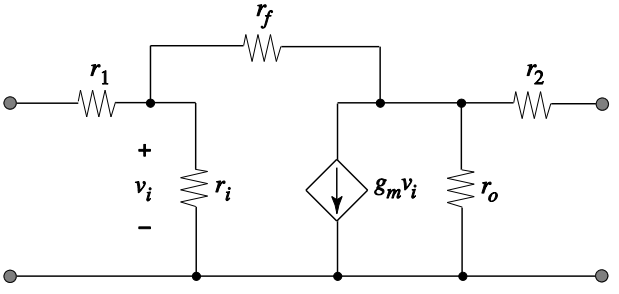


Figure 2-1

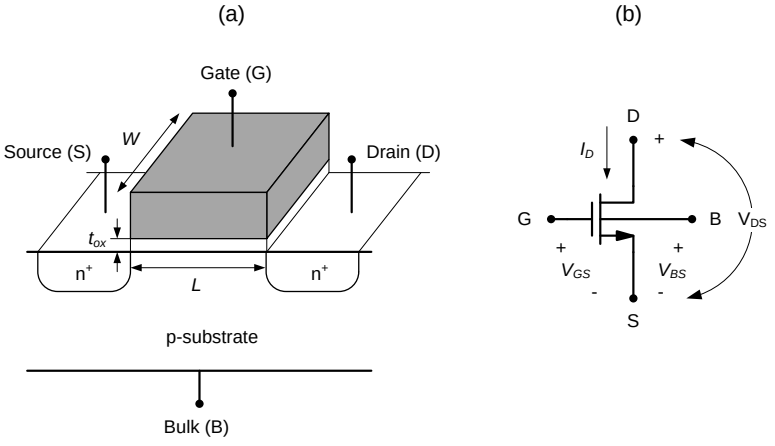
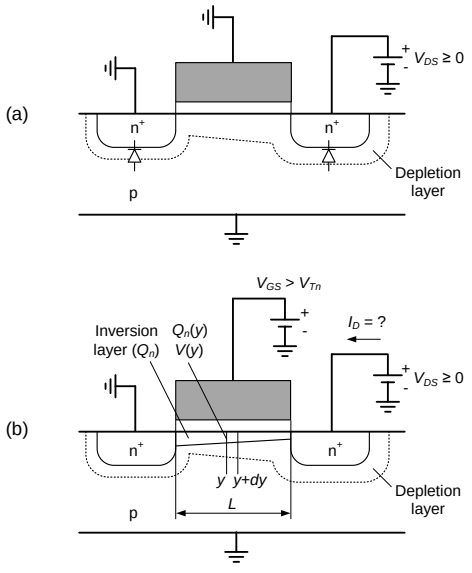


Figure 2-2



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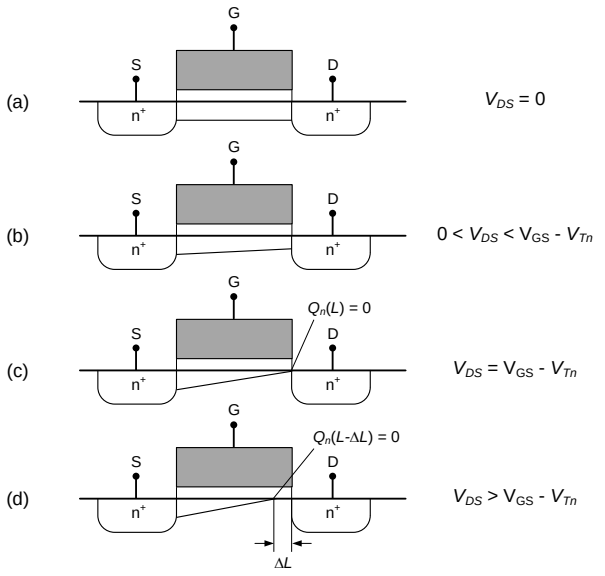


Figure 2-4

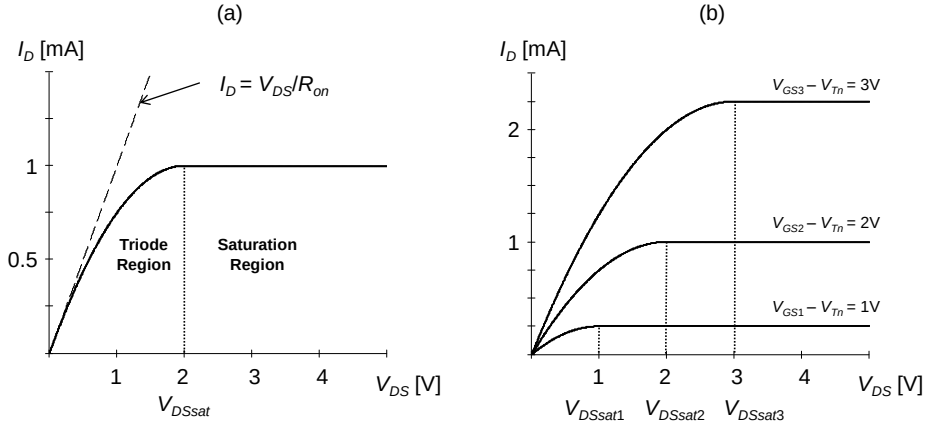


Figure 2-5

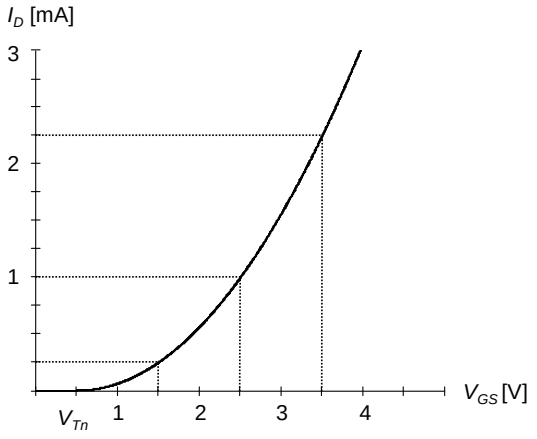
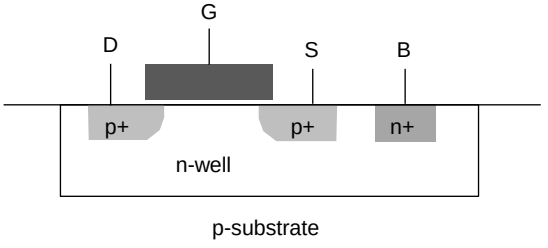


Figure 2-6

(a)



(b)

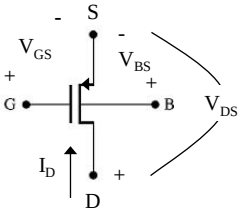


Figure 2-7

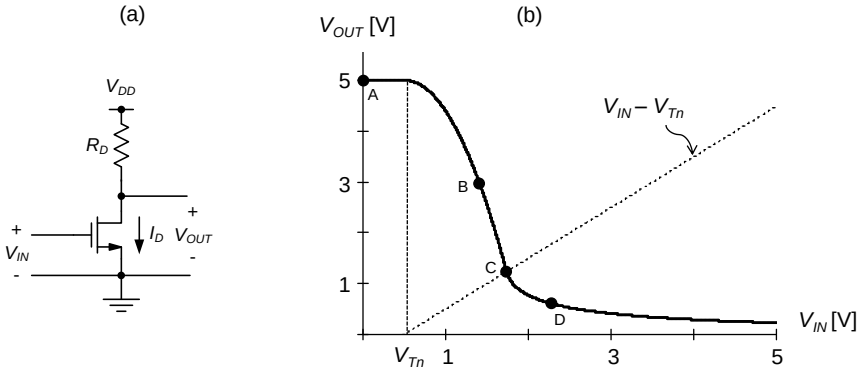


Figure 2-8

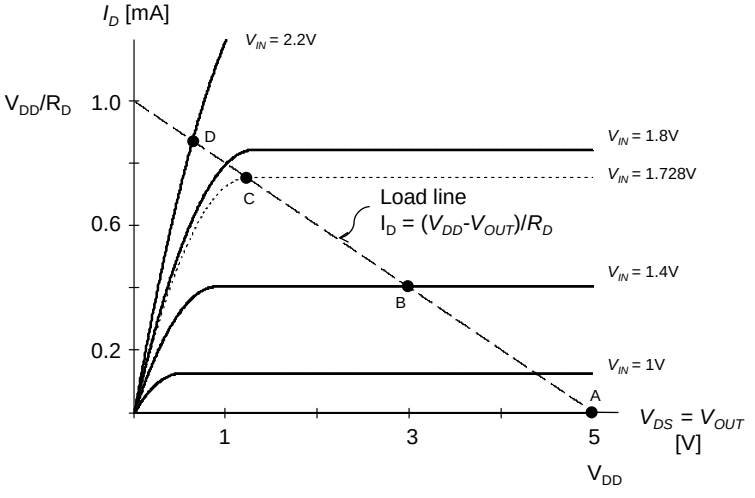


Figure Ex2-3

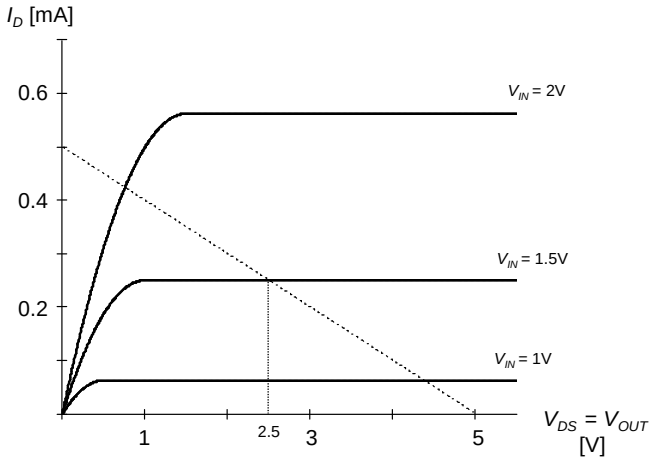


Figure 2-9

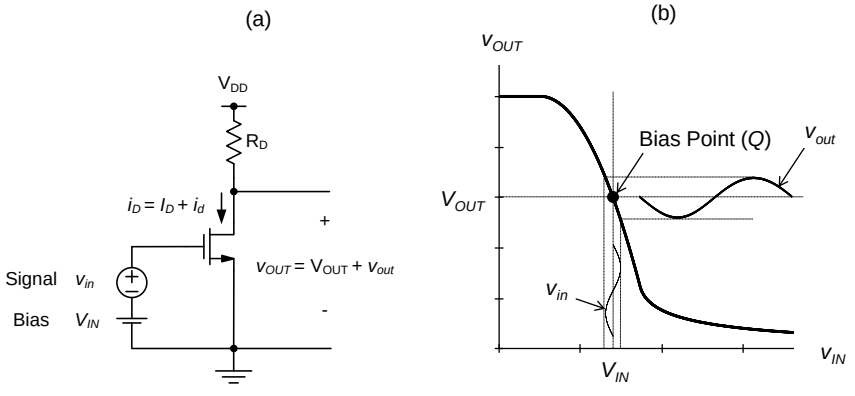


Figure 2-10

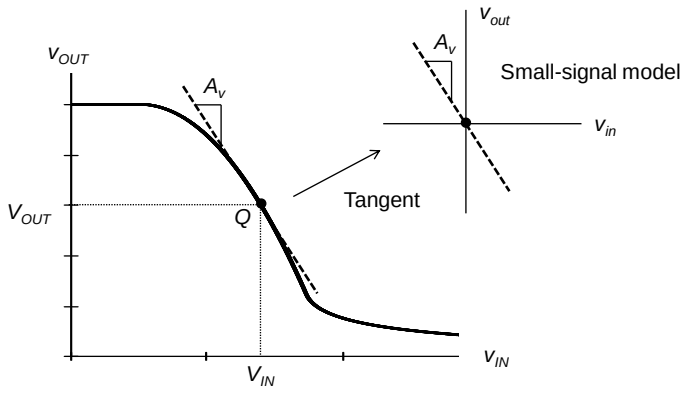


Figure 2-11

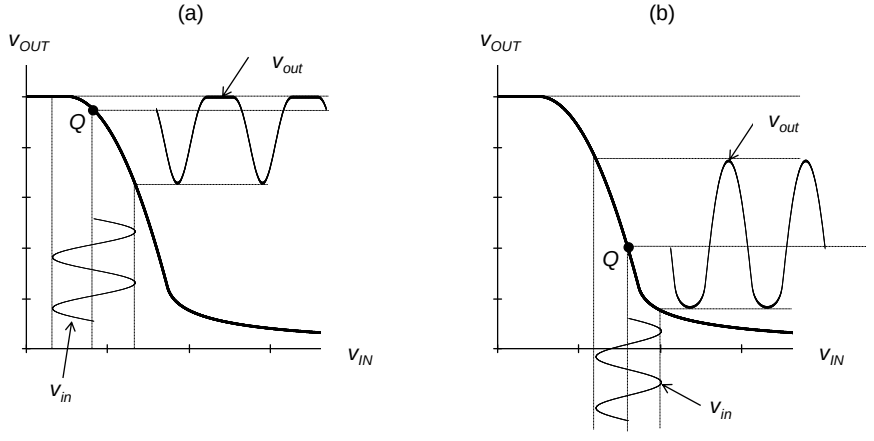


Figure 2-12

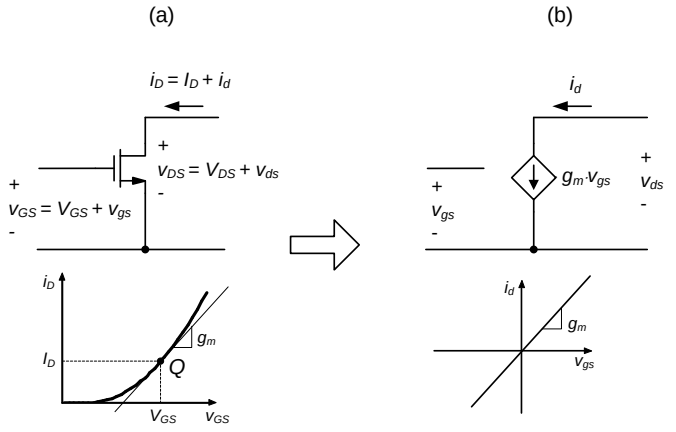


Figure 2-13

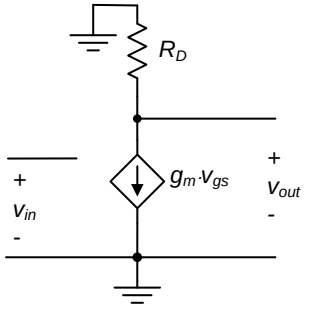


Figure 2-14

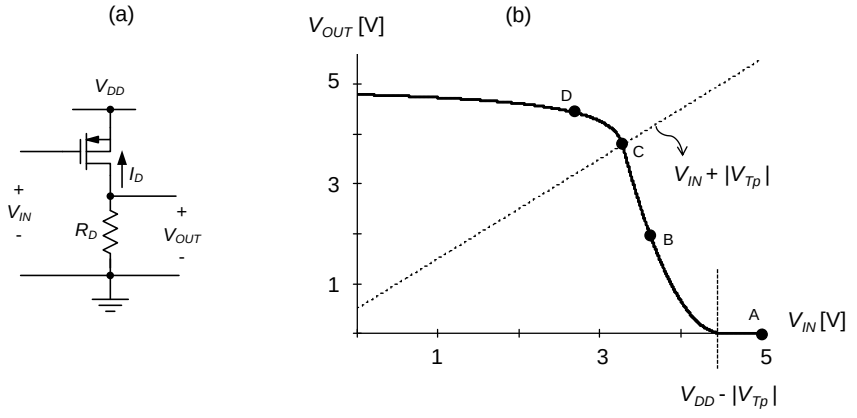
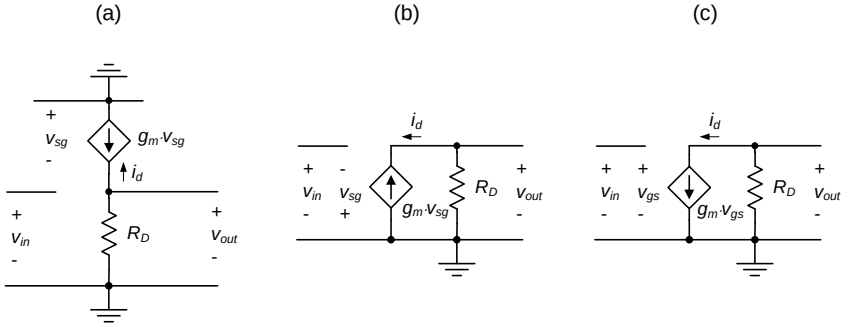


Figure 2-15



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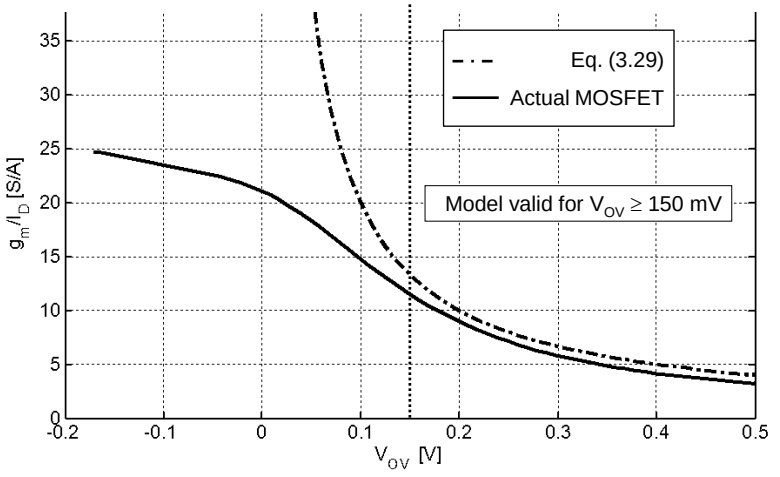
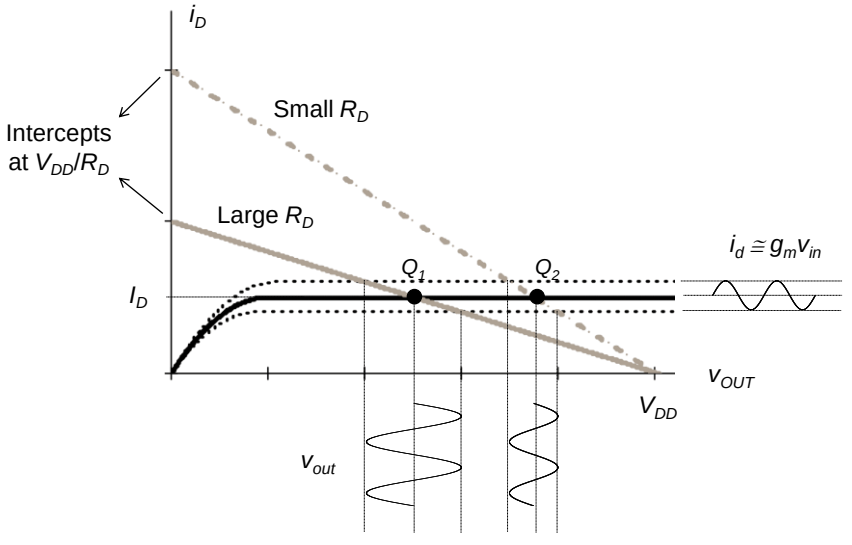


Figure 2-17



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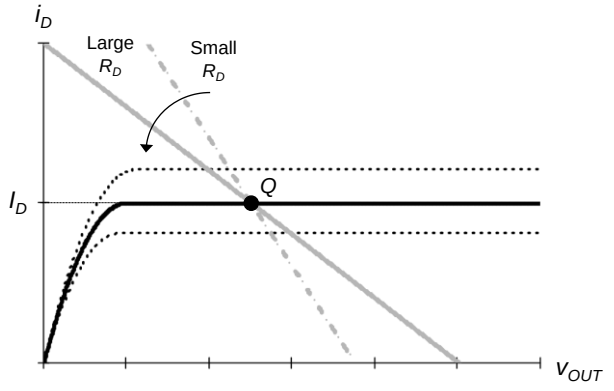

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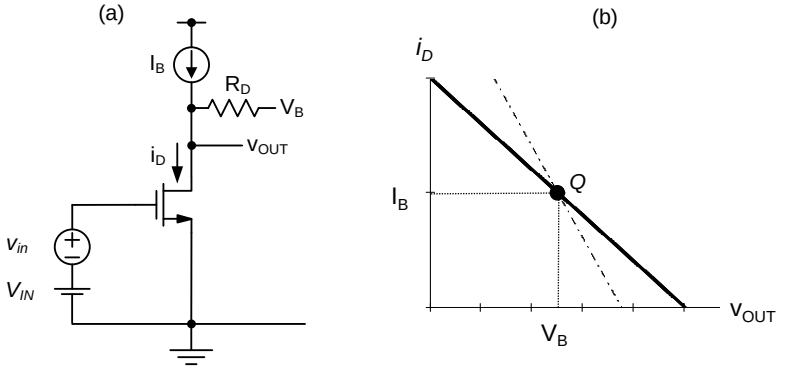
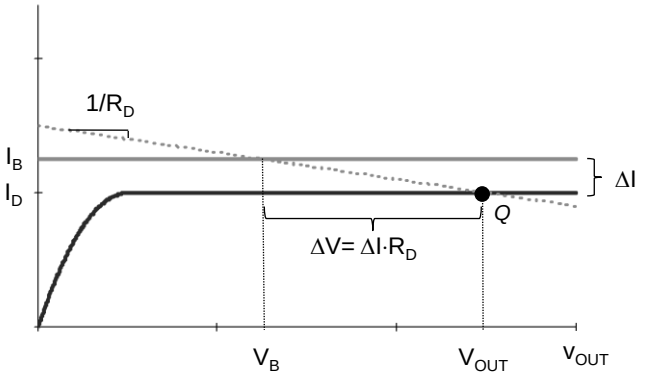


Figure 2-20



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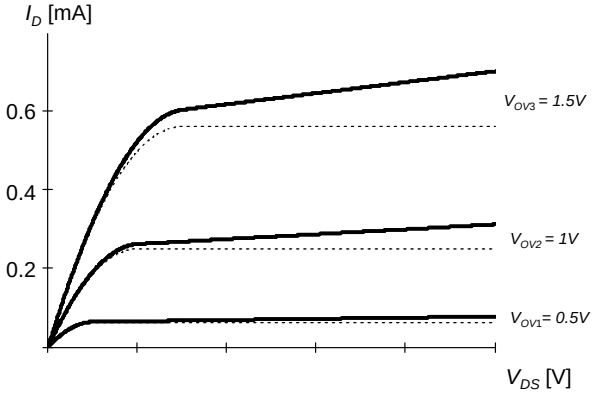


Figure 2-22

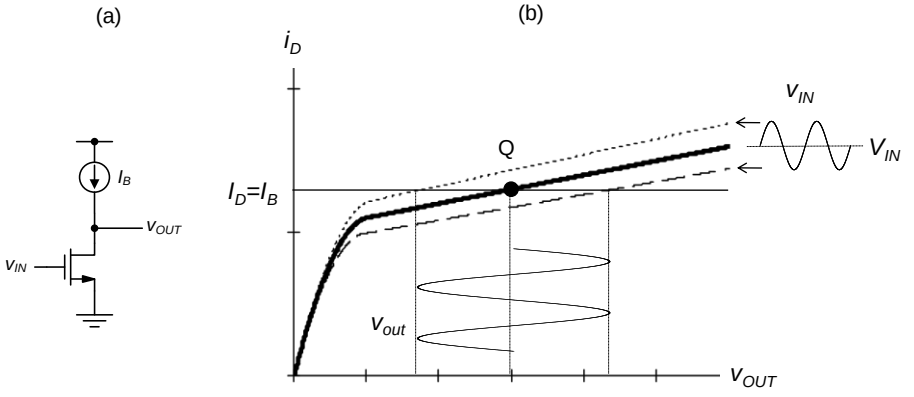


Figure 2-23

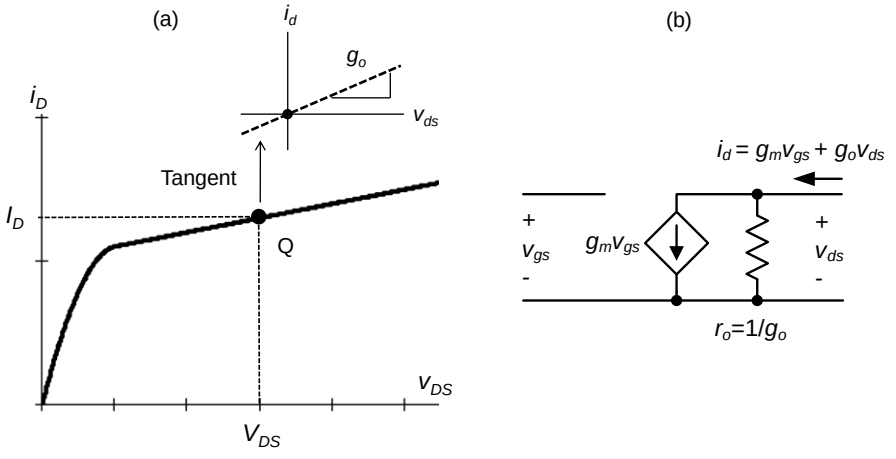


Figure 2-24

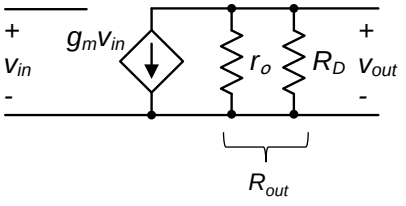


Figure 2-25

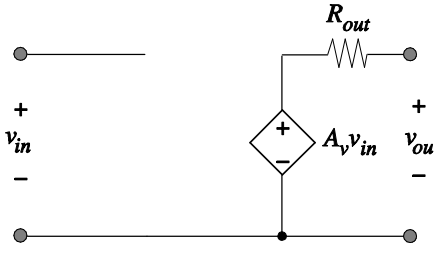


Figure 2-26

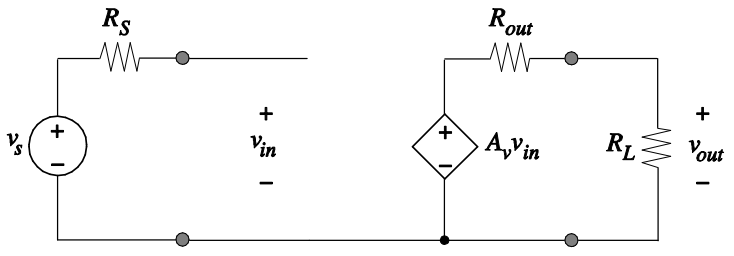


Figure P2-2

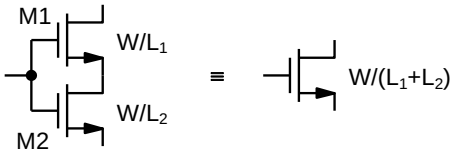


Figure P2-5

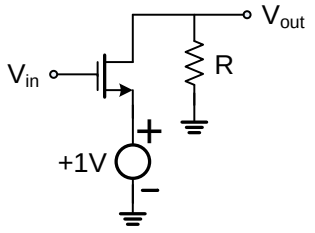


Figure P2-12

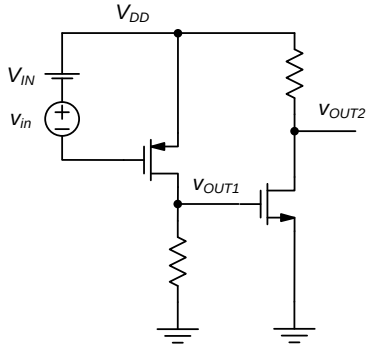


Figure P2-17

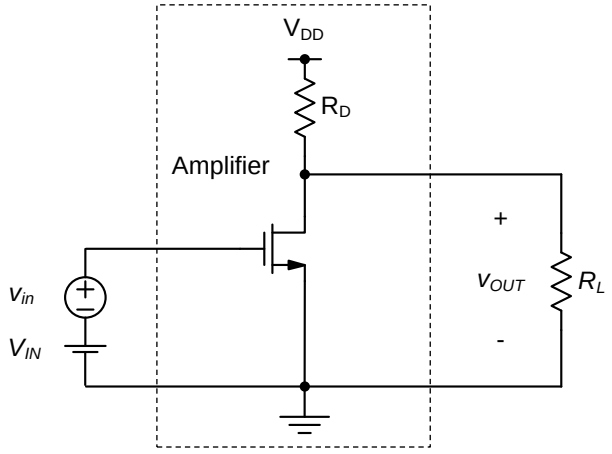


Figure 3-1

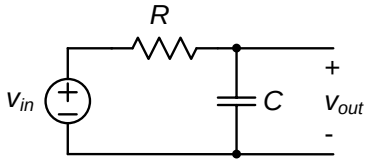
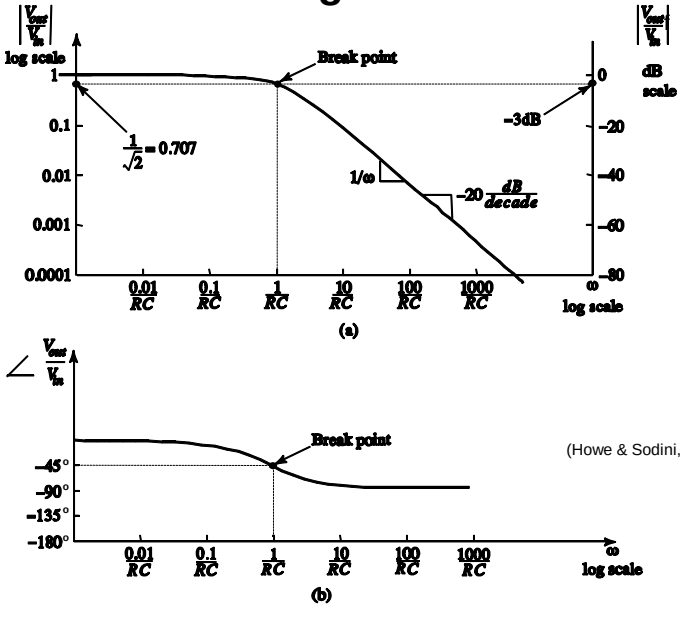


Figure 3-2



(Howe & Sodini, Figure 10.2)

Figure 3-3

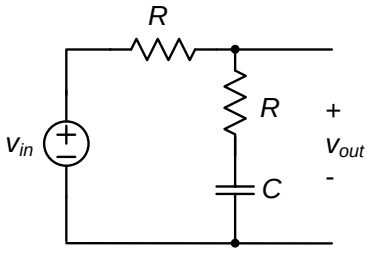
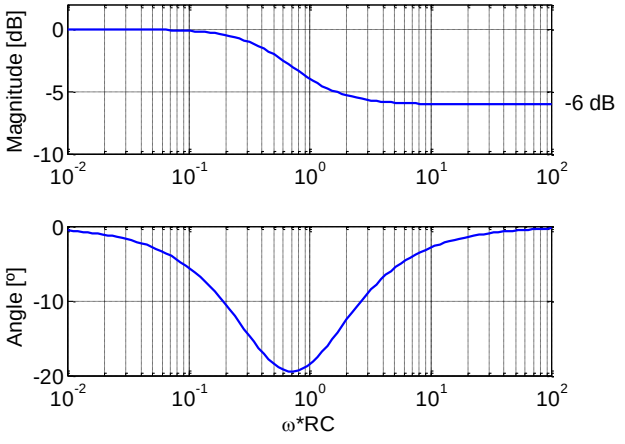


Figure Ex3-2



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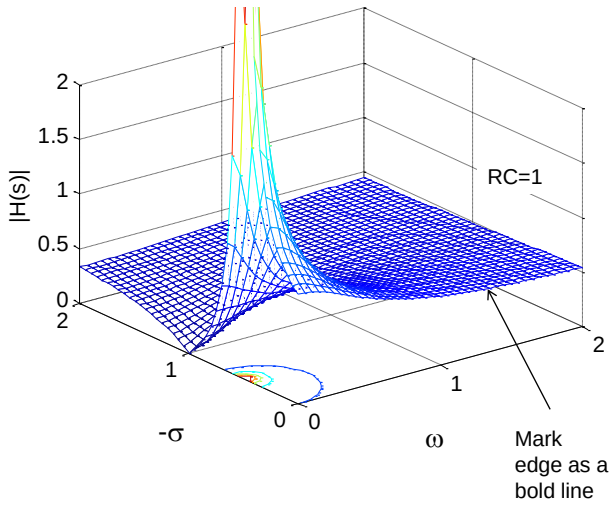

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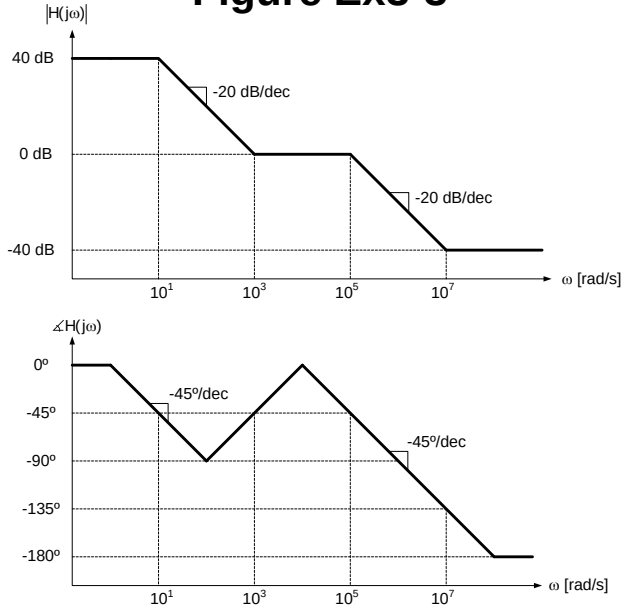

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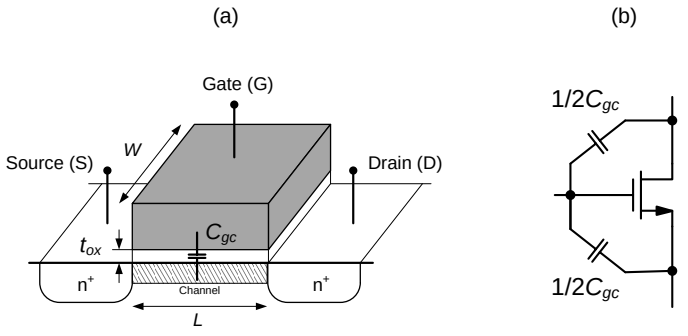

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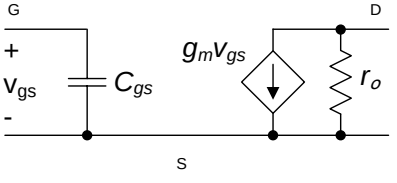

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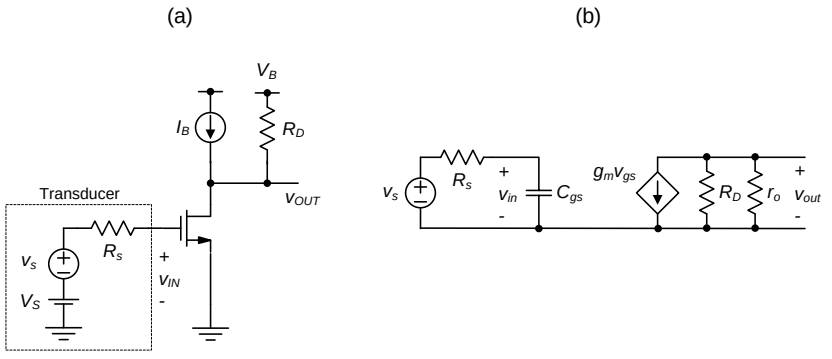

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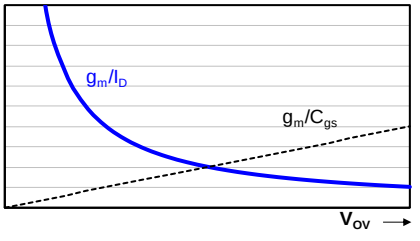

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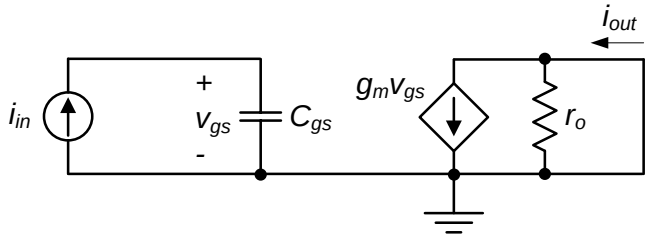

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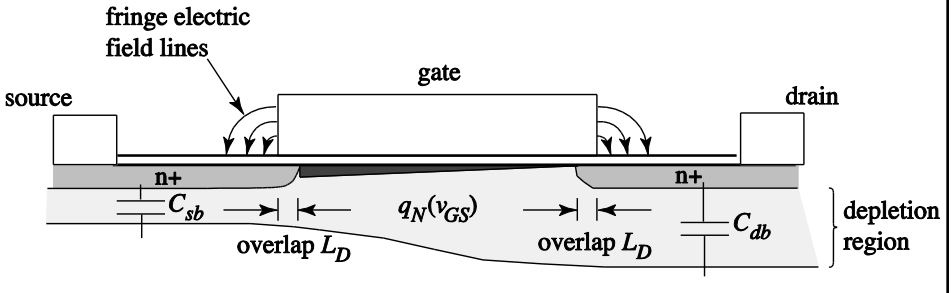


(Howe & Sodini, Figure 4.23)

Figure 3-11

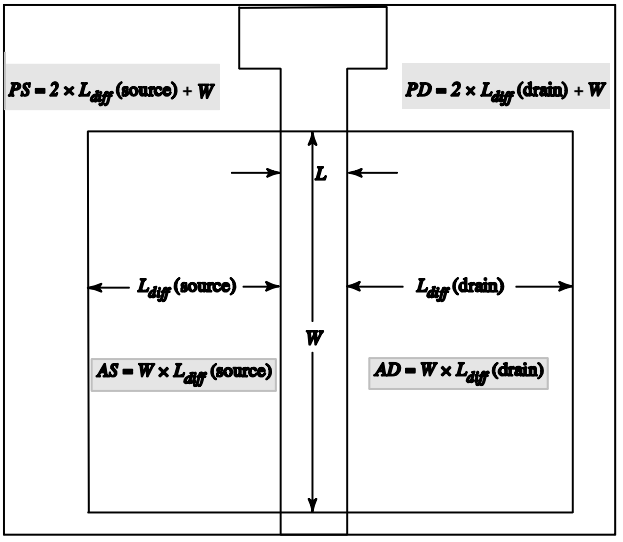


Figure 3-12

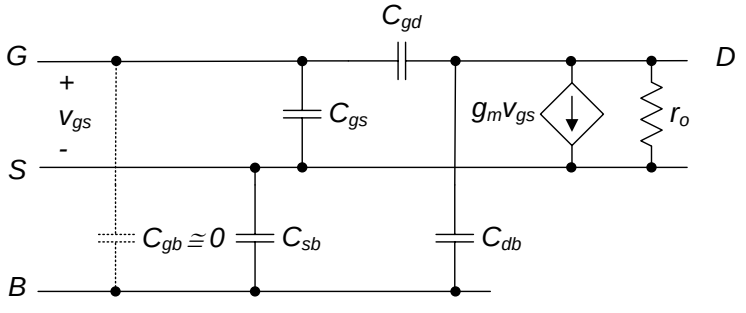
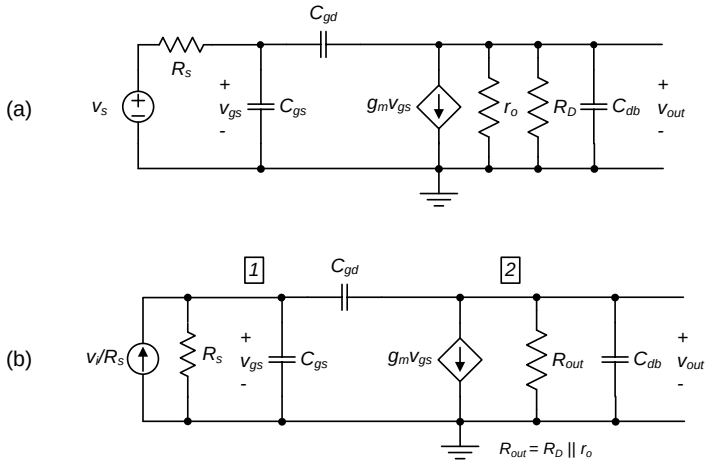


Figure 3-13



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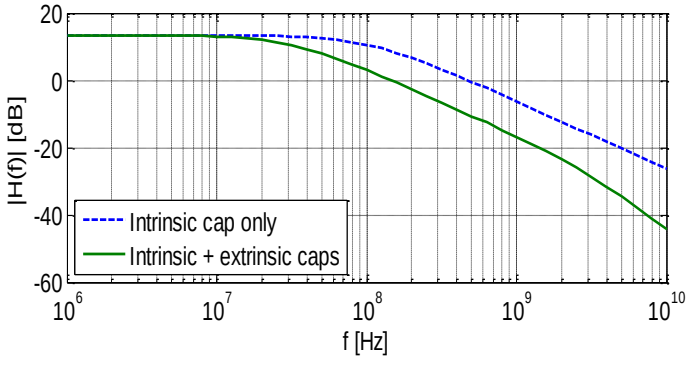

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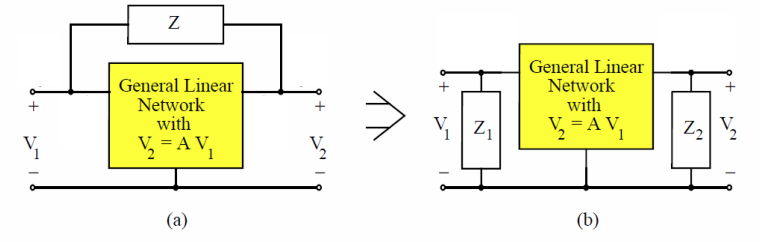

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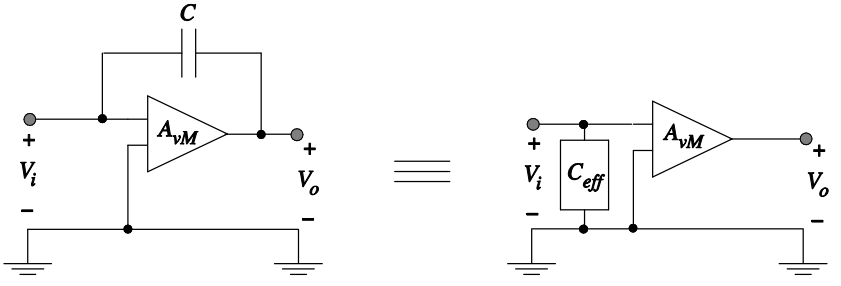


$$C_{eff} = C(1 - A_{vM})$$

Figure 3-16

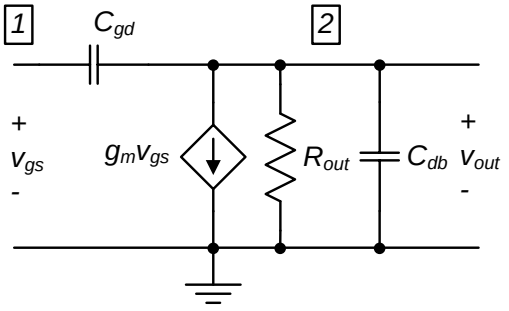
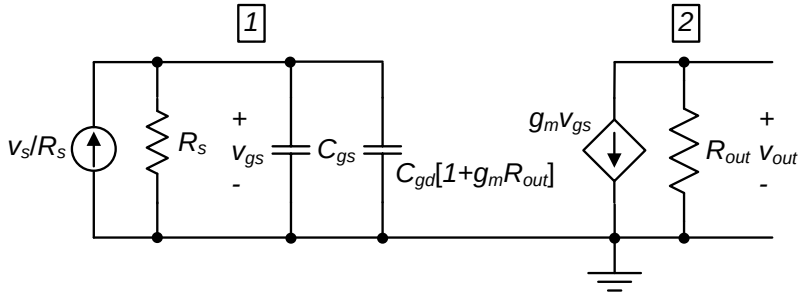


Figure 3-17



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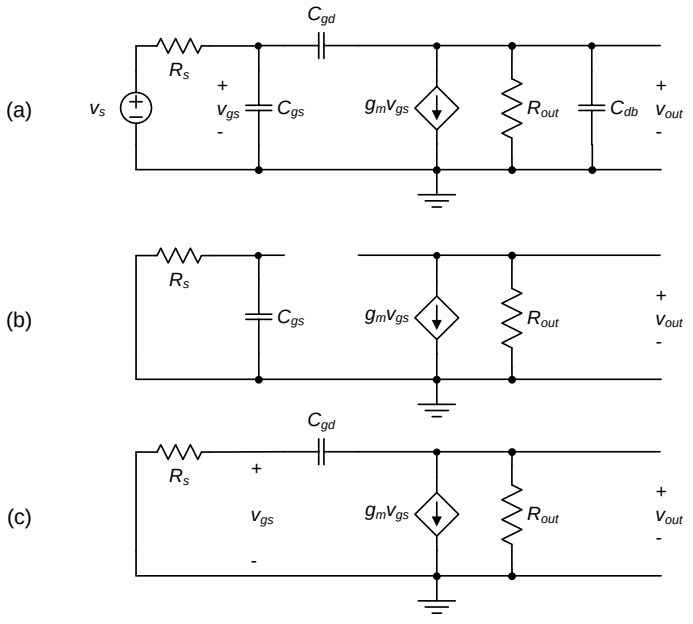

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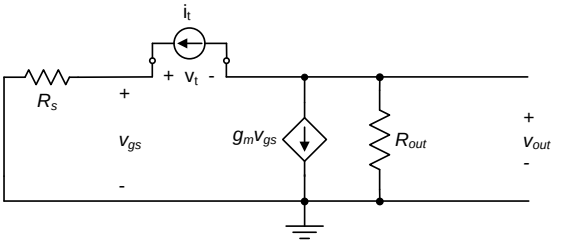

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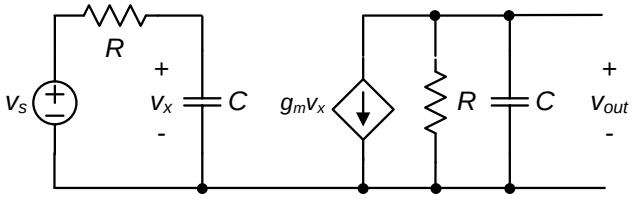

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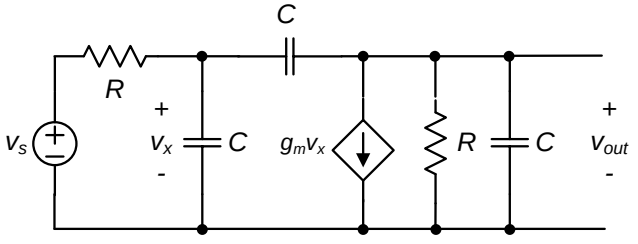


Figure 3-22

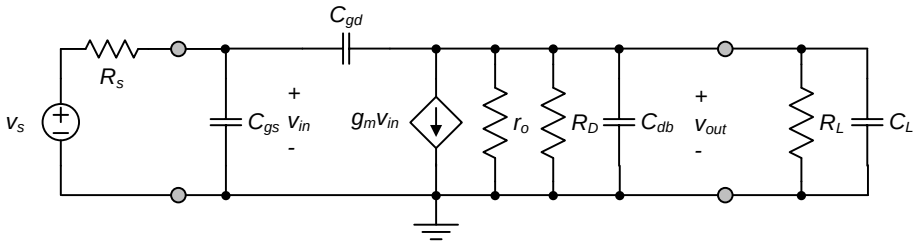


Figure Ex3-8

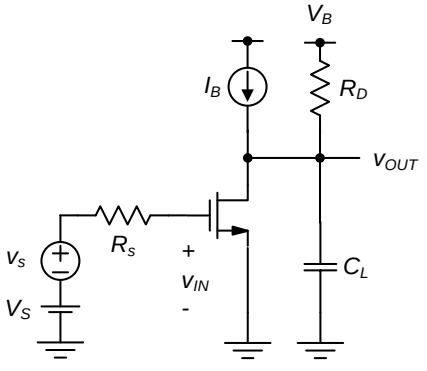
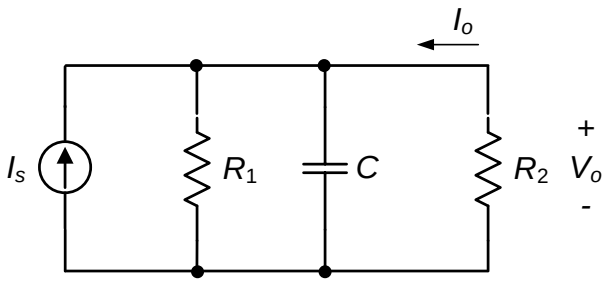


Figure P3.3



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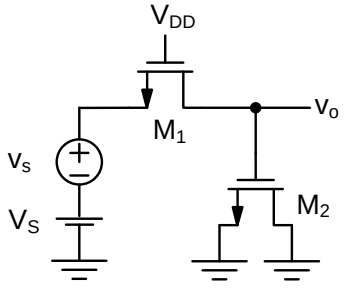


Figure P3-13

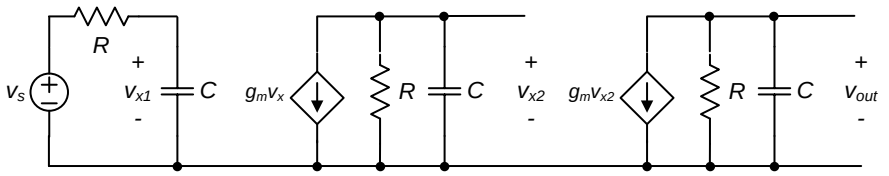


Figure P3-16

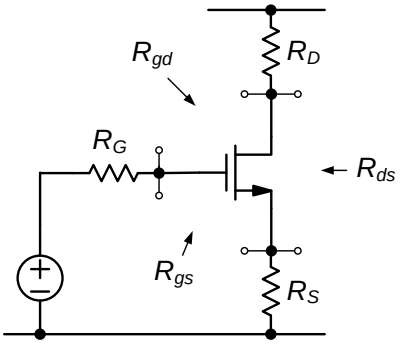


Figure P3-17

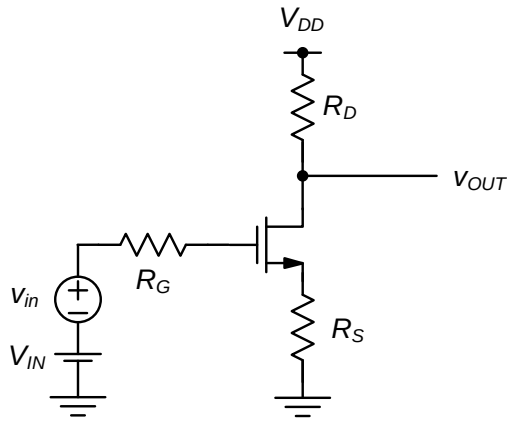
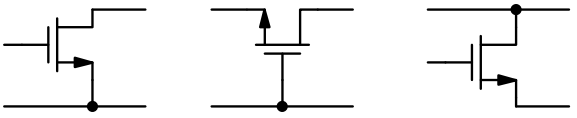


Figure 4-1



Common Source | Common Gate | Common Drain

Figure 4-2

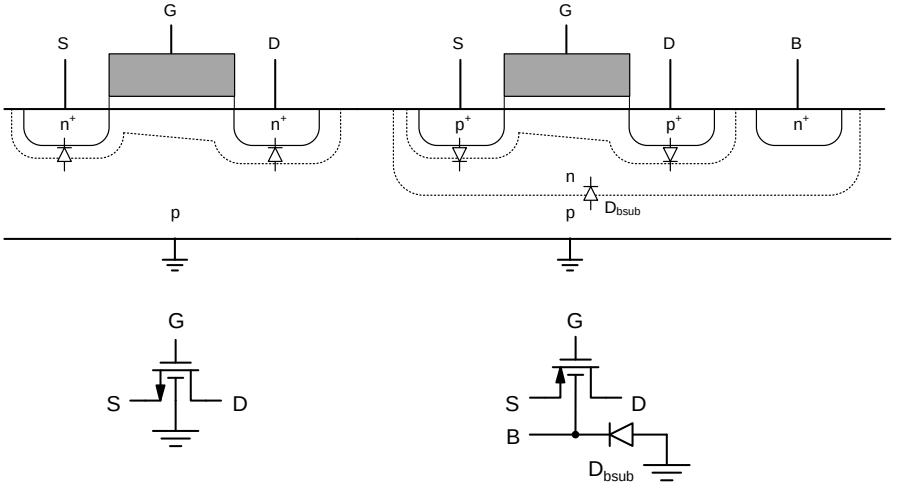
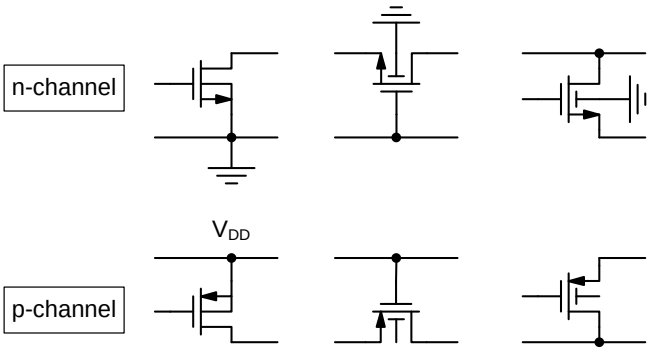
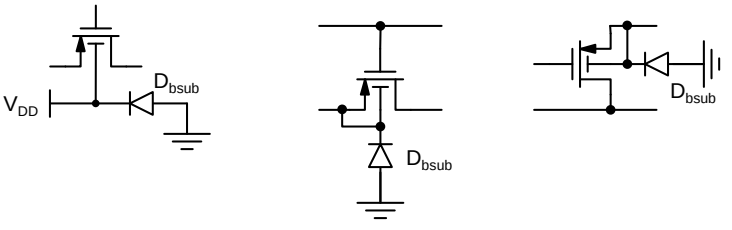


Figure 4-3



Can connect bulk to source or V_{DD}

Figure 4-4



(a) (b) (c)

Figure Ex4-1

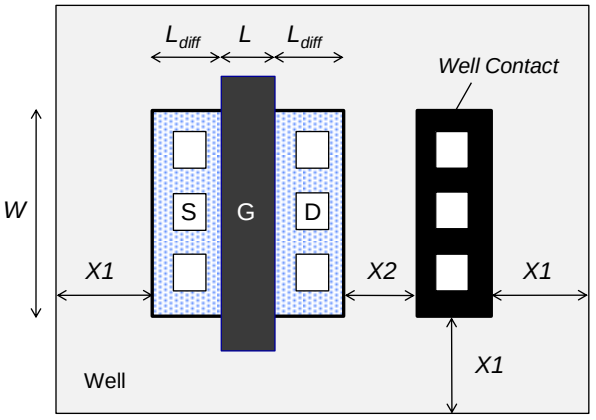


Figure 4-5

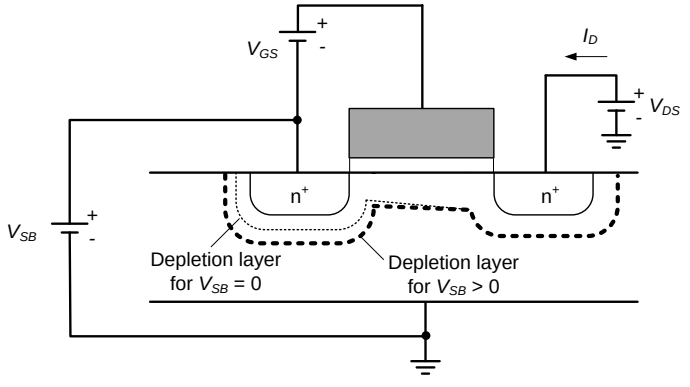


Figure 4-6

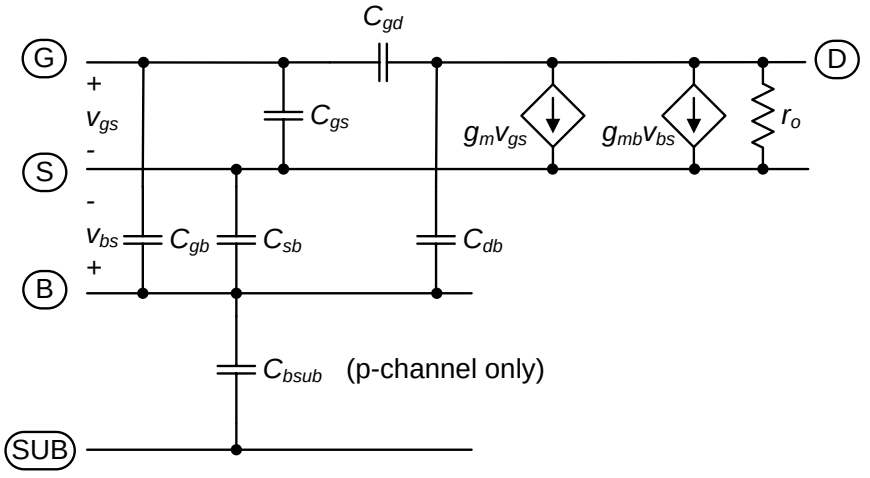


Figure 4-7

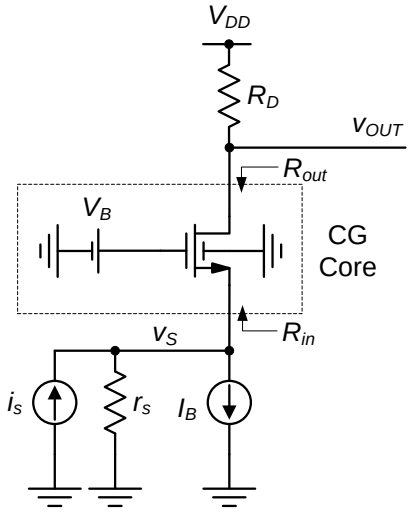


Figure 4-8

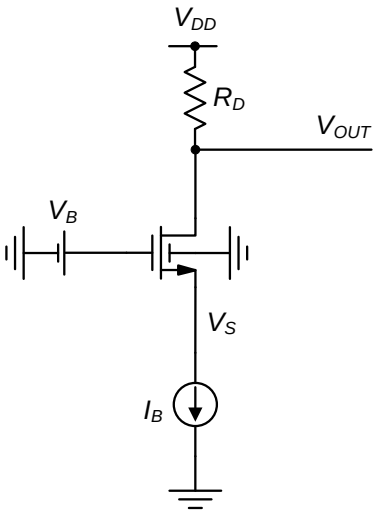
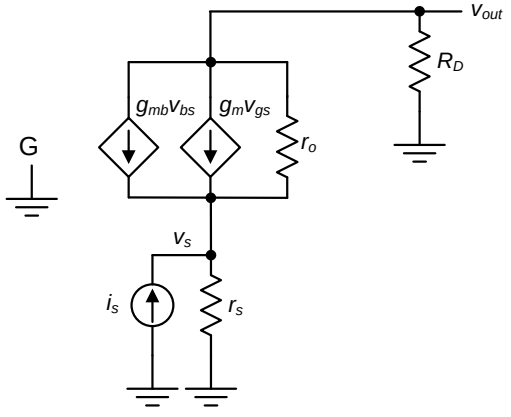


Figure 4-9



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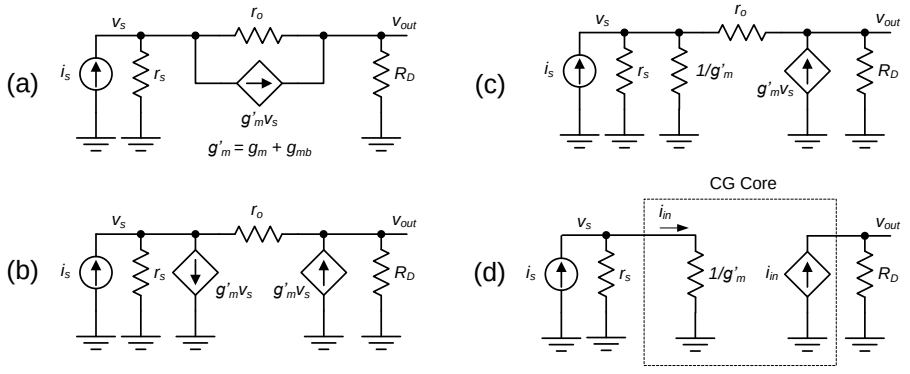

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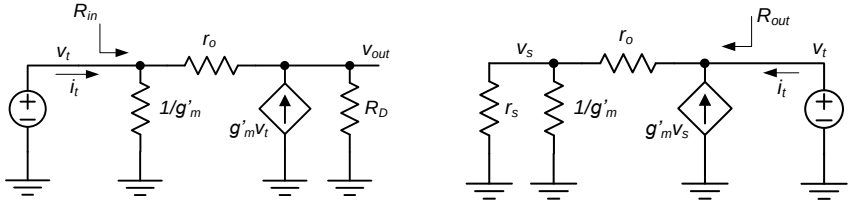


Figure 4-12

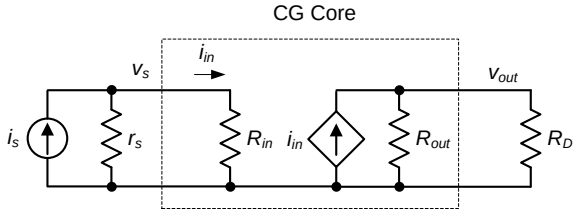


Figure 4-13

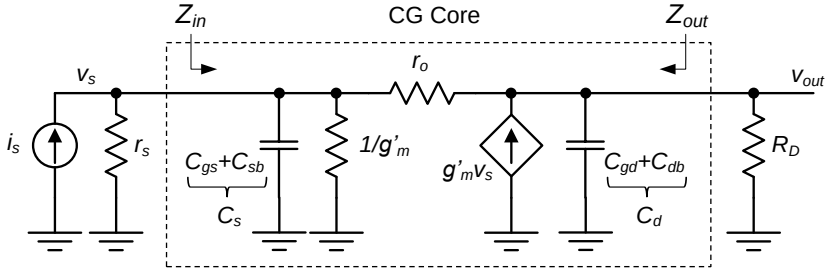
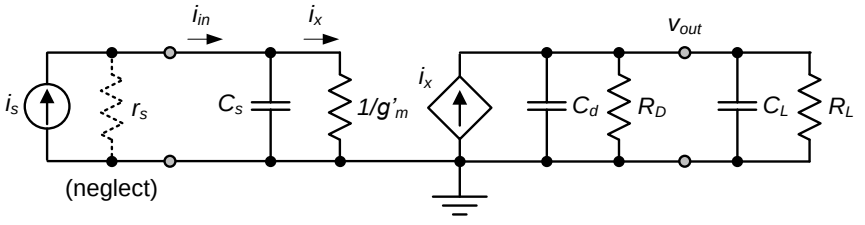


Figure 4-14



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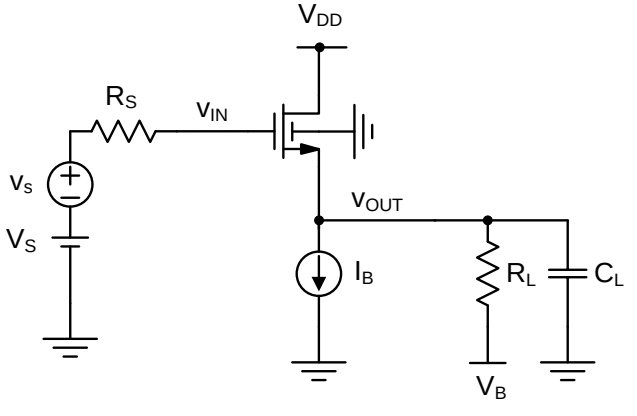


Figure 4-16

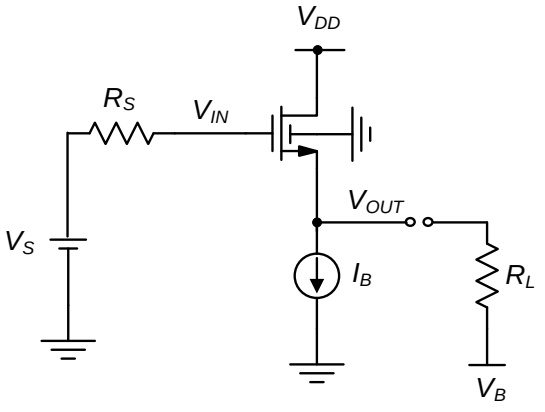
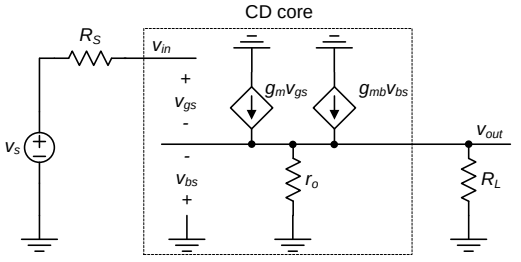


Figure 4-17

(a)



(b)

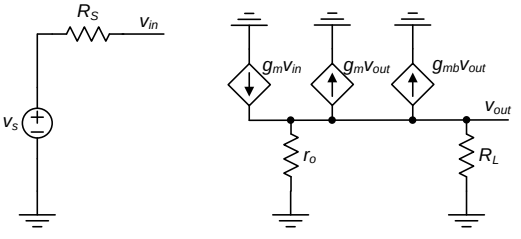


Figure 4-17 (continued)

(c)

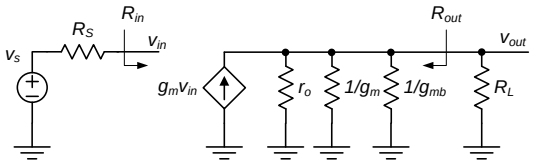
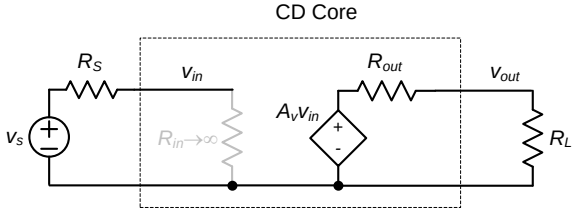


Figure 4-18



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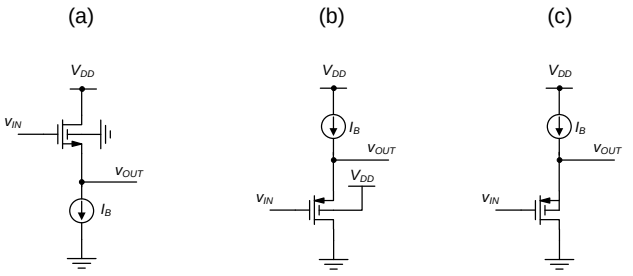


Open-circuit voltage gain

(a) $A_v \cong \dfrac{g_m}{g_m + g_{mb}}$

(b) $A_v \cong \dfrac{g_m}{g_m + g_{mb}}$

(c) $A_v \cong \dfrac{g_m}{g_m + \dfrac{1}{r_o}} \cong 1$

Figure Ex4-5

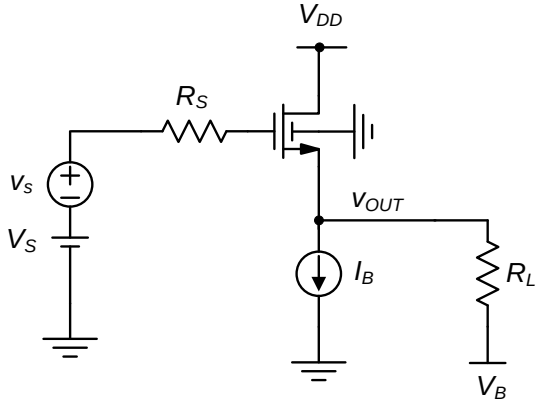


Figure 4-20

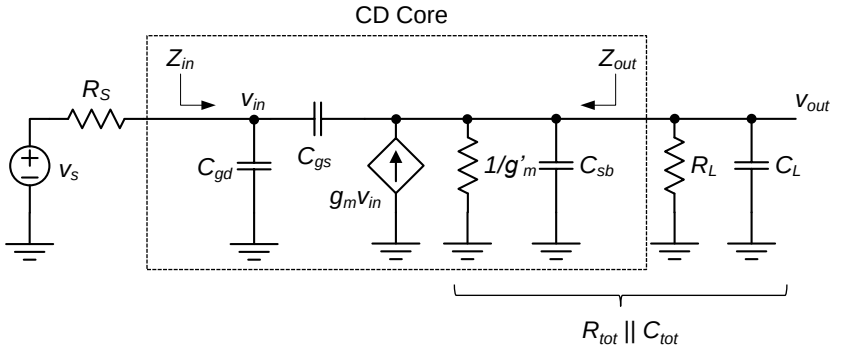


Figure 4-21

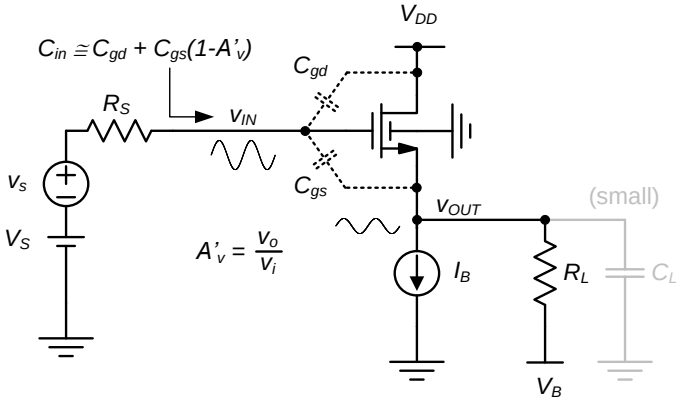


Figure 4-22

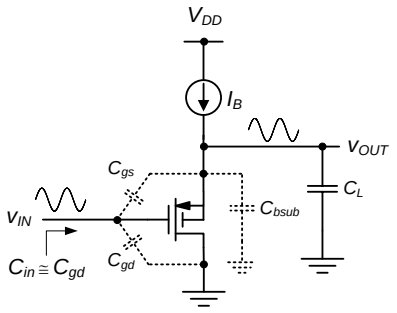
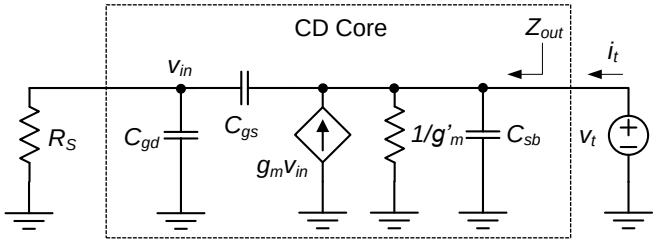


Figure 4-23



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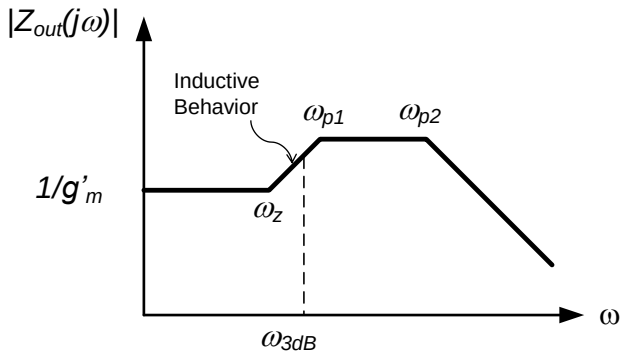


Figure 4-25

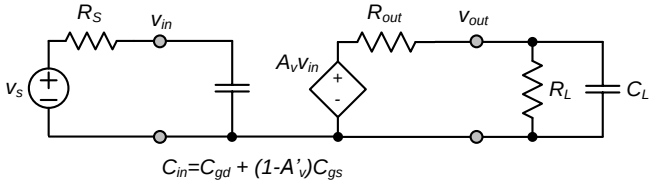
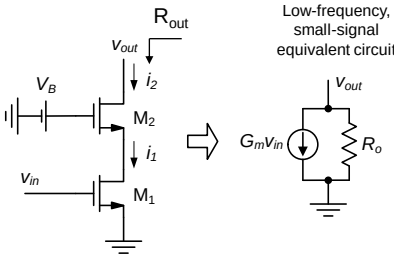


Figure 4-26

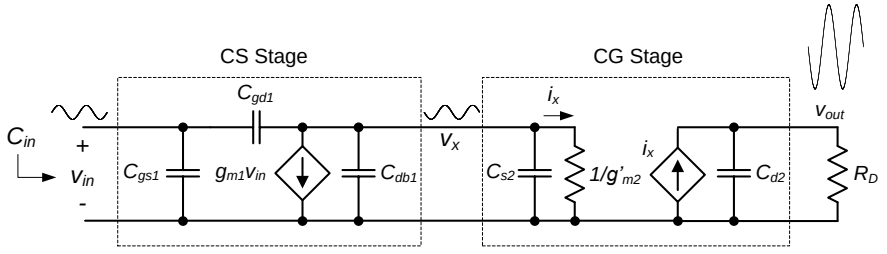


$$G_m = g_{m1} \cdot \frac{i_2}{i_1} \cong g_{m1}$$

$$R_{out} \cong r_{o1} \cdot g'_{m2} r_{o2}$$

$$G_m R_{out} \cong g_{m1} r_{o1} \cdot g'_{m2} r_{o2} \propto \left(g_m r_o\right)^2$$

Figure 4-27



$$C_{in} \cong C_{gs1} + C_{gd1}\left(1 - A_{vM}\right) \qquad A_{vM} \cong -\frac{g_{m1}}{g'_{m2}} \cong -1$$

$$\therefore C_{in} \cong C_{gs} + 2C_{gd}$$

Figure 4-28

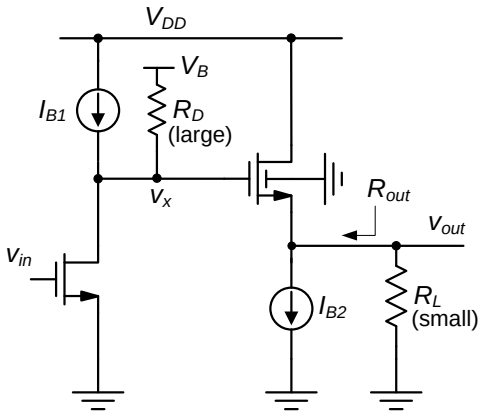


Figure 4-29

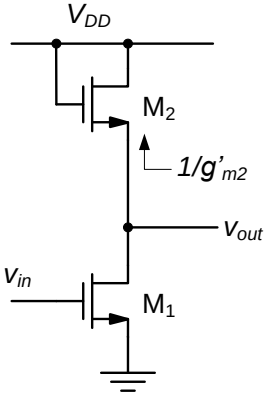


Figure 4-30

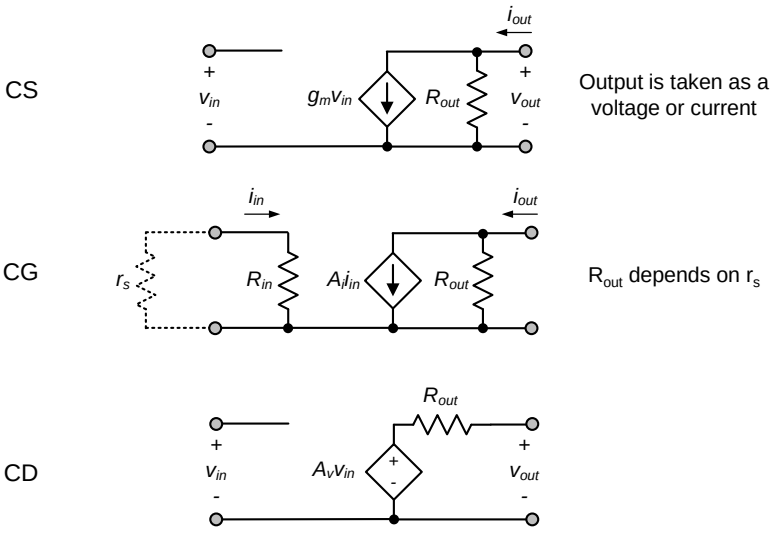


Figure P4.1

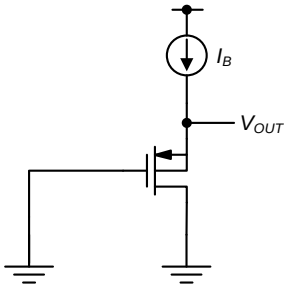


Figure P4.3

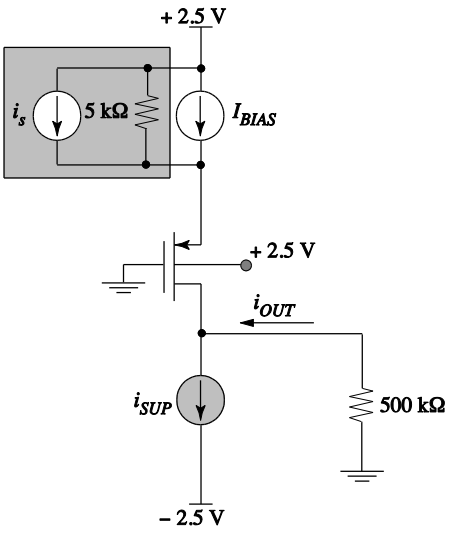


Figure P4.5

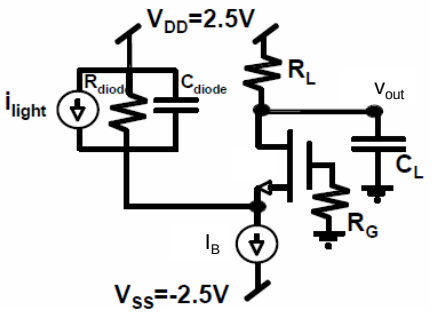
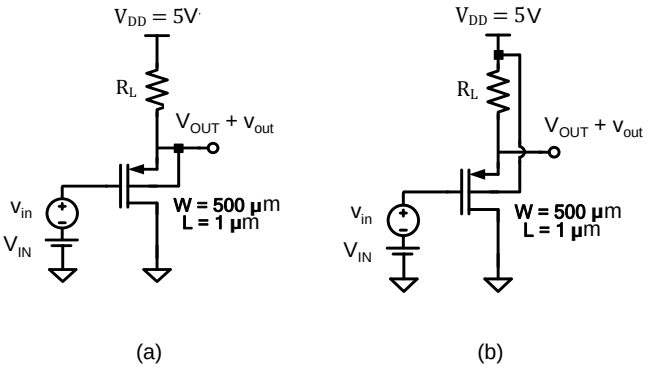


Figure P4.7



(a) (b)

Figure P4.8

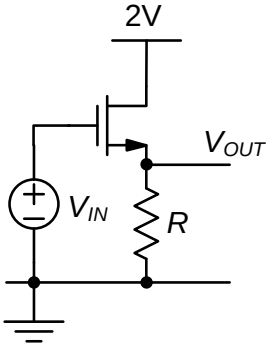


Figure P4.12

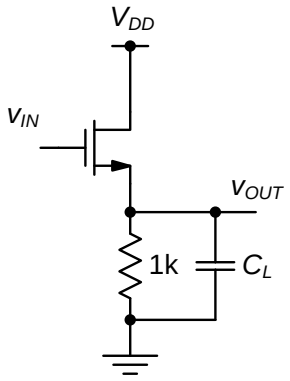


Figure P4.16

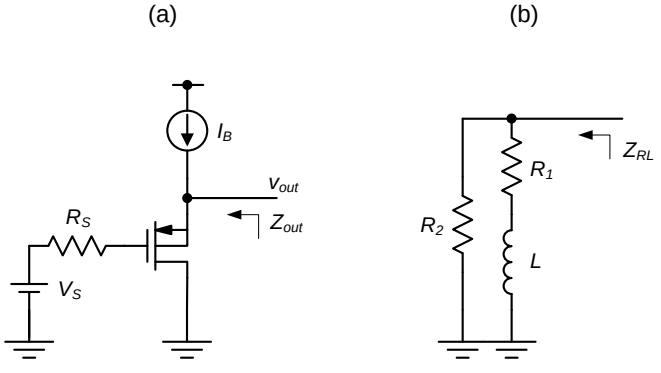


Figure 5-1

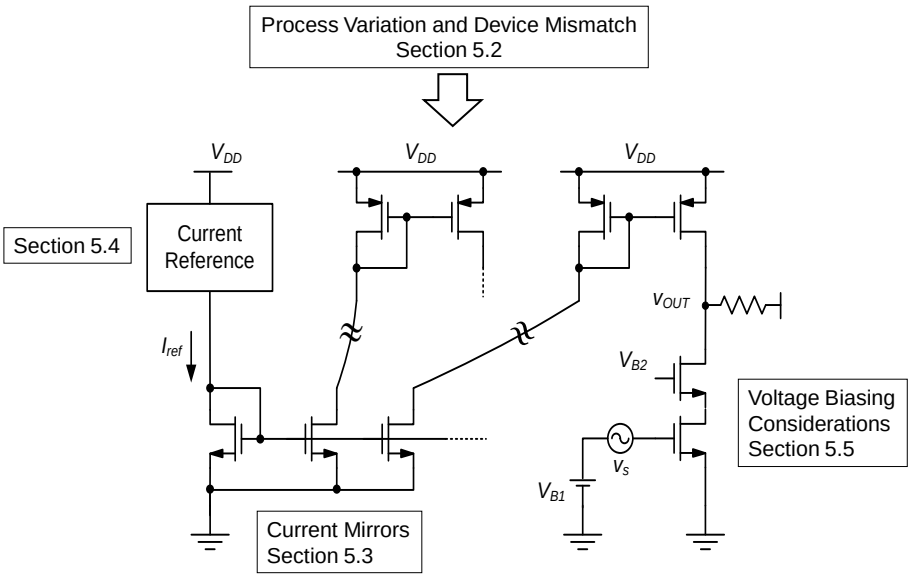


Figure Ex5-1

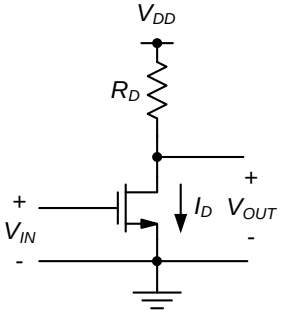


Figure 5-2

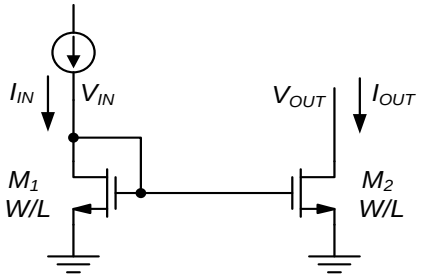


Figure 5-3

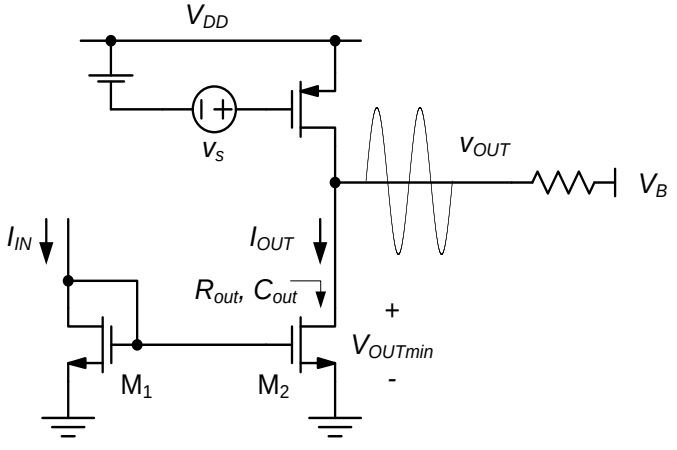


Figure 5-4

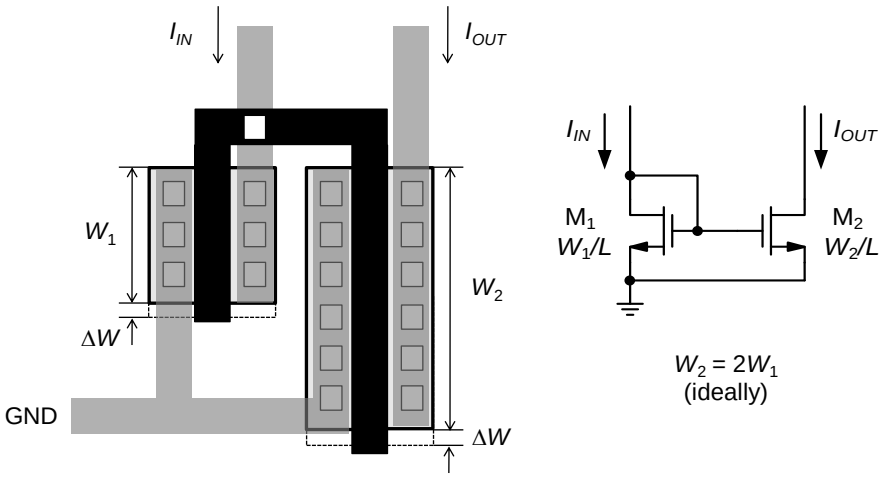


Figure 5-5

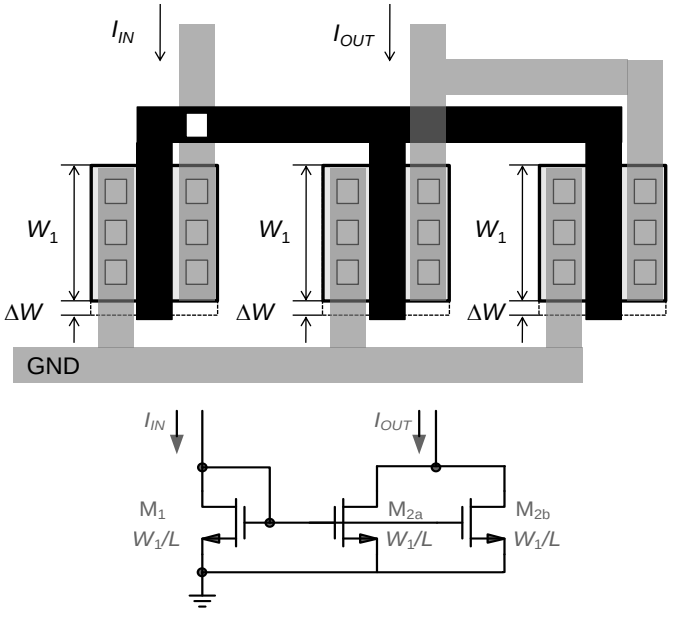
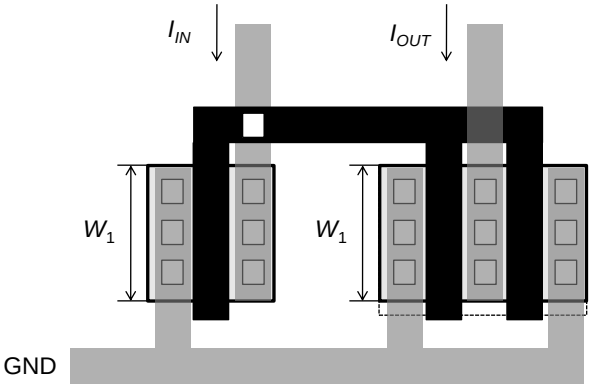
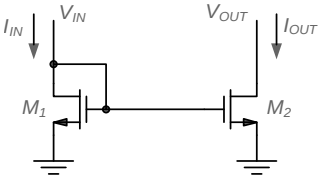


Figure 5-6



$W_2 = 2W_1$

Figure 5-7



$W_1 = W_2 = W$

$L_1 = L_2 = L$

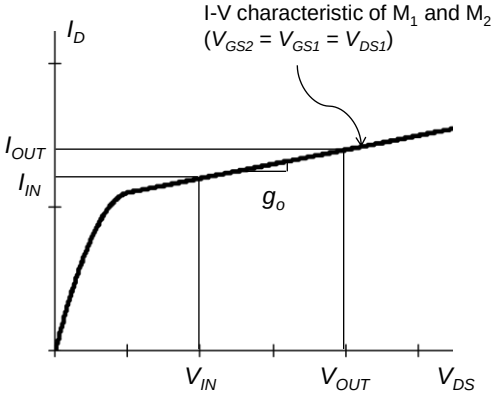
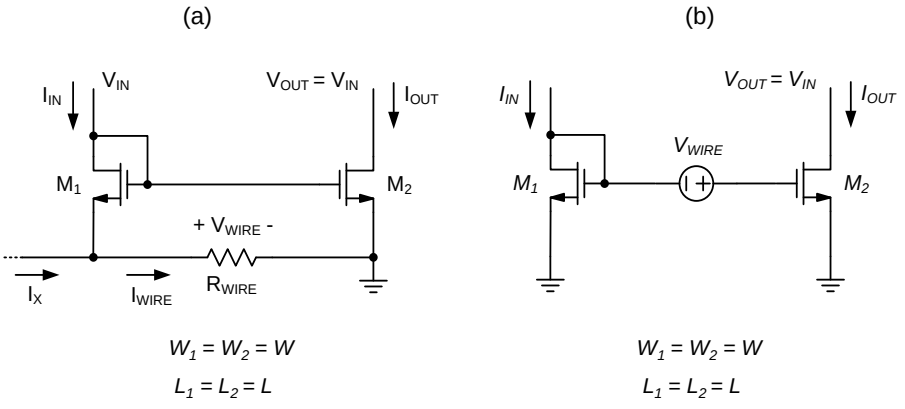


Figure 5-8



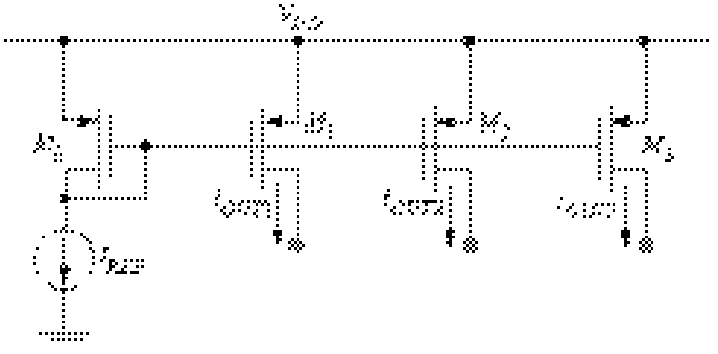
$W_1 = W_2 = W$

$L_1 = L_2 = L$

$W_1 = W_2 = W$

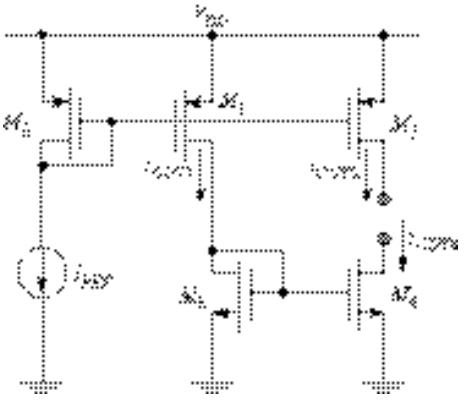
$L_1 = L_2 = L$

Figure 5-9



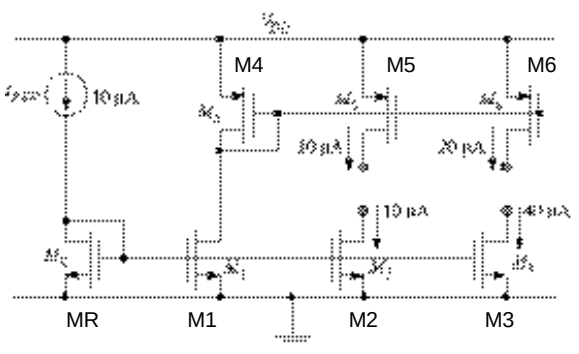
(Howe & Sodini, Figure 9-31)

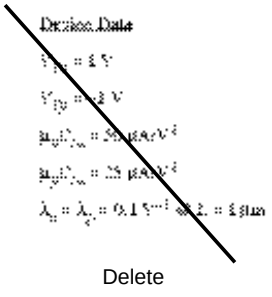
Figure 5-10



(Howe & Sodini, Figure 9-32)

Figure Ex5-3





(Howe & Sodini, Figure Ex 9-8)

Figure 5-11

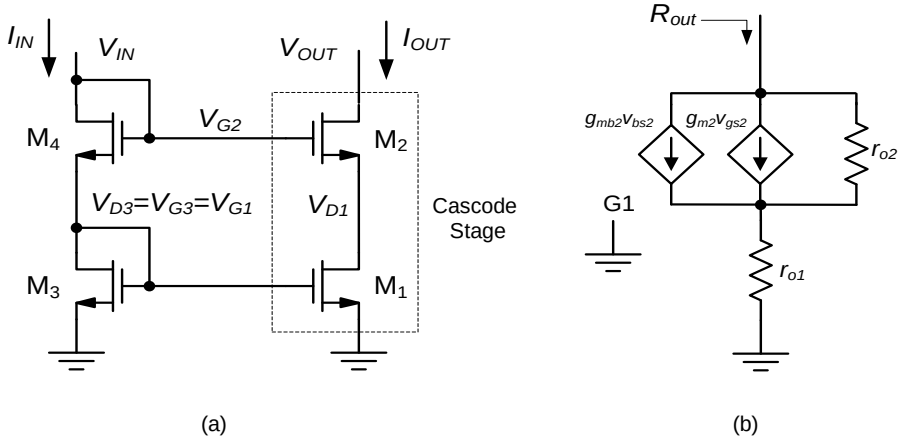


Figure 5-12

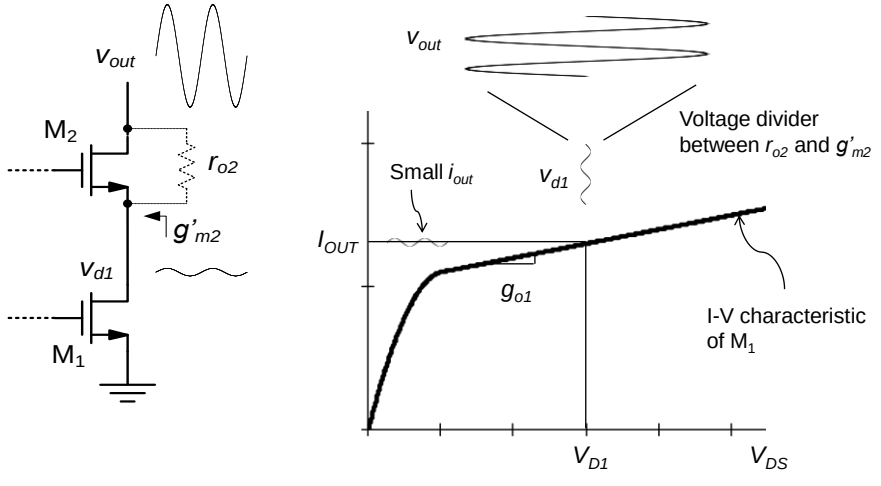


Figure 5-13

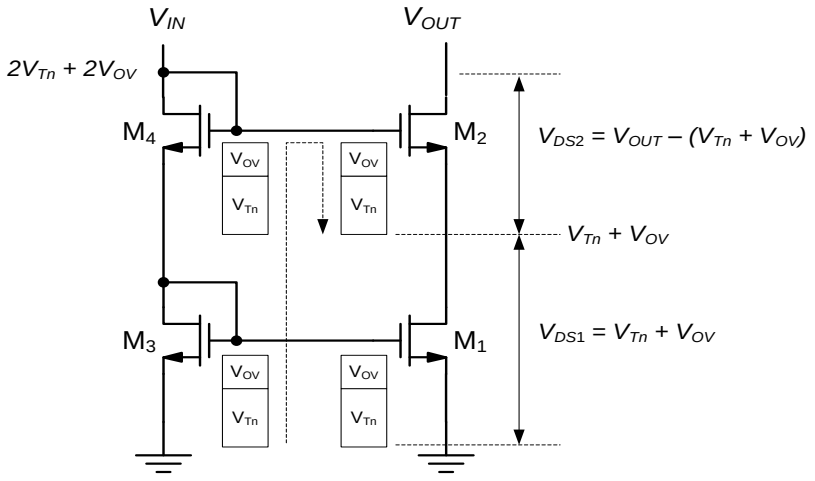


Figure 5-14

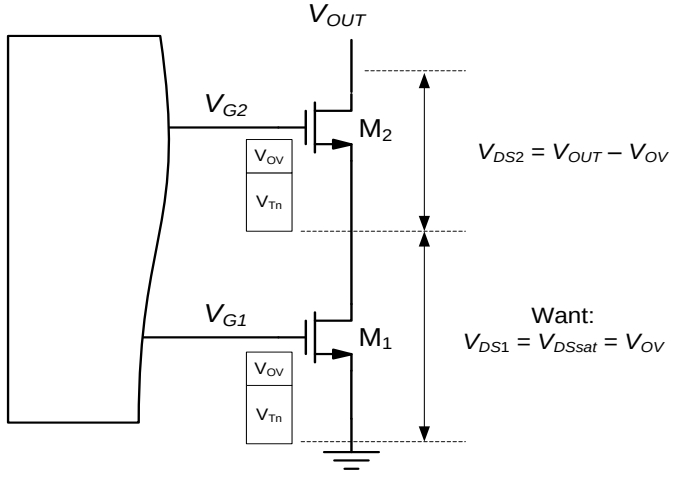


Figure 5-15

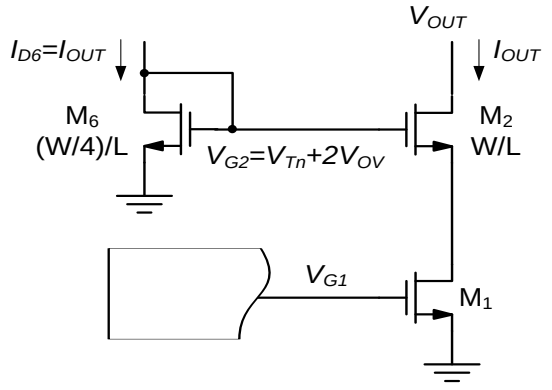
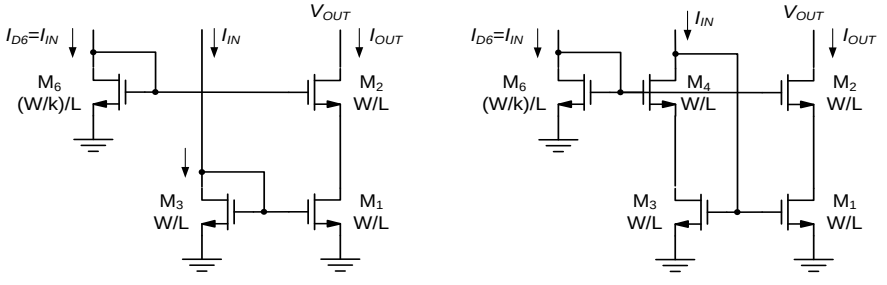
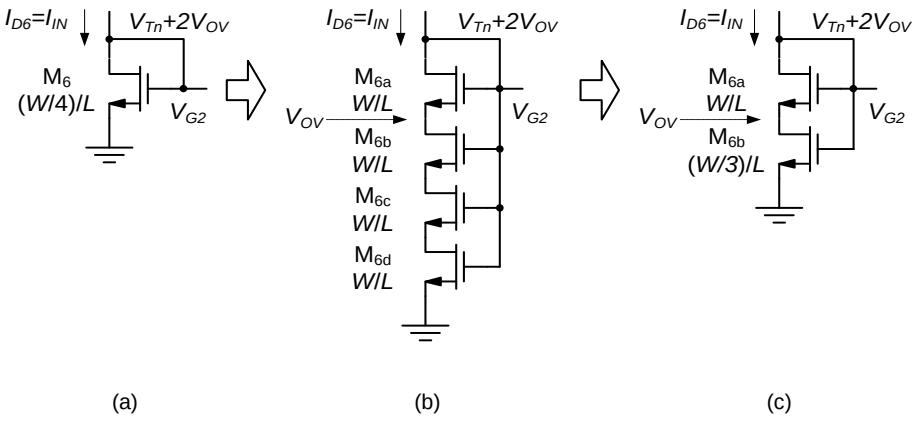


Figure 5-16



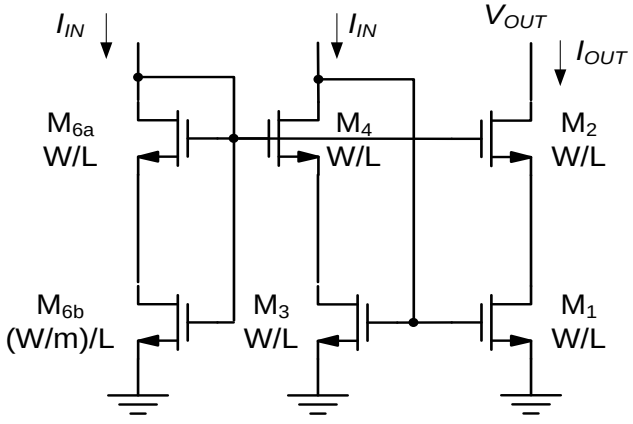
(a) (b)

Figure 5-17

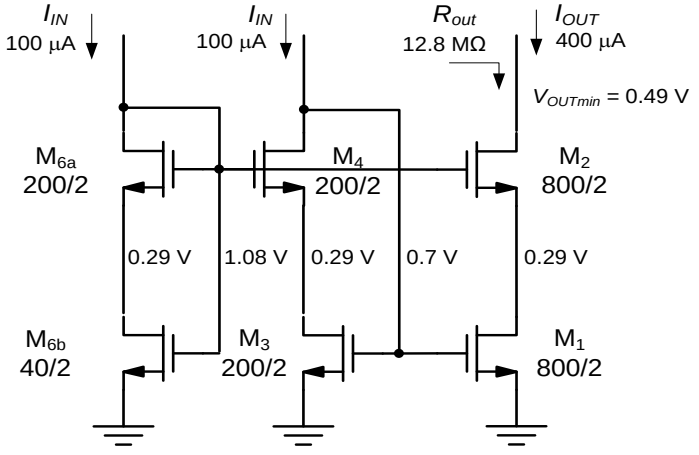


(a) (b) (c)

Figure 5-18



Solution to Ex 5-3



(all device sizes in μm)

Figure 5-19

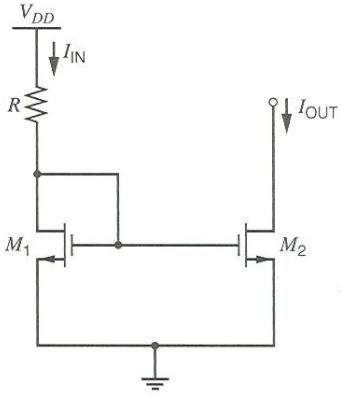
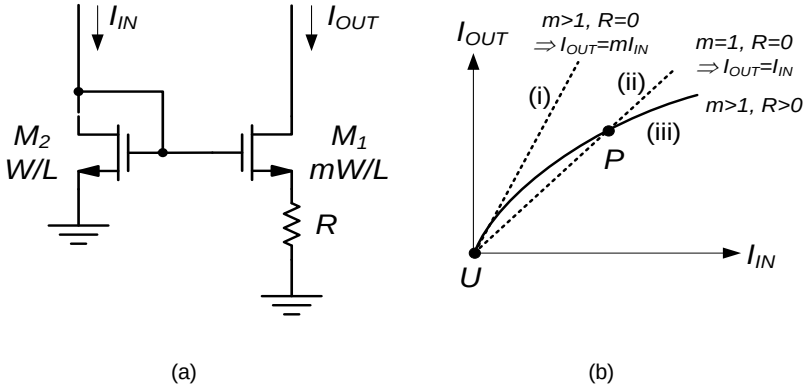


Figure 5-20



(a) (b)

Figure 5-21

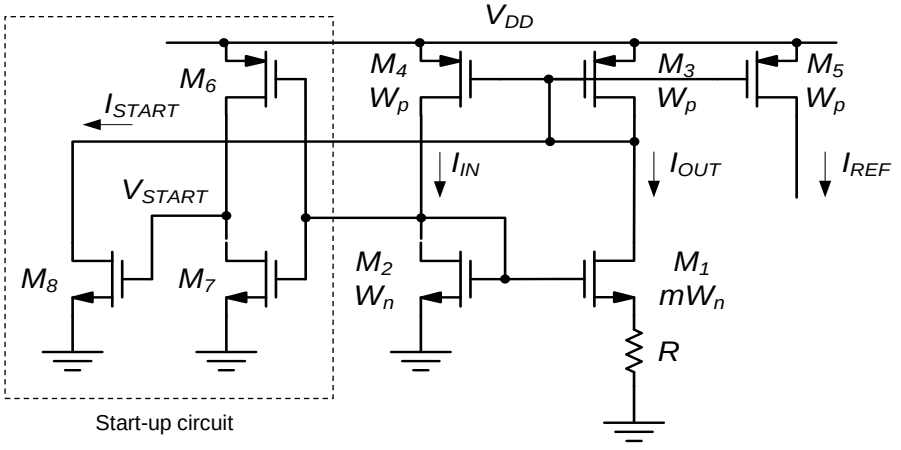


Figure 5-22

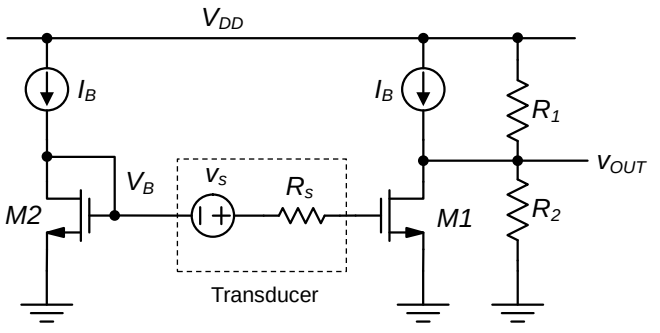


Figure 5-23

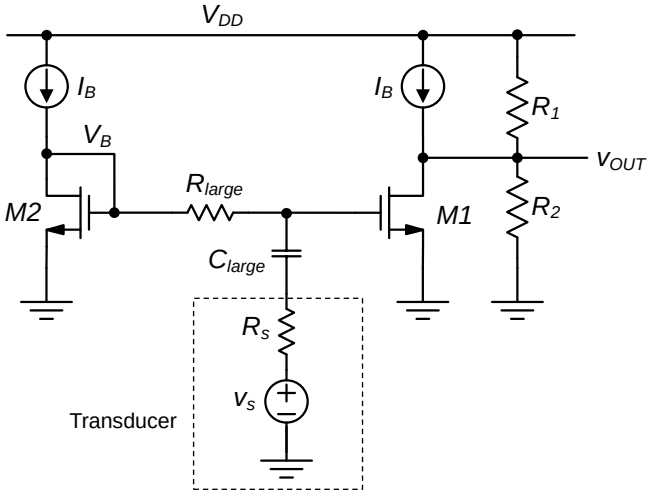


Figure 5-24

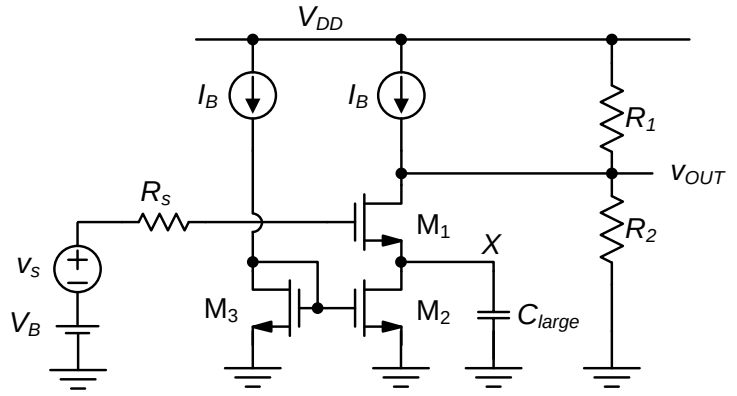
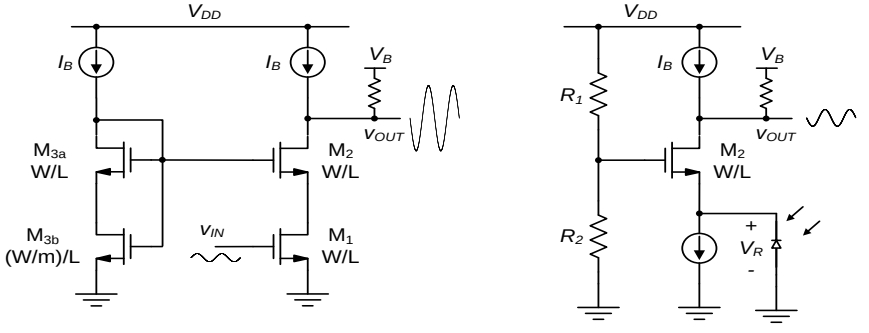


Figure 5-25



(a) (b)

Figure 5-26

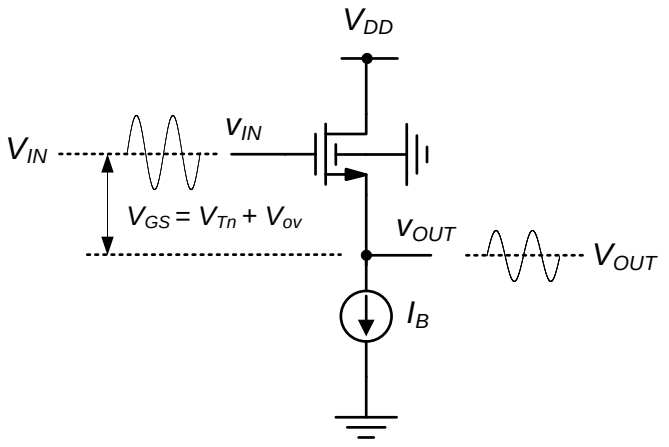
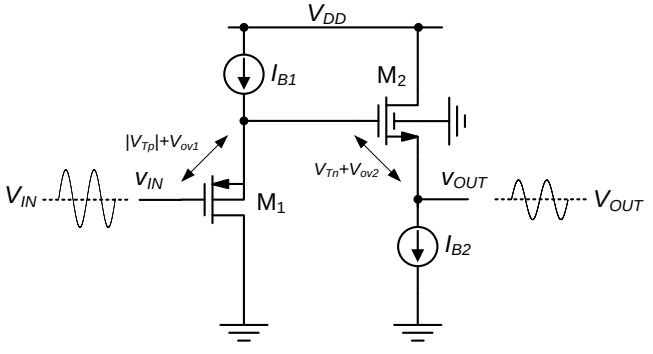
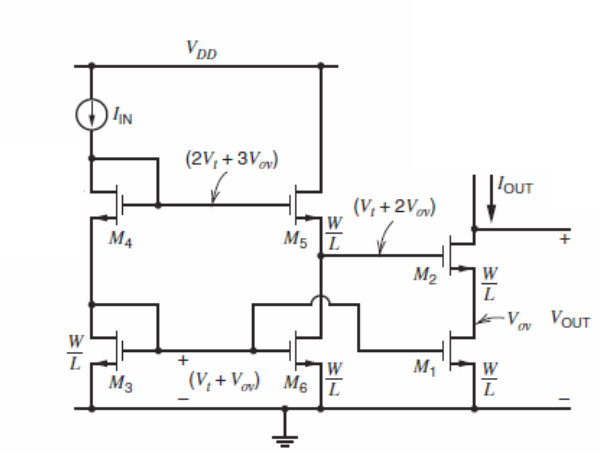


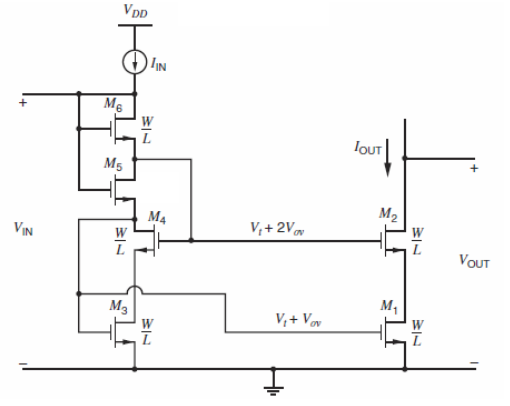
Figure 5-27



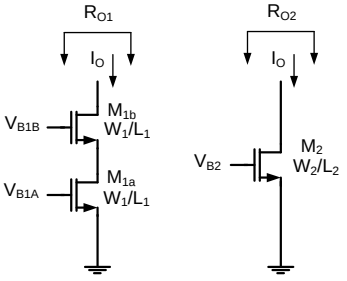
Problem P5.5



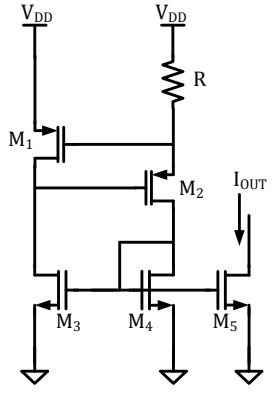
Problem P5.6



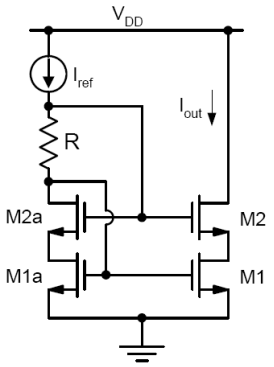
Problem P5.9



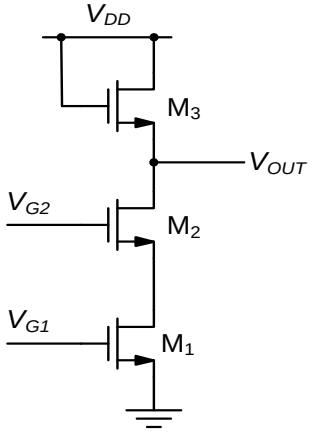
Problem P5.10



Problem P5.11



Problem P5.12



Problem P5.13

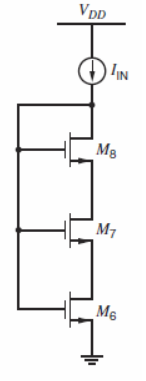


Figure 6-1

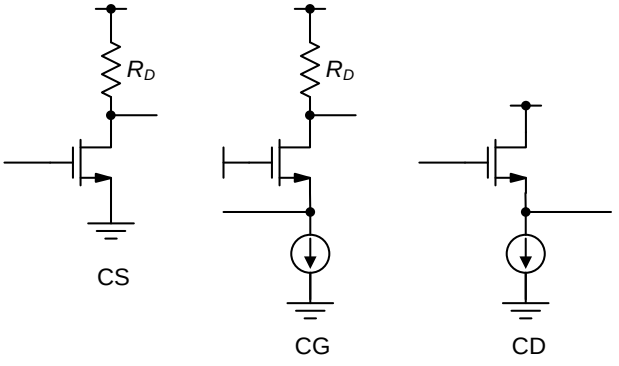


Figure 6-2

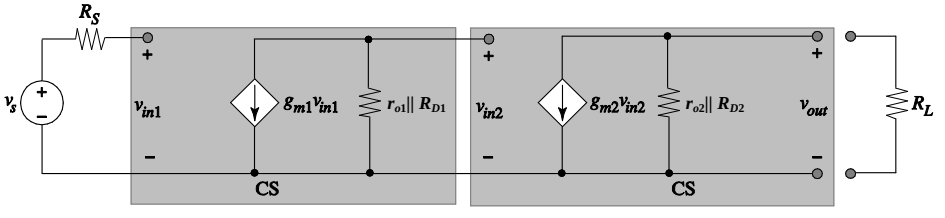


Figure 6-3

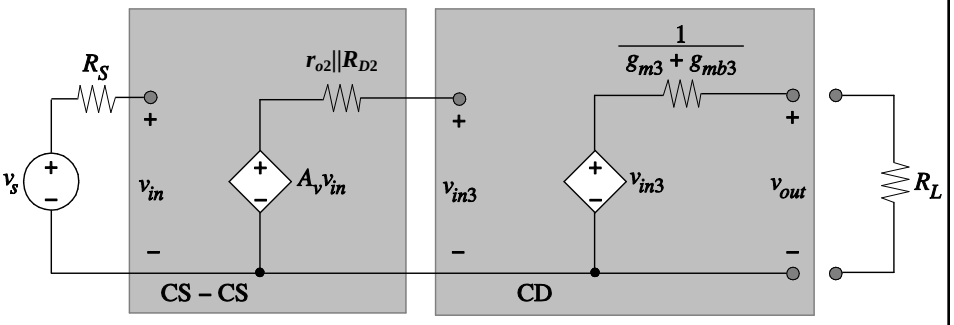


Figure 6-4

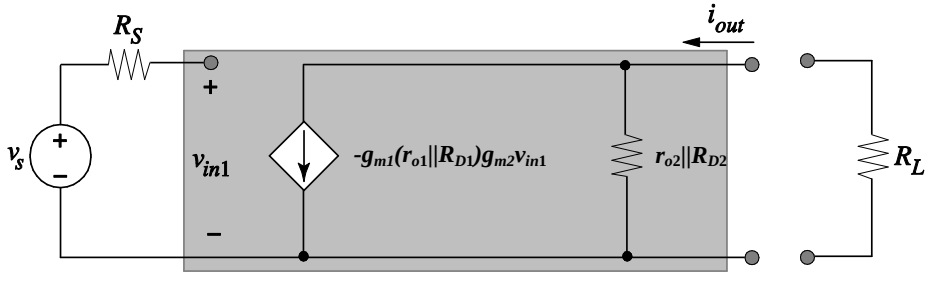


Figure 6-5

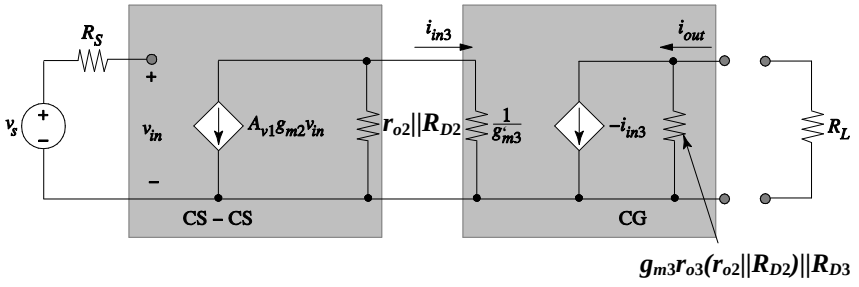


Figure Ex6-1A

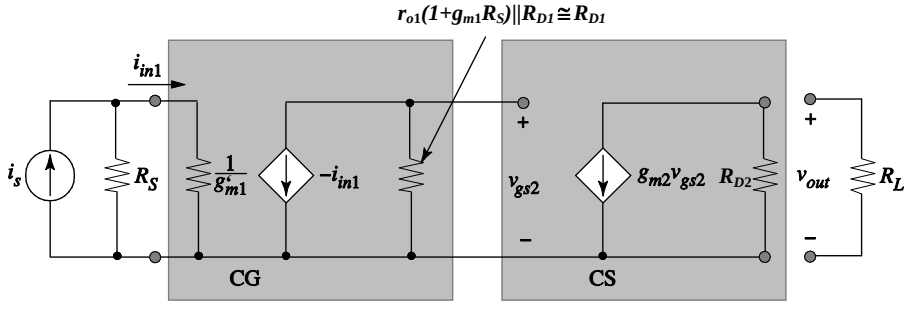


Figure Ex6-1B

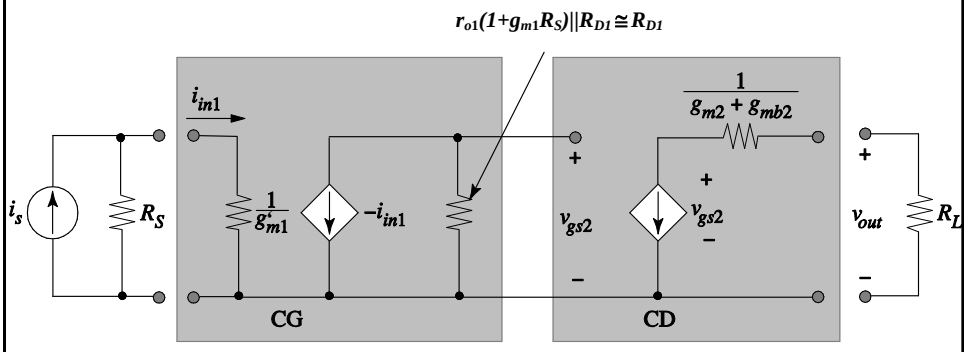


Figure 6-6

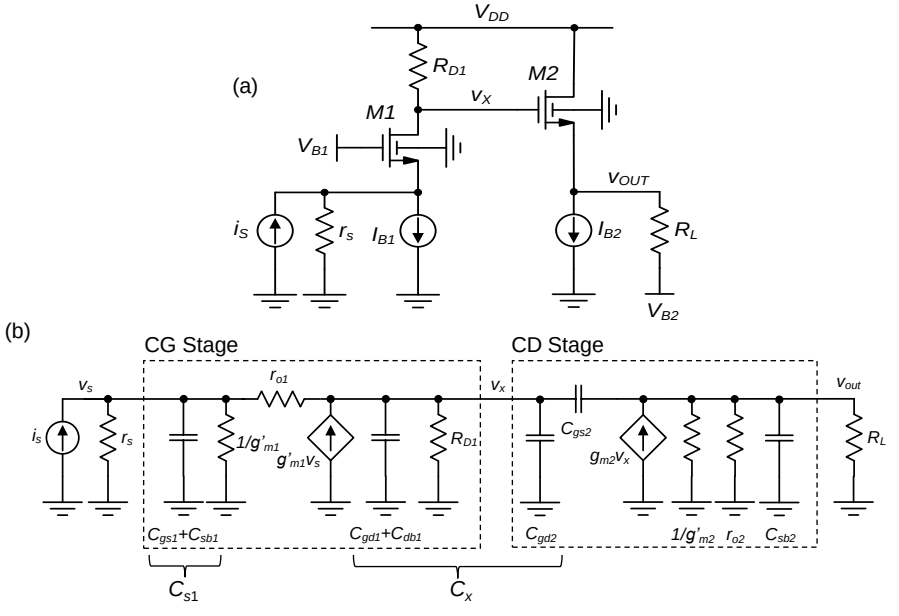
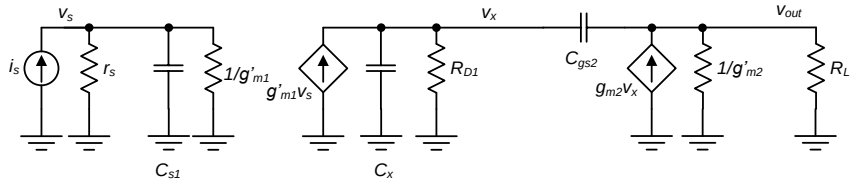
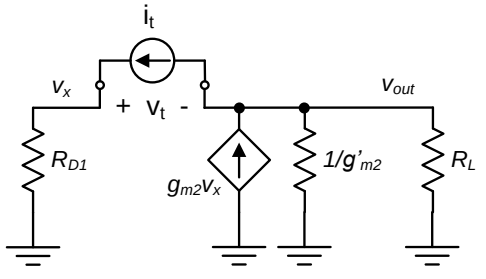


Figure 6-7



Example 6-2 Solution



Example 6-3 Solution

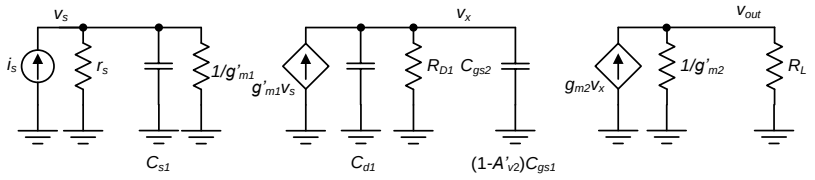


Figure 6-8

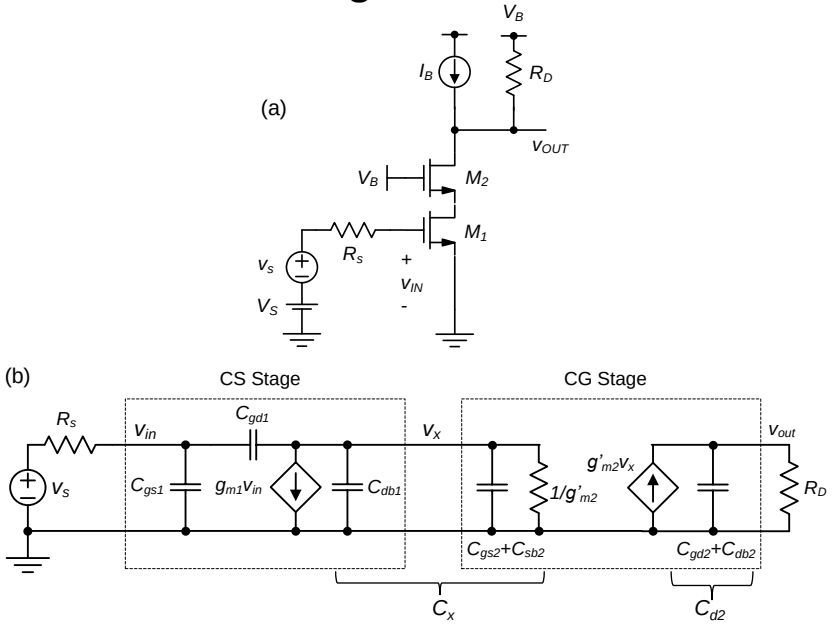


Figure Ex6-3

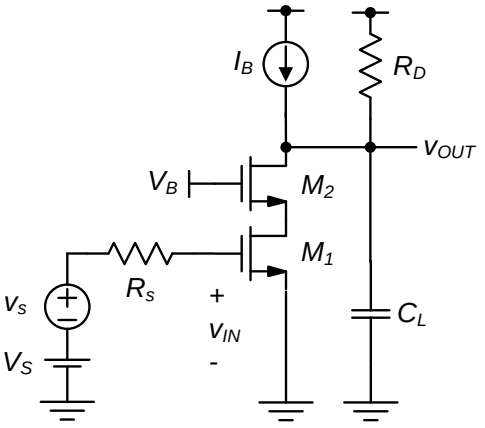


Figure 6-9

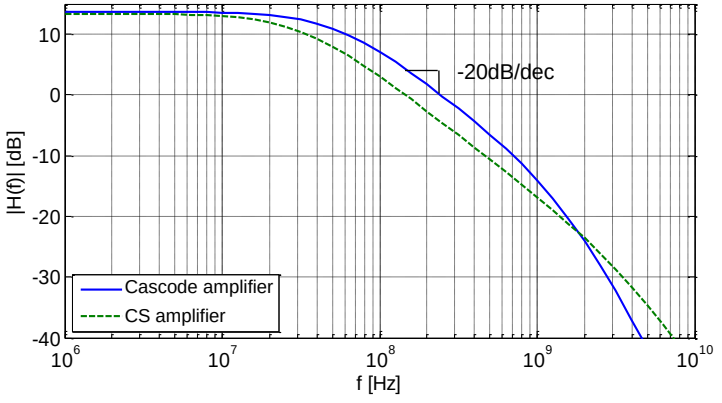


Figure 6-10

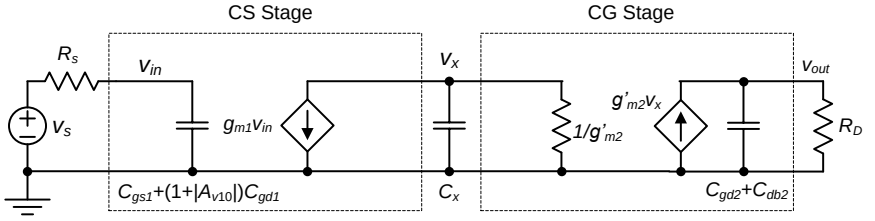


Figure 6-11

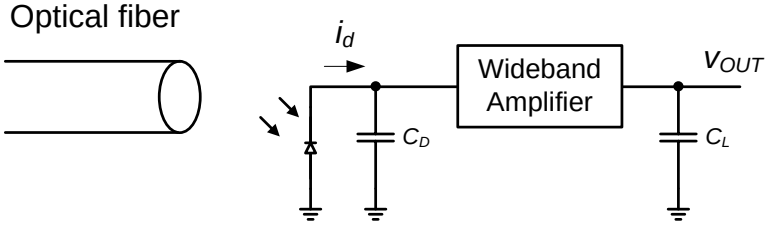


Figure 6-12

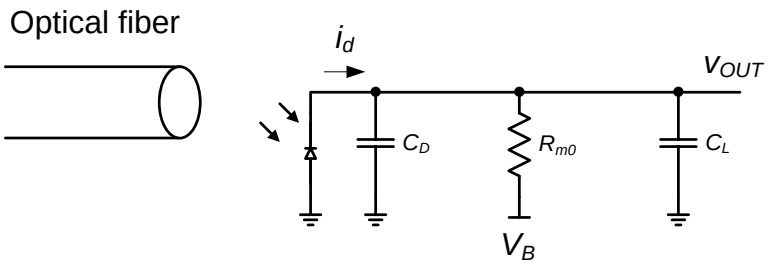


Figure 6-13

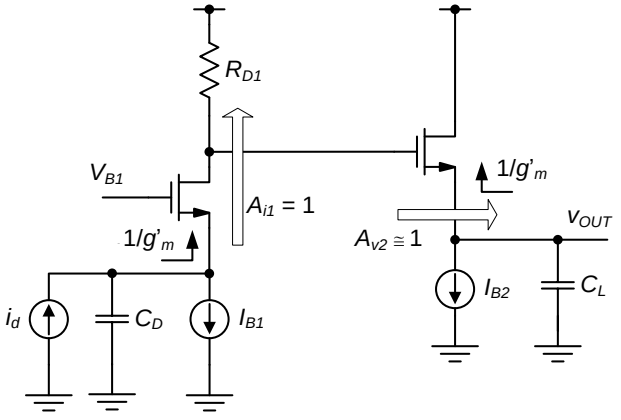


Figure 6-14

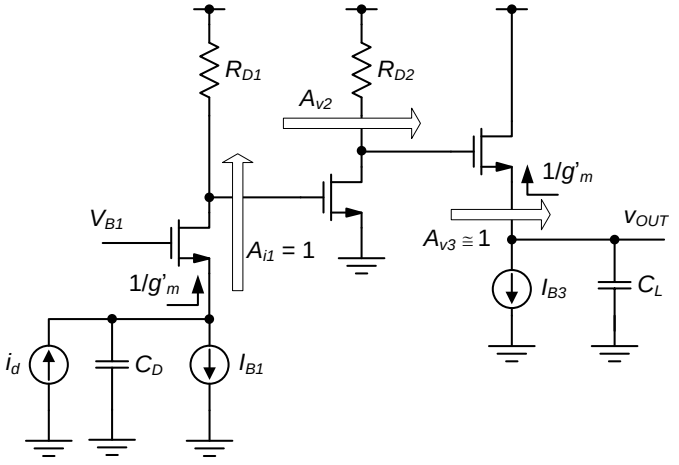


Figure 6-15

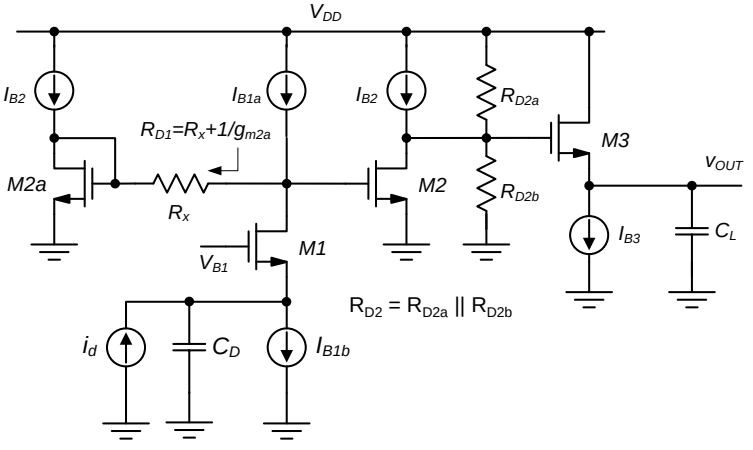


Figure 6-16

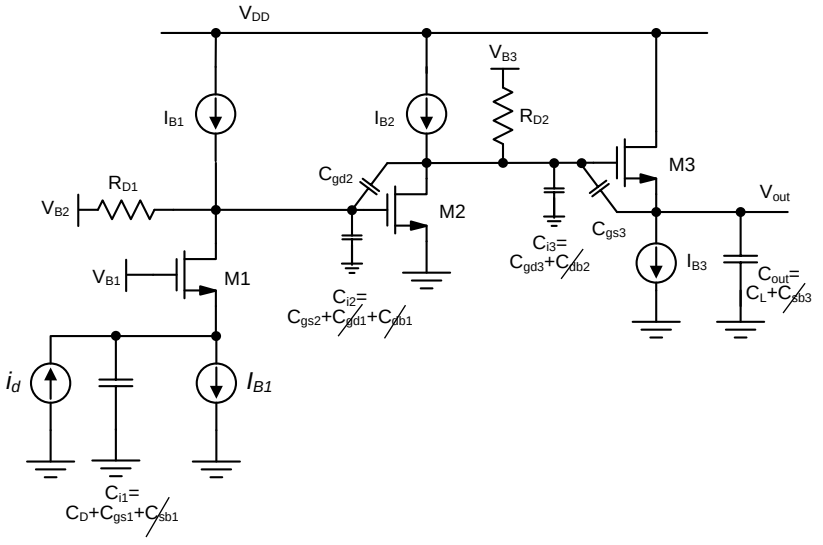


Figure 6-17

```
% Design script for three-stage transresistance amplifier

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Process technology parameters
kp_n = 50e-6;
Cox = 2.3e-3;
mu_n = kp_n/Cox;
Cov = 0.5e-9;
gmb_gm = 0.2;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Design specifications
Rm = 2e3;
CD = 5e-12;
CL = 10e-12;
IDtot = 3e-3;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Design choices
VOV1 = 0.3;
VOV2 = 0.3;
VOV3 = 0.3;
L1 = 1e-6;
L2 = 1e-6;
L3 = 1e-6;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% optimization parameters
ID1_IDtot = 0.25;
ID3_IDtot = 0.25;
Av20 = 10;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Compute drain currents
ID1 = IDtot*ID1_IDtot;
ID3 = IDtot*ID3_IDtot;
ID2 = IDtot - ID1 - ID3;

% Calculations for M1
gm1 = 2*ID1/VOV1;
W1 = 2*ID1/(kp_n/L1*VOV1^2);
Cgs1 = 2/3*W1*L1*Cox + W1*Cov;
tau_in = (Cgs1+CD)/(gm1*(1+gmb_gm));

% Calculations for M3
gm3 = 2*ID3/VOV3;
W3 = 2*ID3/(kp_n/L3*VOV3^2);
Cgs3 = 2/3*W3*L3*Cox + W3*Cov;
Cgd3 = W3*Cov;
Av30 = 1-gmb_gm;
tau_out = (CL+Cgs3)/(gm3*(1+gmb_gm));

% Calculations for M2
gm2 = 2*ID2/VOV2;
W2 = 2*ID2/(kp_n/L2*VOV2^2);
Cgs2 = 2/3*W2*L2*Cox + W2*Cov;
Cgd2 = W2*Cov;
RD1 = Rm/Av20/Av30;
RD2 = Av20/gm2;
tau_core = RD1*(Cgs2 + (1+Av20)*Cgd2) + RD2*(Cgd3+(1-Av30)*Cgs3);

% Total time constant and bandwidth estimate
tau_tot = tau_i1 + tau_core + tau_out
f3dB = 1/2/pi/tau_tot
```

Figure 6-18

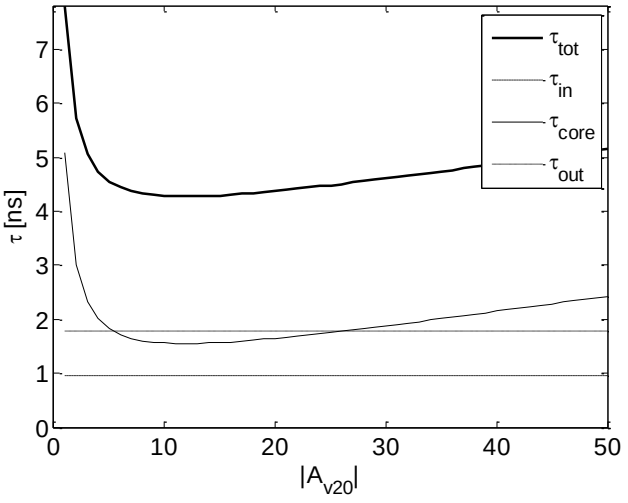
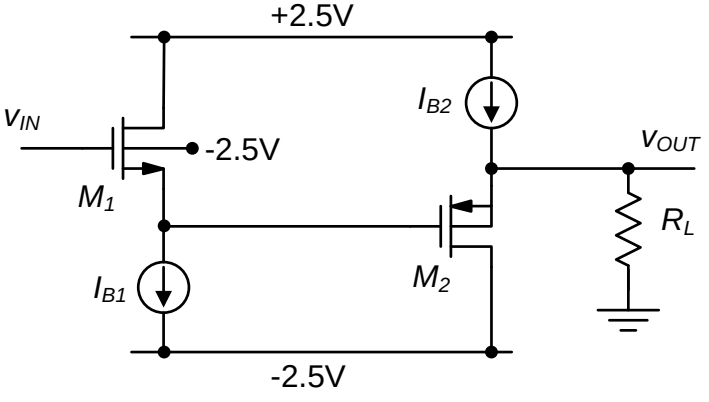
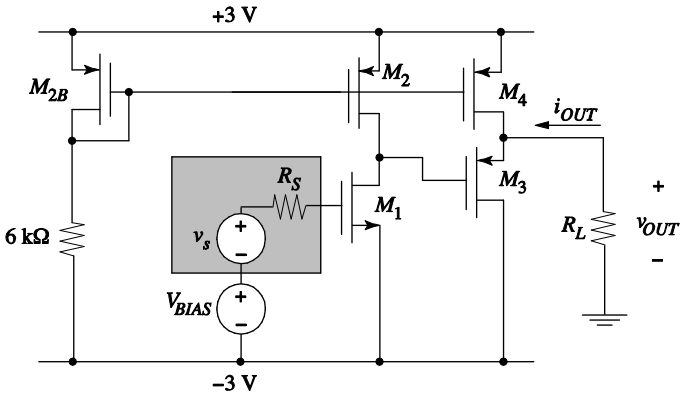


Figure P6-3



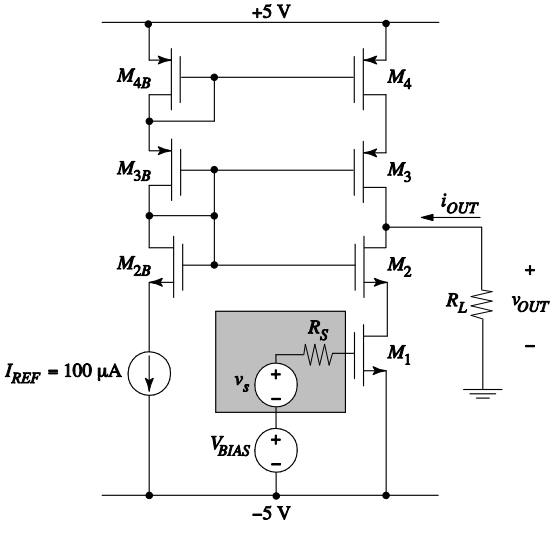
Howe & Sodini, Fig. P9-3

Figure P6-5



Howe & Sodini, Fig. P9-17

Figure P6-6



$M_2 = M_{2B} = 40/1.5$

$M_3 = M_{3B} = 40/1.5$

$M_4 = M_{4B} = 40/1.5$

Howe & Sodini, Fig. P9-20

Figure P6-7

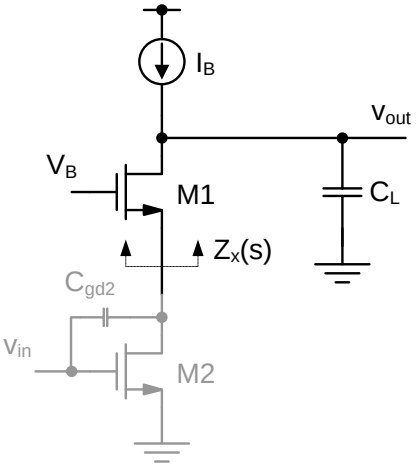


Figure P6-8

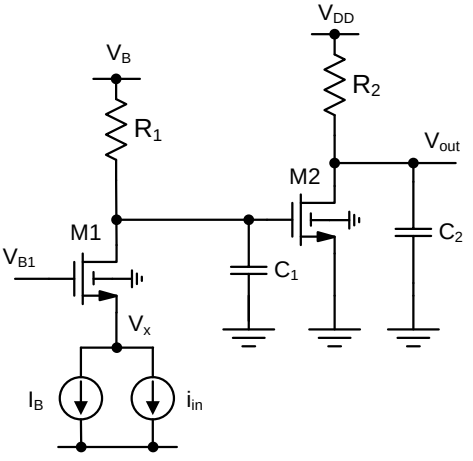


Figure P6-9

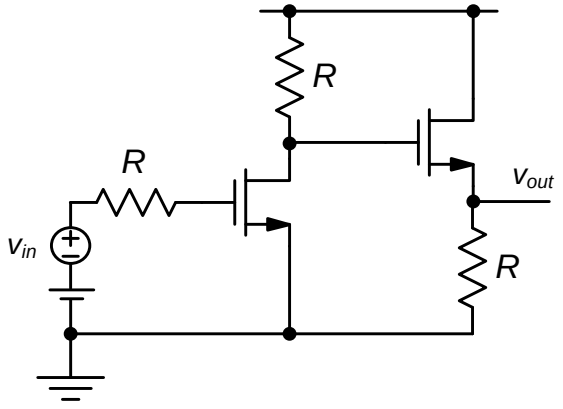


Figure P6-12

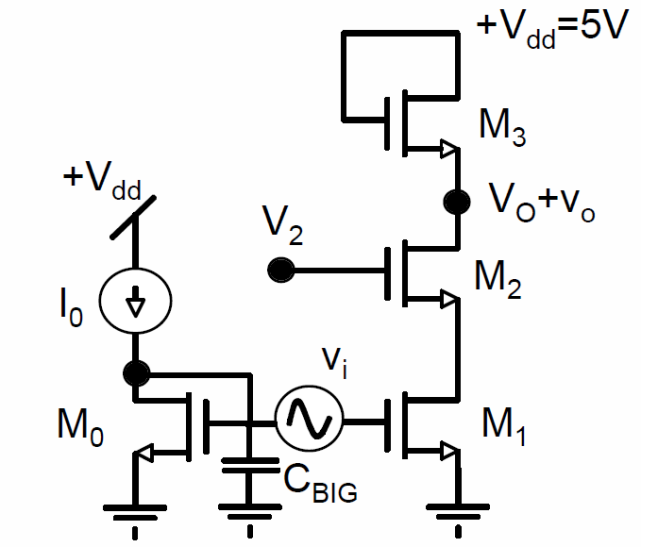


Figure P6-13

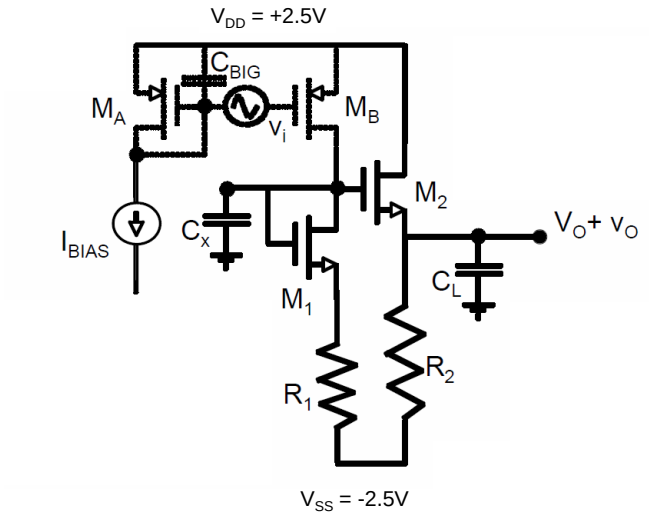


Figure P6-14

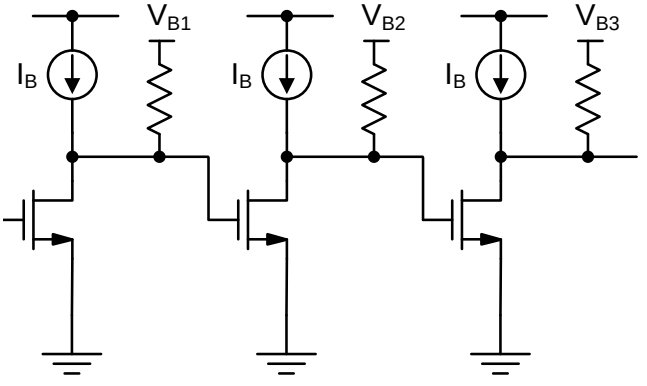
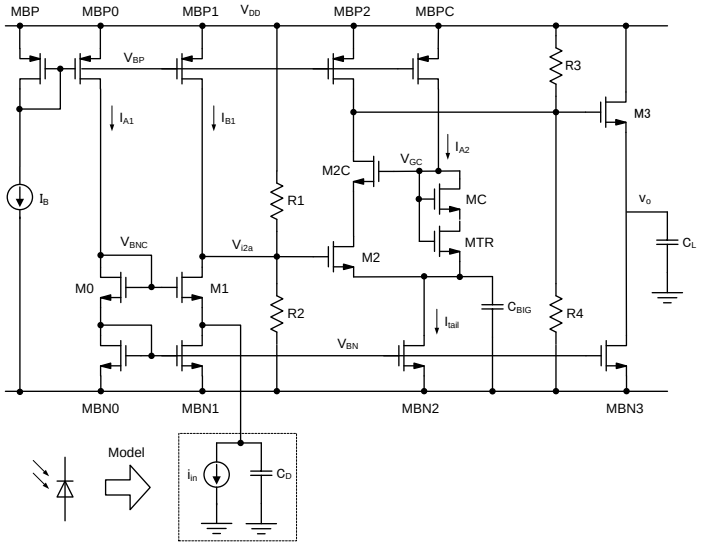


Figure P6-15


MBP
MBP0
MBP1
V_{DD}
MBP2
MBPC
V_{BP}
R3
M3
I_{A1}
I_{B1}
I_{A2}
V_{GC}
M2C
I_B
R1
MC
v_o
MTR
V_{BNC}
V_{i2a}
M2
C_L
M0
M1
C_{BIG}
R2
R4
I_{tail}
V_{BN}
MBN0
MBN1
MBN2
MBN3
Model
i_{in}
C_D