EE538_Wi2021_Midterm_Practice_solution

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Midterm Practice

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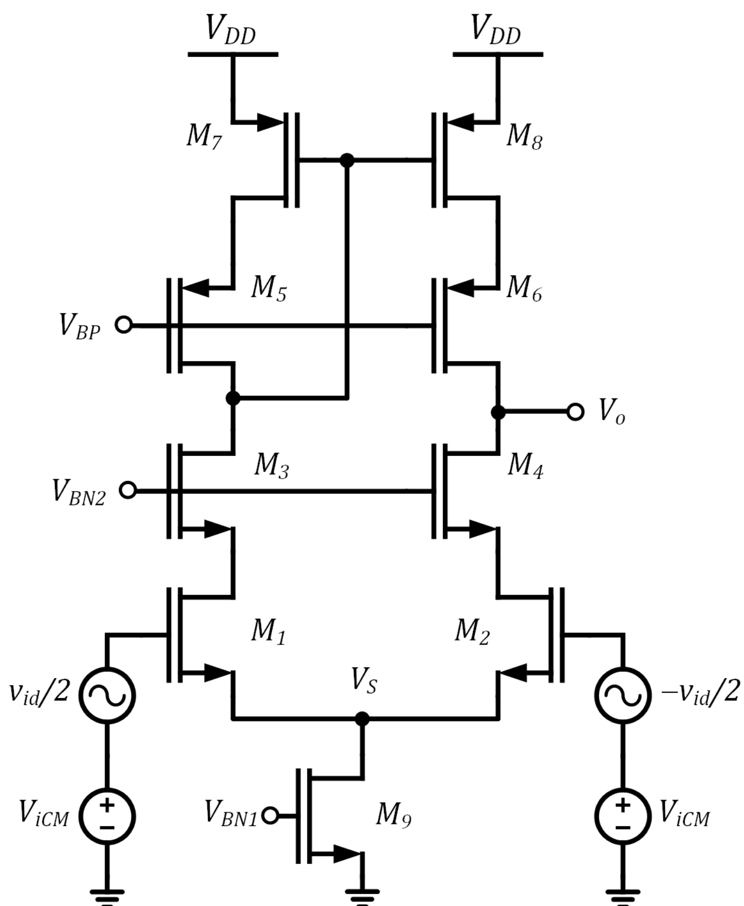
Problem 1:Cascode amplifier design



For the following, use the long channel drain current expression and assume $\lambda = 0$ and $\gamma = 0$ unless otherwise stated.

Use $I_{D9} = 1mA$, $V_{DD} = 3V$, $\mu_n C_{ox} = 100\mu A/V^2$, $\mu_p C_{ox} = 50\mu A/V^2$, $V_{thn} = V_{thp} = 500mV$, $L_n = L_p = L_{eff} = 1\mu m$

[2]:
```python
import numpy as np
I_BIAS = 1e-3
I_D = I_BIAS/2
V_DD = 3
K_n = 100e-6
K_p = 50e-6
V_th = 0.5
L = 1e-6
```

a) Size M_5, M_6, M_7, and M_8 for overdrive voltages of $200mV$. What is the DC output voltage of the amplifier?

[10]:
```python
V_ovp = 0.2
W_p = 2*L*I_D/K_p/V_ovp**2
V_SGp = V_ovp + V_th
V_G7 = V_DD - V_SGp
print('The width of M5 through M8 is', 1e6*W_p, 'um')
print('The DC output voltage is', V_G7, 'V')
```

```
The width of M5 through M8 is 499.9999999999999 um
The DC output voltage is 2.3 V
```

b) Determine the value of V_{BP} required such that $V_{SD7} = V_{SD8} = 300mV$. Based on this value, are M_5 and M_6 in saturation?

[17]:
```python
V_SD7 = 0.3
V_GS5 = V_ov5 + V_th
V_D7 = 3 - V_SD7
V_BP = V_D7 - V_GS5
print('The value of VBP is', V_BP, 'V')
print('The drain voltage of M5 is', V_G7, 'V')
print('The source voltage of M5 is', V_D7, 'V')
print('The source-drain voltage of M5 is ', V_D7 - V_G7, ', which is greater␣
 ↪than the overdrive voltage (M5 and M6 are in saturation.' )
```

```
The value of VBP is 2.0 V
The drain voltage of M5 is 2.3 V
The source voltage of M5 is 2.7 V
The source-drain voltage of M5 is  0.40000000000000036 , which is greater than
the overdrive voltage (M5 and M6 are in saturation.
```

c) Size $M_{1,2}$ for $g_{m1,2} = 10mS$.

[5]:
```python
g_m1 = 10e-3
V_ov1 = 2*I_D/g_m1
W_1 = 2*L*I_D/K_n/V_ov1**2
print('The width of M1 and M2 is', 1e6*W_1, 'um')
```

```
The width of M1 and M2 is 999.9999999999998 um
```

d) Size M_3 and M_4 for overdrive voltages of $200mV$.

[6]:
```
V_ov3 = 0.2
W_3 = 2*L*I_D/K_n/V_ov3**2
print('The width of M3 and M4 is', 1e6*W_3, 'um')
```

```
The width of M3 and M4 is 249.99999999999994 um
```

e) If the maximum value of V_{iCM} is $1.5V$, determine the value of V_{BN2} that ensures $M_{1,2}$ remain in saturation.

[7]:
```
V_iCM = 1.5
V_GS1 = V_ov1 + V_th
V_S1 = V_iCM - V_GS1
V_D1 = V_S1 + V_ov1
V_GS3 = V_ov3 + V_th
V_BN2 = V_D1 + V_GS3
print('The value of VBN2 is', V_BN2, 'V')
```

```
The value of VBN2 is 1.7 V
```

f) If the minimum value of V_{iCM} is $1V$, determine size of M_9 that ensures it remains in saturation.

[21]:
```
V_iCM = 1
V_D9 = V_iCM - V_GS1
V_ov9 = V_D9
W_9 = 2*L*I_BIAS/K_n/V_ov9**2
print('The width of M9 is', 1e6*W_9, 'um')
```

```
The width of M9 is 124.99999999999997 um
```

g) Determine the small-signal gain of the amplifier if $\lambda_n = 0.01V^{-1}$ and $\lambda_p = 0.02V^{-1}$.

[19]:
```
lambda_n = 0.01
lambda_p = 0.02
r_on = 1/lambda_n/I_D
r_op = 1/lambda_p/I_D
g_m6 = 2*I_D/V_ov5
g_m4 = 2*I_D/V_ov3
G_m = g_m1
R_up = g_m6*r_op**2
R_dn = g_m4*r_on**2
R_o = R_up*R_dn/(R_up+R_dn)
A_0 = G_m * R_o
print('The small-signal gain is ', 20*np.log10(A_0), 'dB')
```

```
The small-signal gain is  112.04119982655925 dB
```