1) For the circuit shown in figure 1, and for each of the two limiting cases given below, calculate the poles and zeros of the transfer function $A(f) = \frac{v_{out}}{v_{in}}$ and draw the piece-wise linear approximation of the Bode plot.

Ignore all other capacitances besides the capacitances drawn explicitly in figure 1. Assume $M_{1a} = M_{1b}$, $M_{2a} = M_{2b}$, $M_{3a} = M_{3b}$.

a) $C_2 \ll C_1 / (g_m(r_o,1||r_o,2))$

b) $C_2 \gg C_1 / (g_m(r_o,1||r_o,2))$

![Figure 1.](image-url)
2) For the circuit shown in figure 2:

a) Calculate the low-frequency small-signal gain $A_{dm}$ and use the zero-value time-constant method to estimate the -3dB frequency of $A_{dm}$.

b) Using the .pz analysis in SPICE, determine all the poles and zeros of $A_{dm}$, and compare the lowest pole with the answer found in part a). Explain any differences larger than 10%.

c) Using the .ac analysis in SPICE, make a Bode plot for magnitude and phase of $A_{dm}$, determine the -3dB frequency and compare with part a). Explain any differences larger than 10%.

Assume $V_{DD} = 1.2$ V, $W_1 = W_2 = W_3 = 4$ µm, $W_4 = 8$ µm, $L = 0.13$ µm, $R_D = 4$ KΩ, $R_G = 1$ KΩ, $I_B = 400$ µA.

![Figure 2.](image-url)
SPICE Models

.model nmos
+ nmos level=1 tox=2.6n vt0=0.3 gamma=0.2 phi=0.6 u0=250 ld=0.025u
+ capop=0 acm=3 ldif=0 hdif=0.2u cj=8e-4 cjsw=8e-12 cjgate=8e-11
+ lambda=0.2

.model pmos
+ pmos level=1 tox=2.6n vt0=-0.3 gamma=0.2 phi=0.6 u0=100 ld=0.025u
+ capop=0 acm=3 ldif=0 hdif=0.2u cj=8e-4 cjsw=8e-12 cjgate=8e-11
+ lambda=0.15

SPICE Hints

• .pz analysis: pole-zero analysis

An analysis statement like ‘.pz v(out) vin’ will print all the poles and zeros of the transfer function from the independent source vin to the output voltage v(out) (similar to a .tf analysis)

A pole and zero (or pole-pair and zero-pair) very close to each other, might indicate a numerical artifact, rather than an actual pole and zero.

• .ac analysis: small signal analysis as a function of frequency

An analysis statement like ‘.ac dec 10 1M 1T’ will do an .ac analysis from 1 MHz to 1 THz with 10 points per decade of frequency.

You have to specify at least one independent small signal source, by adding an ‘ac’ option to a small signal source: ‘vin in gnd dc=0.5 ac=1’. The .ac analysis will then calculate the small signal voltage on every single node.