

## ESE411 Homework 7

Obtain the amplitude and phase responses of the voltage gain for amplifiers A, B and C shown in Figures A, B, and C, respectively. All MOSFETs are enhancement mode devices with threshold voltages  $V_{tn} = 0.7 \text{ V}$  and  $V_{tp} = -0.8 \text{ V}$ . All devices operate in saturation with the following transconductances and output resistances:

$g_{m\_n} = g_{m1} = g_{m2} = 0.3 \text{ mA/V}$ ,  $g_{m\_p} = g_{m3} = g_{m4} = 0.5 \text{ mA/V}$ ,

$R_{o\_n} = r_{o1} = r_{o2} = 100 \text{ k}\Omega$ ,  $r_{o\_p} = r_{o3} = r_{o4} = 50 \text{ k}\Omega$

The amplifiers operate on  $C_{load} = 100 \text{ fF}$ . The MOSFET capacitances are as follows:  $C_{gs\_n} = C_{gs1} = C_{gs2} = 20 \text{ fF}$ ,  $C_{gs\_p} = C_{gs3} = C_{gs4} = 120 \text{ fF}$ ,  $C_{gd\_n} = C_{gd1} = C_{gd2} = 5 \text{ fF}$ ,  $C_{gd\_p} = C_{gd3} = C_{gd4} = 30 \text{ fF}$ . For amplifiers A and B: consider a single pole response formed by output resistance  $R_{out}$  and combination of  $C_{load}$ ,  $C_{gd\_n}$ ,  $C_{gd\_p}$ .

For amplifier C consider a two pole response: one pole is formed by  $R_{out}$  and  $C_{load}$ ,  $C_{gd2}$ ,  $C_{gd3}$ . Another pole is formed by combination of  $C_{gs2}$  and  $C_{gd1}$  and the resistance seen by this capacitance. The latter is formed by  $r_{o1}$  and resistance  $R_{in2}$  looking into the source terminal of M2. At high frequencies of interest  $R_{in2} = 1/g_{m2}$  due to small impedance of  $C_{load}$  compared to  $R_{out}$ .

1. Calculate the time constants forming the poles of amplifiers A, B, and C.  
Present calculations of the time constants and pole frequencies in the next page (right side).
2. Sketch the amplitude and phase responses of the voltage gain  $V_{out}/V_{in}$  for amplifiers A, B, C using the same Bode plot template for comparison. Note that inverting amplifiers have a 180 deg phase shift at low frequencies.
3. Estimate the range of output voltage ( $V_{out \text{ max}}$ ,  $V_{out \text{ min}}$ ) for circuits A, B, and C. Within the range of  $V_{out}$  all MOSFETs have to operate in the saturation region. In all circuits  $V_{dd} = +3\text{V}$ .
4. Complete the table template with parameters in the next page. Upload a copy of page 2 to Bb for grading.

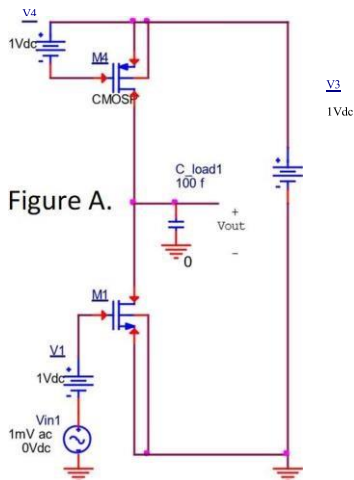


Figure A

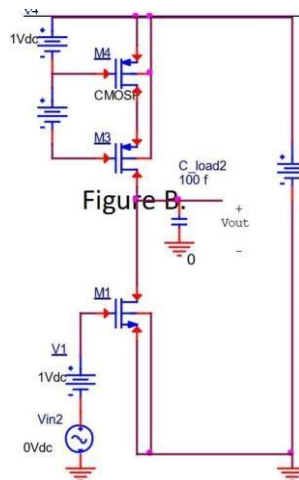


Figure B

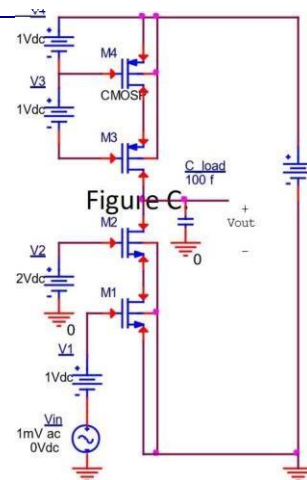
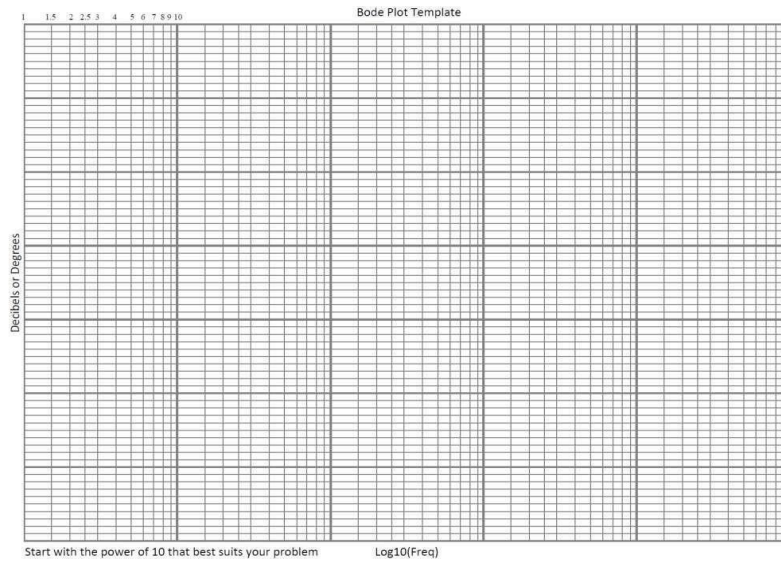


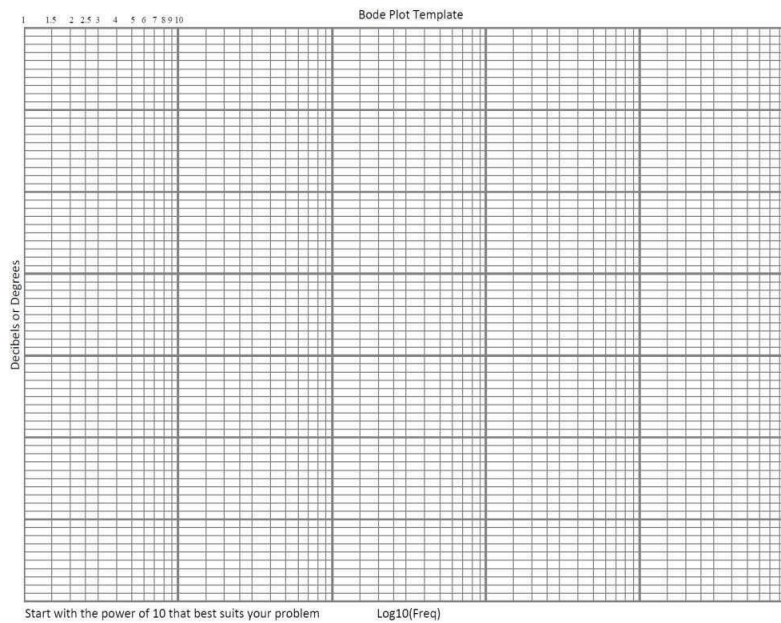
Figure C

Name \_\_\_\_\_ ID \_\_\_\_\_ Date \_\_\_\_\_

1. Amplitude responses of the voltage gain for amplifiers A, B and C.



Phase responses for amplifiers A, B and C.



2. DC voltage gain, bandwidth and output voltage range for the amplifiers:

	A	B	C
DC gain, dB			
Bandwidth (-3 dB), MHz			
Vout max, V			
Vout min, V			

