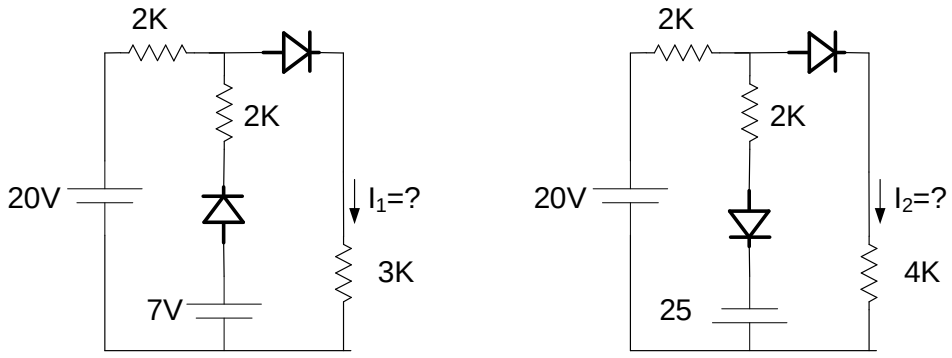
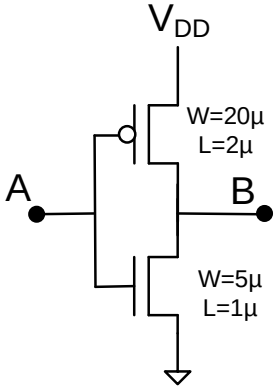
EE 330
Homework 7
Fall 2019 Due Friday Oct 11

Unless specified to the contrary, assume all n-channel MOS transistors have model parameters $\mu_n C_{OX} = 300\mu A/V^2$ and $V_{Tn0} = 0.5V$, all p-channel transistors have model parameters $\mu_p C_{OX} = 75\mu A/V^2$ and $V_{Tp0} = -0.5V$. Correspondingly, assume that at T=300K, all npn BJT transistors have model parameters $J_S = 10^{-14} A/\mu^2$ and $\beta=100$ and all pnp BJT transistors have model parameters $J_S = 10^{-14} A/\mu^2$ and $\beta = 25$. If the emitter area of a transistor is not given, assume it is $100\mu^2$. If parameters are needed for process characterization beyond what is given, use the measured parameters from the TSMC 0.18μ process given below as model parameters.

Problem 1 Determine the currents indicated with a ? in the following circuits. Assume the diodes are ideal.



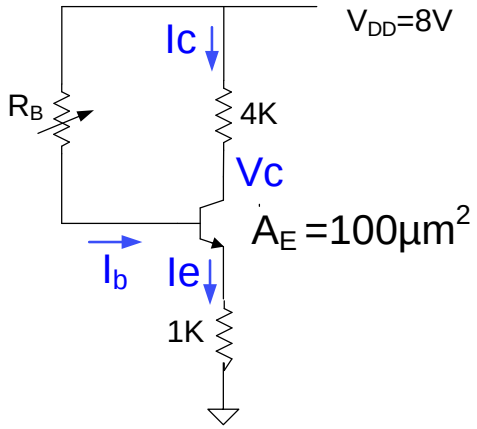
Problem 2 Consider the following inverter. Determine the switch-level model for this inverter that includes the input capacitance and the pull-up and pull-down resistors.



Problem 3 The following circuit was constructed for measuring the β of the bipolar transistor. To obtain the β, the resistor R_B was adjusted so that the current I_c was

precisely 1.000mA. The current I_e was then measured to be 1.0250mA. From these measurements the parameter α of the transistor was obtained and then β was calculated using the well-known relationship between α and β.

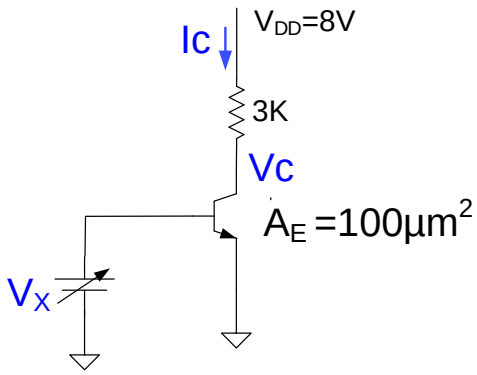
a) What is the value of β for the transistor?
b) What would be the worst-case error (in percent) in measuring the β of the transistor using this approach if the current measurements were only accurate to ±0.5%?



Problem 4 As an alternative to measuring β in the circuit for the previous problem (assuming β is the value determine in part a) of the previous problem), the currents I_b and I_c were measured. What would be the worst-case error (in percent) in measuring the β of the transistor using this alternative approach if the current measurements of I_b and I_c were only accurate to ±0.5%?

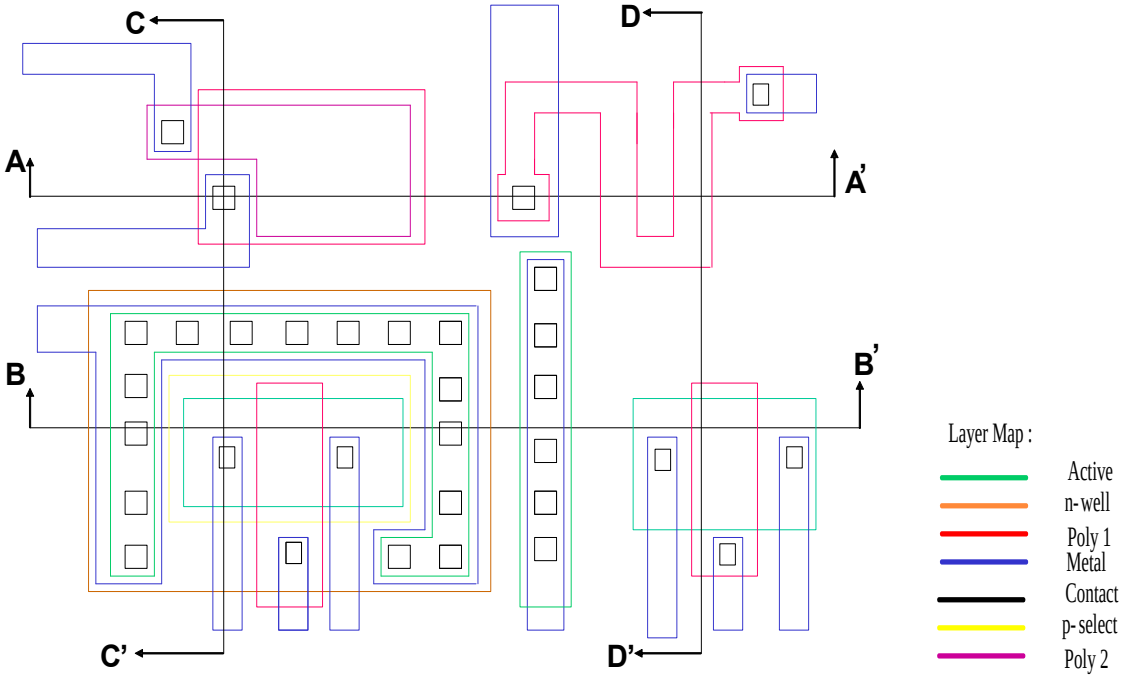
Problem 5 Assume the transistor in the following circuit is operating at T=300K and the β of the transistor is 200. Assume the parameter J_{SX} =20Ma/μ^2.

a) Precisely determine the value of V_X required to force the collector voltage, V_C, to be 5V.
b) If the value of Vx is decreased by 10uV from the value determined by Vx in part a), how much change will occur in the voltage V_C?
c) If the temperature is increased by 1^{o}C, how much will the voltage obtained in part a) change?
d) Comment on how sensitive this circuit is to change in V_X and to changes in T.



Problem 6 Sketch a cross-sectional view along the AA' cross-section line for the CMOS layout shown below. Assume a basic CMOS process in which the n-select mask is generated from the compliment of the p-select mask.

Problem 7 Repeat Problem 6 for the CC' cross-section



Problem 8 and 9

Using Modelsim, create a positive edge trigged D Flip-Flop. The inputs should be D, iRST, and a clock with a frequency of 1MHz. The output will be Q. iRST serves as a reset that will cause the DFF to output zero if iRST=1. Create a test bench to verify that your DFF functions properly for all input states and that it triggers on the positive edge of the clock. Include screenshots of your Verilog code and simulation waveforms.

MOSIS WAFER ACCEPTANCE TESTS

RUN: T68B (MM_NON-EPI) VENDOR: TSMC
TECHNOLOGY: SCN018 FEATURE SIZE: 0.18 microns
Run type: SKD

INTRODUCTION: This report contains the lot average results obtained by MOSIS from measurements of MOSIS test structures on each wafer of this fabrication lot. SPICE parameters obtained from similar measurements on a selected wafer are also attached.

COMMENTS: DSCN6M018_TSMC

TRANSISTOR PARAMETERS	W/L	N-CHANNEL	P-CHANNEL	UNITS
MINIMUM	0.27/0.18			
Vth		0.50	-0.51	volts
SHORT	20.0/0.18			
Idss		547	-250	uA/um
Vth		0.51	-0.51	volts
Vpt		4.8	-5.6	volts
WIDE	20.0/0.18			
Ids0		14.4	-4.7	pA/um
LARGE	50/50			
Vth		0.43	-0.42	volts
Vjbkd		3.1	-4.3	volts
Ijlk		<50.0	<50.0	pA
K' (Uo*Cox/2)		175.4	-35.6	uA/V^2
Low-field Mobility		416.52	84.54	cm^2/V*s

COMMENTS: Poly bias varies with design technology. To account for mask bias use the appropriate value for the parameters XL and XW in your SPICE model card.

Design Technology	XL (um)	XW um)
SCN6M_DEEP (lambda=0.09)	0.00	-0.01
thick oxide	0.00	-0.01
SCN6M_SUBM (lambda=0.10)	-0.02	0.00
thick oxide	-0.02	0.00

FOX TRANSISTORS	GATE	N+ACTIVE	P+ACTIVE	UNITS
Vth	Poly	>6.6	<-6.6	volts

PROCESS PARAMETERS	N+	P+	POLY	N+BLK	PLY+BLK	M1	M2	UNITS
Sheet Resistance	6.7	7.8	8.0	59.7	313.6	0.08	0.08	ohms/sq
Contact Resistance	10.6	11.0	10.0				4.79	ohms
Gate Oxide Thickness	41							angstrom

PROCESS PARAMETERS	M3	POLY_HRI	M4	M5	M6	N_W	UNITS
Sheet Resistance	0.08		0.08	0.08	0.03	930	ohms/sq
Contact Resistance	9.24		14.05	18.39	20.69		ohms

COMMENTS: BLK is silicide block.

CAPACITANCE PARAMETERS	N+	P+	POLY	M1	M2	M3	M4	M5	M6	R_W	D_N_W	M5P	N_W	UNITS
Area (substrate)	942	1163	106	34	14	9	6	5	3		123		125	aF/um^2
Area (N+active)			8484	55	20	13	11	9	8					aF/um^2
Area (P+active)			8232											aF/um^2
Area (poly)				66	17	10	7	5	4					aF/um^2
Area (metal1)					37	14	9	6	5					aF/um^2
Area (metal2)						35	14	9	6					aF/um^2
Area (metal3)							37	14	9					aF/um^2
Area (metal4)								36	14					aF/um^2
Area (metal5)									34				984	aF/um^2
Area (r well)	920													aF/um^2
Area (d well)										582				aF/um^2
Area (no well)	137													aF/um^2
Fringe (substrate)	212	235	41	35	29	21	14							aF/um
Fringe (poly)			70	39	29	23	20	17						aF/um
Fringe (metal1)				52	34		22	19						aF/um
Fringe (metal2)					48	35	27	22						aF/um
Fringe (metal3)						53	34	27						aF/um
Fringe (metal4)							58	35						aF/um
Fringe (metal5)								55						aF/um
Overlap (N+active)			895											aF/um
Overlap (P+active)			737											aF/um

CIRCUIT PARAMETERS			UNITS
Inverters	K		
Vinv	1.0	0.74	volts
Vinv	1.5	0.78	volts
Vol (100 uA)	2.0	0.08	volts
Voh (100 uA)	2.0	1.63	volts
Vinv	2.0	0.82	volts
Gain	2.0	-23.72	
Ring Oscillator Freq.			
D1024_THK (31-stg,3.3V)		300.36	MHz
DIV1024 (31-stg,1.8V)		363.77	MHz
Ring Oscillator Power			
D1024_THK (31-stg,3.3V)		0.07	uW/MHz/gate
DIV1024 (31-stg,1.8V)		0.02	uW/MHz/gate