EE134 Midterm.

1. (10 pts) Draw the layout of an **N**MOSFET. Include the ground tie. Label each layer.

2. (10 pts) Underneath and aligned to the layout of problem (1), draw the cross-section. Label each region of the cross-section. Also label source, drain, gate, and ground tie. Draw the parasitic diodes with the correct polarity.

3. (10 pts) From the MOSIS measured parameters (next page), calculate the delay time through a 100 μm long by 1 μm wide P^+ layer.

4. Design a minimum delay line for driving a 5 pF load. The first inverter has L=0.6 μm and W = 1 μm for both the NMOS and PMOS. Take physical parameters from the SPICE parameters at the bottom of the data sheet attached.
   (a) (10 pts) Calculate $C_{in,1}$
   (b) (10 pts) Calculate N
   (c) (10 pts) Calculate A
   (d) (10 pts) What is the width of the last inverter?
   (e) (10 pts) What is the minimal delay?

5. (10 pts) What is the frequency of an 801 inverter ring oscillator made with L=0.6 μm and W = 1μm inverters?

6. (10 pts) You must layout a large CMOS inverter to drive an output pin. Describe what you will do to reduce the chance of latch-up?

MOSIS PARAMETRIC TEST RESULTS

RUN: T3AF VENDOR: AMI

TECHNOLOGY: SCN05 FEATURE SIZE: 0.5 microns

COMMENTS: American Microsystems, Inc. C5

TRANSISTOR PARAMETERS	W/L	N-CHANNEL	P-CHANNEL	UNITS
MINIMUM	3.0/0.6			
Vth		0.79	-0.94	volts
SHORT	20.0/0.6			
Idss		466	-255	uA/um
Vth		0.67	-0.92	volts
Vpt		10.0	-10.0	volts
WIDE	20.0/0.6			
Ids0		< 2.5	< 2.5	pA/um
LARGE	50/50			
Vth		0.71	-0.96	volts
Vjbkd		11.4	-11.7	volts
Ijlk		<50.0	<50.0	pA
Gamma		0.47	0.59	V^0.5
K' (Uo*Cox/2)		57.0	-18.6	uA/V^2
Low-field Mobility		465.50	151.90	cm^2/V*s

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

Design Technology	XL (um)	XW (um)
SCMOS_SUBM (lambda=0.30)	0.10	0.00
SCMOS (lambda=0.35)	0.00	0.20

FOX TRANSISTORS	GATE	N+ACTIVE	P+ACTIVE	UNITS
Vth	Poly	>15.0	<-15.0	volts

PROCESS PARAMETERS	N+	P+	POLY	PLY2_HR	POLY2	MTL1	MTL2	UNITS
Sheet Resistance	82.3	105.7	21.8	995	40.5	0.09	0.09	ohms/sq
Contact Resistance	55.0	136.1	14.5		25.0		0.89	ohms
Gate Oxide Thickness	141							angstrom

PROCESS PARAMETERS	MTL3	N\PLY	N_W	UNITS
Sheet Resistance	0.05	831	820	ohms/sq
Contact Resistance	0.85			ohms

COMMENTS: N\POLY is N-well under polysilicon.

CAPACITANCE PARAMETERS	N+	P+	POLY	POLY2	M1	M2	M3	N_W	UNITS
Area (substrate)	428	726	87		33	17	10	42	aF/um^2
Area (N+active)			2456		36	17	12		aF/um^2
Area (P+active)			2366						aF/um^2
Area (poly)				883	62	16	9		aF/um^2
Area (poly2)					53				aF/um^2
Area (metal1)						31	13		aF/um^2
Area (metal2)							32		aF/um^2
Fringe (substrate)	308	253			76	59	39		aF/um
Fringe (poly)					63	38	28		aF/um
Fringe (metal1)						51	34		aF/um
Fringe (metal2)							49		aF/um
Overlap (N+active)			217						aF/um
Overlap (P+active)			298						aF/um

CIRCUIT PARAMETERS	K		UNITS
Inverters			
Vinv	1.0	2.03	volts
Vinv	1.5	2.30	volts
Vol (100 uA)	2.0	0.12	volts
Voh (100 uA)	2.0	4.87	volts
Vinv	2.0	2.48	volts
Gain	2.0	-18.10	
Ring Oscillator Freq.			
DIV256 (31-stg,5.0V)		98.84	MHz
D256_WIDE (31-stg,5.0V)		157.58	MHz
Ring Oscillator Power			
DIV256 (31-stg,5.0V)		0.47	uW/MHz/gate
D256_WIDE (31-stg,5.0V)		0.99	uW/MHz/gate

COMMENTS: SUBMICRON

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* Temp= 27
.MODEL CMOSN NMOS (                                LEVEL  = 3
+ TOX    = 1.4E-8          NSUB   = 1E17           GAMMA  = 0.5483559
+ PHI    = 0.7             VTO    = 0.7640855      DELTA  = 3.0541177
+ UO     = 662.6984452     ETA    = 3.162045E-6    THETA  = 0.1013999
+ KP     = 1.259355E-4     VMAX   = 1.442228E5     KAPPA  = 0.3
+ RSH    = 7.513418E-3     NFS    = 1E12           TPG    = 1
+ XJ     = 3E-7            LD     = 1E-13          WD     = 2.334779E-7
+ CGDO   = 2.15E-10        CGSO   = 2.15E-10       CGBO   = 1E-10
+ CJ     = 4.258447E-4     PB     = 0.9140376      MJ     = 0.435903
+ CJSW   = 3.147465E-10    MJSW   = 0.1977689      )
*
.MODEL CMOSP PMOS (                                LEVEL  = 3
+ TOX    = 1.4E-8          NSUB   = 1E17           GAMMA  = 0.6243261
+ PHI    = 0.7             VTO    = -0.9444911     DELTA  = 0.1118368
+ UO     = 250             ETA    = 0              THETA  = 0.1633973
+ KP     = 3.924644E-5     VMAX   = 1E6            KAPPA  = 30.1015109
+ RSH    = 33.9672594      NFS    = 1E12           TPG    = -1
+ XJ     = 2E-7            LD     = 5E-13          WD     = 4.11531E-7
+ CGDO   = 2.34E-10        CGSO   = 2.34E-10       CGBO   = 1E-10
+ CJ     = 7.285722E-4     PB     = 0.96443        MJ     = 0.5
+ CJSW   = 2.955161E-10    MJSW   = 0.3184873      )
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