Diode Review

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11-29-10 diode_review.ppt

OUTLINE

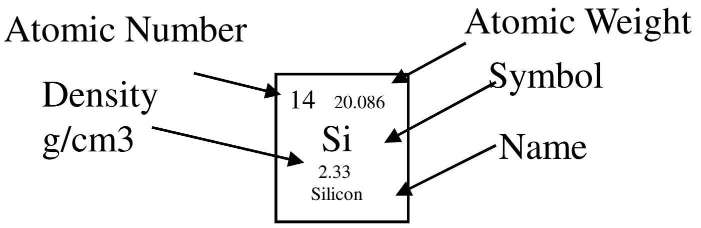
Uniform Doped pn Junction
Real pn Junctions
Diode Temperature Sensors
Photodiodes
Other Semiconductors
LEDs

CONSTANTS

Electronic charge	q	1.602 E -19 Coulomb
Speed of light in vacuum	c	2.998E8 m/s
Permittivity of vacuum	εo	8.854 E -14 F/cm
Free electron Mass	m_o	9.11E-31 Kg
Planck constant	h	6.625E-34 J s
Boltzmann constant	k	1.38 E-23 J /°K = 8.625E-5 eV/°K
Avogadro’s number	A_o	6.022E23 molecules/gm- mole
Thermal voltage	kT/q	@ 300 °K = 0.02586

PLAY

PERIODIC TABLE OF THE ELEMENTS



1 1.0079 H 0.0899 Hydrogen																	2 4.0026 He 0.1787 Helium
3 6.914 Li 0.53 Lithium	4 9.01218 Be 1.85 Beryllium											5 10.81 B 2.34 Boron	6 12.011 C 2.62 Carbon	7 14.0067 N 1.251 Nitrogen	8 15.9994 O 1.429 Oxygen	9 18.9984 F 1.696 Fluorine	10 20.179 Ne 0.901 Neon
11 22.9898 Na 0.97 Sodium	12 24.305 Mg 1.74 Magnesium											13 26.9815 Al 2.70 Aluminum	14 20.086 Si 2.33 Silicon	15 30.97376 P 1.82 Phosphorous	16 32.06 S 2.07 Sulfur	17 35.453 Cl 3.17 Clorine	18 39.948 Ar 1.784 Argon
19 39.0983 K 0.86 Potassium	20 40.08 Ca 1.55 Calcium	21 44.9559 Sc 3.0 Scandium	22 47.90 Ti 4.50 Titanium	23 50.941 V 5.8 Vanadium	24 51.996 Cr 7.19 Chromium	25 54.938 Mn 7.43 Manganese	26 55.847 Fe 7.86 Iron	27 58.9332 Co 8.90 Selenium	28 58.70 Ni 8.90 Nickel	29 63.546 Cu 8.96 Copper	30 65.238 Zn 7.14 Zinc	31 69.72 Ga 5.98 Gallium	32 72.59 Ge 5.32 Germanium	33 74.9216 As 5.72 Arsenic	34 78.96 Se 4.80 Selenium	35 79.904 Br 3.12 Bromine	36 83.80 Kr 3.74 Krypton
37 85.468 Rb 1.53 Rubidium	38 87.62 Sr 2.8 Strontium	39 88.906 Y 4.5 Yttrium	40 91.22 Zr 6.49 Zirconium	41 92.906 Nb 8.55 Niobium	42 95.94 Mo 10.2 Molybdenum	43 98 Tc 11.5 Technetium	44 101.07 Ru 12.2 Rhodium	45 102.9055 Rh 12.4 Rhodium	46 106.4 Pd 12.0 Palladium	47 107.868 Ag 10.5 Silver	48 112.41 Cd 8.65 Cadmium	49 114.82 In 7.31 Indium	50 118.69 Sn 7.30 Tin	51 121.75 Sb 6.68 Antimony	26 55.847 Te 6.24 Tellurium	26 127.60 Fe 7.86 Tellurium	54 131.30 Xe 5.89 Xenon
55 132.90 Cs 1.87 Cesium	56 137.33 Ba 3.5 Barium	57 138.906 La 6.7 Lanthanum	58 178.49 Hf 13.1 Hafnium	59 180.95 Ta 16.6 Tantalum	60 183.85 W 19.3 Tungstem	61 186.207 Re 21.0 Rhenium	76 190.2 Os 22.4 Osmium	77 192.22 Ir 27.16 Iridium	78 195.09 Pt 21.4 IPlatinum	79 196.9665 Au 19.3 Gold	80 200.59 Hg 13.53 Mercury	81 204.37 Tl 11.85 Thallium	82 207.2 Pb 11.4 Lead	83 206.980 Bi 9.8 Bismuth	84 209 Po 9.4 Polonium	85 210 At ??? Astatine	86 222 Rn 9.91 Radon
87 223 Fr ??? Francium	88 226.02 Ra 5 Radium	89 227.02 Ac 10.07 Actinium	104 261 Unq ???? Unnilquadium	105 262 Unp Unnilpentium	106 263 Unh ???? Unnilhexium												
				58 140.12 Ce 6.78 Cerium	59 140.91 Pr 6.77 Praseoymium	60 144.24 Nd 7.00 Neodymium	61 145 Pm 6.475 Promethium	62 150.4 Sm 7.54 Samarium	63 151.96 Eu 5.26 Europium	64 157.25 Gd 7.89 Gadolinium	65 158.92 Tb 8.27 Terbium	66 162.5 Dy 8.54 Dysprosium	67 164.93 Ho 8.90 Holmium	68 167.26 Er 9.06 Erbium	69 169.93 Tm 9.33 Thulium	70 173.04 Yb 6.98 Ytterbium	71 174.97 Lu 9.84 Lutetium
				90 232.0 Th 11.7 Thorium	91 231 Pa 15.4 Protactinium	92 238.02 U 18.90 Uranium	93 237 Np 20.4 Neptunium	94 237 Pu 19.8 Plutonium	95 243 Am 13.6 Americium	96 247 Cm 13.511 Curium	97 247 Bk ???? Berkelium	98 251 Cf ???? Californium	99 252 Es ???? Einsteinium	100 257 Fm ???? Fermiumr	101 258 Md ???? Mendelevium	102 259 No ???? Nobelium	103 260 Lr ???? Lawrencium

PLAY

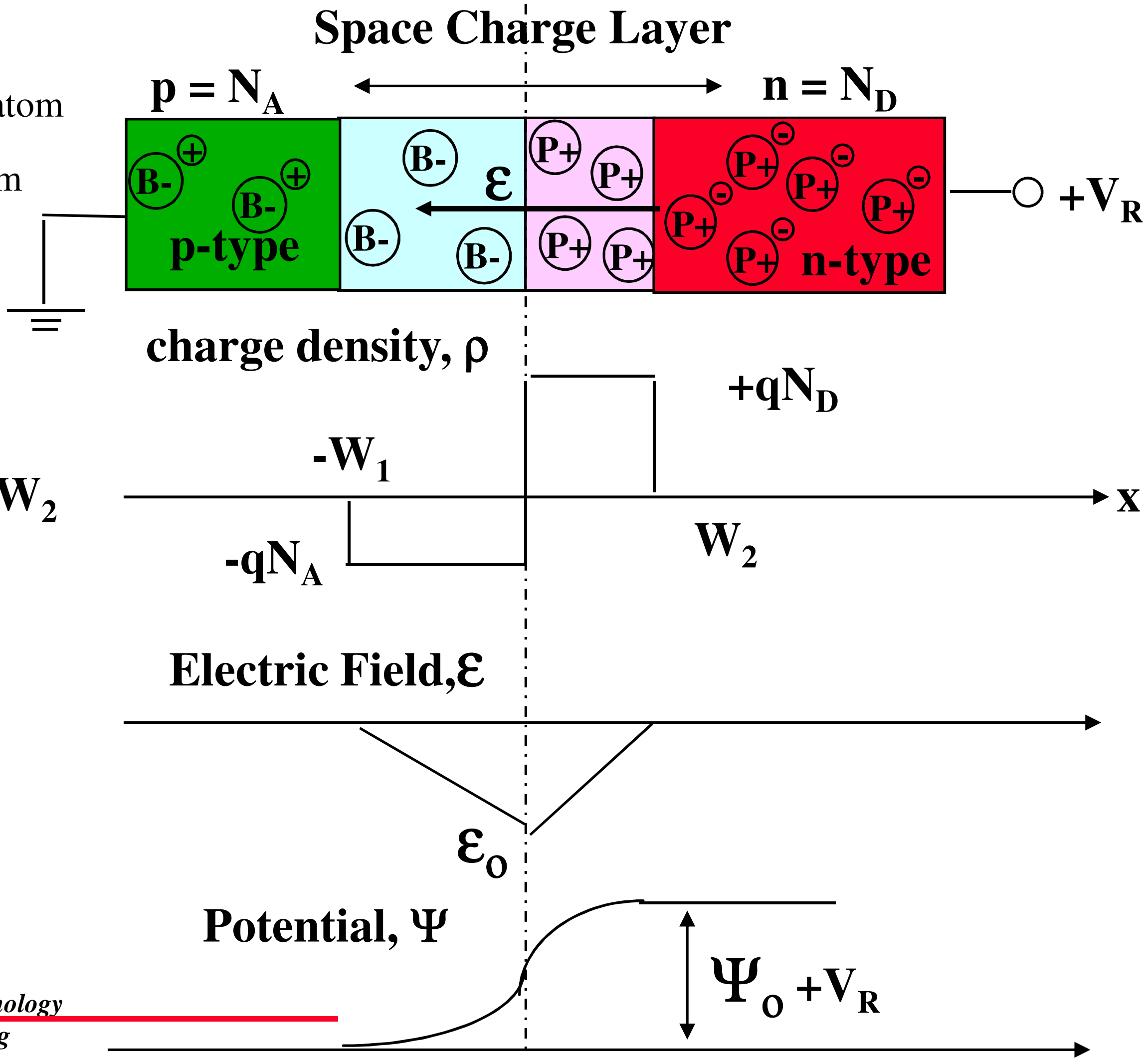
MATERIAL PROPERTIES

	Symbol	Units	Si	Ge	GaAs	GaP	SiO_2	Si_3N_4
Atoms per unit cell			8	8	8	8		
Atomic Number	Z		14	32	31/33	31/15	14/8	14/7
Atomic weight	MW	g/g-mole	28.09	72.59	144.64	100.70	60.08	140.28
Lattice constant	ao	nm	0.54307	0.56575	0.56532	0.54505		0.775
Atomic density	No	cm^{-3}	5.00E22	4.42E22	2.21E22	2.47E22	2.20E22	1.48E22
Density	d	g cm^{-3}	2.328	5.323	5.316	4.13	2.19	3.44
Energy Gap 300°K	Eg	eV	1.124	0.67	1.42	2.24	8~9	4.7
Relative permittivity	εr		11.7	16.0	13.1	10.2	3.9	7.5
Index of refraction	n		3.44	3.97	3.3	3.3	1.46	2.0
Melting point	Tm	°C	1412	937	1237	1467	1700	
Specific heat	Cp	J (gK)$^{-1}$	0.70	0.32	0.35		1.4	0.17
Thermal diffusivity	K	w(cmK)$^{-1}$	0.87	0.36	0.44	0.004	0.32	
Coefficient expansion	Dth	K^{-1}	2.5E-6	5.7E-6	5.9E-6	5.3E-6	5E-6	2.8E-6
Intrinsic carrier conc	ni	cm^{-3}	1.45E10	2.4E13	9.0E6			
Electron Mobility	µn	cm^2/Vs	1417	3900	8800	300	20	
Hole Mobility	µp	cm^2/Vs	471	1900	400	100	10E-8	
Density of States conduction	Nc	cm^{-3}	2.8E19	1.04E19	4.7E17			
Density of States valance	Nv	cm^{-3}	1.04E19	6.0E18	7.0E18			
Breakdown Electric Field	E	V/cm	3E5	8E4	3.5E5		6~9E6	
Effective mass electron	mn*/mo		1.08	0.55	0.068	0.5		
Effective mass hole	mp*/mo		0.81	0.3	0.5	0.5		
Electron affinity	qX	eV	4.05	4.00	4.07	4.3	1.0	

UNIFORMLY DOPED PN JUNCTION

- (P+)⊖ Phosphrous donor atom and electron
- (P+) Ionized Immobile Phosphrous donor atom
- (B-) Ionized Immobile Boron acceptor atom
- (B-)⊕ Boron acceptor atom and hole

$$qN_A W_1 = qN_D W_2$$



UNIFORMLY DOPED pn JUNCTION

From Physical Fundamentals:

Potential Barrier - Carrier Concentration: $\Psi_o = KT/q \ \ln (N_A N_D / ni^2)$

From Electric and Magnetic Fields :

Gauss's Law, Maxwells 1st eqn: $\rho = \nabla \bullet D$

Relationship between electric flux D and electric field E : $D = \varepsilon E$

Poisson's Equation: $\nabla^2 \Psi_o = - \rho / \varepsilon$

Definition of Electric Field: $E = - \nabla V$

Ψ_o FROM PHYSICS (FERMI STATISTICS)

$$q(Vbi) = (Ei - Ef)\text{p-side} + (Ef-Ei)\text{ n-side}$$

$$p= ni\ e^{(Ei-Ef)/KT/q} \qquad n= ni\ e^{(Ef-Ei)/KT/q}$$

$$\ln(p/ni) = \ln e^{(Ei-Ef)/KT/q} \qquad \ln(n/ni) = \ln e^{(Ef-Ei)/KT/q}$$

$$KT/q\ \ln(p/ni) = (Ei-Ef)_{\text{p-side}} \qquad KT/q\ \ln(n/ni) = (Ef-Ei)_{\text{n-side}}$$

$$\boxed{\Psi_o = KT/q\ \ \ln (N_A N_D /ni^2)}$$

$ni = 1.45E10\ cm^{-3}$ for silicon

Where N_A=~p in p-type silicon and N_D=~n in n-type silicon

UNIFORMLY DOPED PN JUNCTION

Built in Voltage: $\Psi_o = KT/q \;\; \ln (N_A N_D / ni^2)$

$ni = 1.45E10 \text{ cm}^{-3}$

Width of Space Charge Layer, W: with reverse bias of V_R volts

$$W = (W_1 + W_2) = [\,(2\varepsilon/ q)\,(\Psi_o + V_R)\,(1/N_A + 1/N_D)]^{1/2}$$

W_1 width on p-side

$W_1 = W\,[N_D/(N_A + N_D)]$

W_2 width on n-side

$W_2 = W\,[N_A/(N_A + N_D)]$

Maximum Electric Field:

$$E_o = -\;[(2q/\varepsilon)\,(\Psi_o + V_R)\,(N_A N_D/(N_A + N_D))]^{1/2}$$

Junction Capacitance per unit area:

$$C_j' = \varepsilon_o\,\varepsilon_r/W \;\; = \varepsilon_o\,\varepsilon_r/[(2\varepsilon/ q)\,(\Psi_o + V_R)\,(1/N_A + 1/N_D)]^{1/2}$$

$\varepsilon = \varepsilon_o\,\varepsilon_r = 8.85E^{-12}\,(11.7)$ F/m

$= 8.85E^{-14}\,(11.7)$ F/cm

EXAMPLE

Example: If the doping concentrations are Na=1E15 and Nd=3E15 cm^{-3} and the reverse bias voltage is 0, then find the built in voltage, width of the space charge layer, width on the n-side, width on the p-side, electric field maximum and junction capacitance. Repeat for reverse bias of 10, 40, and 100 volts.

Ψ_o = Vbi = KT/q ln ($N_A N_D$/ni^2) =

W = (W_1 + W_2) = [(2ε/q) (Ψ_o +V_R) (1/N_A+ 1/N_D)]$^{1/2}$ =

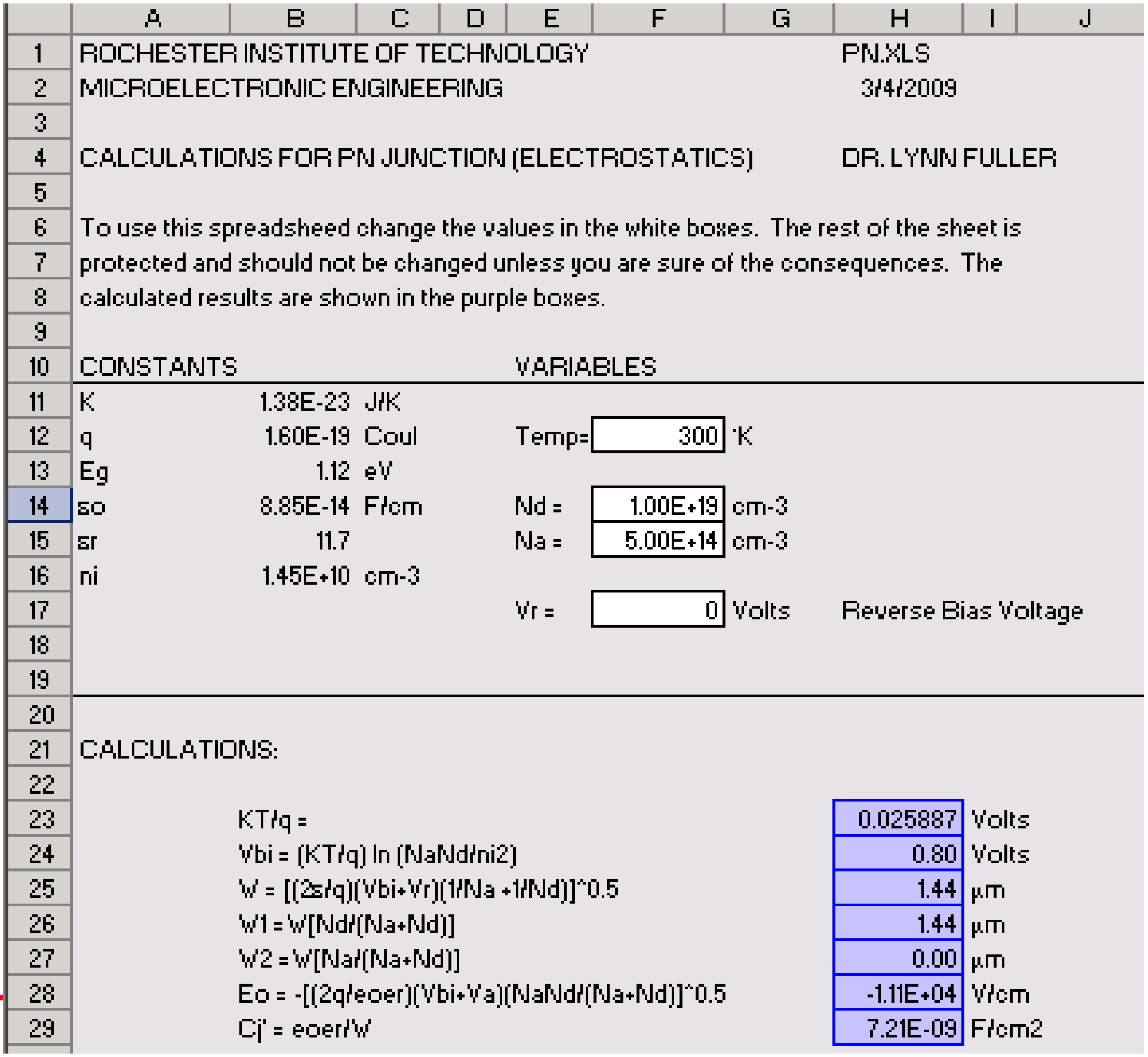
W1 =

W2 =

Emax =

Cj =

EXAMPLE CALCULATIONS

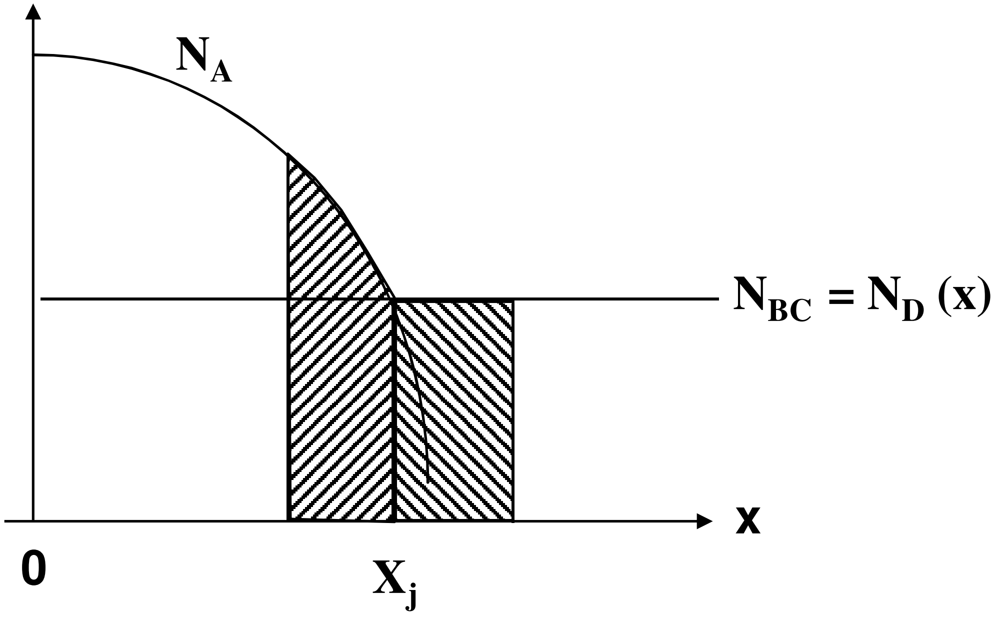


	A	B	C	D	E	F	G	H	I	J
1	ROCHESTER INSTITUTE OF TECHNOLOGY							PN.XLS		
2	MICROELECTRONIC ENGINEERING							3/4/2009		
3										
4	CALCULATIONS FOR PN JUNCTION (ELECTROSTATICS)							DR. LYNN FULLER		
5										
6	To use this spreadsheed change the values in the white boxes. The rest of the sheet is									
7	protected and should not be changed unless you are sure of the consequences. The									
8	calculated results are shown in the purple boxes.									
9										
10	CONSTANTS				VARIABLES					
11	K	1.38E-23	J/K							
12	q	1.60E-19	Coul		Temp=	300	°K			
13	Eg	1.12	eV							
14	so	8.85E-14	F/cm		Nd =	1.00E+19	cm-3			
15	sr	11.7			Na =	5.00E+14	cm-3			
16	ni	1.45E+10	cm-3							
17					Vr =	0	Volts	Reverse Bias Voltage		
18										
19										
20										
21	CALCULATIONS:									
22										
23		KT/q =						0.025887	Volts	
24		Vbi = (KT/q) ln (NaNd/ni2)						0.80	Volts	
25		W = [(2s/q)(Vbi+Vr)(1/Na +1/Nd)]^0.5						1.44	µm	
26		W1 = W[Nd/(Na+Nd)]						1.44	µm	
27		W2 = W[Na/(Na+Nd)]						0.00	µm	
28		Eo = -[(2q/eoer)(Vbi+Va)(NaNd/(Na+Nd)]^0.5						-1.11E+04	V/cm	
29		Cj' = eoer/W						7.21E-09	F/cm2	

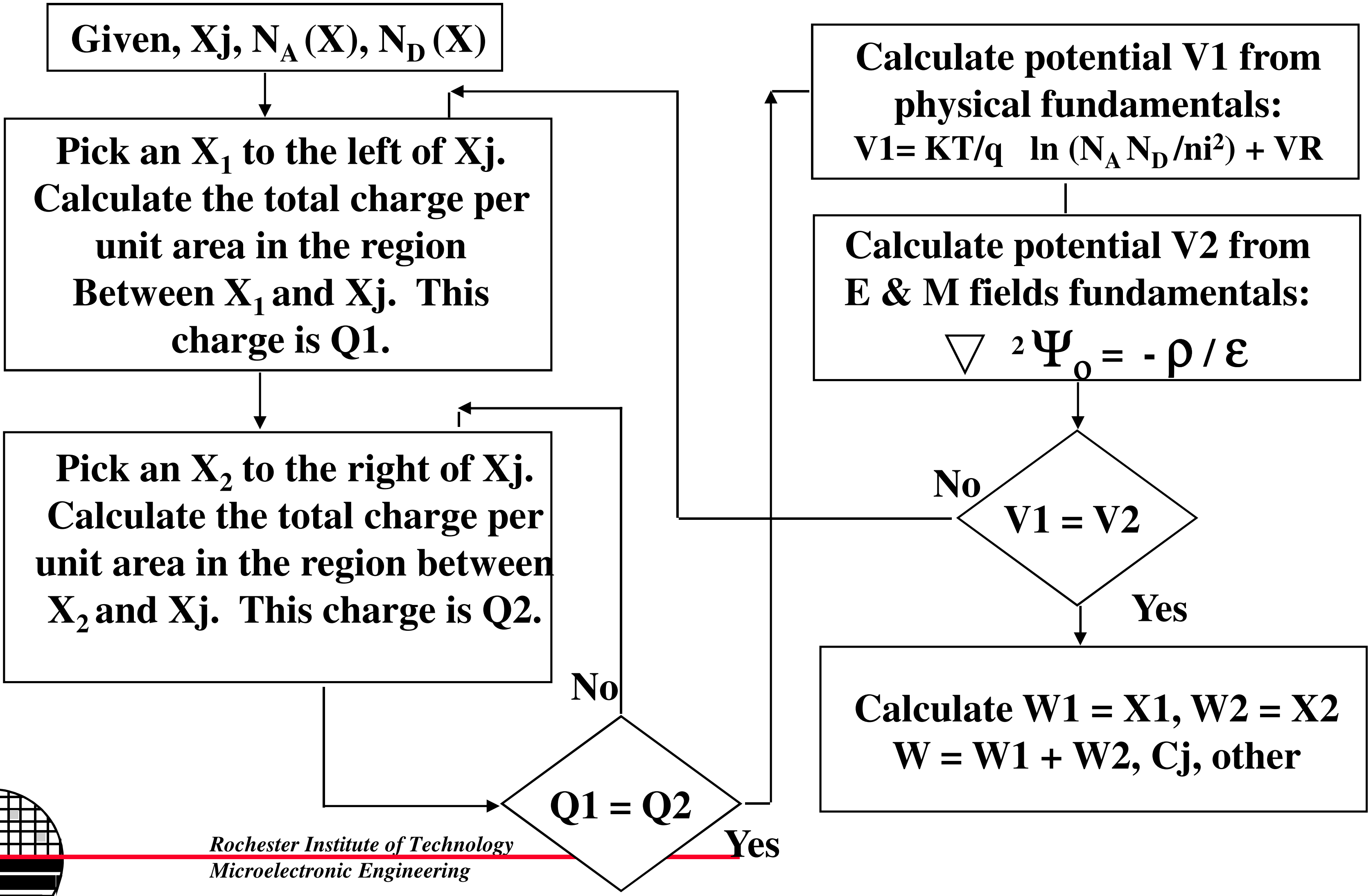
REAL JUNCTION

Real pn junctions: The uniformly doped abrupt junction is rarely obtained in integrated circuit devices. (epi layer growth is close).

Diffused pn junction:



REAL pn JUNCTION



Given, Xj, N_A (X), N_D (X)

Pick an X_1 to the left of Xj. Calculate the total charge per unit area in the region Between X_1 and Xj. This charge is Q1.

Pick an X_2 to the right of Xj. Calculate the total charge per unit area in the region between X_2 and Xj. This charge is Q2.

$Q1 = Q2$

No

Yes

Calculate potential V1 from physical fundamentals:

$V1 = KT/q \quad \ln (N_A N_D / ni^2) + VR$

Calculate potential V2 from E & M fields fundamentals:

$\nabla^2 \Psi_o = - \rho / \varepsilon$

$V1 = V2$

No

Yes

Calculate W1 = X1, W2 = X2
W = W1 + W2, Cj, other

REAL, UNIFORM DOPED, SINGLE SIDED DIODES

Example: assume that the heavily doped side of a pn junction is doped at 1E20, calculate the doping necessary on the lightly doped side such that the space charge layer is ~0.1 µm. With 5 volts reverse bias.

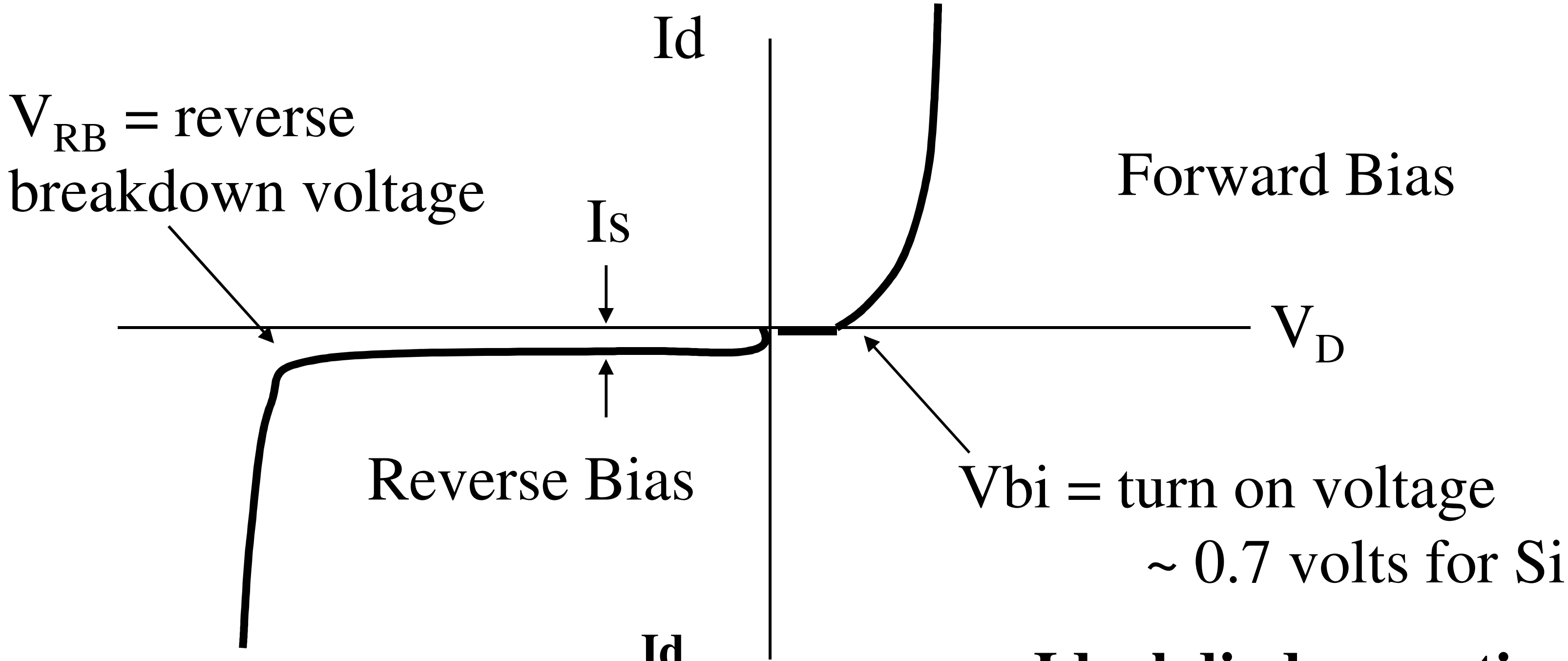
$$\Psi_o = KT/q \ \ \ln\,(N_A N_D / ni^2)$$

guess ~0.9 volts

$$W = (W_1 + W_2) = [\,(2\varepsilon/q)\,(\underbrace{\Psi_o + V_R}_{5.9V})\,(1/N_A + \underbrace{1/N_D}_{0})]^{1/2} = 0.1\ \mu m = 0.1E\text{-}4\ cm$$

$$N = 2\,(11.7)(8.85E{-}14)5.9/(1.6E{-}19)(0.1E{-}4)^2 = 7.6E17\ \ cm^{-3}$$

CURRENTS IN PN JUNCTIONS

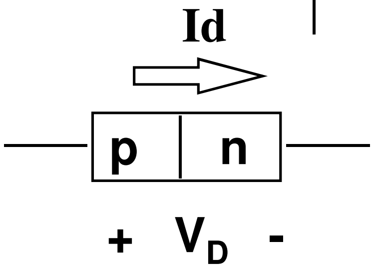


V_{RB} = reverse breakdown voltage

Forward Bias

Reverse Bias

Vbi = turn on voltage
~ 0.7 volts for Si

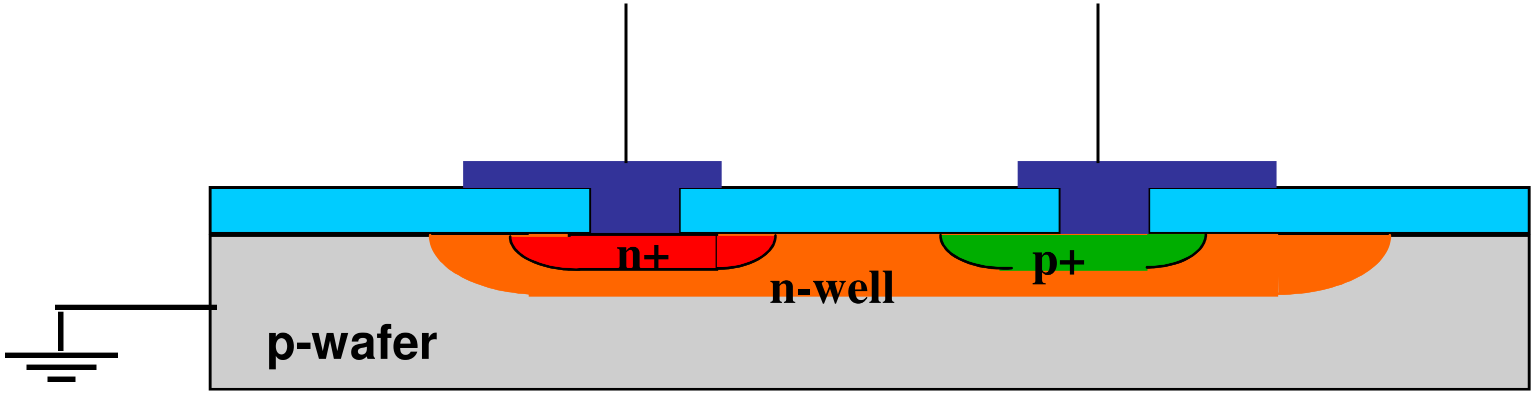


Ideal diode equation

$$Id = Is\ [EXP^{(q\ VD/KT)} - 1]$$

$$Is = qA\ (Dp/(LpNd) + Dn/(LnNa))ni^2$$

INTEGRATED DIODES

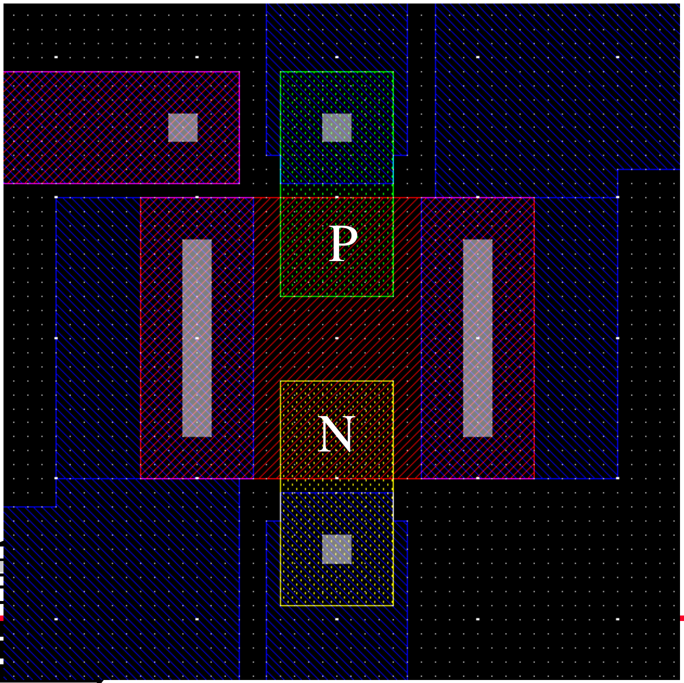


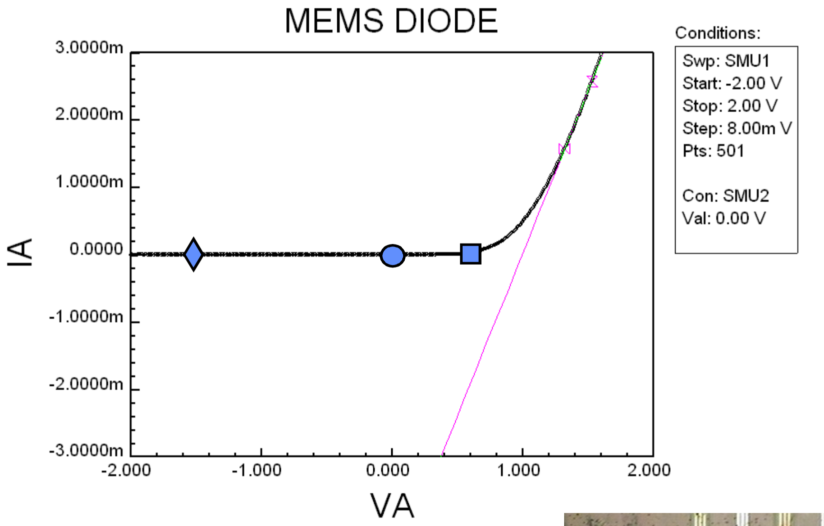
p+ means heavily doped p-type
n+ means heavily doped n-type
n-well is an n-region at slightly higher doping than the p-wafer

Note: there are actually two pn junctions, the well-wafer pn junction should always be reverse biased

REAL DIODES

Series Resistance =1/4.82m=207
Junction Capacitance ~ 2 pF
Is = 3.02E-9 amps
BV = > 100 volts
Size 80µ x 160µ





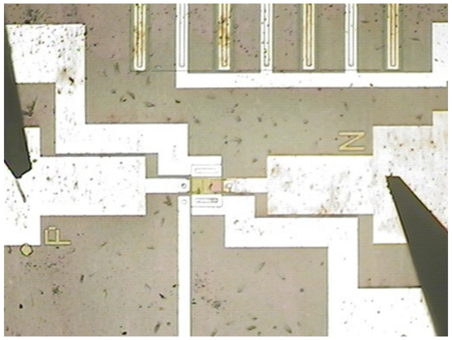
Conditions:
Swp: SMU1
Start: -2.00 V
Stop: 2.00 V
Step: 8.00m V
Pts: 501

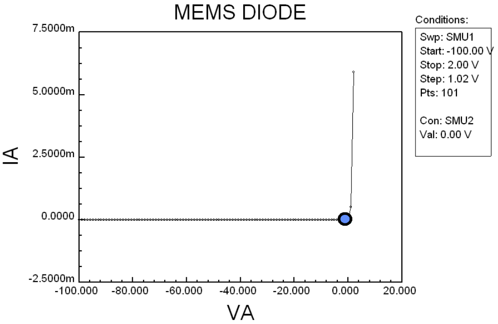
Con: SMU2
Val: 0.00 V

Fit #1:	Fit #2:
Type: Cursor	None
Slp:4.82m	****
Yint:-4.79m	****
Xint:0.99	***

ICS 10:11:40
03/05/2009

Cursors:	X	Y
□	0.60	0.03m
◇	-1.52	-3.02n
○	0.00	0.38n
⧗	1.53	2.57m
⋈	1.32	1.57m
△		





Conditions:
Swp: SMU1
Start: -100.00 V
Stop: 2.00 V
Step: 1.02 V
Pts: 101

Con: SMU2
Val: 0.00 V

DIODE SPICE MODEL

Model Parameter	Default Value	MEMS Diode Extracted Value
Is reverse saturation current	1e-14 A	3.02E-9 A
N emission coefficient	1	1
RS series resistance	0	207 ohms
VJ built-in voltage	1 V	0.6
CJ0 zero bias junction capacitance	0	2pF
M grading coefficient	0.5	0.5
BV Breakdown voltage	infinite	400
IBV Reverse current at breakdown	1E-10 A	-

```
DXXX N(anode) N(cathode) Modelname
.model Modelname  D Is=1e-14 Cjo=.1pF Rs=.1
.model RITMEMS D IS=3.02E-9 N=1 RS=207
+VJ=0.6 CJ0=2e-12 M-0.5 BV=400
```

DIODE TEMPERATURE DEPENDENCE

$$Id = I_S\ [EXP^{(q\ VD/KT)} -1]$$

Neglect the –1 in forward bias, Solve for VD

$$VD = (KT/q)\ \ln\ (Id/I_S) = (KT/q)\ (\ln(Id) - \ln(Is)) \qquad \text{eq 1}$$

Take dVD/dT: note Id is not a function of T but Is is

$$dVD/dT = (KT/q)\ (d\ln(Id)/dT - d\ln(Is)/dT) + K/q\ (\ln(Id) - \ln(Is))$$

zero

VD/T from eq 1

Rewritten

$$dVD/dT = VD/T - (KT/q)\ ((1/Is)\ dIs/dT\ ) \qquad \text{eq 2}$$

Now evaluate the second term, recall

$$Is = qA\ (Dp/(LpNd) + Dn/(LnNa))ni^2$$

Note: Dn and Dp are proportional to 1/T

DIODE TEMPERATURE DEPENDENCE

and $n_i^2(T) = A\,T^3\ e^{-qEg/KT}$

This gives the temperature dependence of Is

$$Is = C\,T^2\ e^{-qEg/KT} \qquad \text{eq 3}$$

Now take the natural log

$$\ln Is = \ln (C\,T^2\ e^{-qEg/KT)}$$

Take derivative with respect to T

$$(1/Is)\ d\,(Is)/dT = d\,[\ln (C\,T^2\ e^{-qEg/KT)}]/dT = (1/Is)\ d\,(CT^2e^{-qEg/KT})dT$$

$$= (1/Is)\ [CT^2\,e^{-qEg/KT}(qEg/KT^2) + (Ce^{-qEg/KT})2T]$$

$$= (1/\cancel{Is})\ [\cancel{Is}(qEg/KT^2) + (2\cancel{Is}/T)]$$

Back to eq 2

$$dVD/dT = VD/T - (KT/q)\ [(qEg/KT^2) + (2/T)])$$

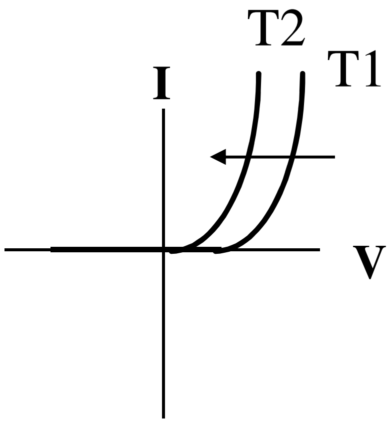
$$\boxed{dVD/dT = VD/T - Eg/T - 2K/q)}$$

EXAMPLE: DIODE TEMPERATURE DEPENDENCE

$$\boxed{dVD/dT = VD/T - Eg/T - 2K/q}$$

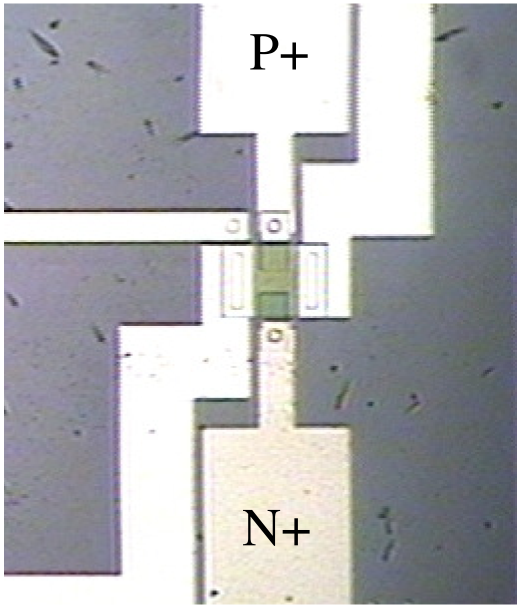
Silicon with Eg ~ 1.2 eV, VD = 0.6 volts, T=300 °K

$$dVD/dT = .6/300 – 1.2/300) - (2(1.38E-23)/1.6E-19$$
$$= -2.2\ mV/°$$

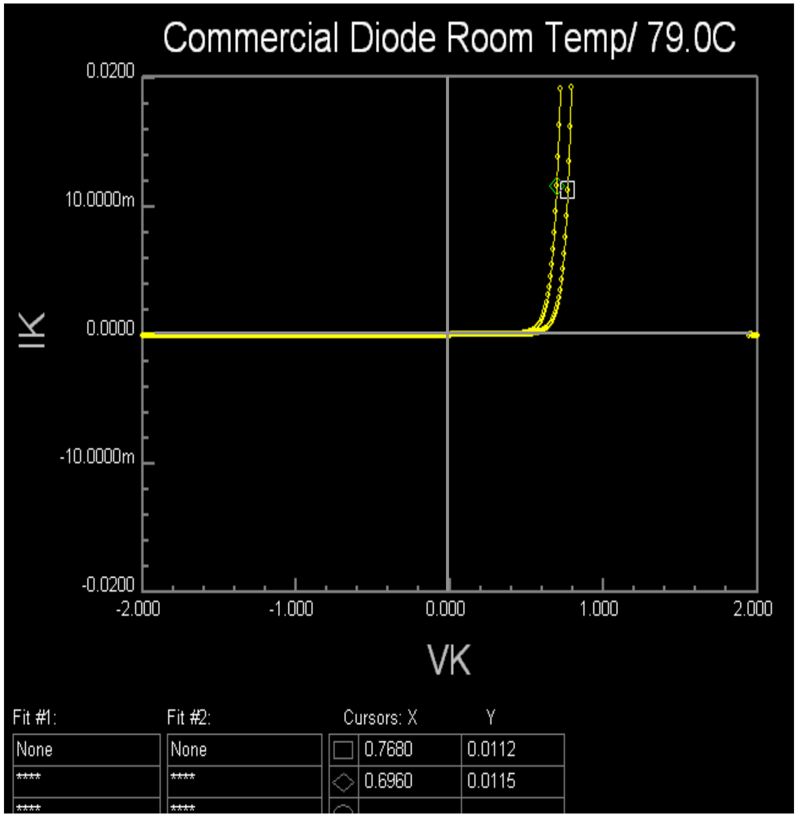


T1<T2

EXPERIMENTAL DATA



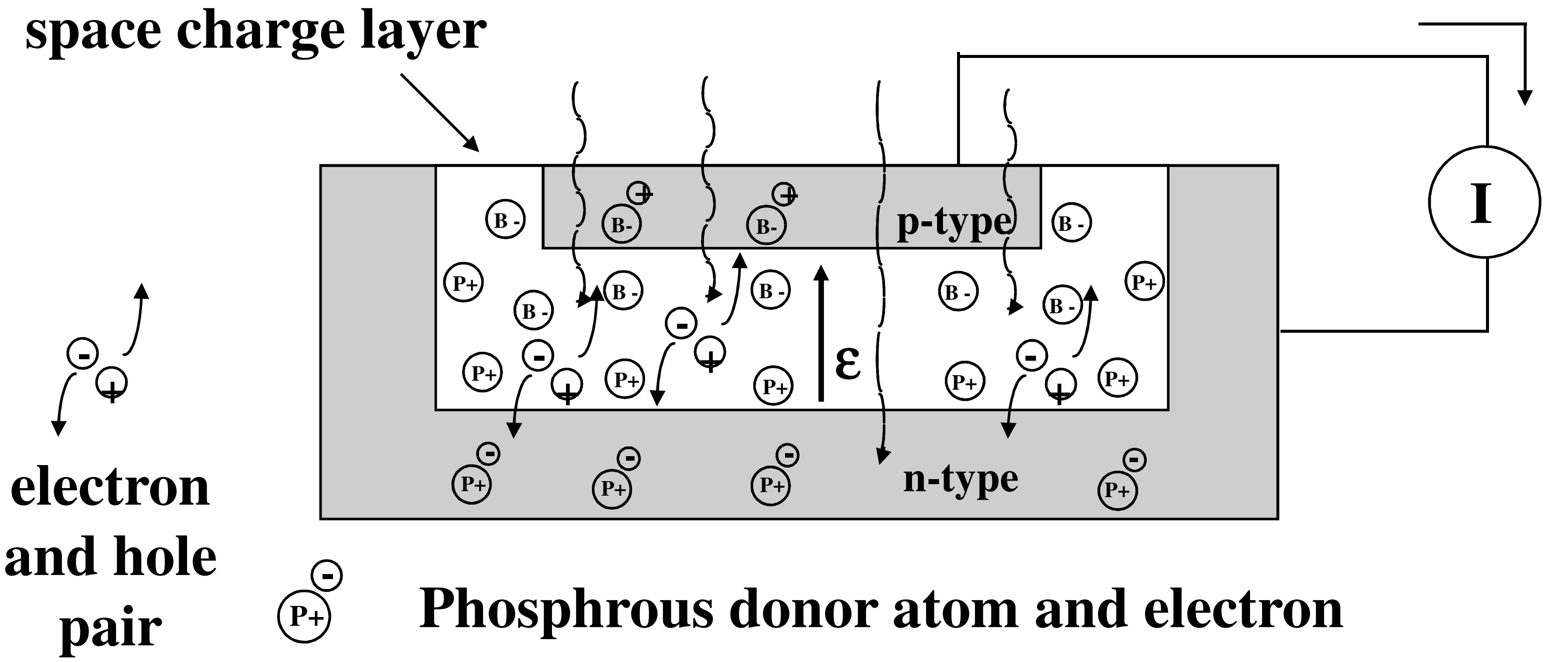
Poly Heater, Buried pn Diode,
N+ Poly to Aluminum Thermocouple



Fit #1:	Fit #2:	Cursors: X	Y
None	None	☐ 0.7680	0.0112
****	****	◇ 0.6960	0.0115
****	****	○	

Compare with theoretical -2.2mV/°C

PHOTODIODE



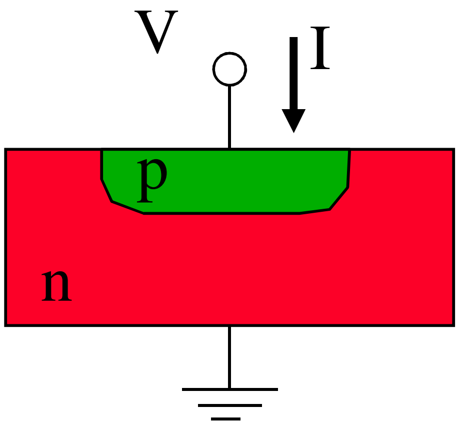
P+ − Phosphrous donor atom and electron

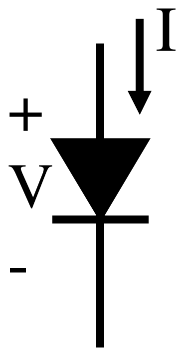
P+ Ionized Immobile Phosphrous donor atom

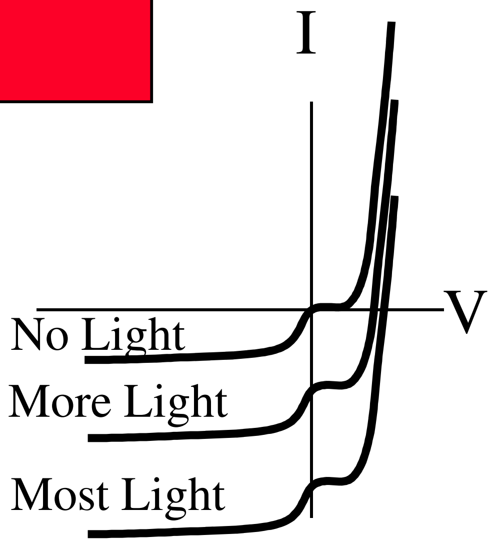
B - Ionized Immobile Boron acceptor atom

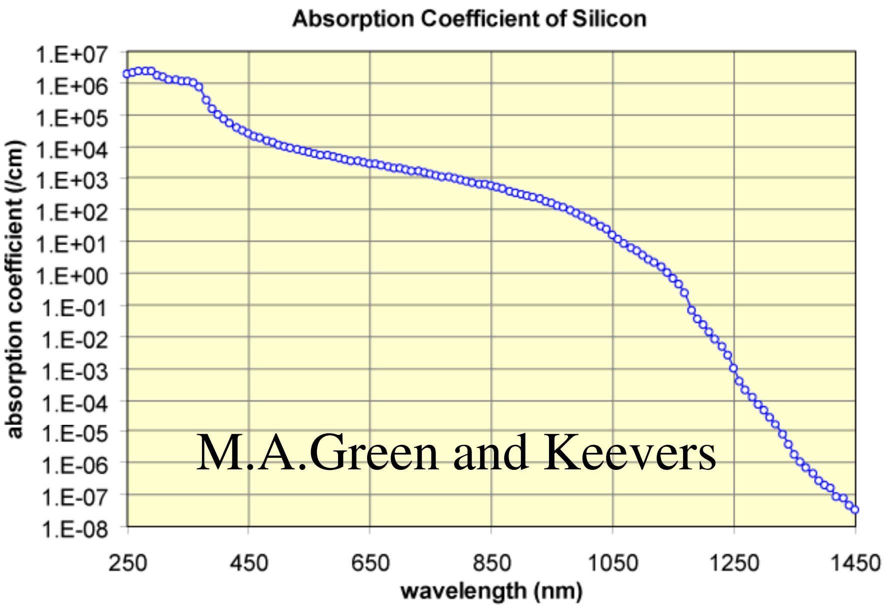
B- + Boron acceptor atom and hole

PHOTODIODE









M.A.Green and Keevers

$$\phi(x) = \phi(0)\ \exp^{-\alpha\ x}$$

Find % adsorbed for Green light at x=5 µm and Red light at 5 µm

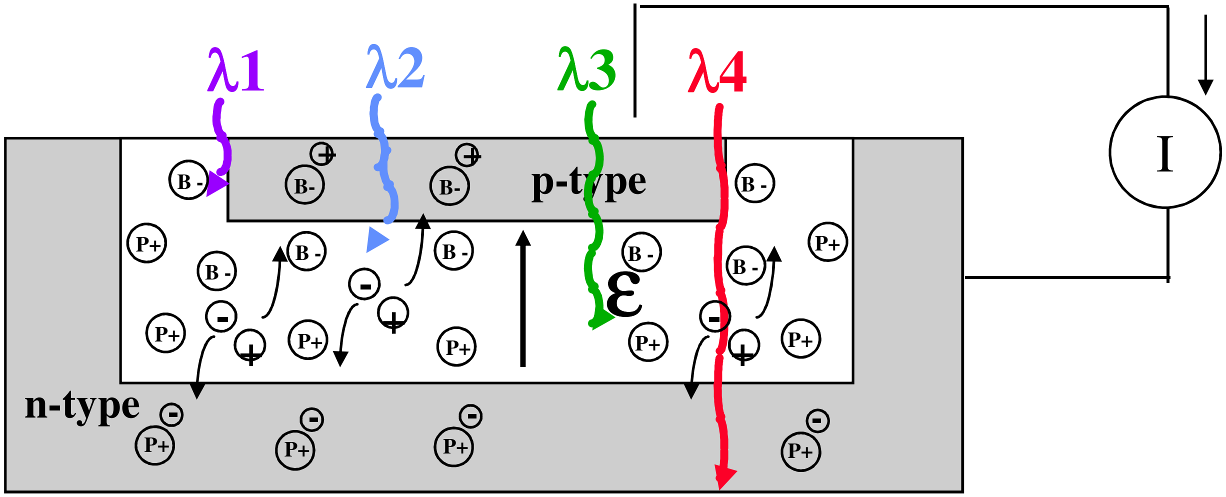
CHARGE GENERATION vs WAVELENGTH

$E = h\nu = hc / \lambda$

$h = 6.625\text{ e-}34\text{ j/s}$

$= (6.625\text{ e-}34/1.6\text{e-}19)\text{ eV/s}$

E = 1.55 eV (red)
E = 2.50 eV (green)
E = 4.14 eV (blue)

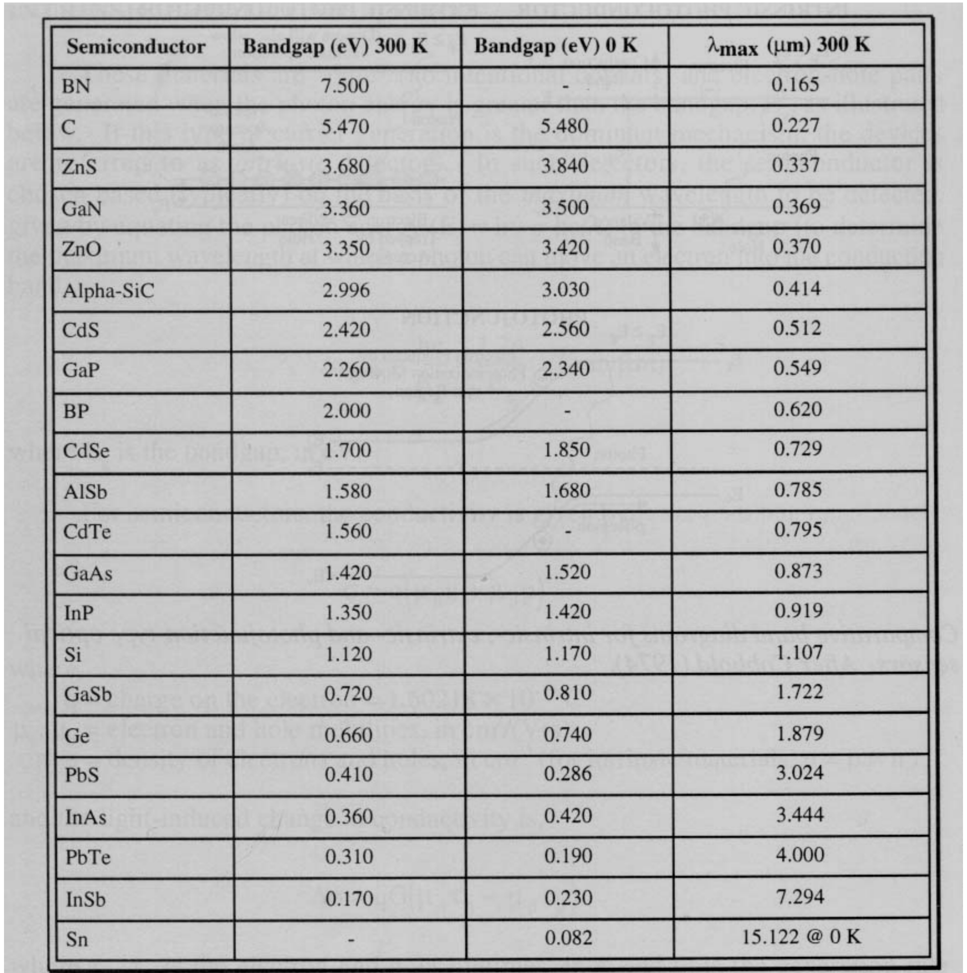


VARIOUS SEMICONDUCTORS

$$E = h\nu = hc / \lambda$$

What wavelengths will not generate e-h pairs in silicon. Thus silicon is transparent or light of this wavelength or longer is not adsorbed?

h = Plank's constant
c = speed of light



Semiconductor	Bandgap (eV) 300 K	Bandgap (eV) 0 K	λ_{max} (µm) 300 K
BN	7.500	-	0.165
C	5.470	5.480	0.227
ZnS	3.680	3.840	0.337
GaN	3.360	3.500	0.369
ZnO	3.350	3.420	0.370
Alpha-SiC	2.996	3.030	0.414
CdS	2.420	2.560	0.512
GaP	2.260	2.340	0.549
BP	2.000	-	0.620
CdSe	1.700	1.850	0.729
AlSb	1.580	1.680	0.785
CdTe	1.560	-	0.795
GaAs	1.420	1.520	0.873
InP	1.350	1.420	0.919
Si	1.120	1.170	1.107
GaSb	0.720	0.810	1.722
Ge	0.660	0.740	1.879
PbS	0.410	0.286	3.024
InAs	0.360	0.420	3.444
PbTe	0.310	0.190	4.000
InSb	0.170	0.230	7.294
Sn	-	0.082	15.122 @ 0 K

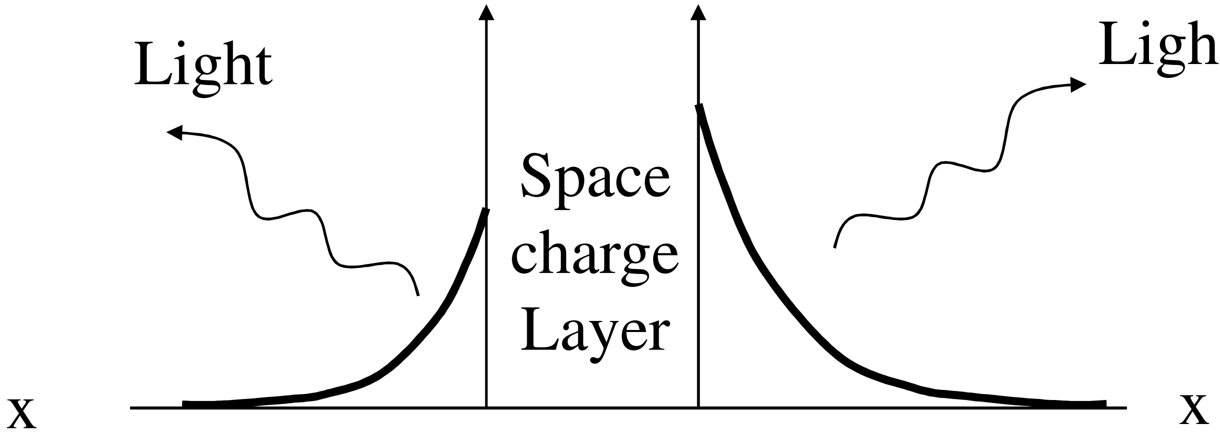
Table of various semiconductors in order of increasing λ_{max}. From Sze (1981).

Kovacs

LIGHT EMITTING DIODES (LEDs)

Electron concentration vs distance

Hole concentration vs distnace



P-side

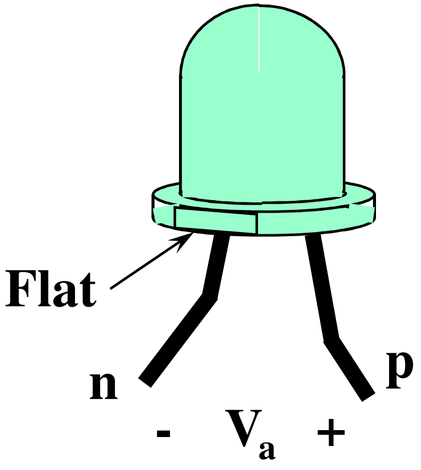
N-side

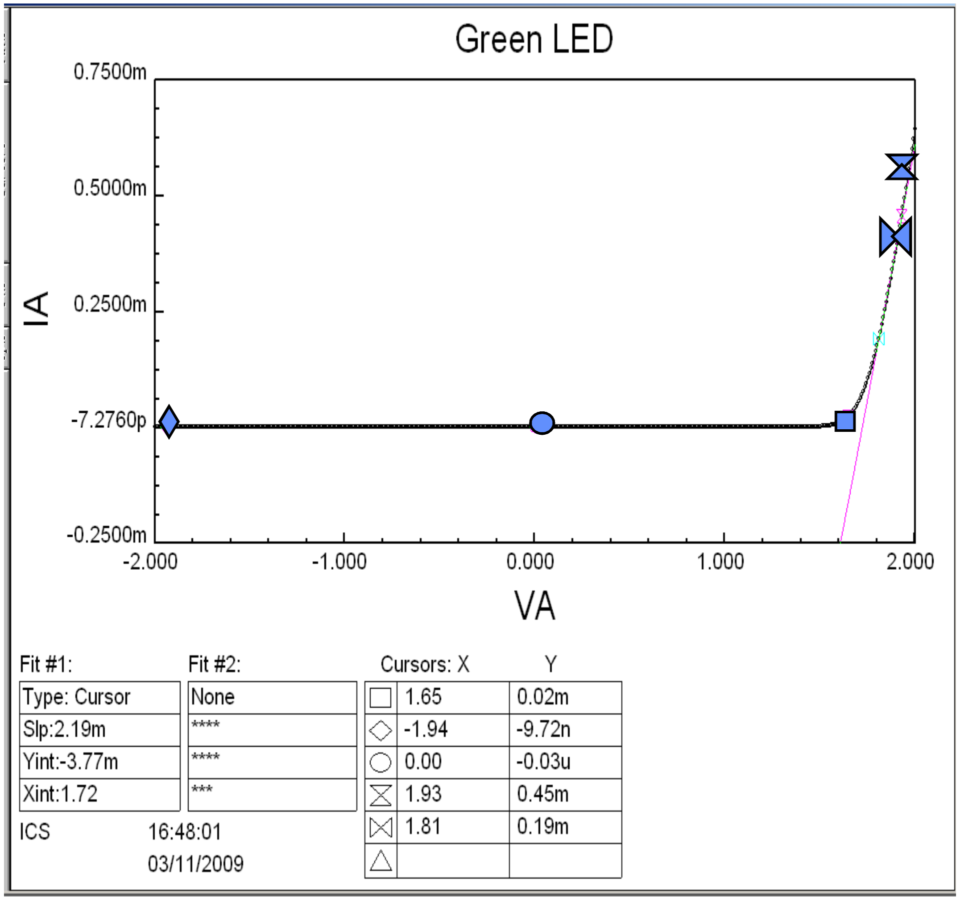
In the forward biased diode current flows and as holes recombine on the n-side or electrons recombine on the p-side, energy is given off as light, with wavelength appropriate for the energy gap for that material. $\lambda = h\,c\,/\,E$

h = Plank’s constant
c = speed of light

LED

Light Emitting Diode -LED





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Yint:-3.77m	****
Xint:1.72	***

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03/11/2009

Cursors:	X	Y
□	1.65	0.02m
◇	-1.94	-9.72n
○	0.00	-0.03u
⧗	1.93	0.45m
⋈	1.81	0.19m
△		

OPTICAL LINK CIRCUIT DESIGN

Lets design a LED/Photo Detector circuit for a digital communication link.

Assumptions:

Block Diagram:

Circuit Diagram:

REFERENCES

1. Micromachined Transducers, Gregory T.A. Kovacs, McGraw-Hill, 1998.
2. Chapter 3 of Microelectronic Circuits, by Sedra and Smith
3. http://www.digikey.com

HOMEWORK: DIODE REVIEW

1. Look up the 1N4448 diode on the Digikey.com webpage, find the unit price, max current, max reverse voltage, package types, etc.

2. A pn junction has Na=2e16 and Nd=5e17. At 0 volts bias calculate the Vbi, W, W1, W2, Emax, and Cj.

3. Calculate the reverse breakdown voltage for a pn junction with Nd=1e19 and Na=2.75e16.

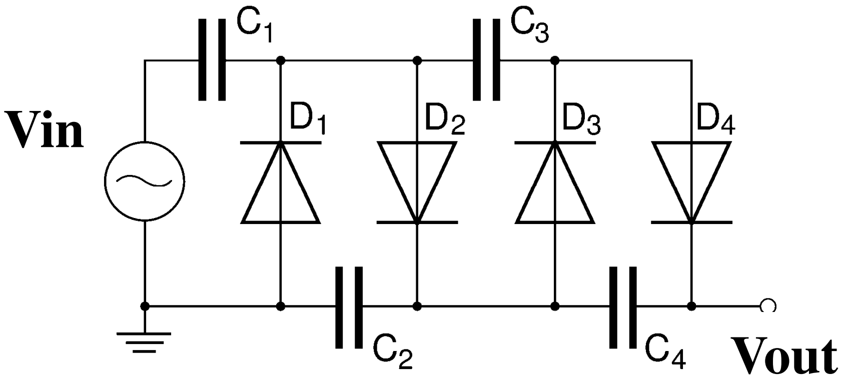
4. Design a pn junction and an amplifier circuit that will make a good photo detector for red light. State reasonable assumptions.

5. A diode is used to rectify an ac voltage from a transformer and charge a 1uF capacitor. Estimate how long it will take the capacitor to discharge from 3 volts to 1.5 volts (once ac voltage is turned off) a) with no load b) with a scope probe across the capacitor.

HOMEWORK: DIODE REVIEW

6. Repeat problem 5 but use the largest value 3 volt super capacitor available from digikey.com.

7. Diodes and capacitors can be used to create a very large dc voltage from a relatively small ac voltage. These circuits are called voltage multipliers. Using a 5 volt peak ac voltage estimate the dc output voltage of this multiplier circuit.

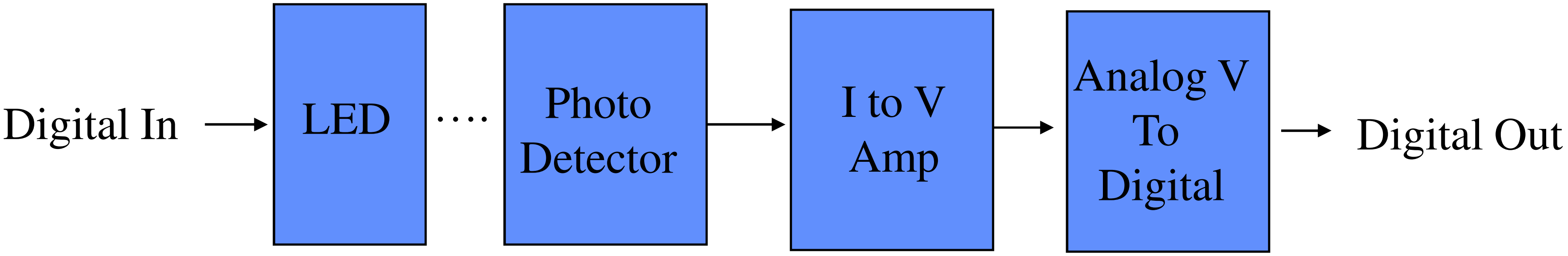


OPTICAL LINK CIRCUIT DESIGN

Design a LED/Photo Detector circuit for a digital communication link.

Assumptions: Assume we have +5 and -5 volts available and the digital signal is 0 or 5 volts.

Block Diagram:



Circuit Design: