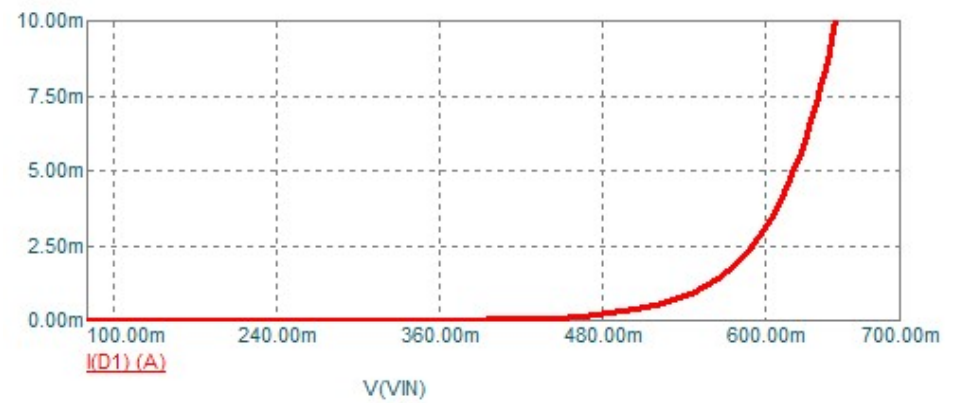
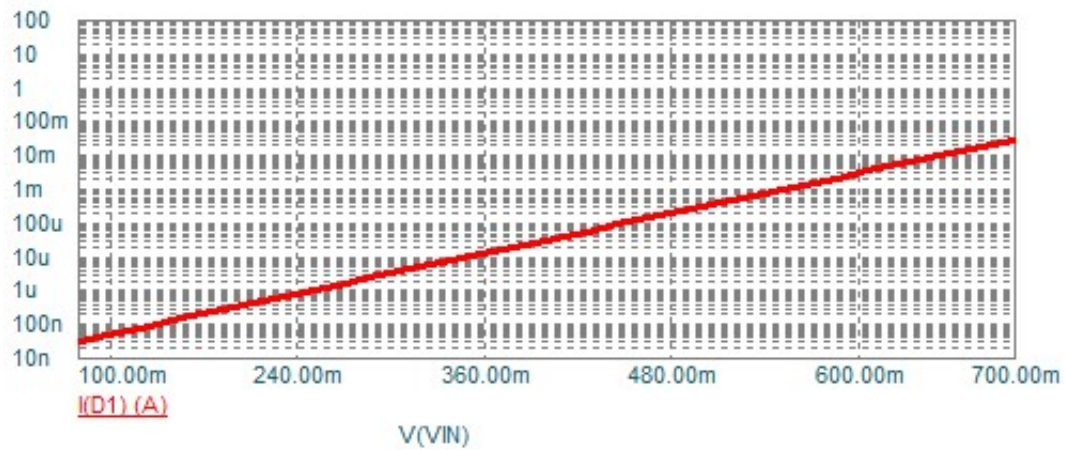
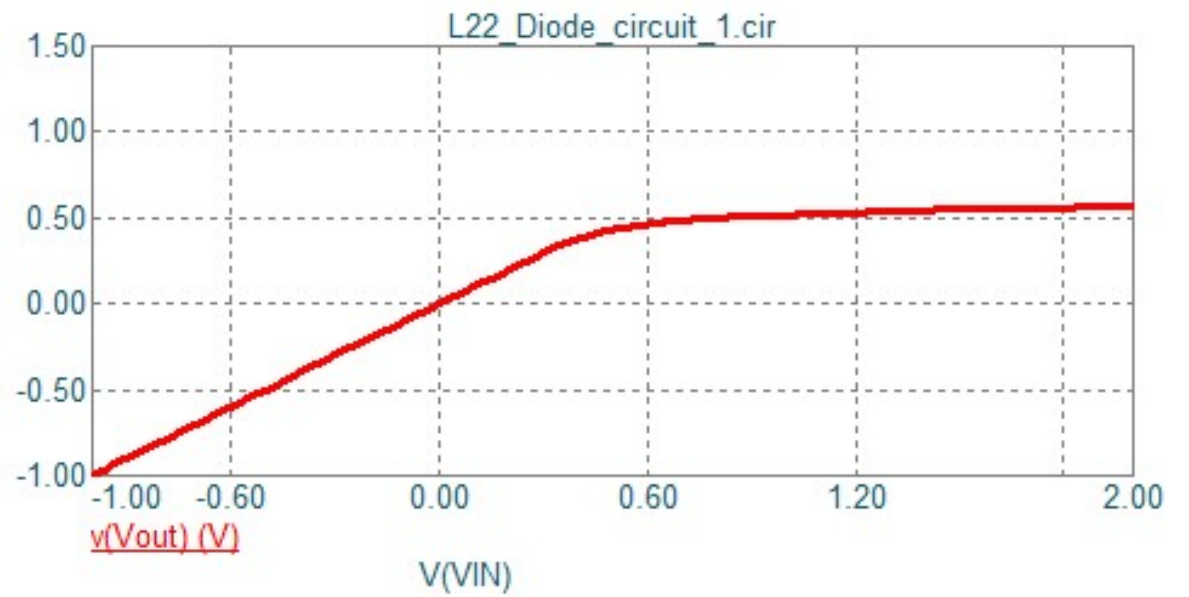
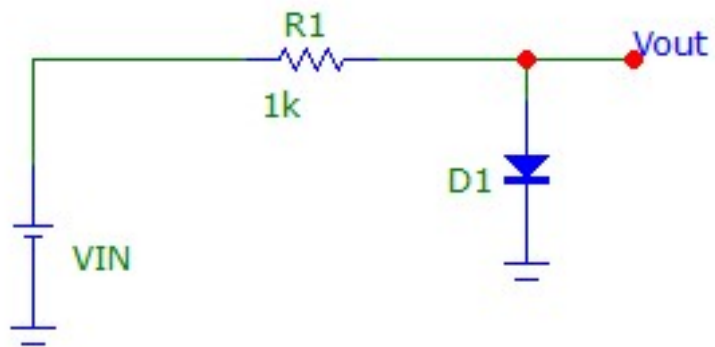
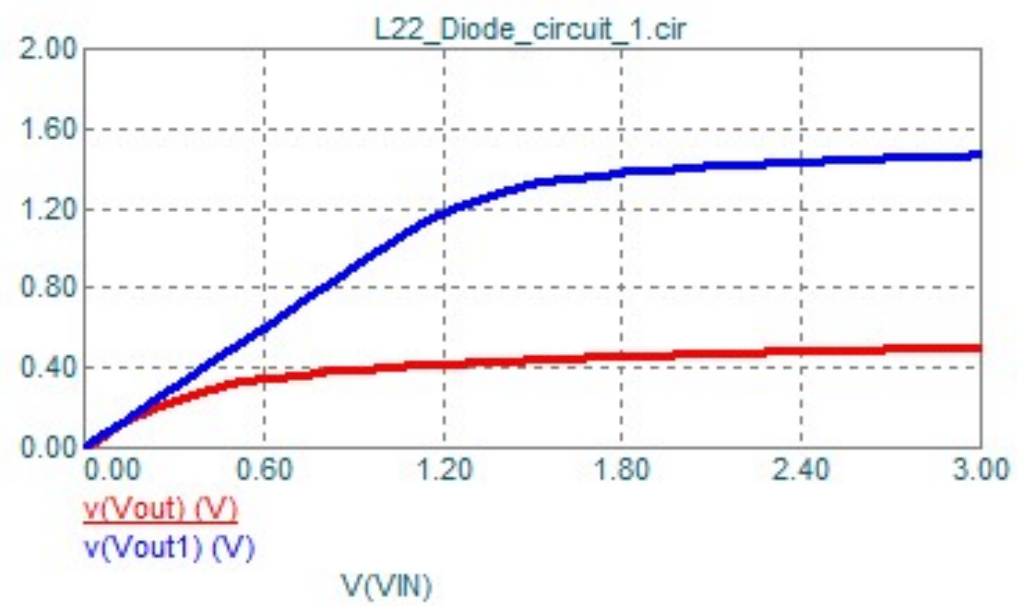
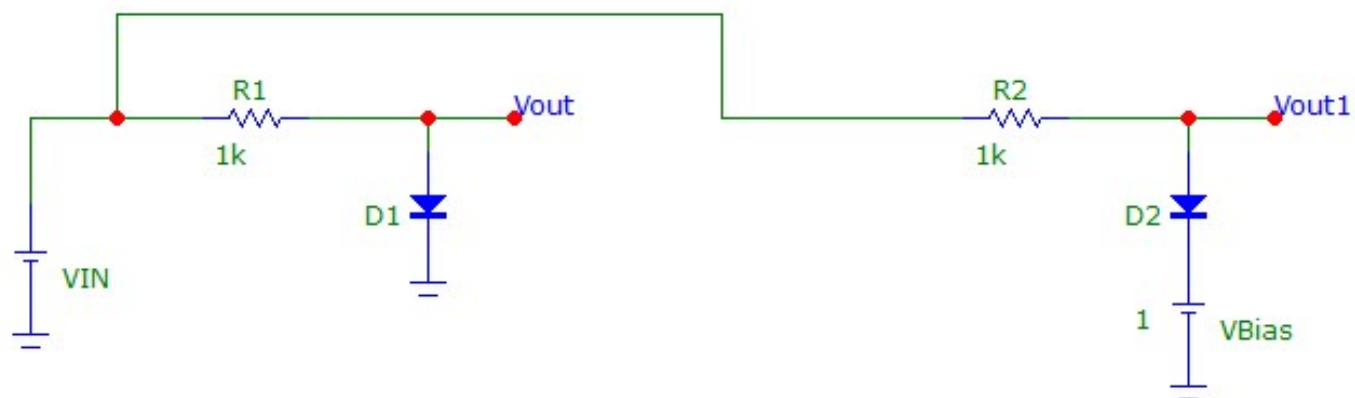


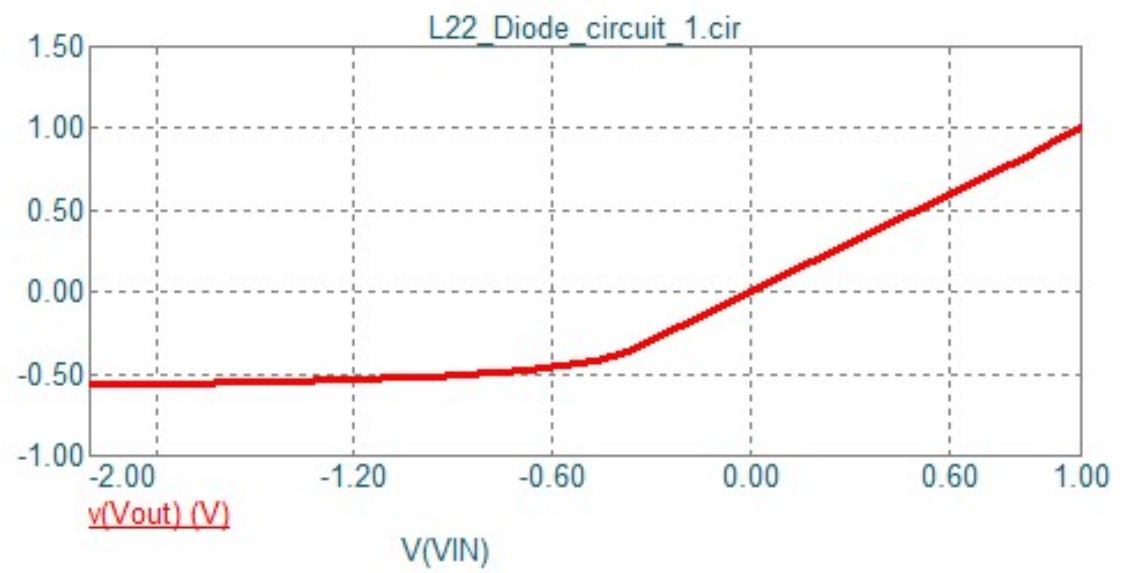
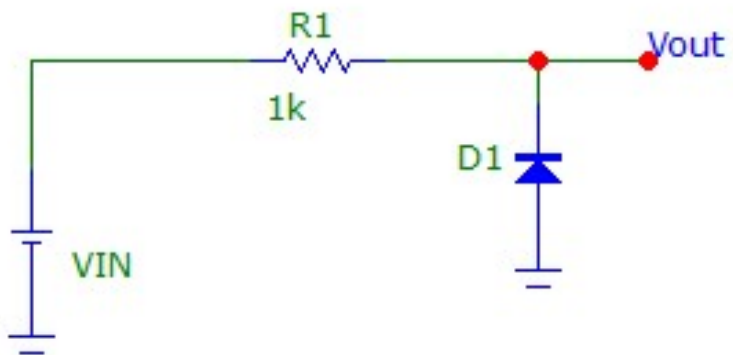
ESC201T : Introduction to Electronics

Lecture 22: Diode Circuits

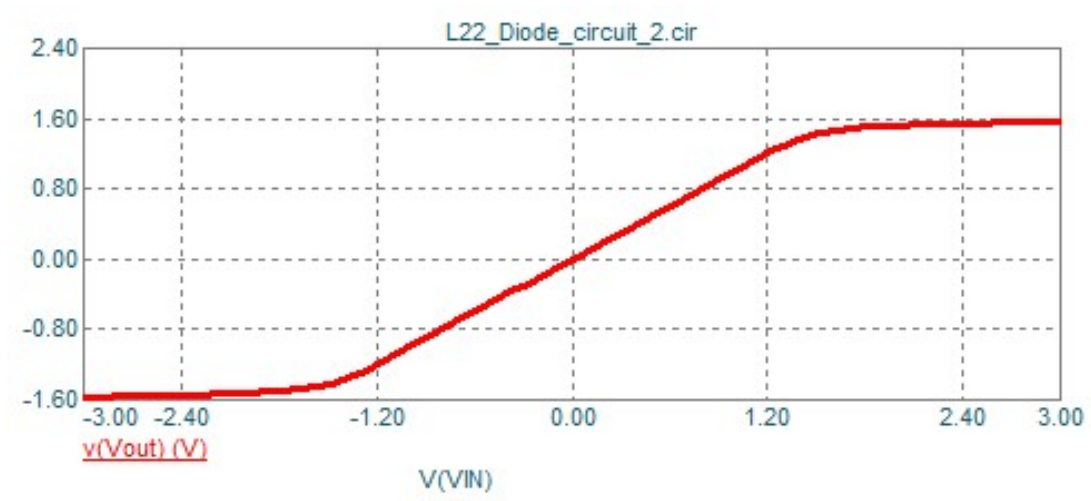
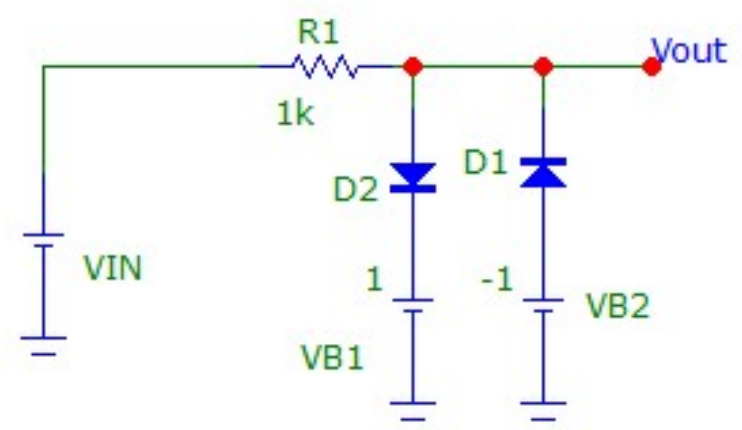
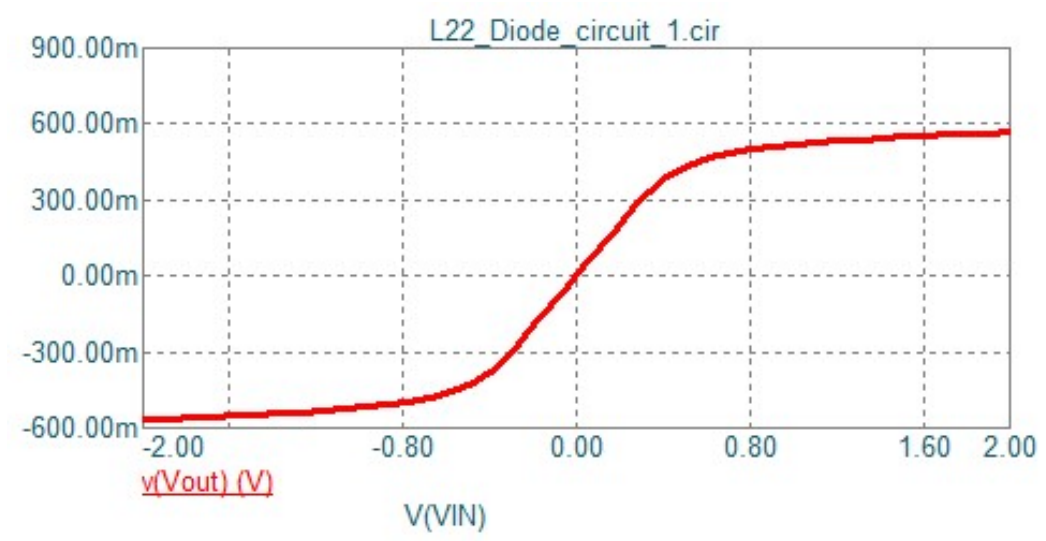
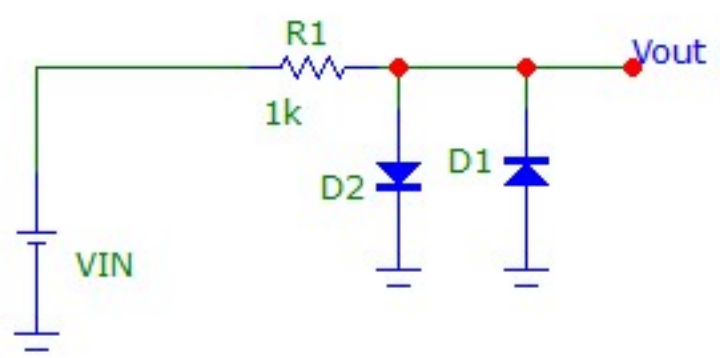
B. Mazhari
Dept. of EE, IIT Kanpur

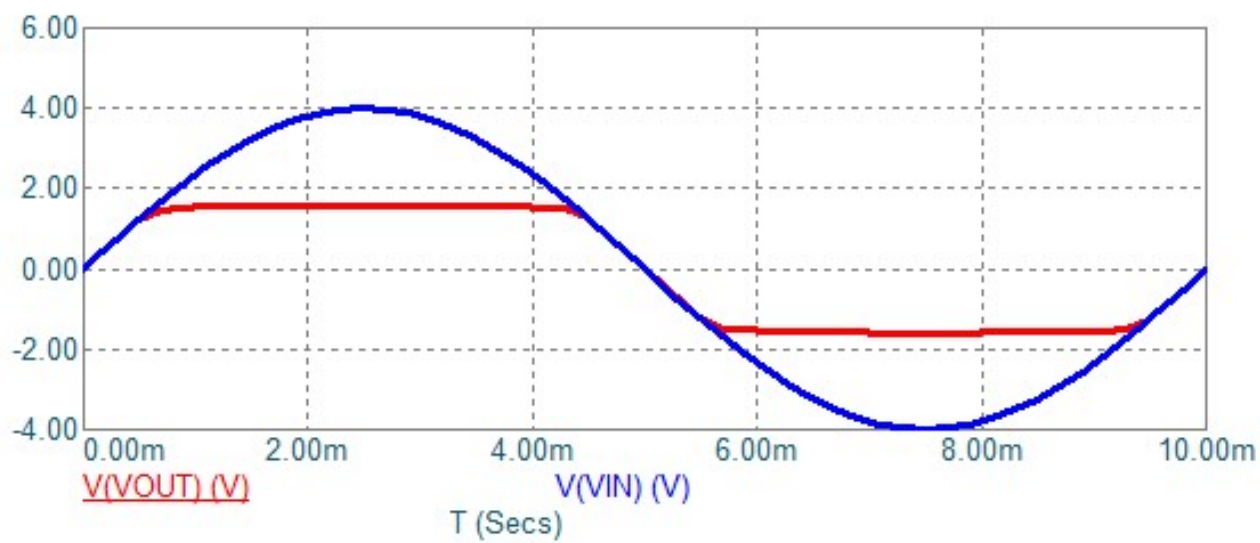
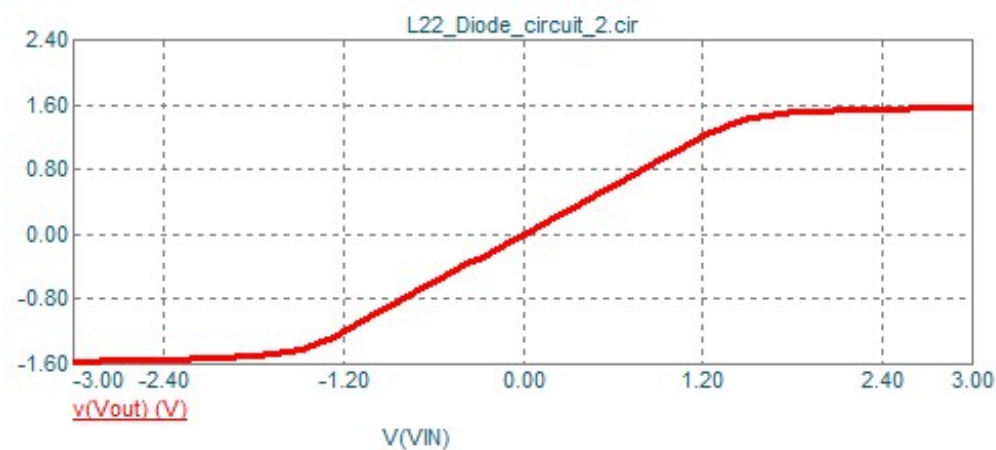
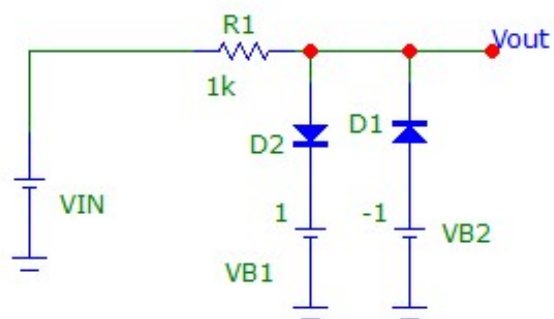




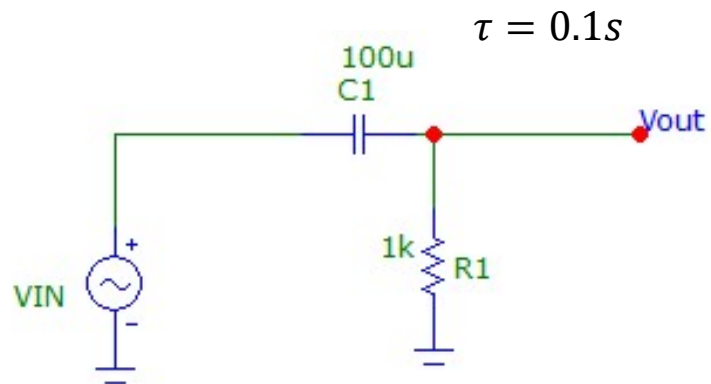


Clipper Circuit



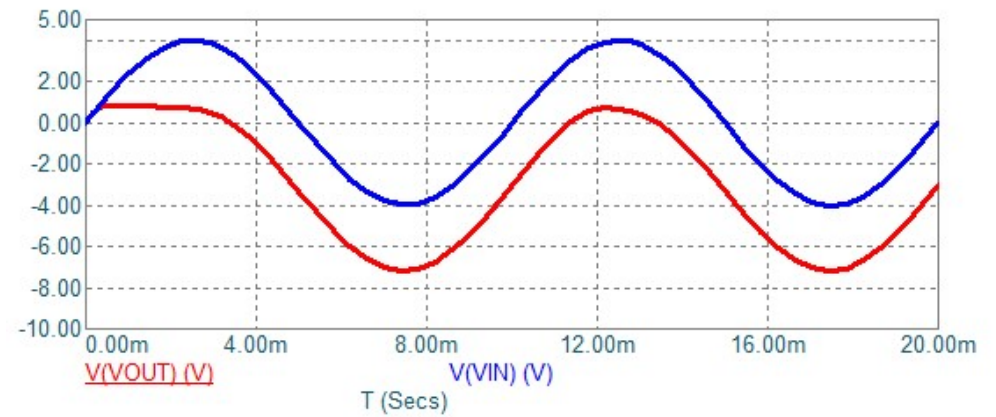
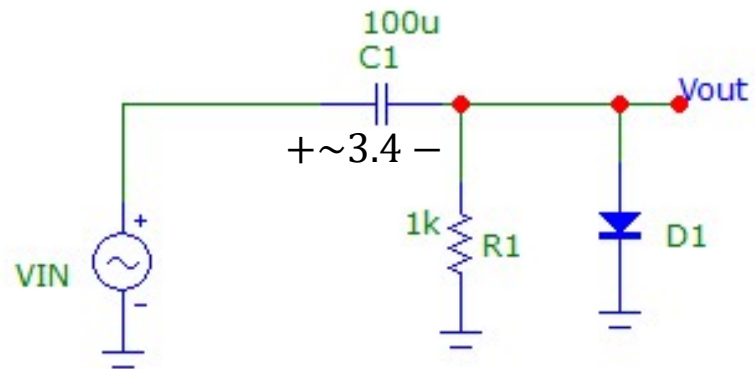
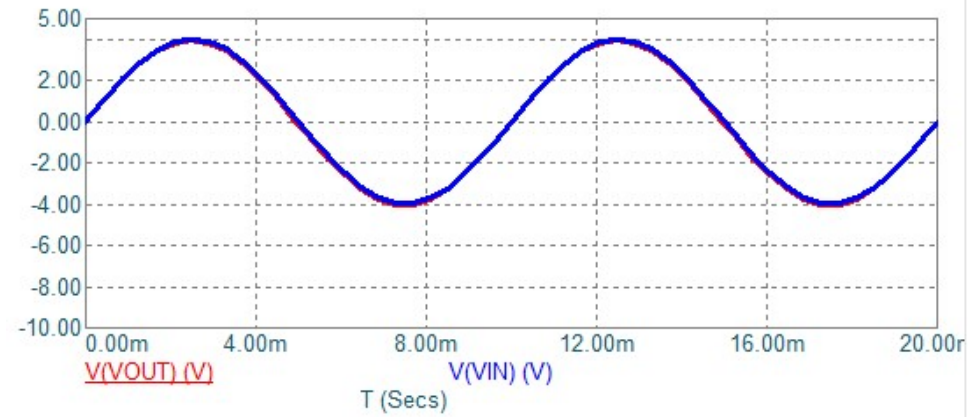


Negative Clamper

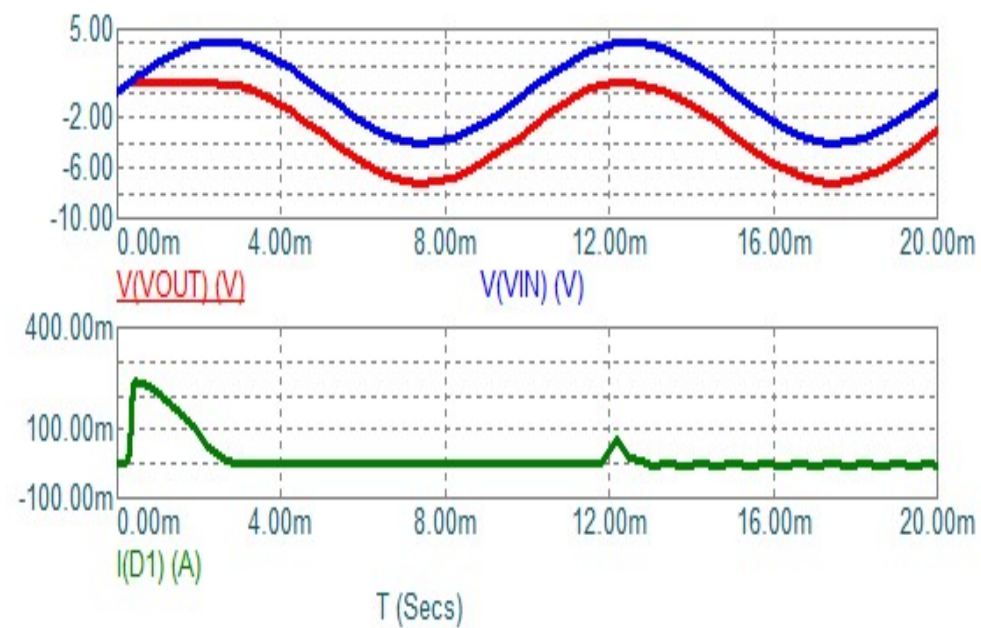
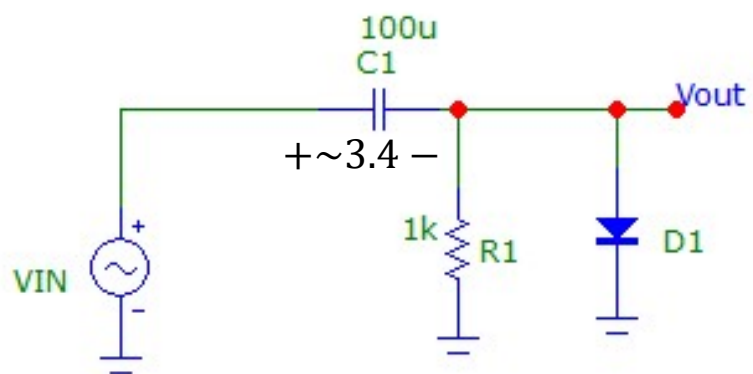


$$4V\sin(\omega t)$$

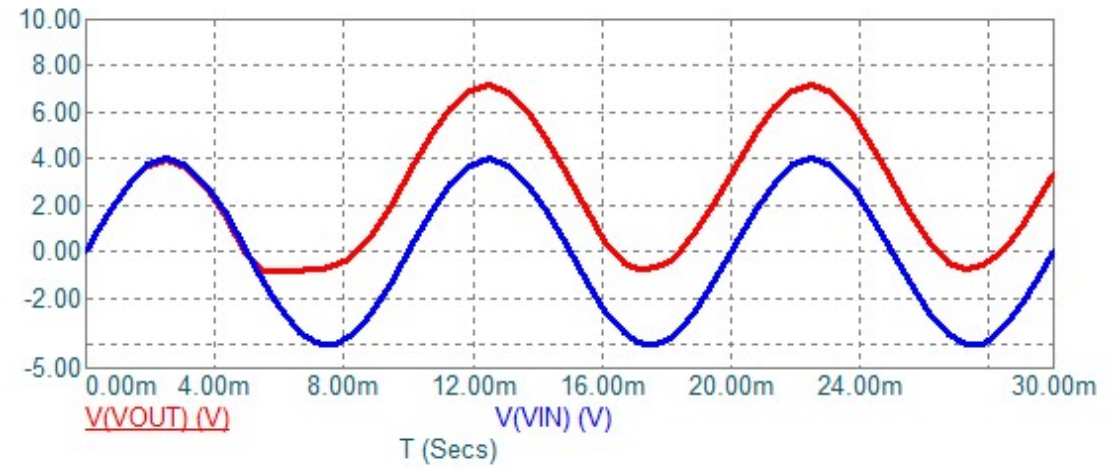
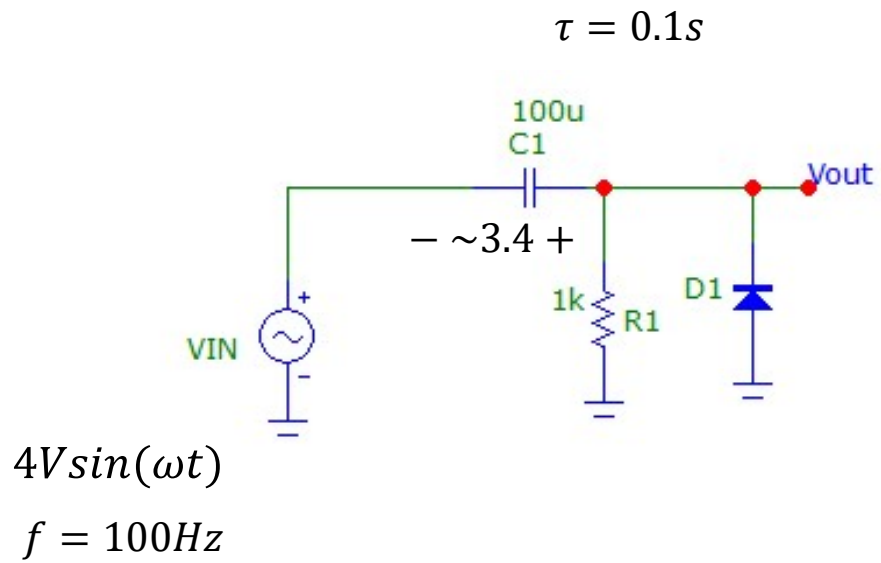
$$f = 100Hz$$



$$V_{IN} - V_{OUT} \sim 3.4 \Rightarrow V_{OUT} = V_{IN} - 3.4$$

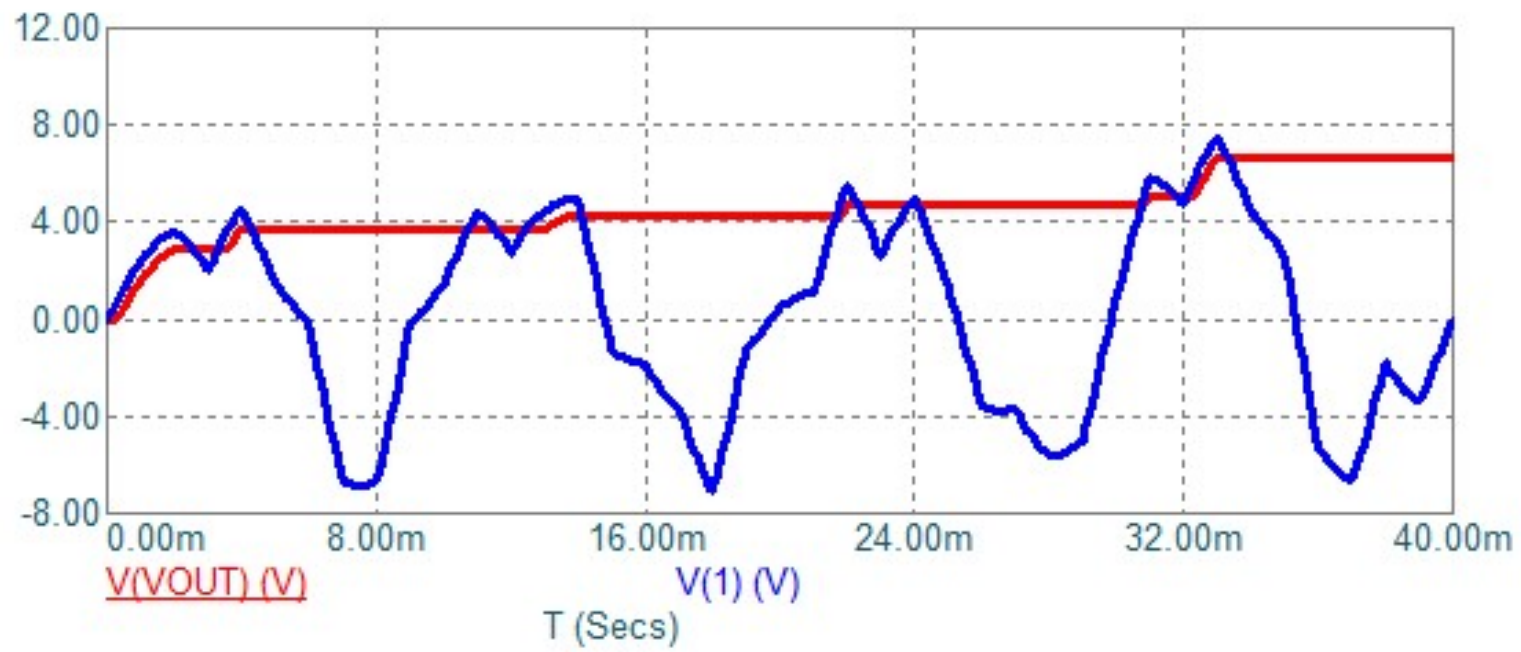
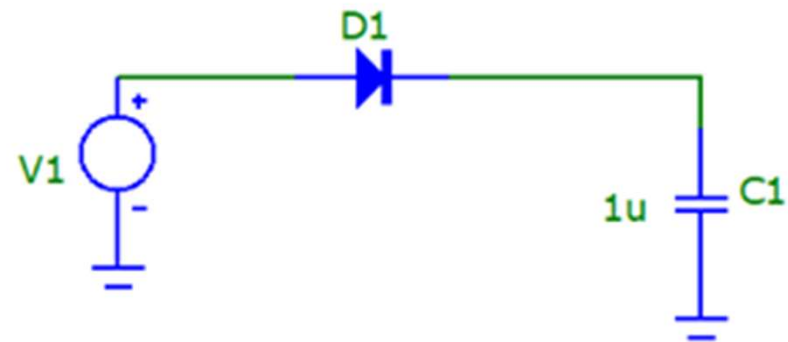


Positive Clamper

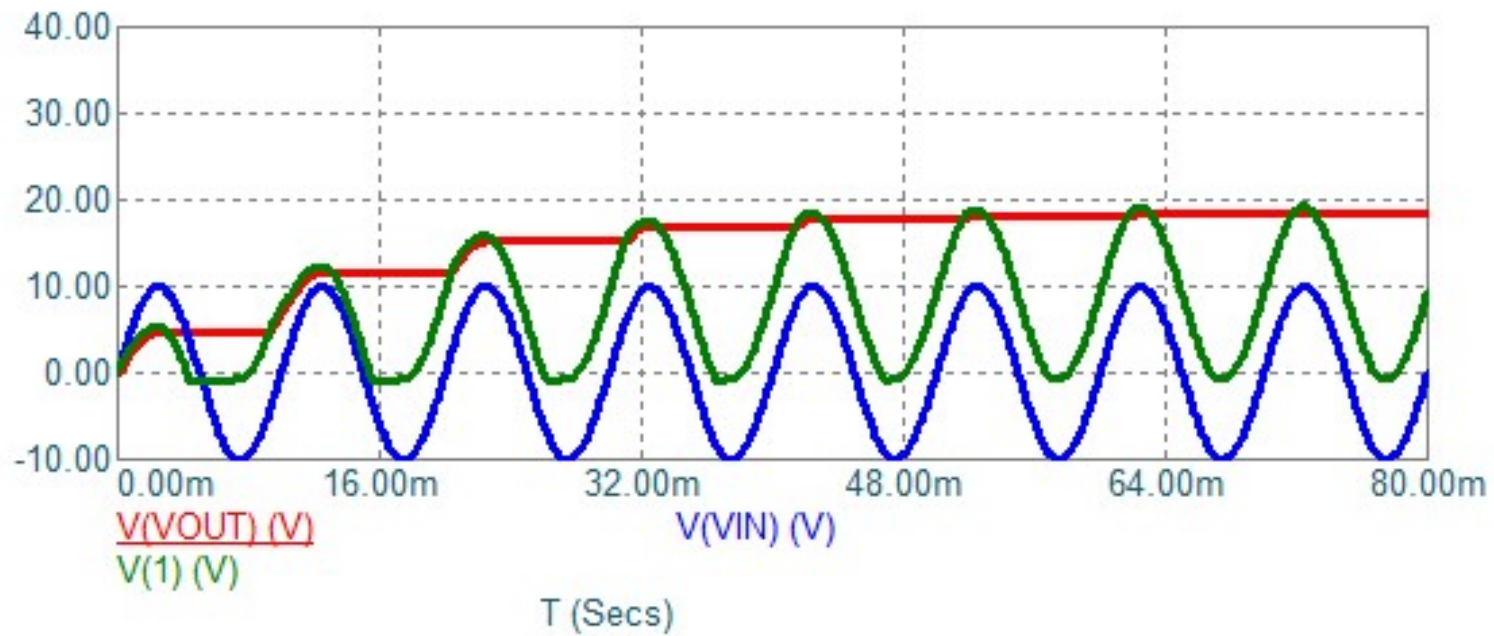
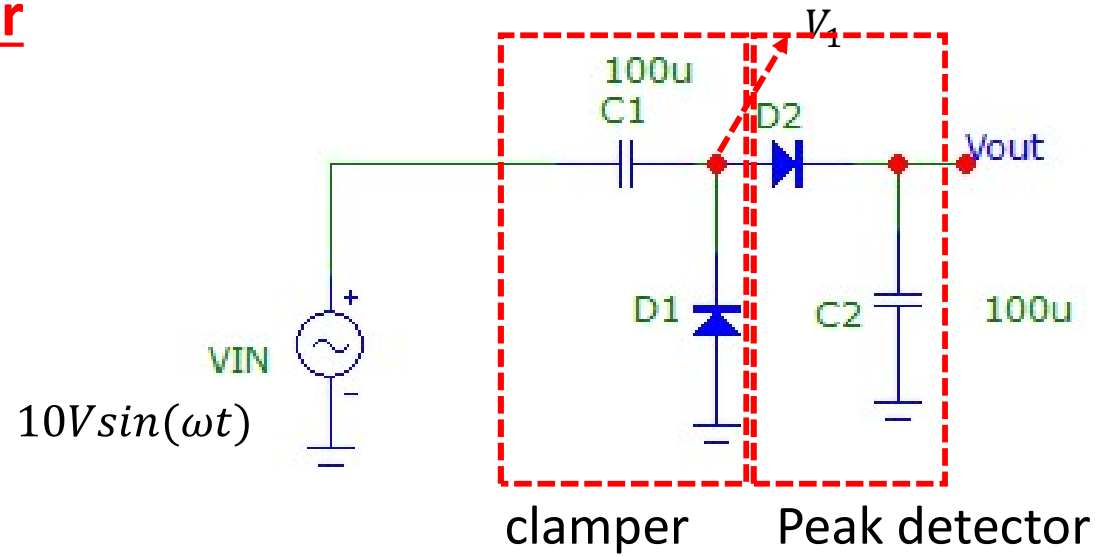


$$V_{IN} - V_{OUT} \sim -3.4 \Rightarrow V_{OUT} = V_{IN} + 3.4$$

Peak Detector

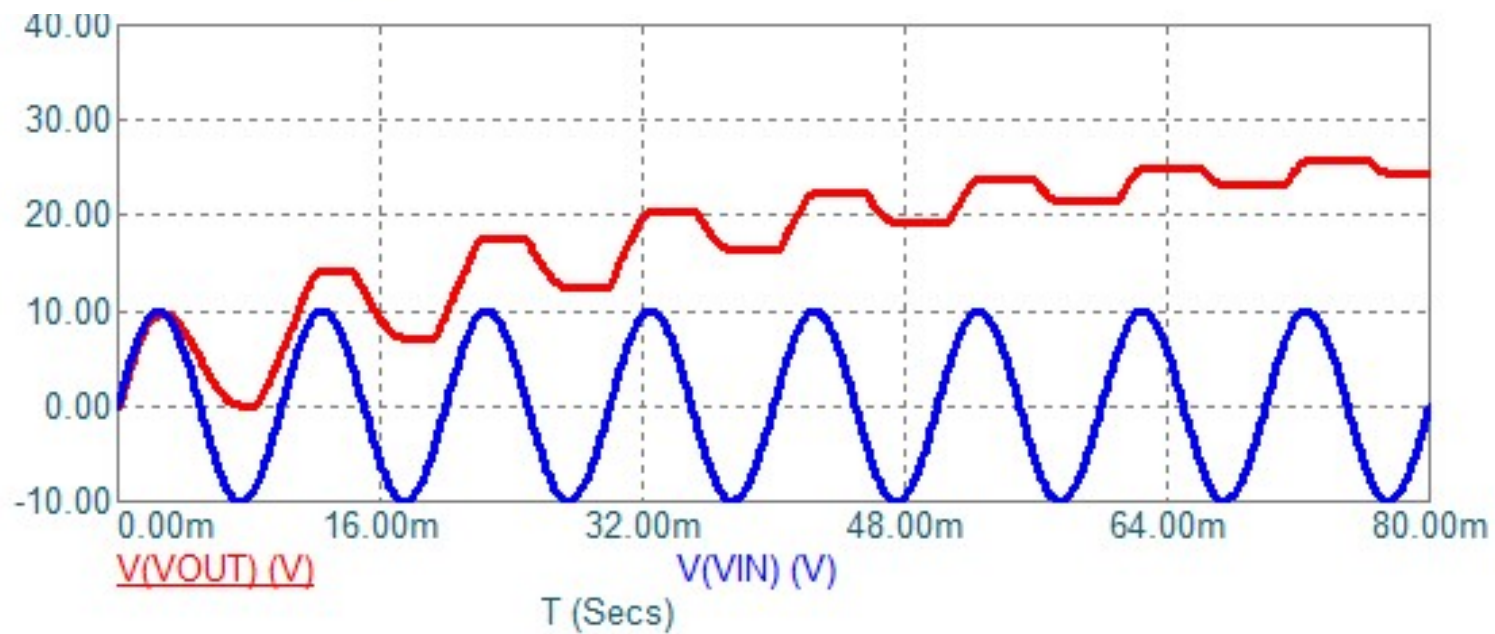
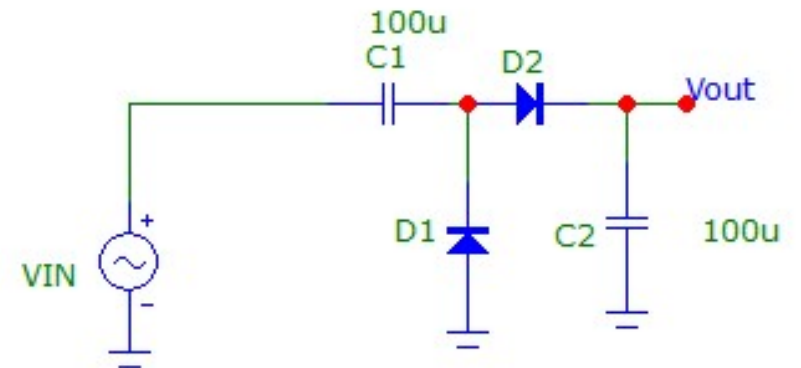
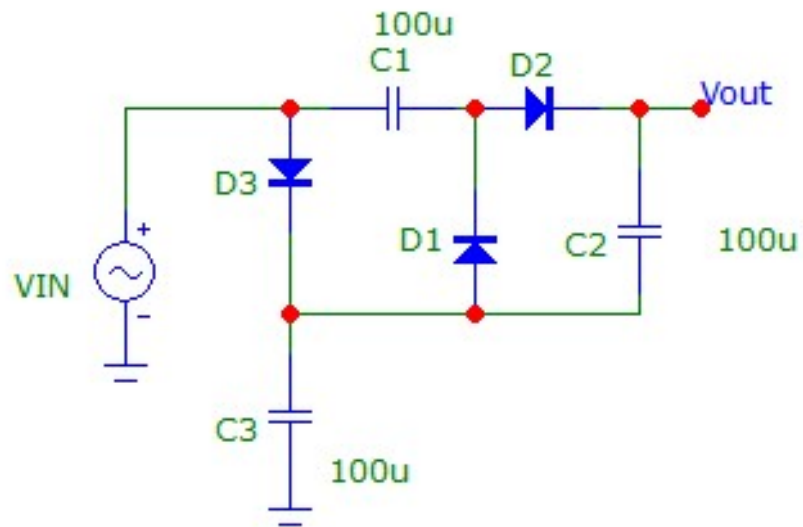


Voltage Doubler



Voltage Tripler

$$10V\sin(\omega t)$$



Temperature dependence of diode characteristics

$$I_D = I_S \times \left\{ \exp\left(\frac{V_d}{V_T}\right) - 1 \right\}$$

$$V_T = \frac{kT}{Q}$$

$$I_S \propto n_i^2 \propto e^{-\frac{E_g}{kT}}$$

Reverse saturation current increases with temperature. For forward bias, even though V_T increases, current still increases because of greater influence of I_S

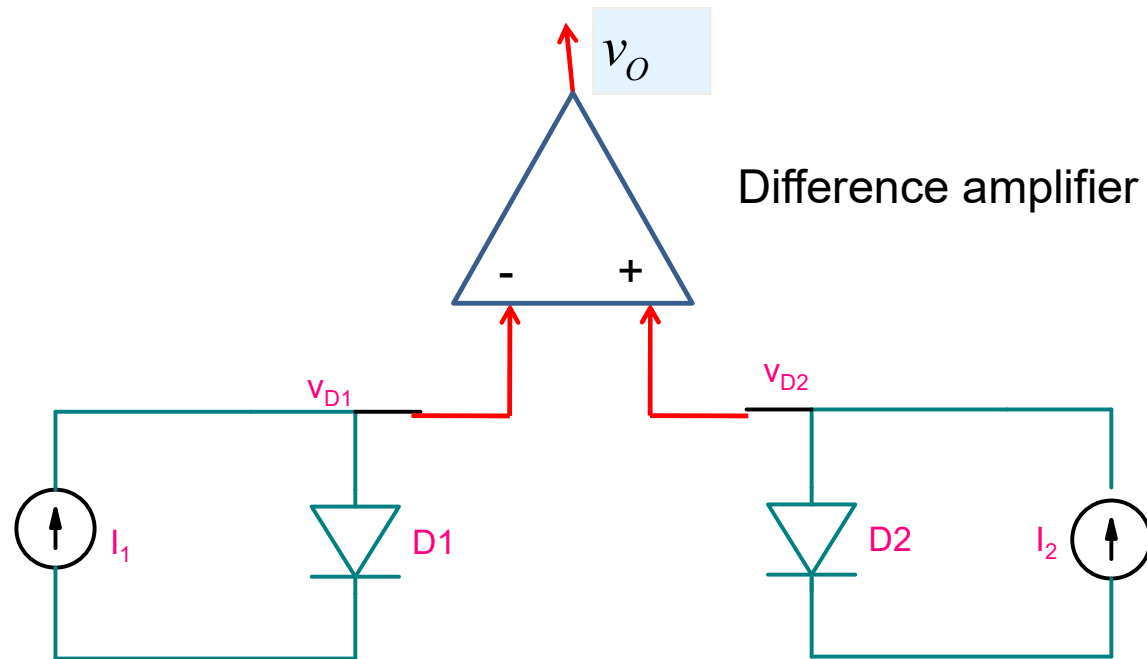
For a diode in forward bias at a fixed current I_O : $v_D = V_T \times \ln(I_O/I_S + 1)$

For Silicon diodes, v_D decreases at the rate of $\sim -2\text{mV}/^\circ\text{C}$

If the diode voltage is 0.7 at 27°C , then at 100°C it would be only :

$$0.7 - 2 \times 10^{-3} \times (100 - 27) = 0.554V$$

Measurement of temperature using a pn junction diode



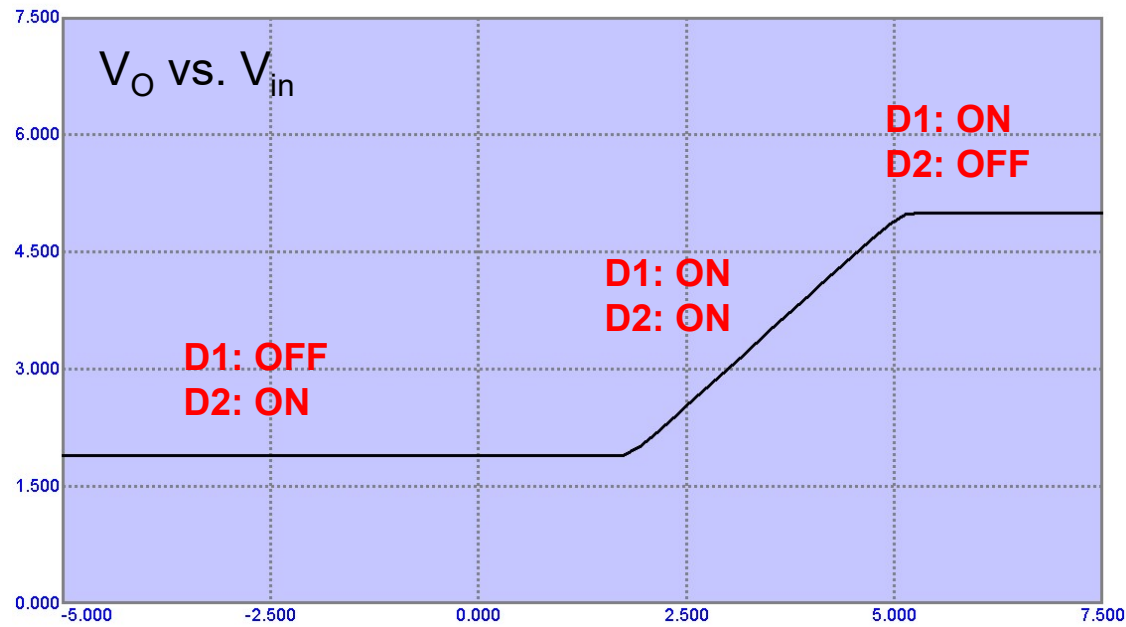
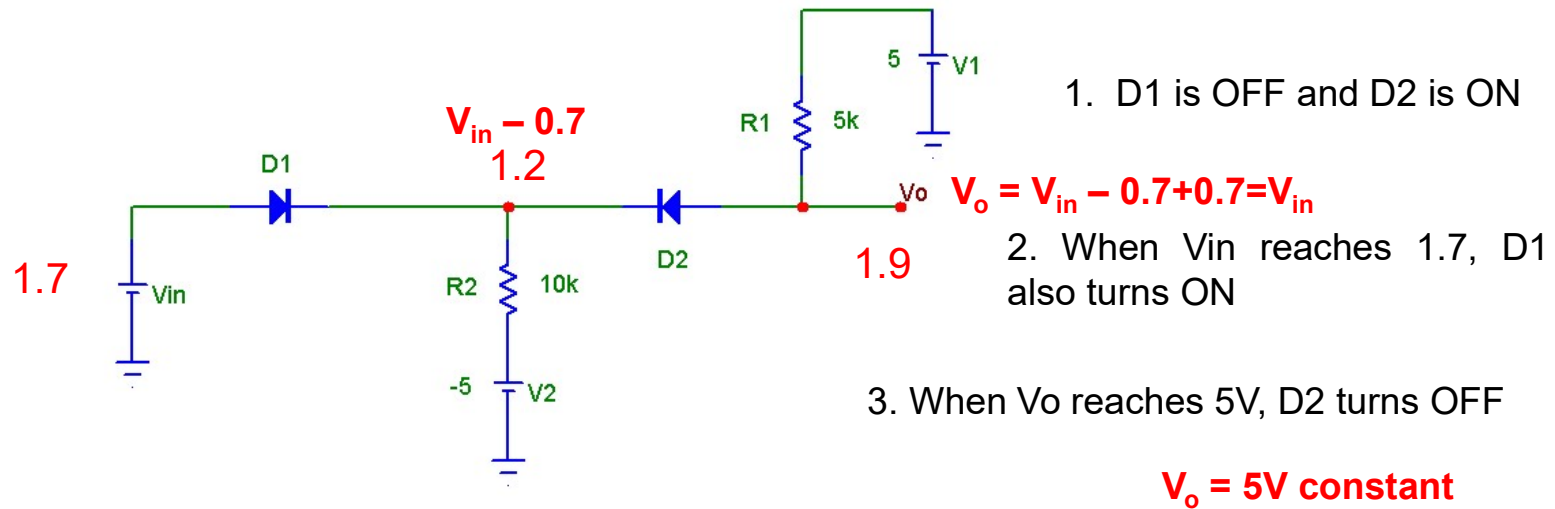
$$v_{D1} = V_T \times \ln(I_1/I_S + 1)$$

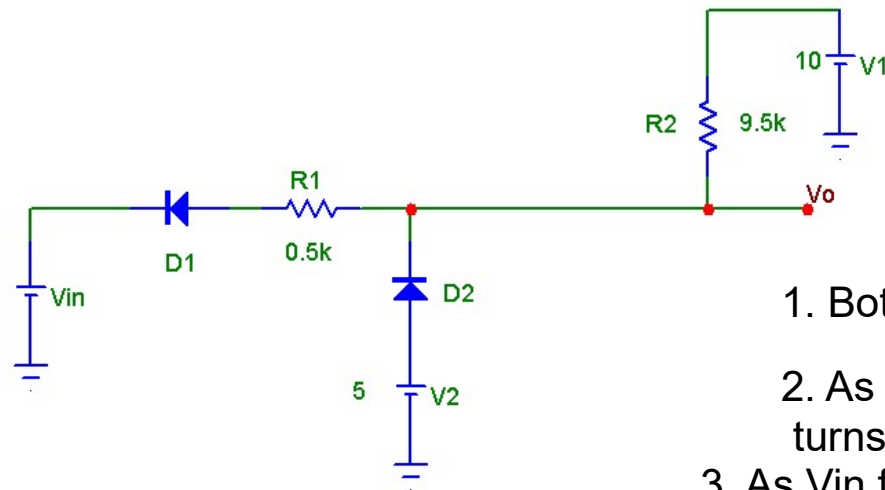
$$v_{D2} = V_T \times \ln(I_2/I_S + 1)$$

$$v_O = C \times (v_{D2} - v_{D1})$$

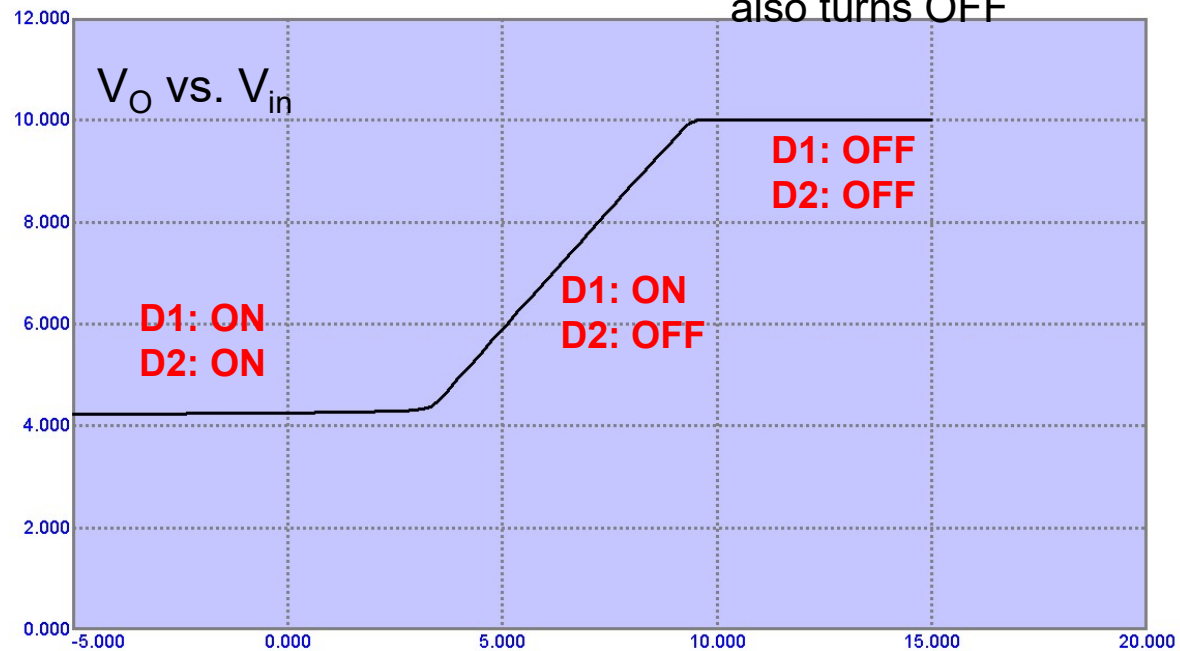
$$v_O = \left(C \times \frac{k}{q} \times \ln\left(\frac{I_2}{I_1}\right) \right) \times T$$

Multiple-diode Circuits



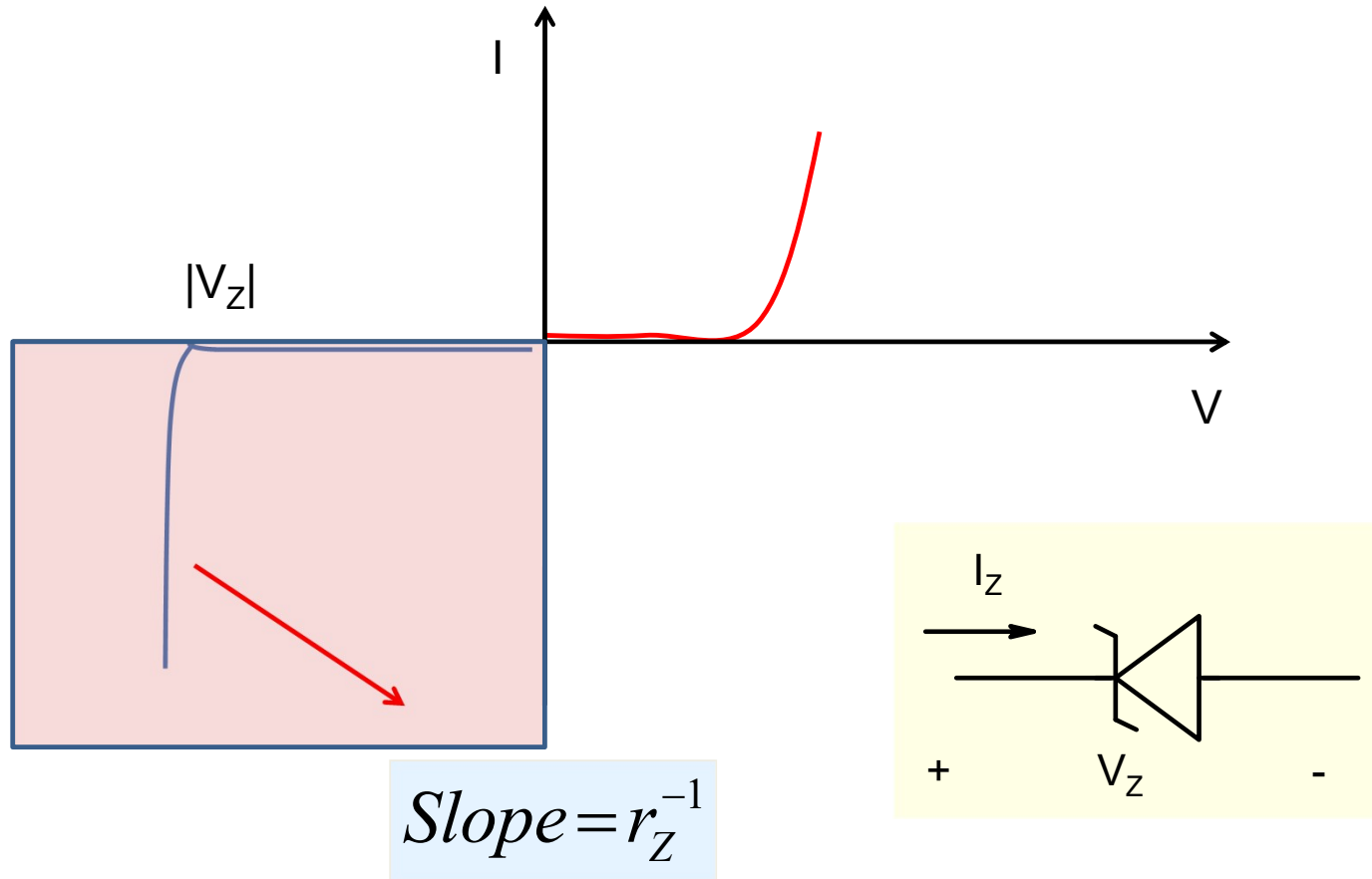


1. Both diodes are initially ON
2. As V_{in} increases, eventually $D2$ turns OFF
3. As V_{in} further increases, eventually $D1$ also turns OFF

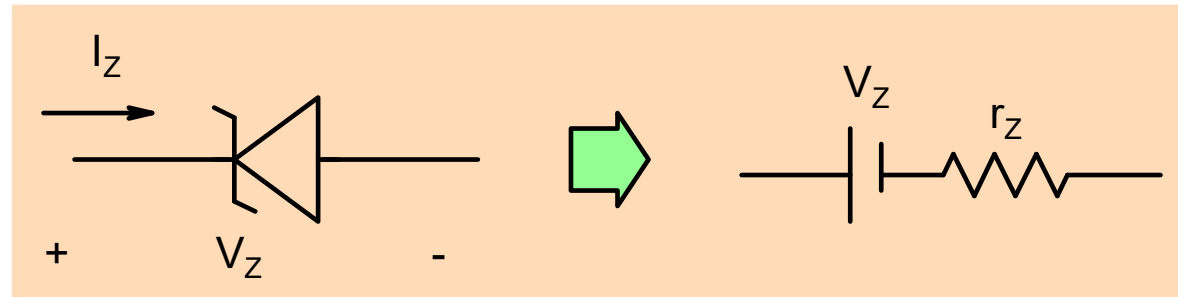


Zener Diode

A diode specially designed to operate in reverse bias in 'breakdown' region



Model



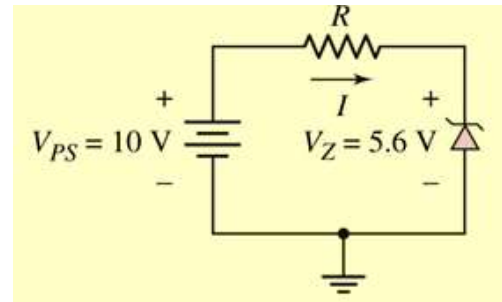
Often we will assume that r_z is negligible

Example

Given $V_Z = 5.6\text{V}$

$r_z = 0\Omega$

Find a value for R such
that the current through the
diode is limited to 3mA



$$I = \frac{V_{PS} - V_Z}{R}$$

$$R = \frac{V_{PS} - V_Z}{I} = \frac{10\text{V} - 5.6\text{V}}{3\text{mA}} = 1.47\text{k}\Omega$$

$$P_Z = I_Z V_Z = 3\text{mA} \cdot 5.6\text{V} = 1.68\text{mW}$$

Datasheet

Zeners 1N4728A - 1N4752A

Absolute Maximum Ratings* T_A = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
P _D	Power Dissipation Derate above 50°C	1.0 6.67	W mW/°C
T _{STG}	Storage Temperature Range	-55 to +200	°C
T _J	Operating Junction Temperature	+ 200	°C
R _{θJL}	Thermal resistance Junction to Lead	53.5	°C/W
R _{θJA}	Thermal resistance Junction to Ambient	100	°C/W
	Lead Temperature (1/16" from case for 10 seconds)	+ 230	°C
	Surge Power**	10	W

Tolerance: A = 5%



*These ratings are limiting values above which the serviceability of the diode may be impaired.

**Non-recurrent square wave PW = 8.3 ms, TA = 55 degrees C.

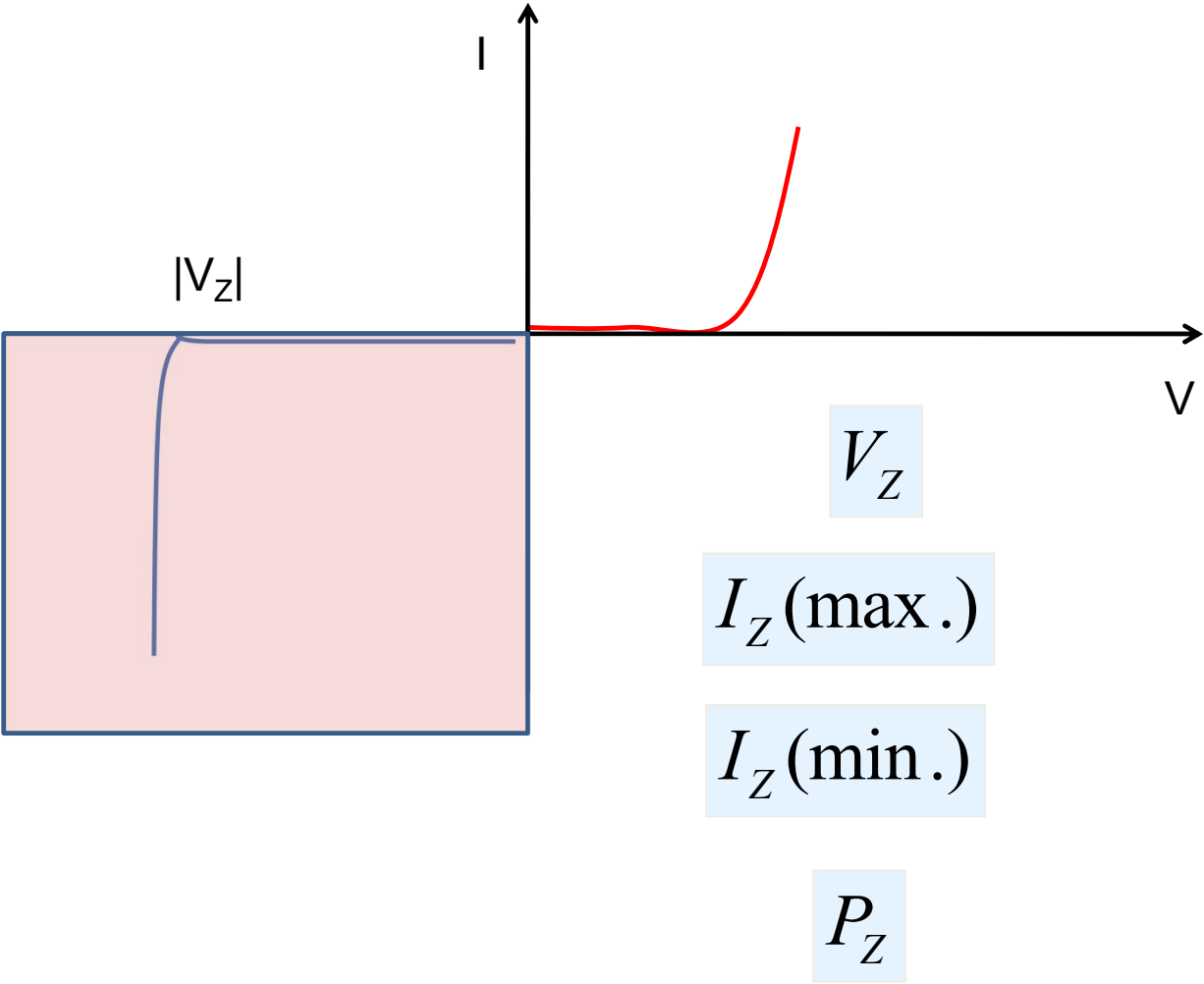
NOTES:

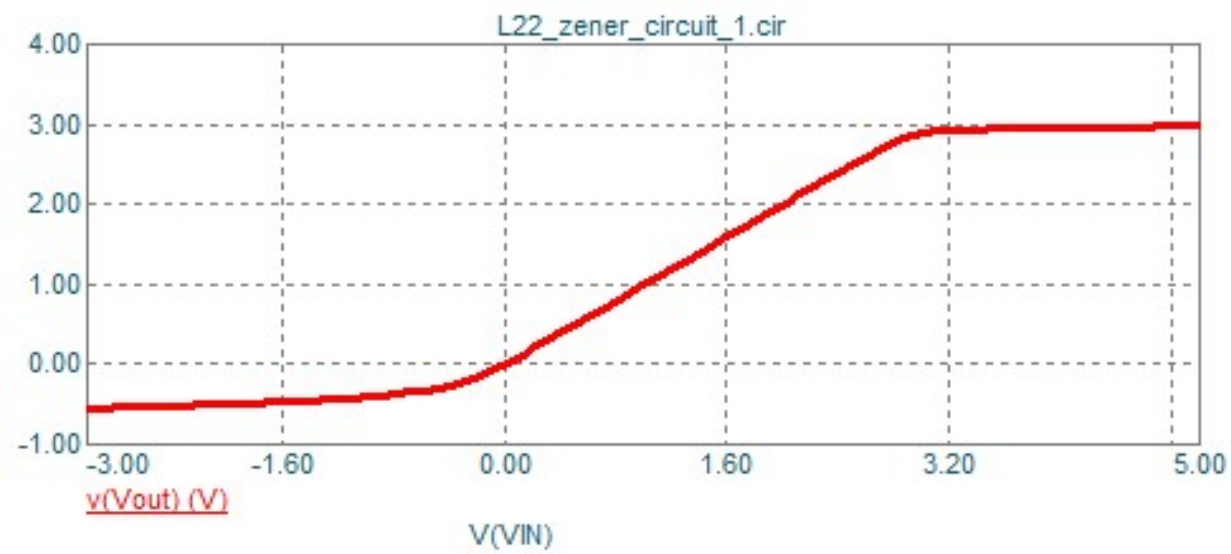
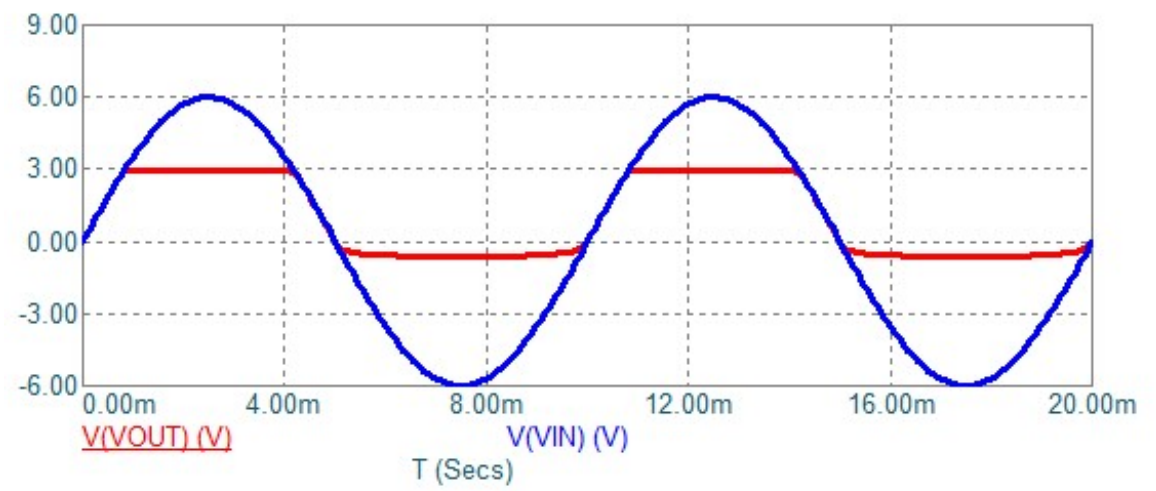
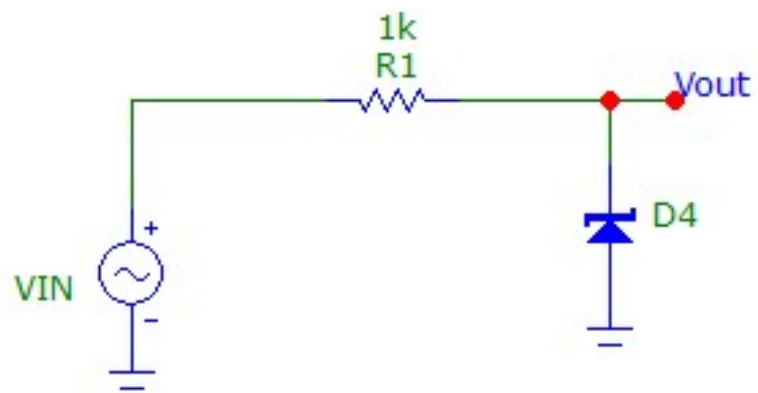
- These ratings are based on a maximum junction temperature of 200 degrees C.
- These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Electrical Characteristics T_A = 25°C unless otherwise noted

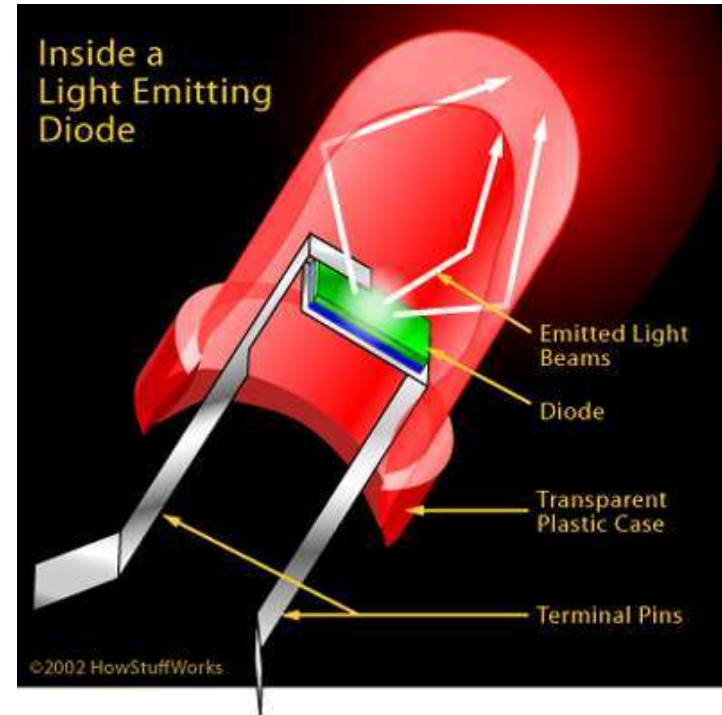
Device	V _Z (V)	Z _Z @ (Ω)	I _{ZT} (mA)	Z _{ZK} @ (Ω)	I _{ZK} (mA)	V _R @ (V)	I _R (μA)	I _{SURGE} (mA)	I _{ZM} (mA)
1N4728A	3.3	10	76	400	1.0	1.0	100	1380	276
1N4729A	3.6	10	89	400	1.0	1.0	100	1260	252
1N4730A	3.9	9.0	84	400	1.0	1.0	50	1190	234
1N4731A	4.3	9.0	58	400	1.0	1.0	10	1070	217
1N4732A	4.7	8.0	53	500	1.0	1.0	10	970	193
1N4733A	5.1	7.0	49	550	1.0	1.0	10	890	178
1N4734A	5.6	5.0	45	600	1.0	2.0	10	810	162
1N4735A	6.2	2.0	41	700	1.0	3.0	10	730	146
1N4736A	6.8	3.5	37	700	1.0	4.0	10	660	133
1N4737A	7.5	4.0	34	700	0.5	5.0	10	605	121
1N4738A	8.2	4.5	31	700	0.5	6.0	10	550	110
1N4739A	9.1	5.0	28	700	0.5	7.0	10	500	100
1N4740A	10	7.0	25	700	0.25	7.6	10	454	91
1N4741A	11	8.0	23	700	0.25	8.4	5.0	414	83
1N4742A	12	9.0	21	700	0.25	9.1	5.0	380	76
1N4743A	13	10	19	700	0.25	9.9	5.0	344	69
1N4744A	15	14	17	700	0.25	11.4	5.0	304	61
1N4745A	16	16	15.5	700	0.25	12.2	5.0	285	57
1N4746A	18	20	14	750	0.25	13.7	5.0	250	50
1N4747A	20	22	12.5	750	0.25	15.2	5.0	225	45
1N4748A	22	23	11.5	750	0.25	16.7	5.0	205	41
1N4749A	24	25	10.5	750	0.25	18.2	5.0	190	38
1N4750A	27	35	9.5	750	0.25	20.6	5.0	170	34
1N4751A	30	40	8.5	1000	0.25	22.8	5.0	150	30

Zener diode: Important Characteristics

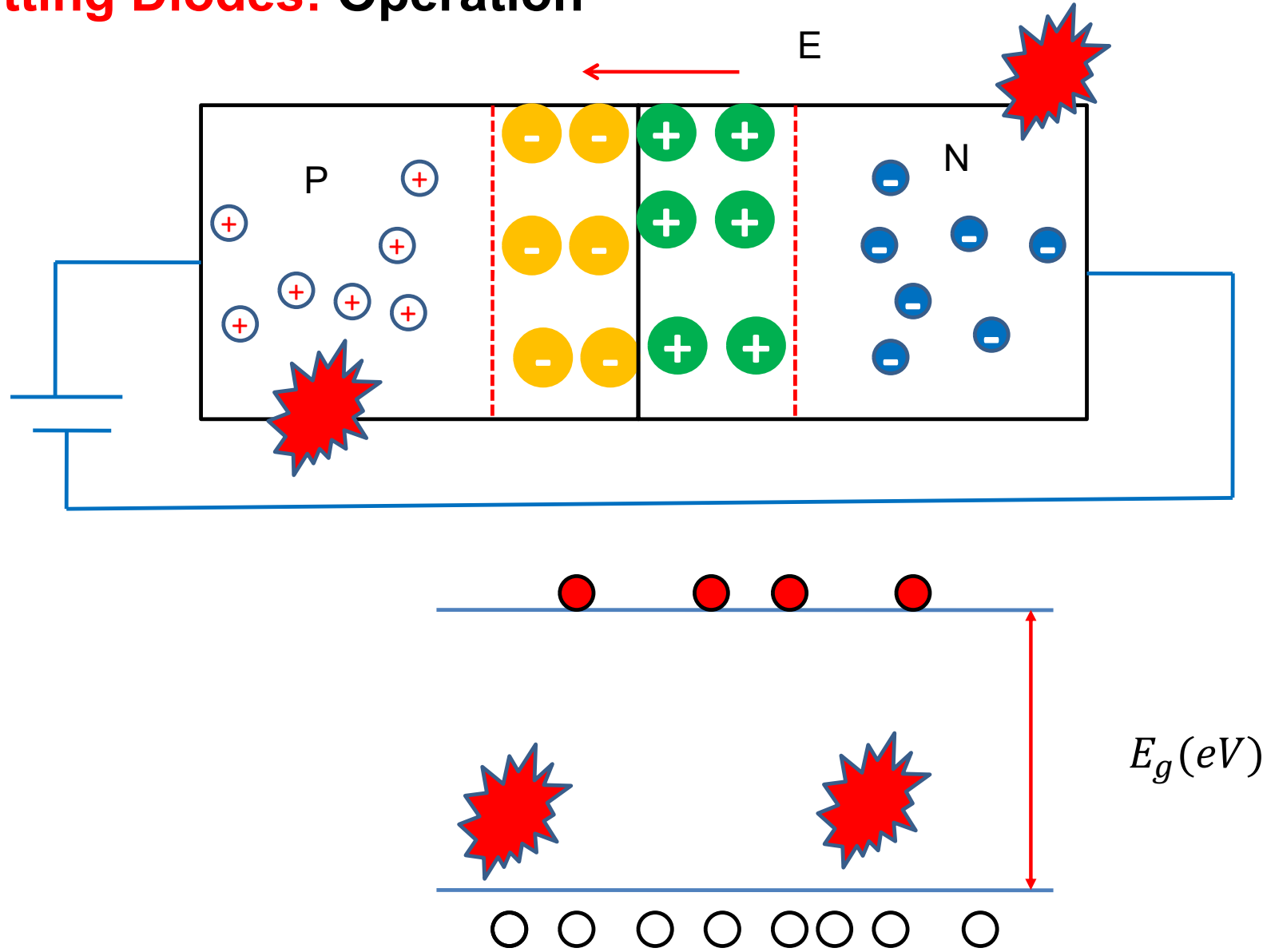




Light Emitting Diodes



Light Emitting Diodes: Operation



Invention of LED



Nick Holonyak
1962; Red LED using GaAsP

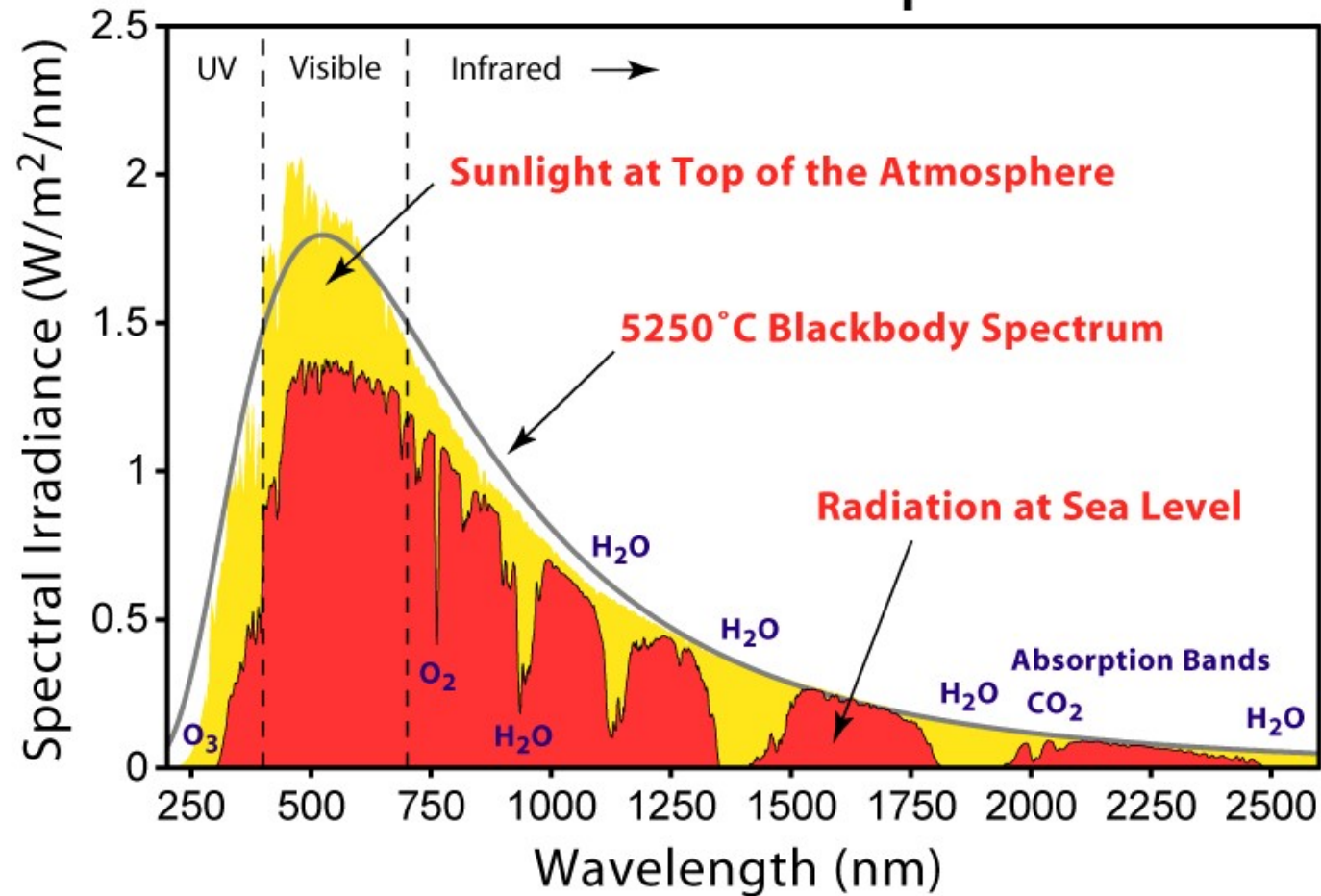


Shuji Nakamura
Blue LED using GaN, 1992
Nobel Prize, 2014

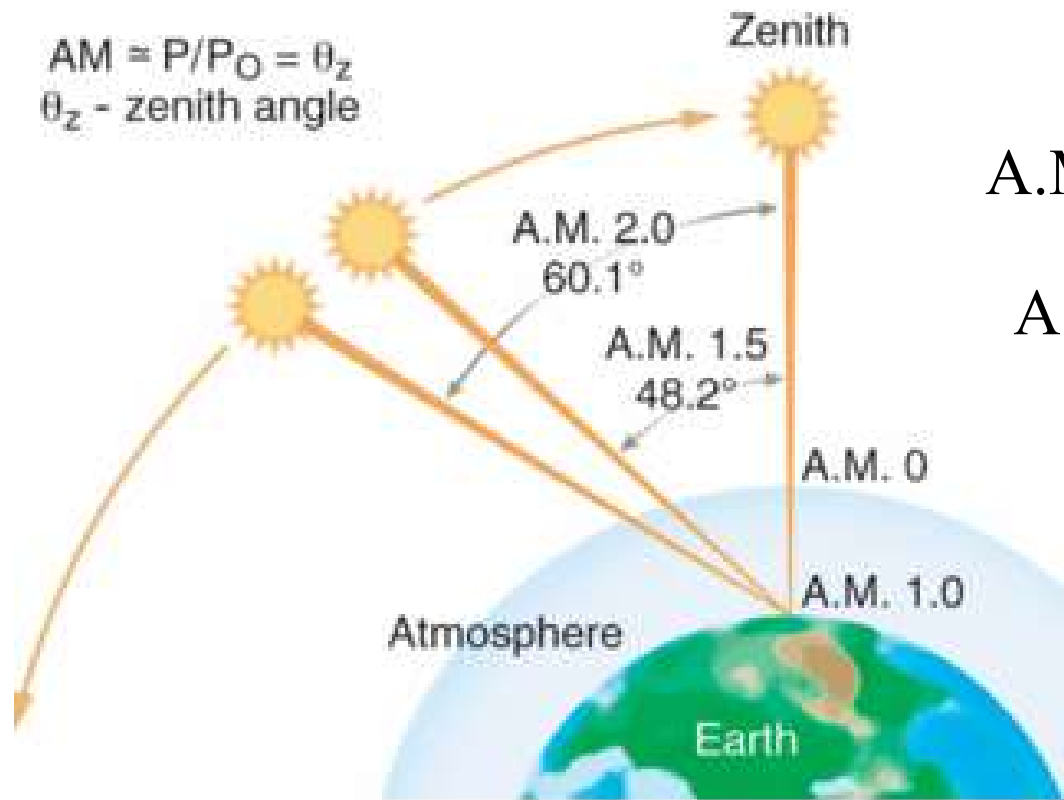
PN Junction as a Solar Cell

Sun as a source of energy

Solar Radiation Spectrum



Sun as a source of energy



A.M.0 ~1367 W/m²

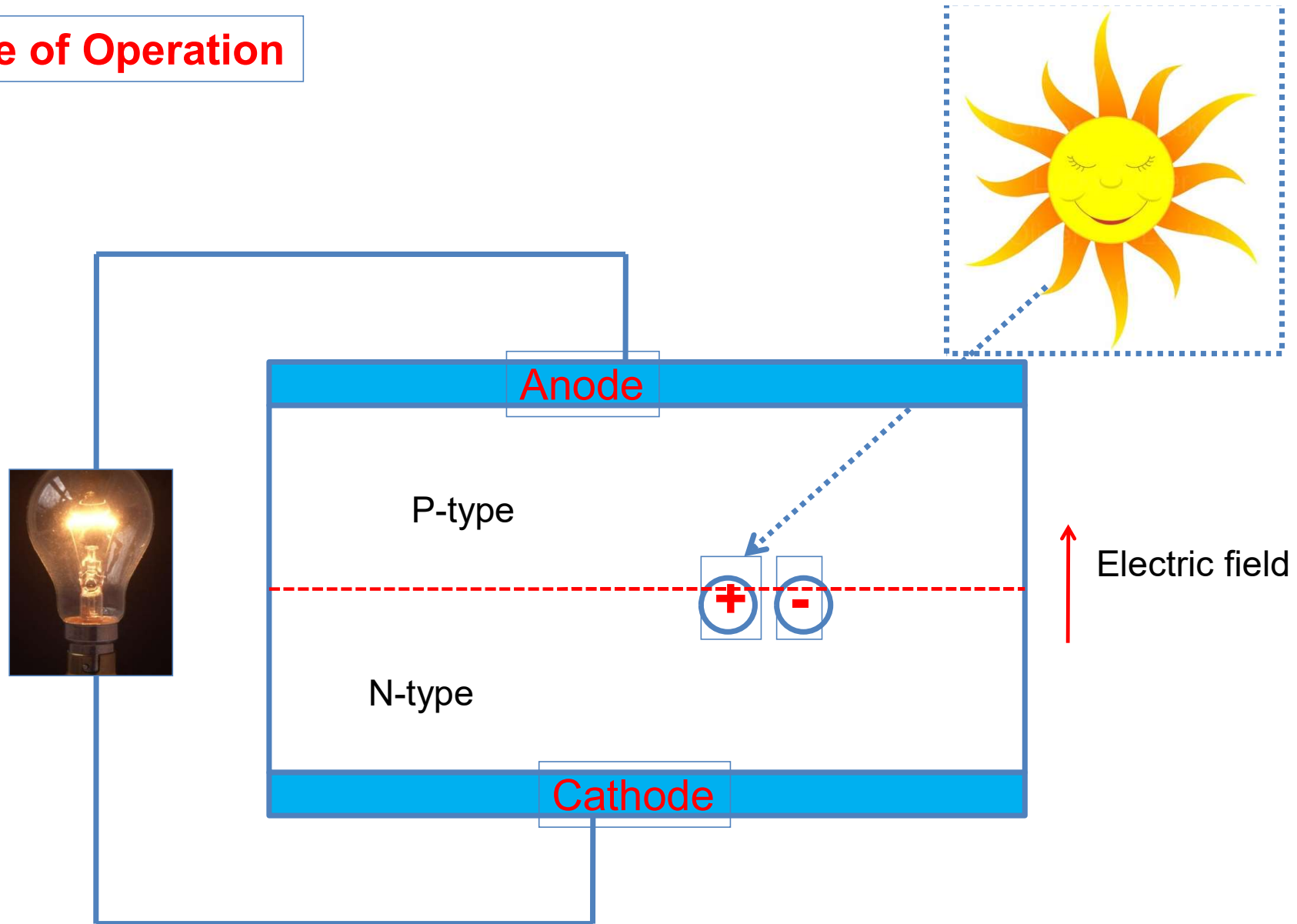
A.M.1 ~925 W/m²

A.M.1.5 ~844 W/m²

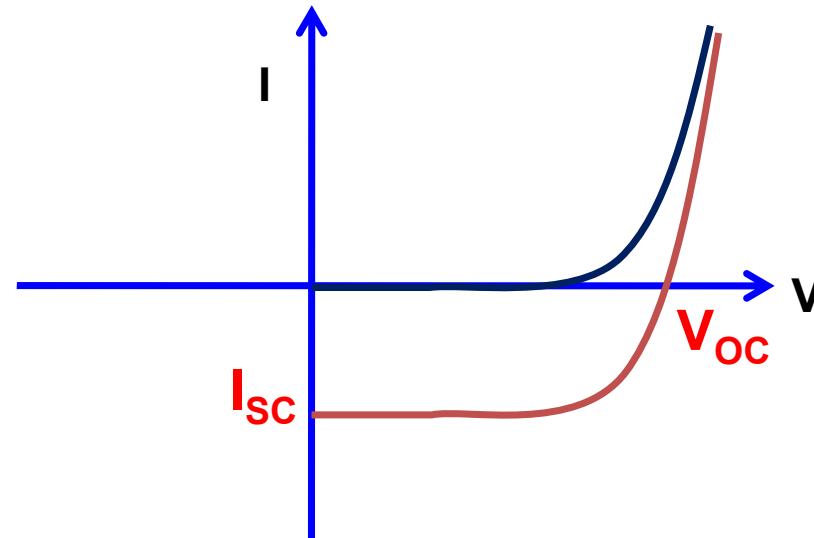
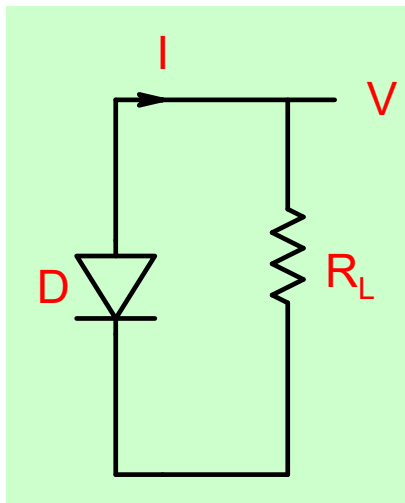
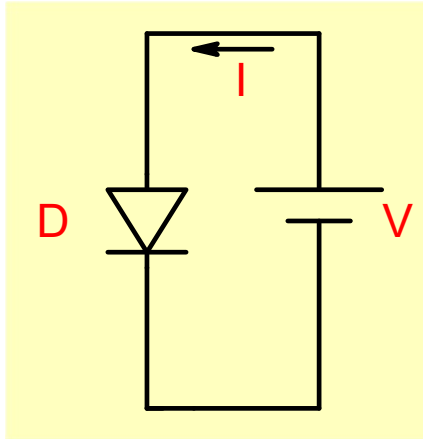
A.M.2 ~691 W/m²

AM: air mass

Principle of Operation

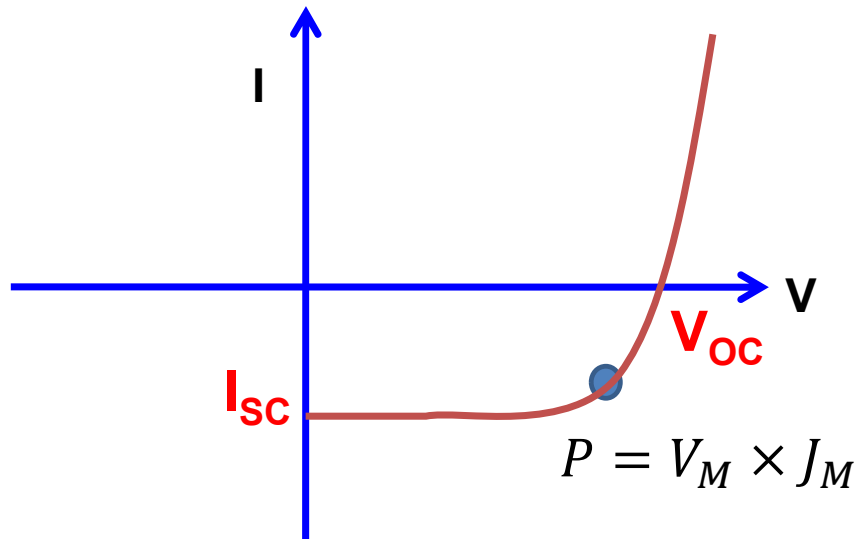


Solar cell is a diode



V_{oc} : Open circuit voltage
 I_{sc} : Short circuit current

What is the maximum power that can be extracted?



$$P = \frac{V_M \times J_M}{V_{OC} \times J_{SC}} \times V_{OC} \times J_{SC}$$

$$P = FF \times V_{OC} \times J_{SC}$$

Parameters of the Ideal Silicon Cell and the Best PERL Cell, and Achievable Parameters of a PERL Cell (AM1.5)

	J _{sc} (mA/cm ²)	V _{oc} (mV)	FF (%)	Eff. (%)
ideal cell[15]	43.0	769	89.0	29
best PERL[18]	40.8	708	83.1	24
achievable cell[19]	42.5	730	84.0	>26



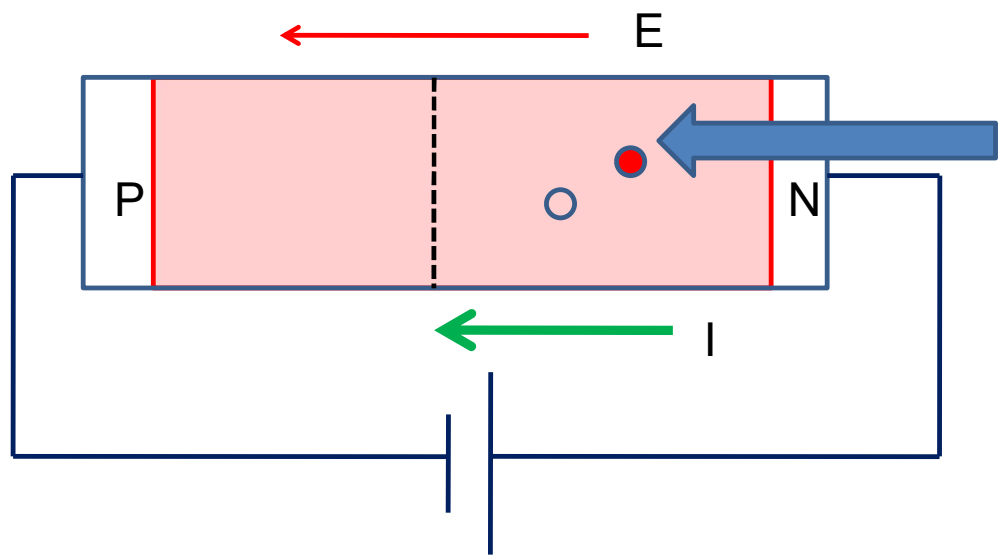
$$P_{ext} = J_{SC} \times V_{OC} \times FF = 43 \times 0.769 \times 0.89 = 29.4\text{mW for } 100\text{mW of incident solar power (1 sun)}$$

CITY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG.
AGRA	3.58	4.65	5.53	5.96	6.33	5.98	4.94	4.51	4.68	4.69	3.91	3.42	4.85
ALLAHABAD	3.79	4.83	5.93	6.39	6.55	5.68	4.56	4.31	4.48	4.8	4.23	3.6	4.93
GORAKHPUR	3.41	4.25	5.28	5.88	6.5	6.34	5.66	5.35	5.02	4.54	3.74	3.2	4.93
KANPUR	3.62	4.63	5.68	6.19	6.54	5.88	4.78	4.45	4.45	4.83	4.14	3.52	4.89
LUCKNOW	3.62	4.63	5.68	6.19	6.54	5.88	4.78	4.45	4.45	4.83	4.14	3.52	4.89
MEERUT	3.6	4.53	5.73	6.7	7.28	6.68	5.54	4.9	5.17	5.01	4.15	3.47	5.23

kWh / m² / day

18% efficient solar panel of 1m² would generate 0.9kWh

PN Junction as a Photodiode or detector



A specially designed Reverse-biased PN junction is used to detect light.

