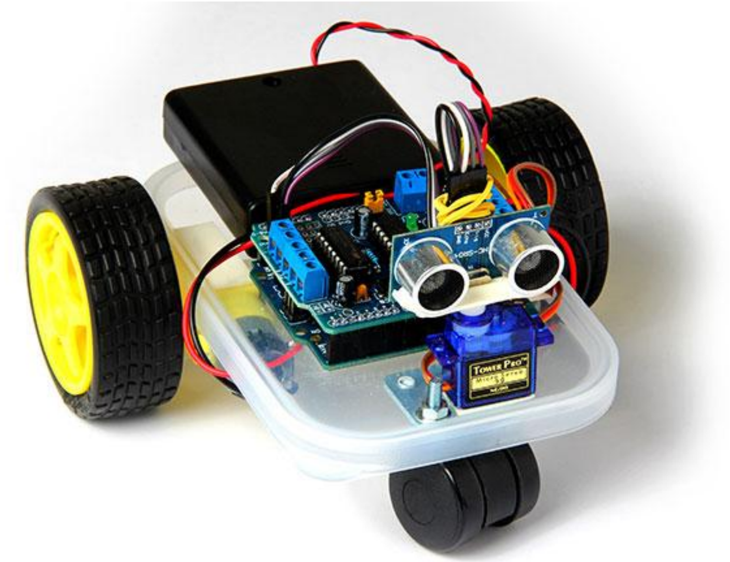
EP486 Microcontroller Applications

Topic 3

Review of Electronics



Department of Engineering Physics

University of Gaziantep

Oct 2013

Content

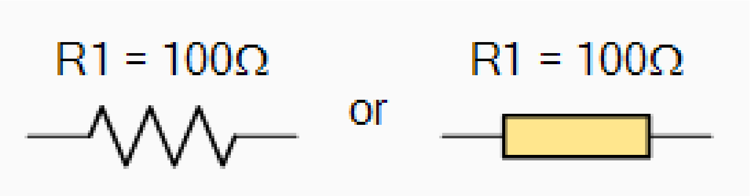
We’ll see the most fundamental and commonly used Electronic circuit components:

- Resistors
- Semiconductors
- Diodes
- Transistors (BJT)
- Binary & Hexadcimal Notation
- Digital Electronics
- Some Sensors

Resistors

- The job of a resistor to “resist”, regulate or to set the flow of electrons (current) through them by using the type of conductive material from which they are composed.

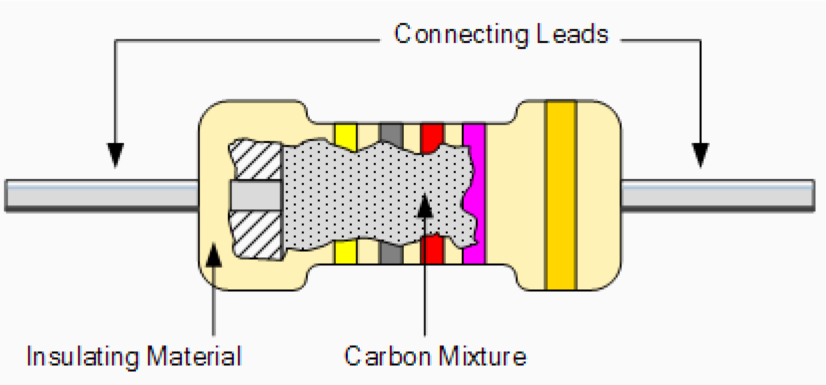
- Symbol

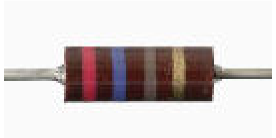


- Resistors can also be connected together in various series and parallel combinations to form resistor networks.

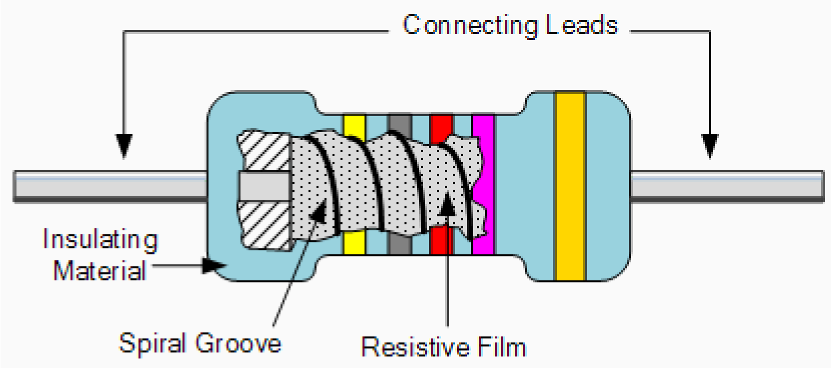
Resistor Types:

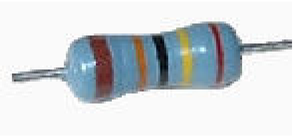
Carbon Resistors





Film Resistors





Color Codes

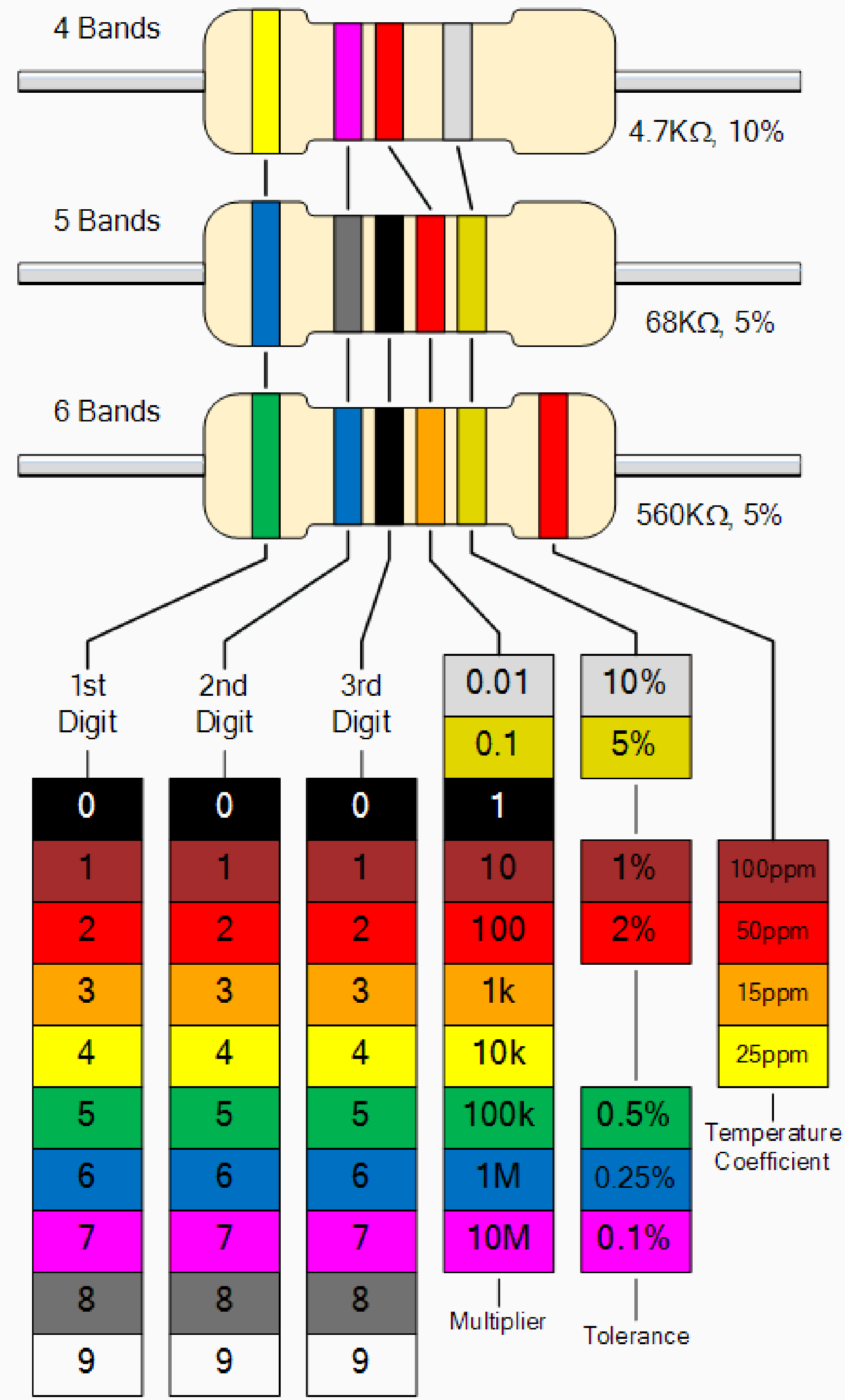
Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1,000	
Yellow	4	10,000	
Green	5	100,000	± 0.5%
Blue	6	1,000,000	± 0.25%
Violet	7	10,000,000	± 0.1%
Grey	8		
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%

Digit, Digit, Multiplier =

Colour Colour x 10^{colour} in Ohm's

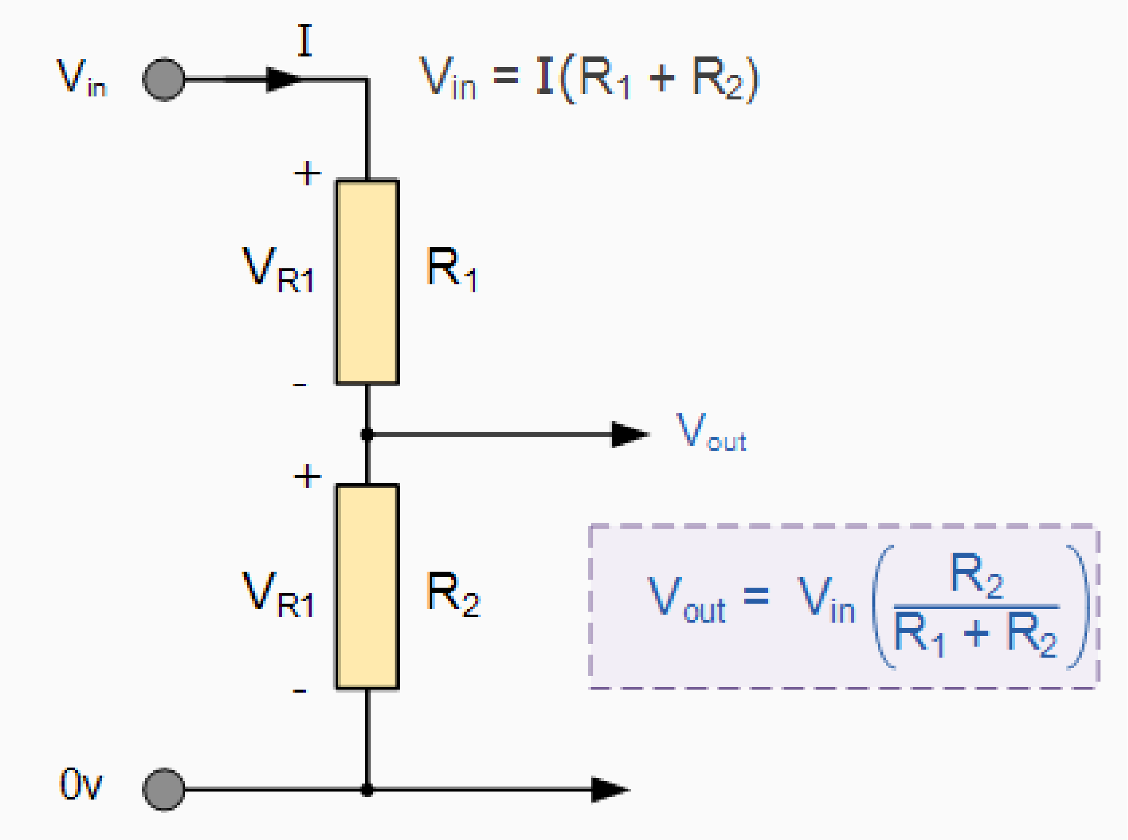
Yellow Violet Red =

4 7 2 = 4 7 x 10^2 = 4700Ω



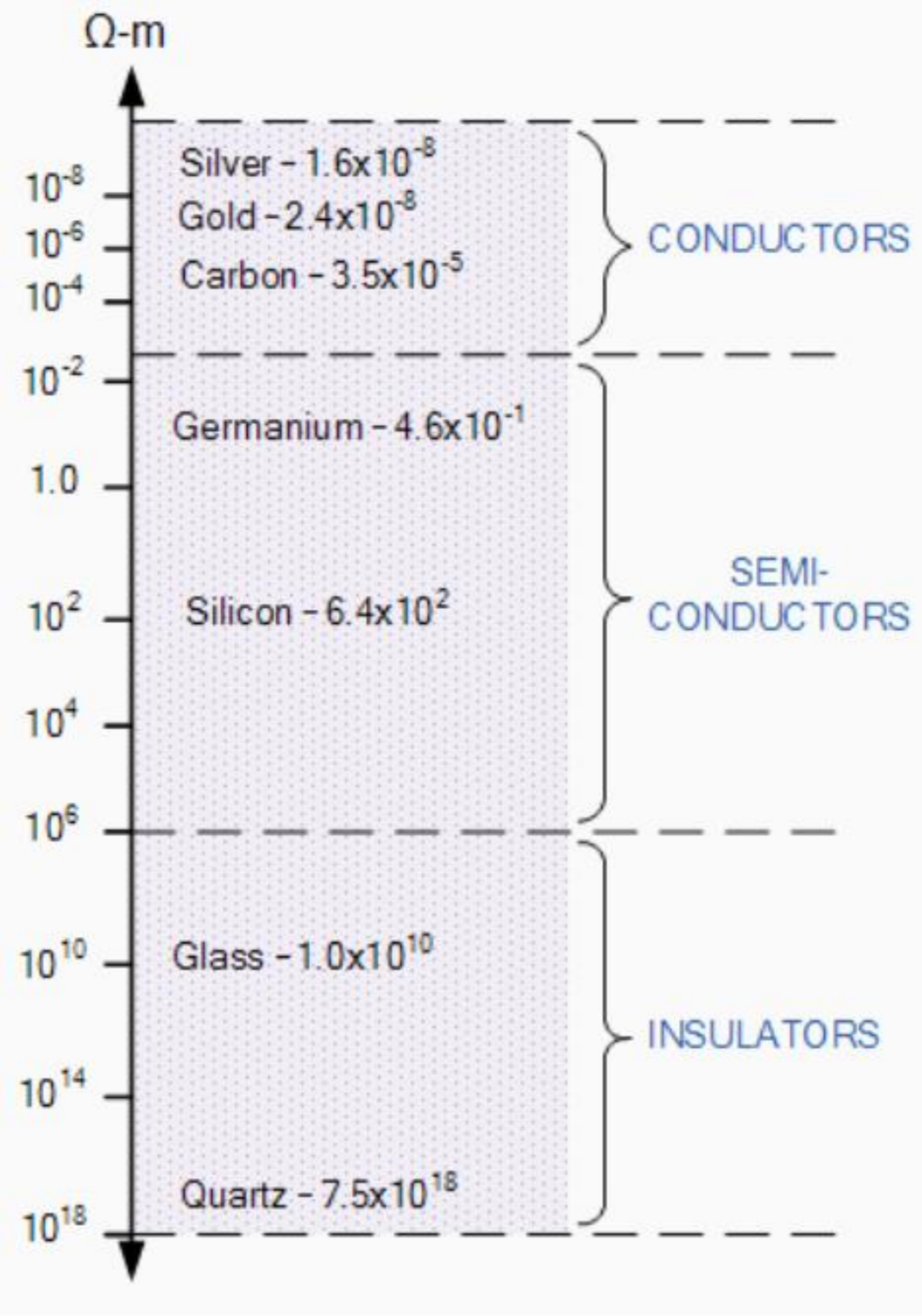
BS 1852 Codes for Resistor Values
0.47Ω = R47 or 0R47
1.0Ω = 1R0
4.7Ω = 4R7
47Ω = 47R
470Ω = 470R or 0K47
1.0KΩ = 1K0
4.7KΩ = 4K7
47KΩ = 47K
470KΩ = 470K or 0M47
1MΩ = 1M0

Voltage Divider Rule



Semiconductors

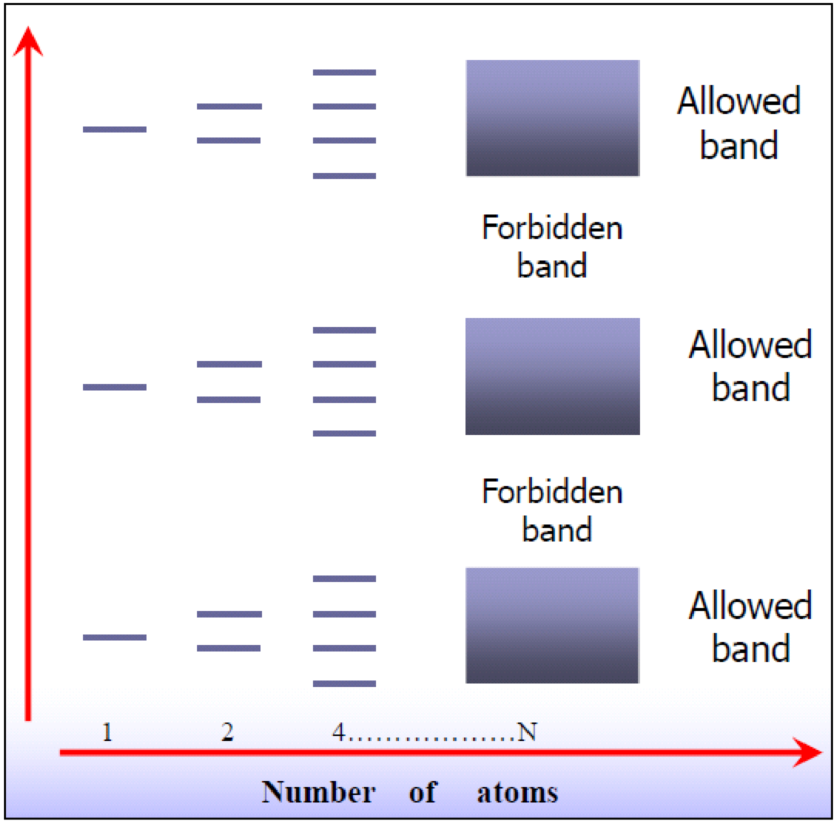
- Materials can be categorized into **conductors**, **insulators** or **semiconductors** (S/C) by their ability to conduct electricity.
- Resistivity (Ohm-meter)



Band Structure

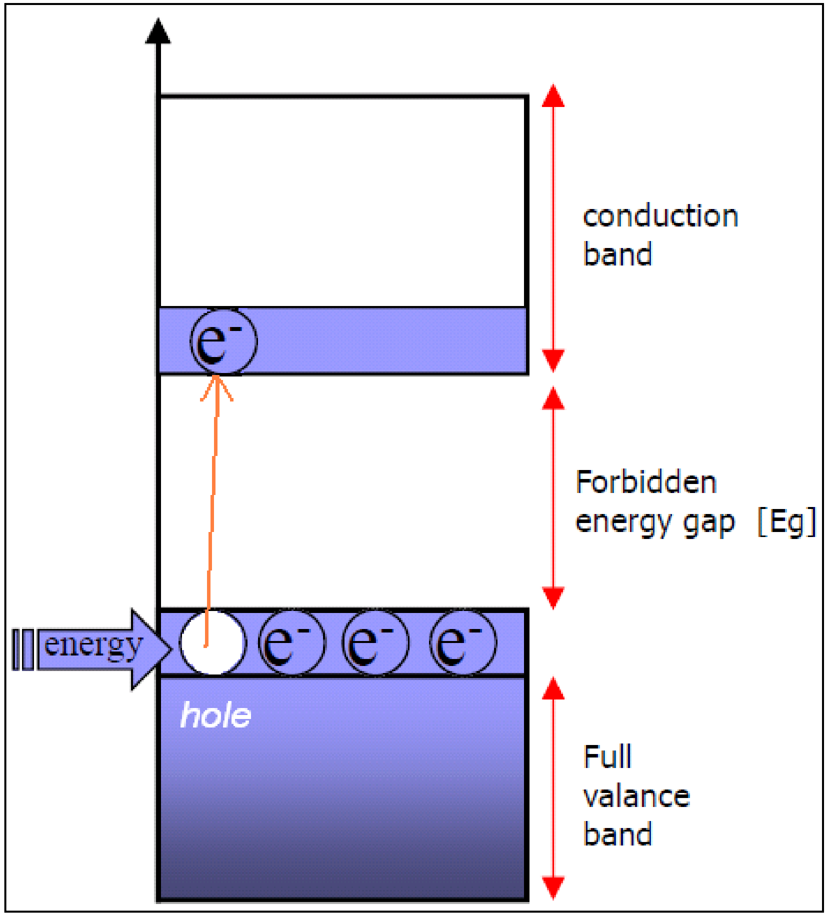
- The electrons surrounding a nucleus have certain well-defined energy-levels.

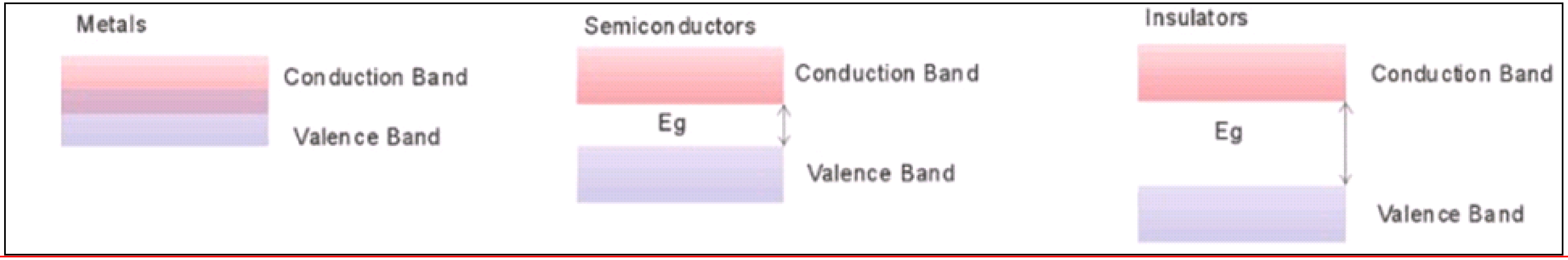
- Electrons don’t like to have the same energy in the same potential system.



- Hence the band structure of solid take place.

- Assume some kind of energy is provided to the electron (valence electron) sitting at the top of the valance band.
- This electron contributes to the conductivity and this electron is called as a conduction electron.
- When enough energy is supplied to the e- at the top of the valance band, e- can make a transition to the bottom of the conduction band.
- This electron leaves behind a missing electron state called hole.
- Hole behaves as a positive charge carrier.

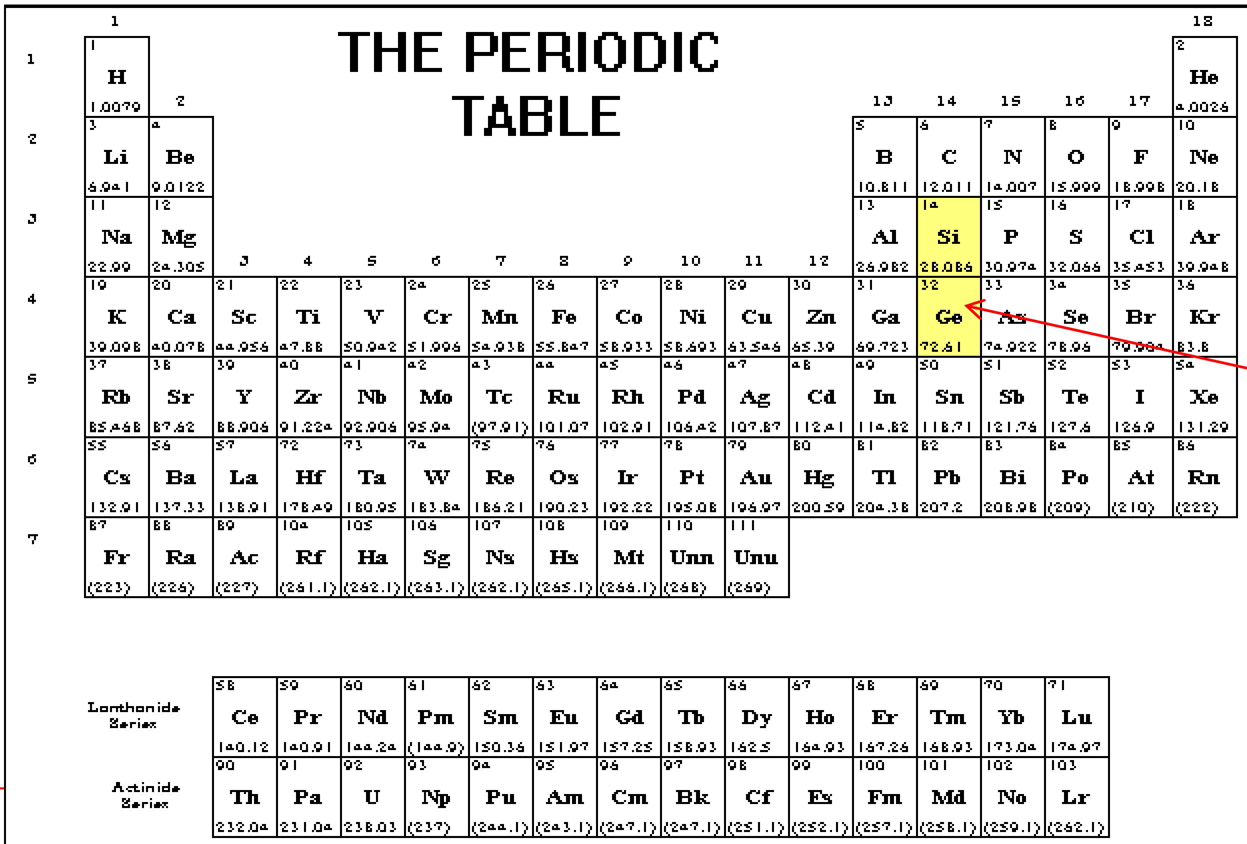




Elemental semiconductors are semiconductors where each atom is of the same type. *Examples are Ge, Si*.

Adding impurity atoms from 3A or 5A elements (about 1 in 10^6) to the pure S/C (Si) crystal makes S/C a good conductor.

Compound semiconductors are made of two or more elements. *Common examples are GaAs or CdS*.



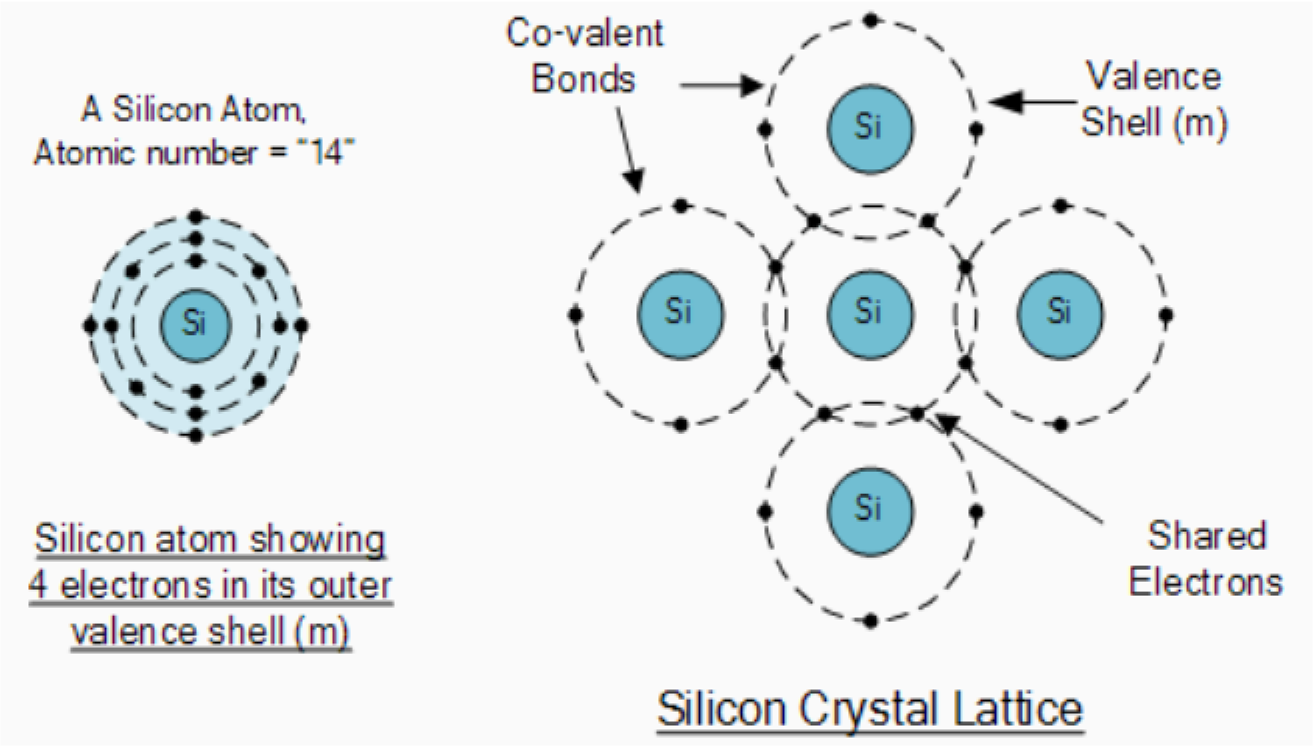
THE PERIODIC TABLE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.0079																	2 He 4.0026
2	3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br [illegible]	36 Kr 83.8
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc (97.91)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.6	53 I 126.9	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261.1)	105 Ha (262.1)	106 Sg (263.1)	107 Ns (262.1)	108 Hs (265.1)	109 Mt (266.1)	110 Unn (268)	111 Unu (269)							

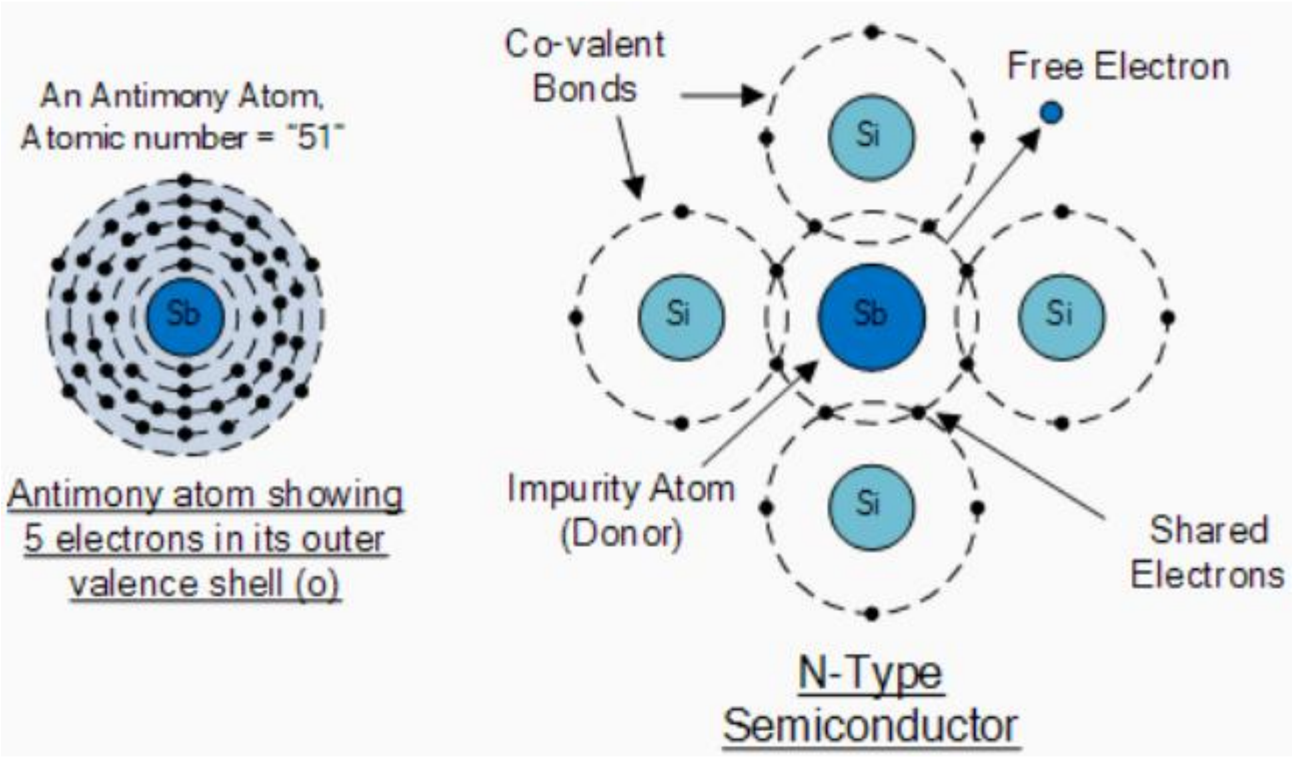
Lanthanide Series	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.9)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinide Series	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244.1)	95 Am (243.1)	96 Cm (247.1)	97 Bk (247.1)	98 Cf (251.1)	99 Es (252.1)	100 Fm (257.1)	101 Md (258.1)	102 No (259.1)	103 Lr (262.1)

Example 4A S/C Elements

A Silicon Atom Structure

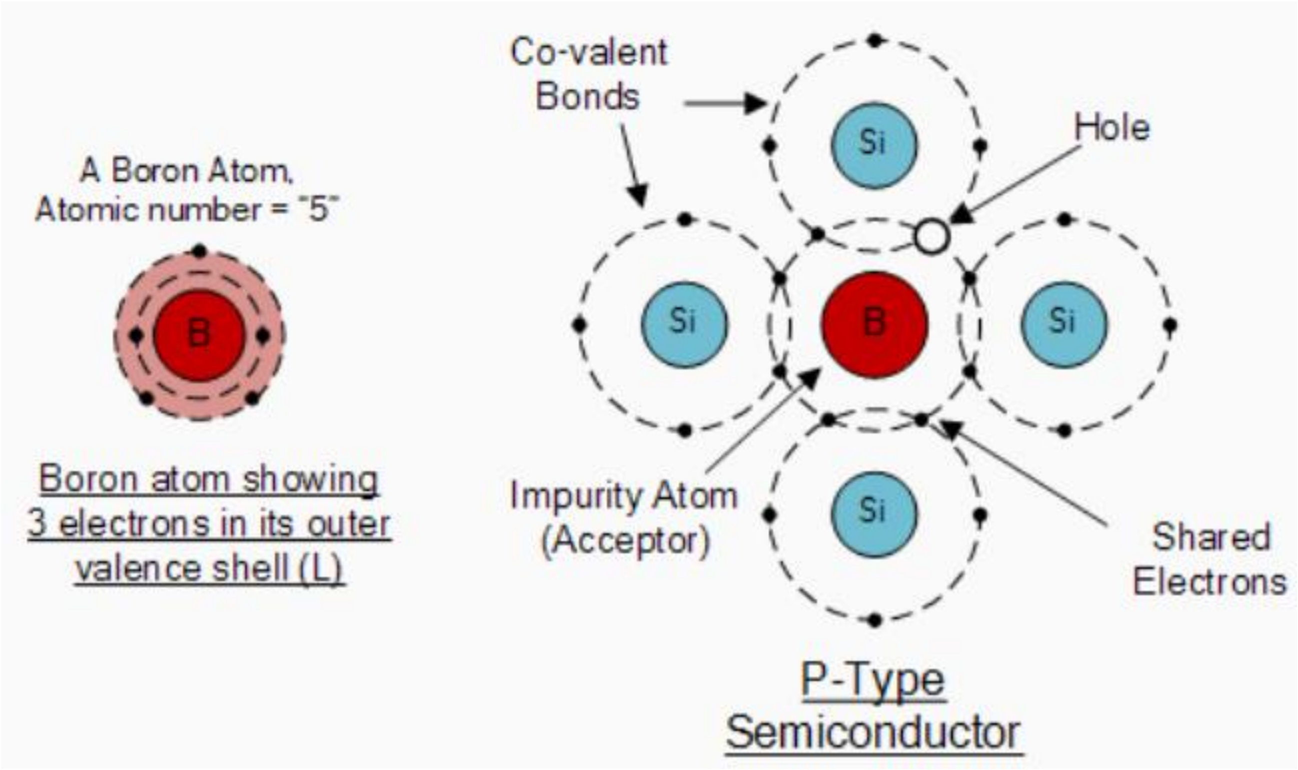


n-Type Semiconductor



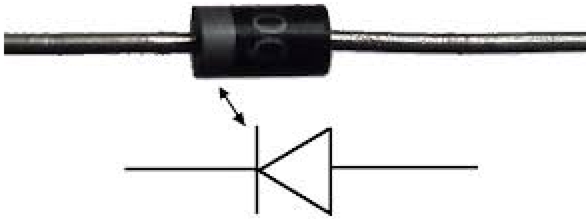
The diagram above shows the structure and lattice of the donor impurity atom Antimony.

p-Type Semiconductor



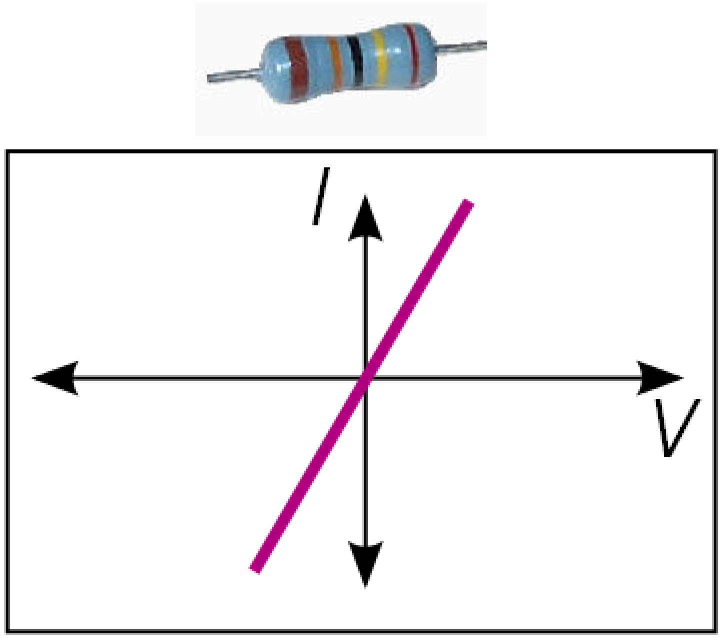
The diagram above shows the structure and lattice of the acceptor impurity atom Boron.

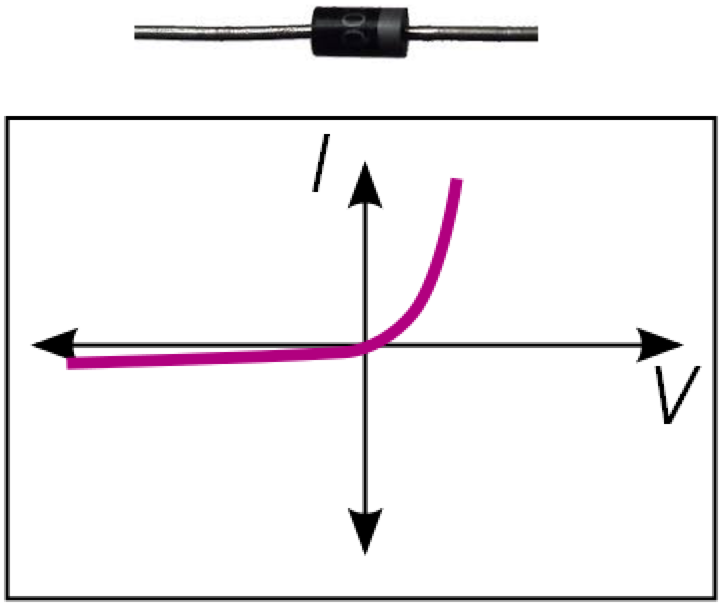
Diodes



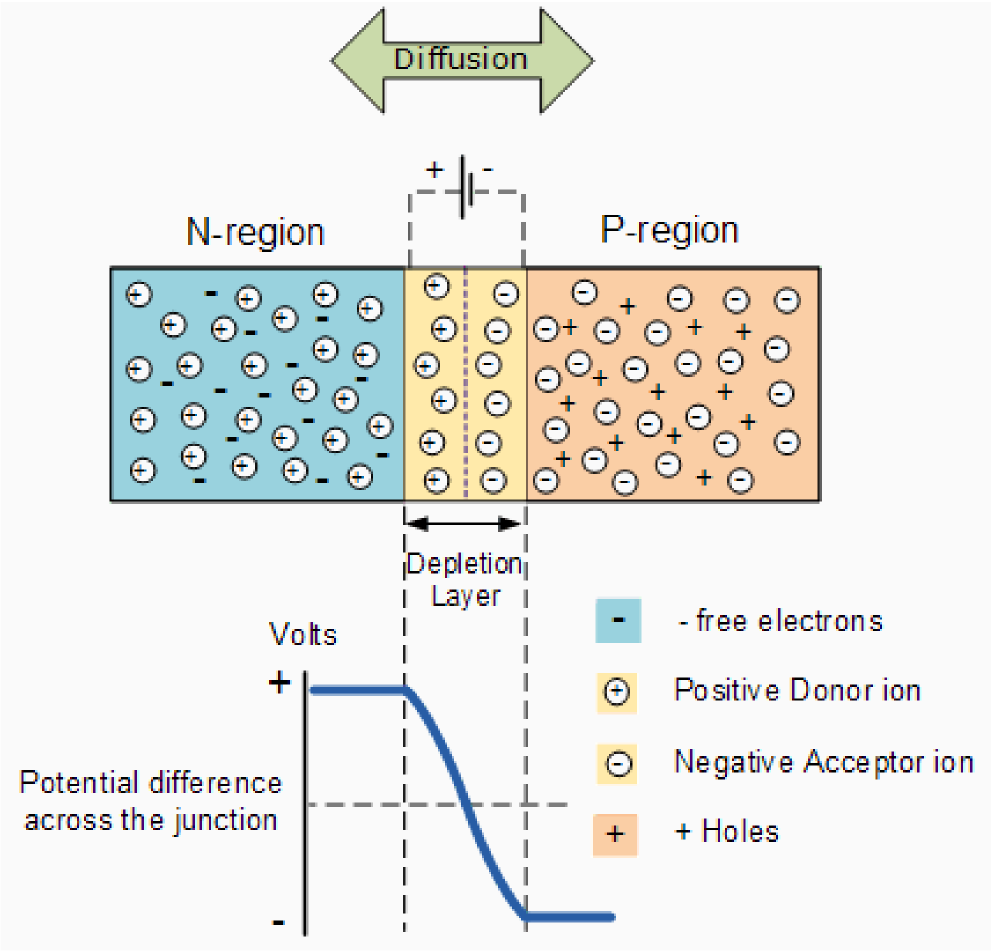
- The Resistor is a basic passive component in electronic circuits.
- The Diode is the most basic “Active” component.

I-V Characteristics

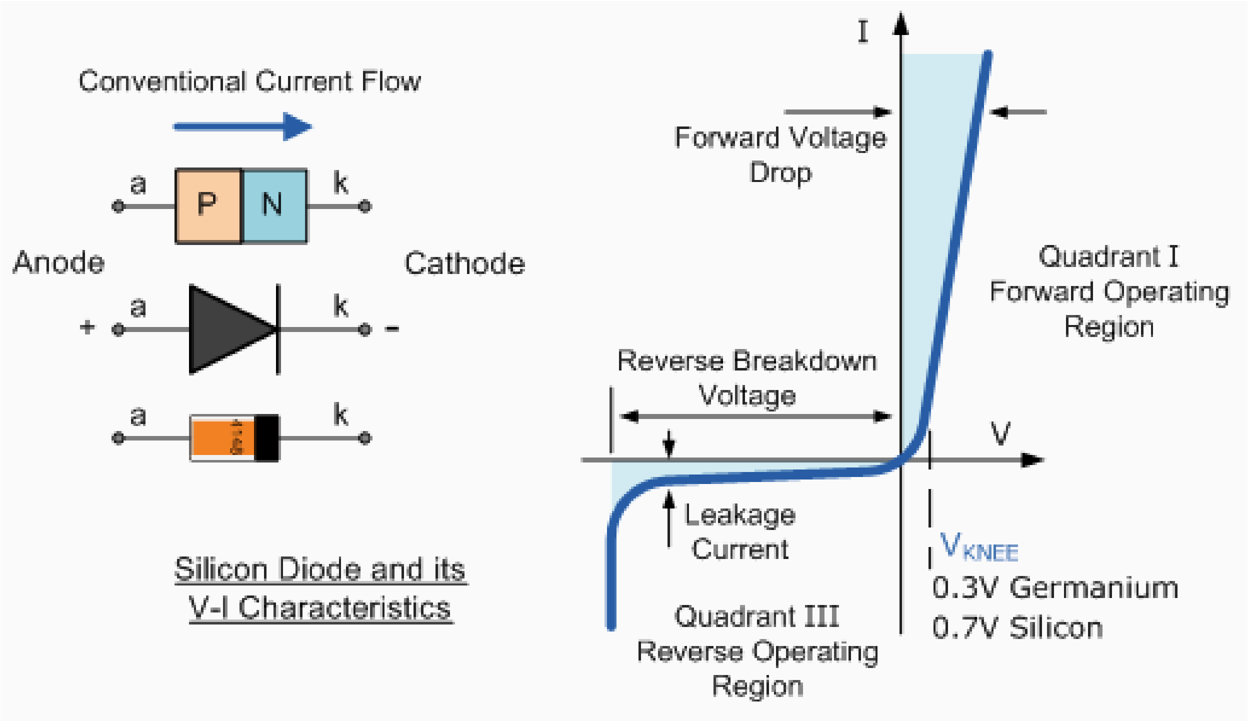


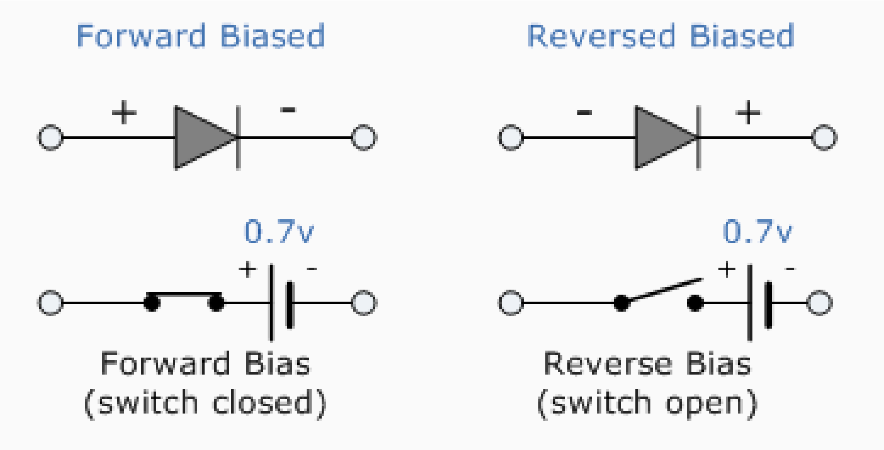


PN Junction

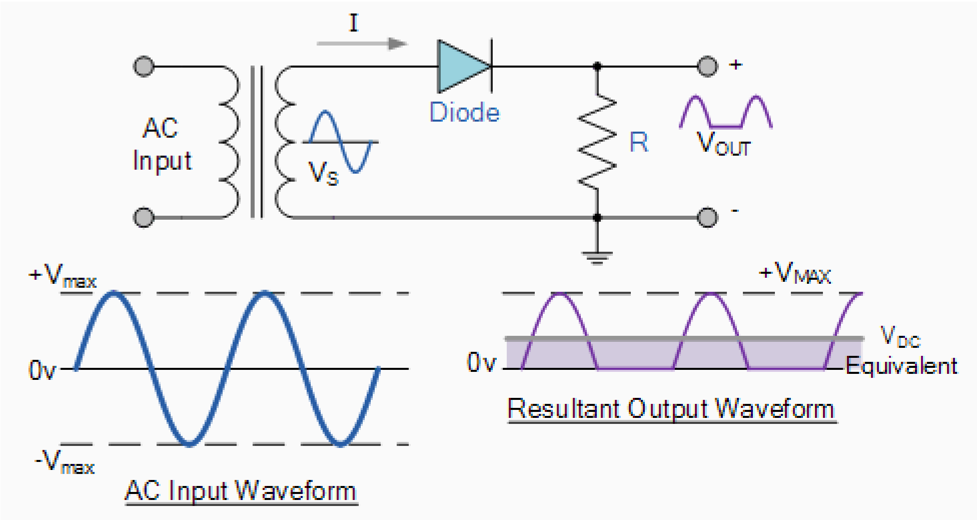


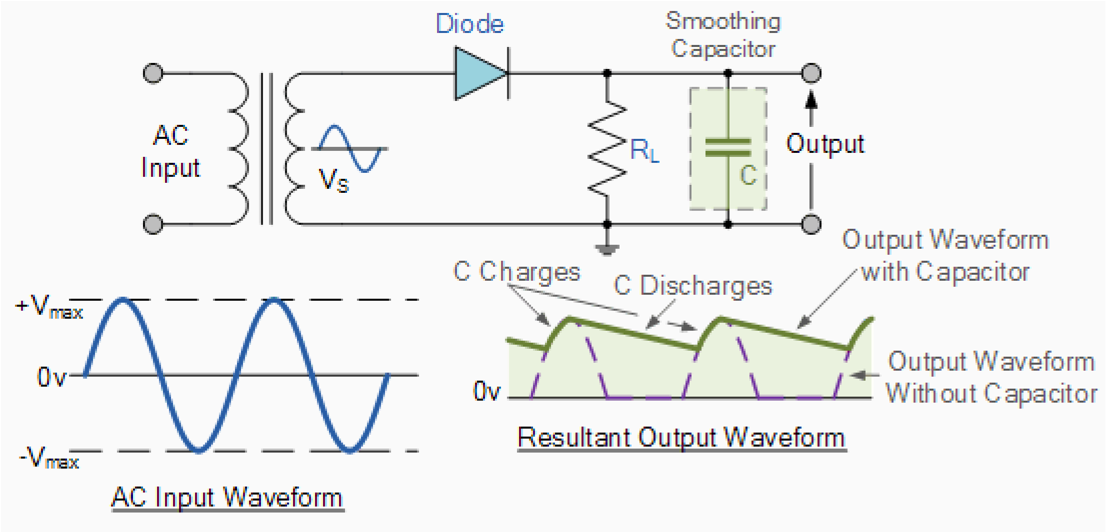
Diffusion
+
-
N-region
P-region
Depletion
Layer
Volts
+
-
Potential difference
across the junction
- free electrons
Positive Donor ion
Negative Acceptor ion
+ Holes


Conventional Current Flow
a
P
N
k
Anode
Cathode
+
a
k
-
a
k
Silicon Diode and its
V-I Characteristics
I
Forward Voltage
Drop
Quadrant I
Forward Operating
Region
Reverse Breakdown
Voltage
V
Leakage
Current
VKNEE
0.3V Germanium
0.7V Silicon
Quadrant III
Reverse Operating
Region

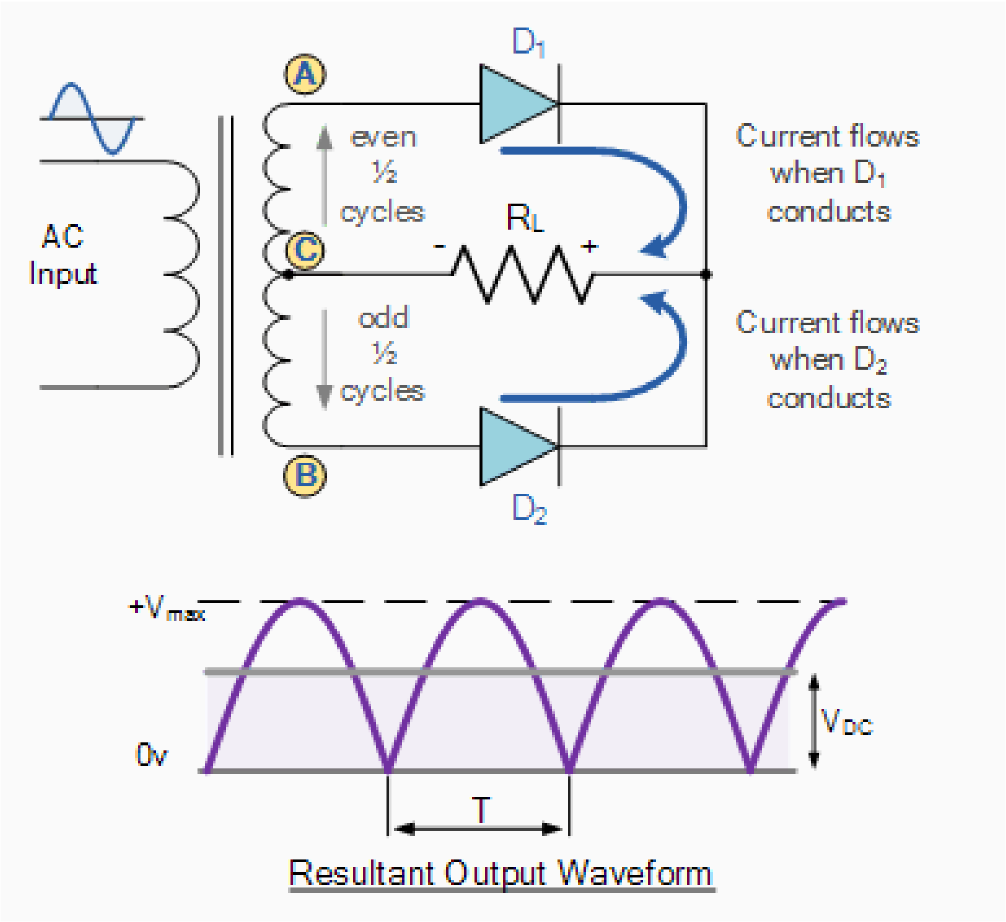

Forward Biased
Reversed Biased
+
-
-
+
0.7v
+
-
0.7v
+
-
Forward Bias
(switch closed)
Reverse Bias
(switch open)

Half-Wave Rectifier



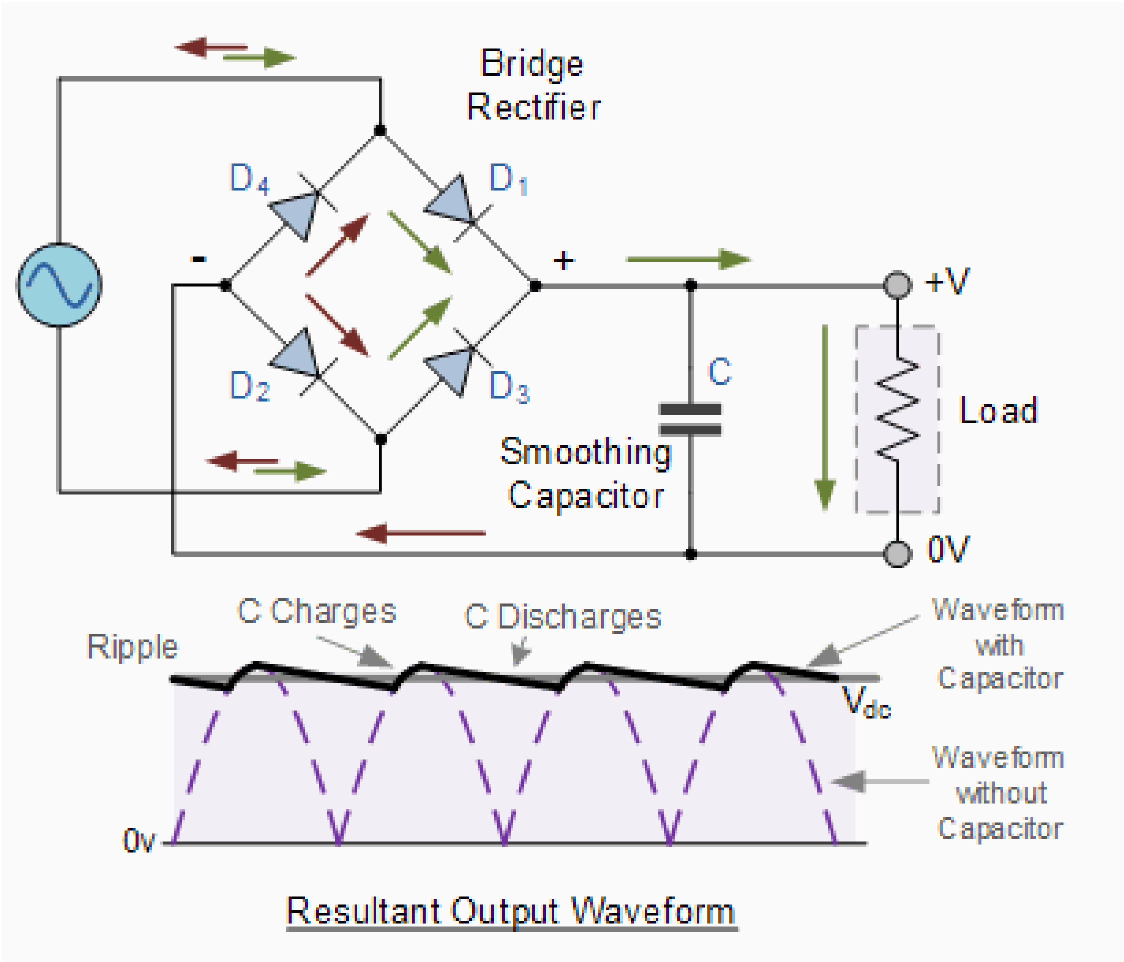


Full-Wave Rectifier

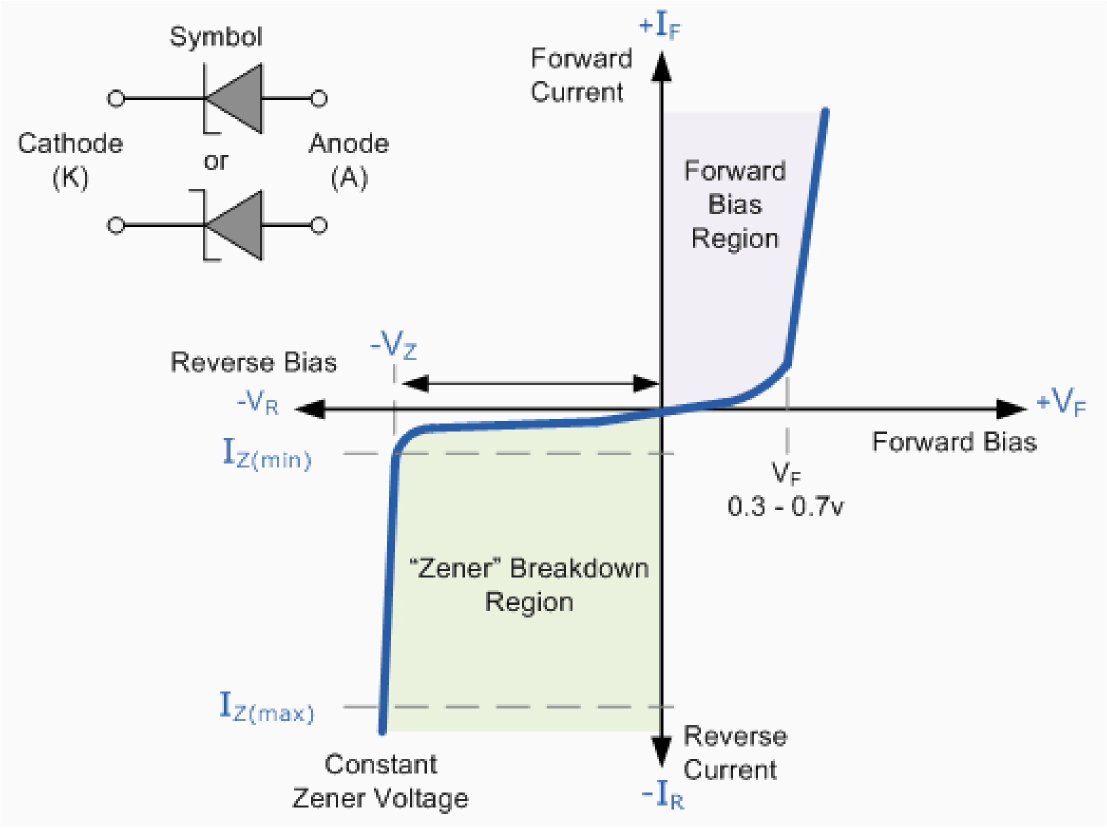


$$V_{d.c.} = \frac{2V_{\max}}{\pi} = 0.637V_{\max} = 0.9V_{RMS}$$

Full-Wave Rectifier

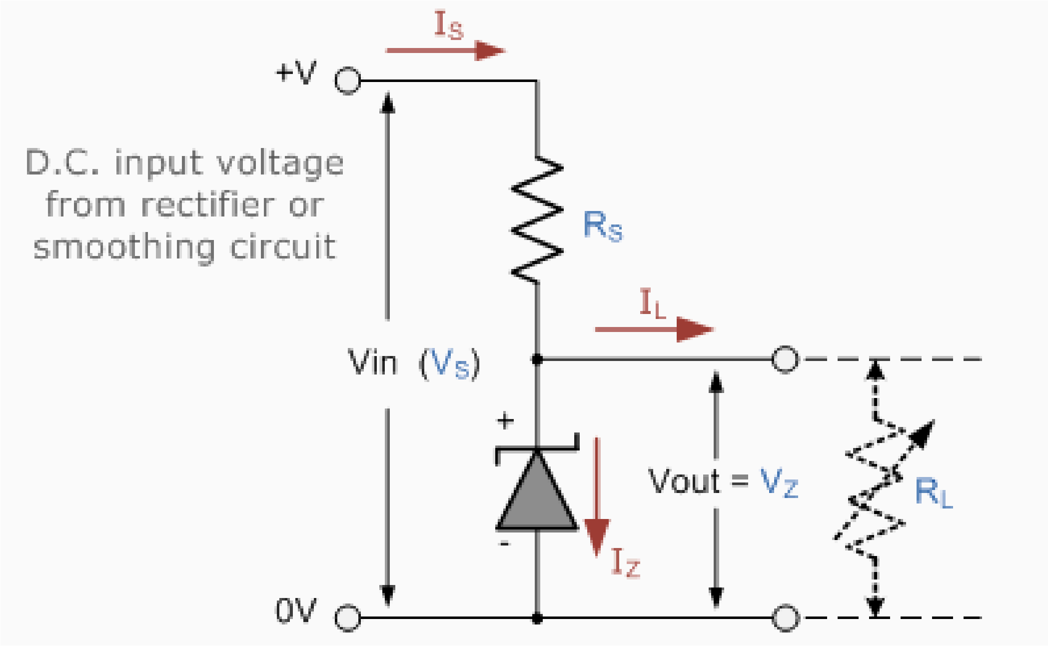


Zener Diyode



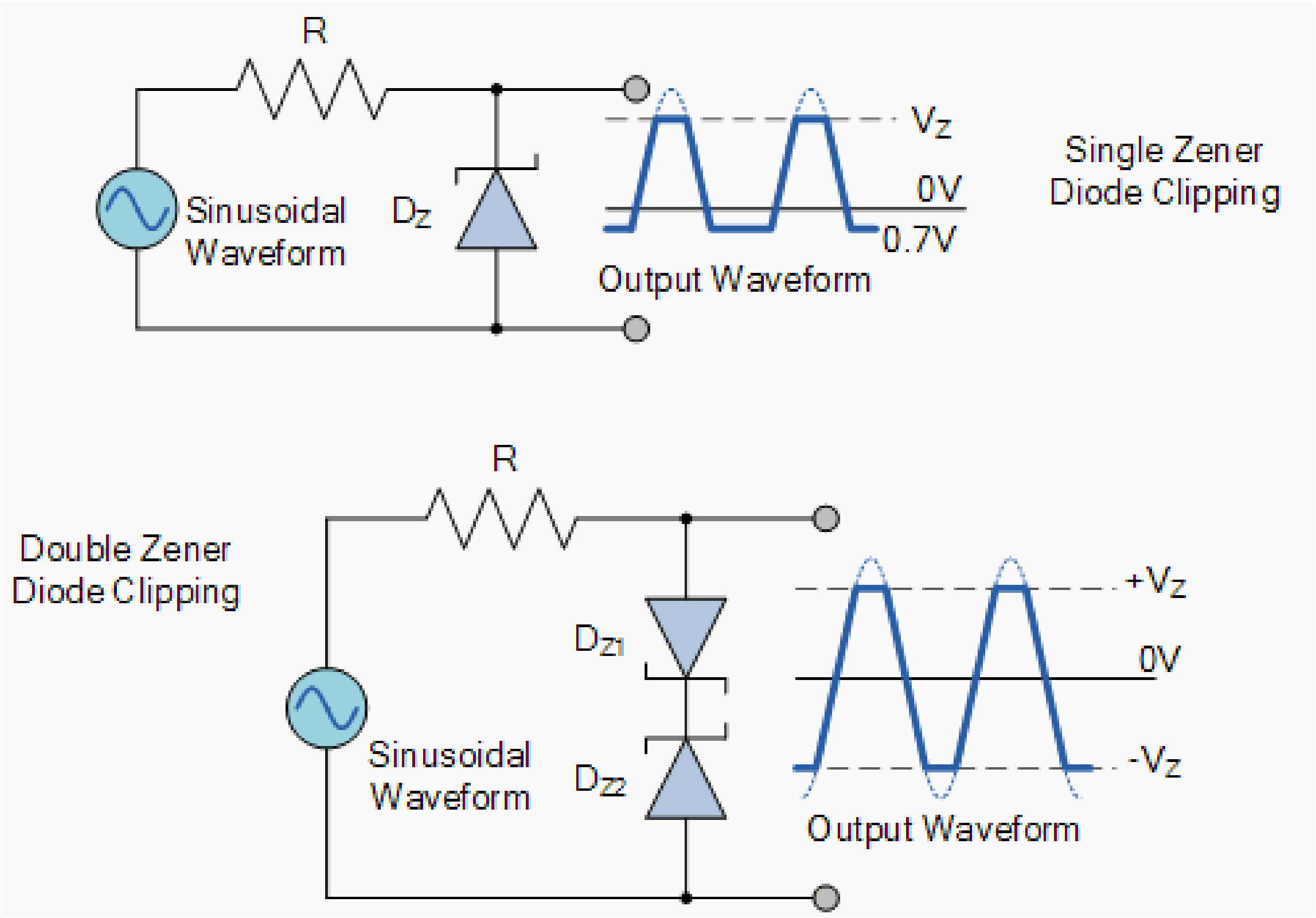
Zener Diyode as Regulator

Consider a 5.0 V stabilized power supply is required to be produced from a V = 12V DC power supply input source.
The maximum power rating of the zener diode is P_Z = 2W.



* Max. current flowing through the zener diode: IZ = 2 W / 5V = 0.4 A.
* Min. Value of resistor: Rs= (12 - 5) / 0.4 = 17.5 Ohm.
* If R_L = 1 kOhm => I_L = 5 /1000 = 5 mA.
* $I_Z = I_s – I_L$ = 400 – 5 = 395 mA.

Zener Diode to form a Square Wave



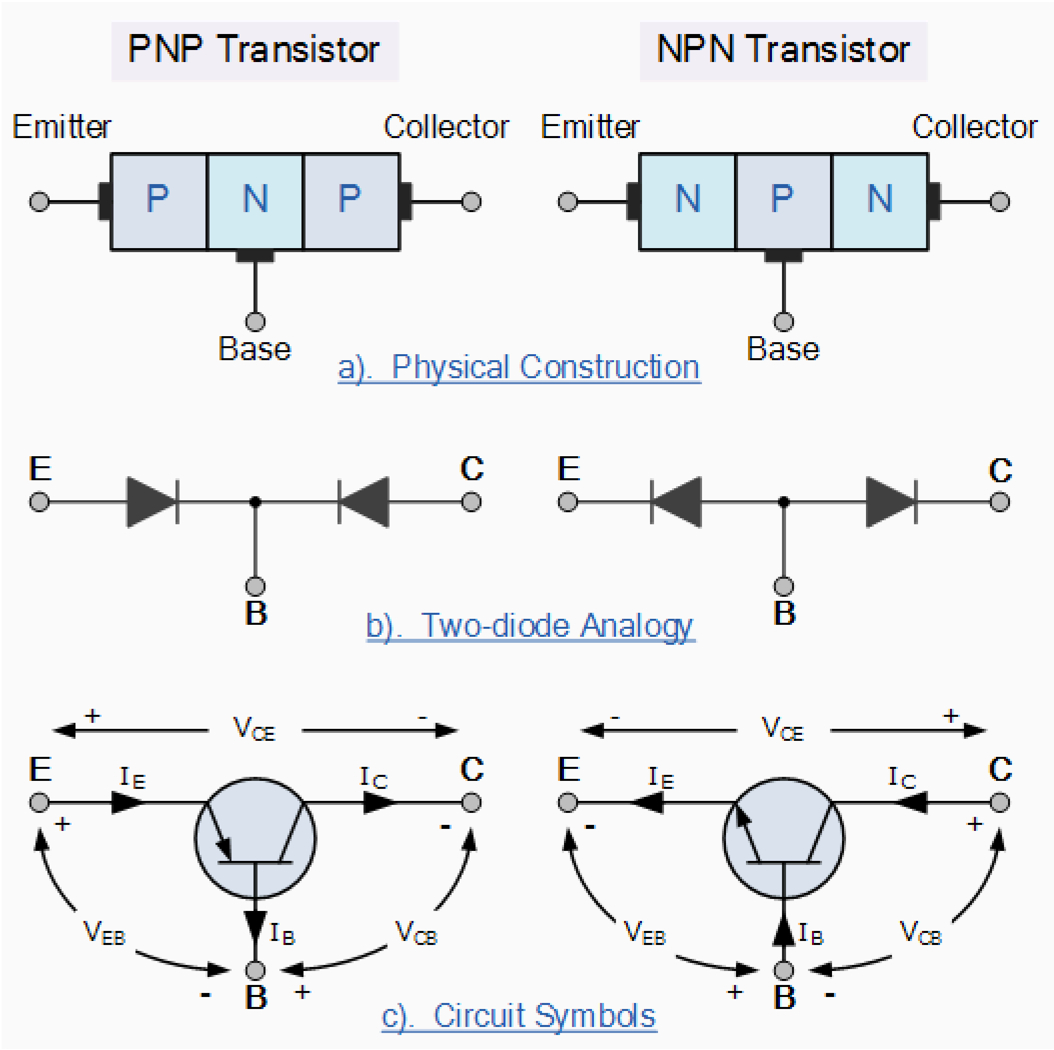
Transistors (BJT only)

- The fusion of two diodes produces a three layer, two junction, three terminal device forming the basis of a Bipolar Junction Transistor, or BJT for short.

- BJTs can operate within three different regions:

  - Active Region: transistor operates as an amplifier and Ic = β*Ib
  - Saturation: transistor is "Fully-ON" operating as a switch and Ic=Is
  - Cut-off: transistor is "Fully-OFF" operating as a switch and Ic=0

BJT Construction



BJT Construction

Common Base Configuration:

=> *has Voltage Gain but no Current Gain*.

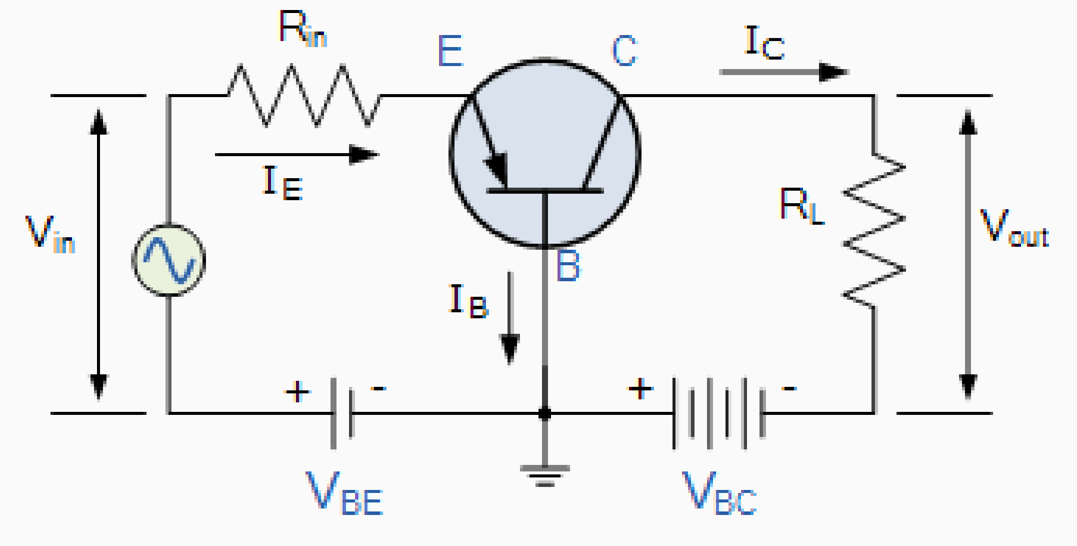
Common Emitter Configuration

=> *has both Current and Voltage Gain*.

Common Collector Configuration

=> *has Current Gain but no Voltage Gain*.

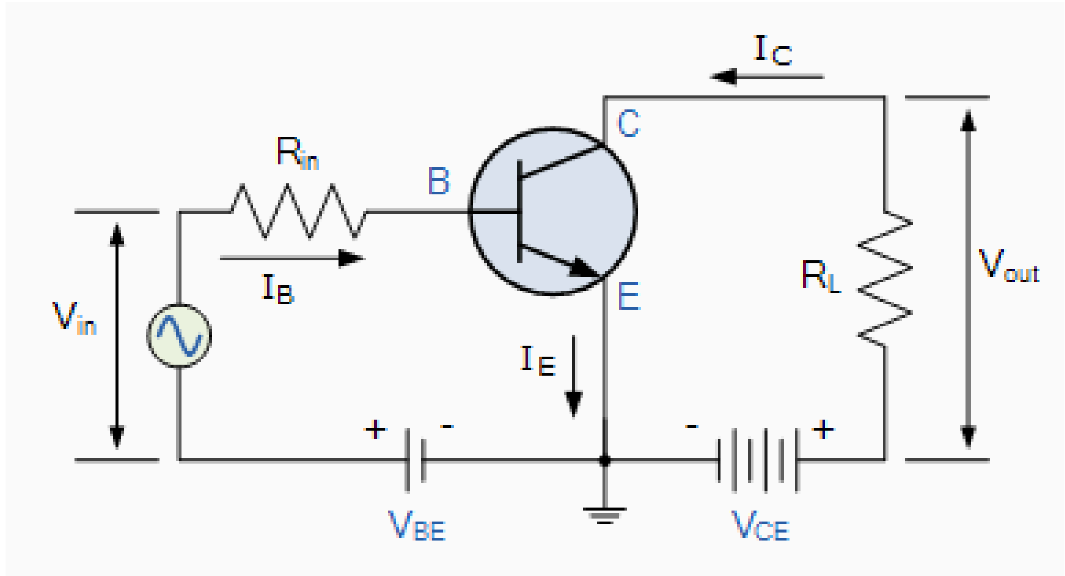
Common Base Circuit



Voltage Gain:

$$A_V = \frac{Vout}{Vin} = \frac{I_C \times R_L}{I_E \times R_{IN}}$$

Common Emitter Circuit



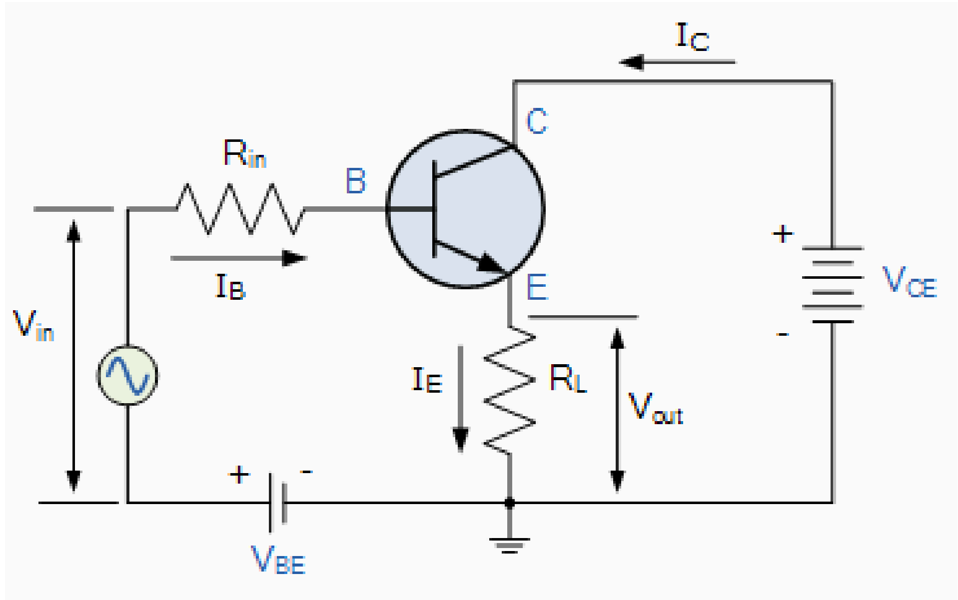
$$\text{Alpha}, (\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta}, (\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha . I_E = \beta . I_B$$

$$\text{as:} \quad \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

$$I_E = I_C + I_B$$

Common Collector Circuit



Current gain:

$$I_E = I_C + I_B$$

$$A_i = \frac{I_E}{I_B} = \frac{I_C + I_B}{I_B}$$

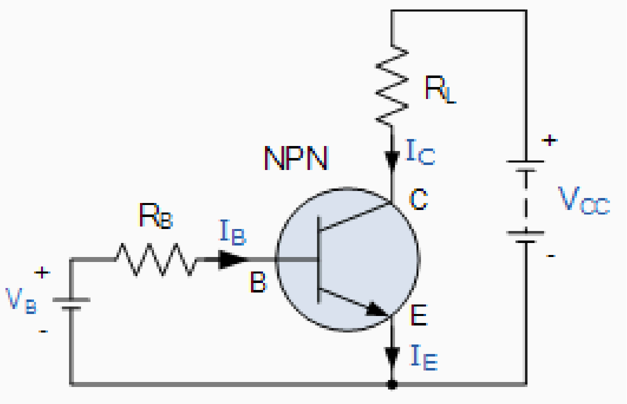
$$A_i = \frac{I_C}{I_B} + 1$$

$$A_i = \beta + 1$$

Example:

An NPN Transistor has a DC current gain, beta = 200. Calculate the base current Ib required to switch a resistive load of 4mA.

$$I_B = \frac{I_C}{\beta} = \frac{4 \times 10^{-3}}{200} = 20\mu A$$



NPN Transistor Connection

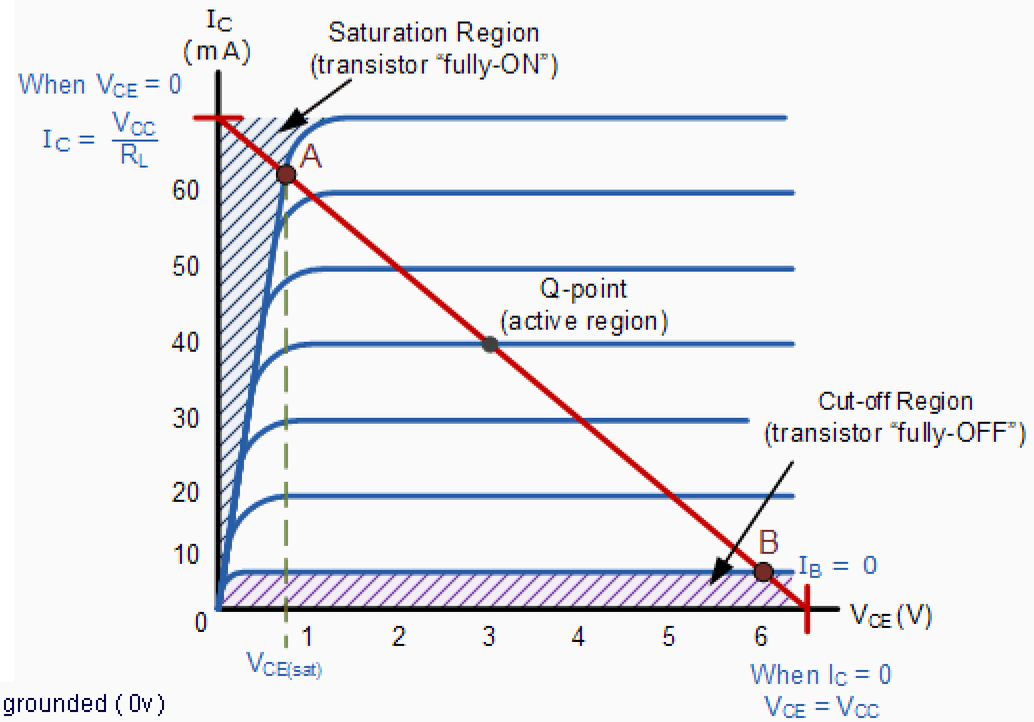
If V_B =10V and an input base resistor, R_B =100kΩ.

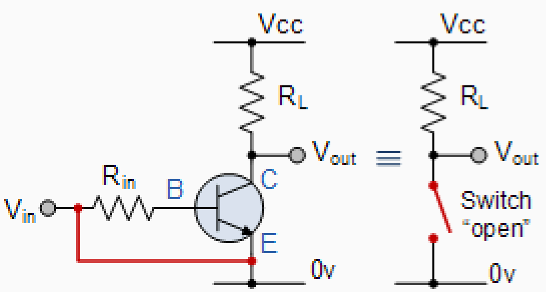
What will be the value of the base current into the transistor?

$$I_B = \frac{V_B - V_{BE}}{R_B} = \frac{10 - 0.7}{100k\Omega} = 93\mu A$$

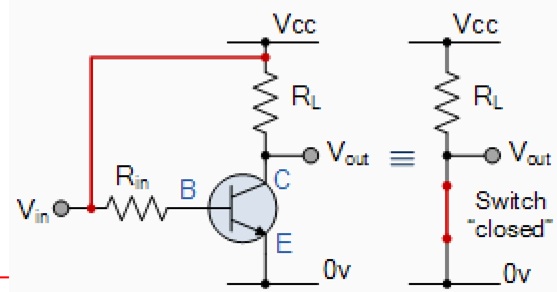
Transistor as a Switch:

Cut-off





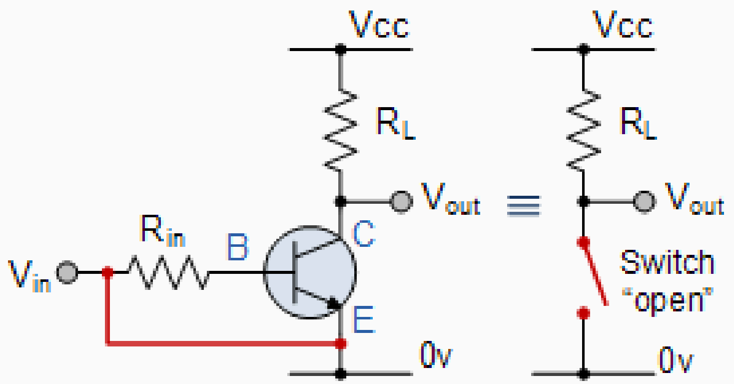
- The input and Base are grounded (0v)
- Base-Emitter voltage $V_{BE} < 0.7v$
- Base-Emitter junction is reverse biased
- Base-Collector junction is reverse biased
- Transistor is "fully-OFF" (Cut-off region)
- No Collector current flows ($I_C = 0$)
- $V_{OUT} = V_{CE} = V_{CC} =$ "1"
- Transistor operates as an "open switch"



- The input and Base are connected to V_{CC}
- Base-Emitter voltage $V_{BE} > 0.7v$
- Base-Emitter junction is forward biased
- Base-Collector junction is forward biased
- Transistor is "fully-ON" (saturation region)
- Max Collector current flows ($I_C = Vcc/R_L$)
- $V_{CE} = 0$ (ideal saturation)
- $V_{OUT} = V_{CE} =$ "0"
- Transistor operates as a "closed switch"

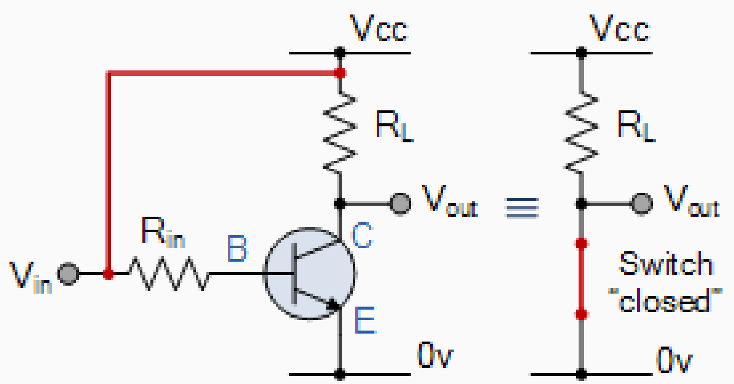
Transistor as a Switch:

Cut-off Region:



- The input and Base are grounded (0v)
- Base-Emitter voltage $V_{BE} < 0.7v$
- Base-Emitter junction is reverse biased
- Base-Collector junction is reverse biased
- Transistor is "fully-OFF" (Cut-off region)
- No Collector current flows ($I_C = 0$)
- $V_{OUT} = V_{CE} = V_{CC} = "1"$
- Transistor operates as an "open switch"

Saturation Region:



- The input and Base are connected to V_{CC}
- Base-Emitter voltage $V_{BE} > 0.7v$
- Base-Emitter junction is forward biased
- Base-Collector junction is forward biased
- Transistor is "fully-ON" (saturation region)
- Max Collector current flows ($I_C = Vcc/R_L$)
- $V_{CE} = 0$ (ideal saturation)
- $V_{OUT} = V_{CE} = "0"$
- Transistor operates as a "closed switch"

Example:

Using the transistor values from the previous example:

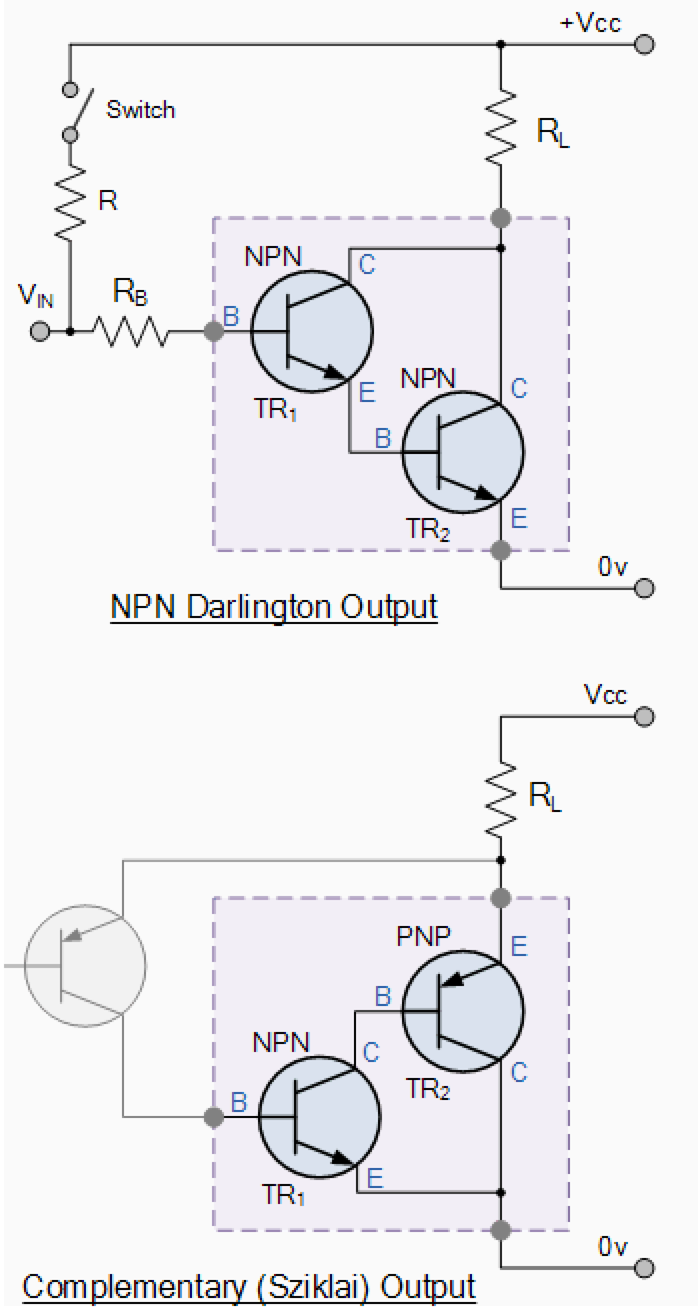
$\beta = 200$, $I_C = 4mA$ and $I_B = 20uA$, find the value of the base resistor (R_B) required to switch the load fully "ON" when the input terminal voltage exceeds 2.5v.

$$R_B = \frac{V_{in} - V_{BE}}{I_B} = \frac{2.5v - 0.7v}{20x10^{-6}} = 90k\Omega$$

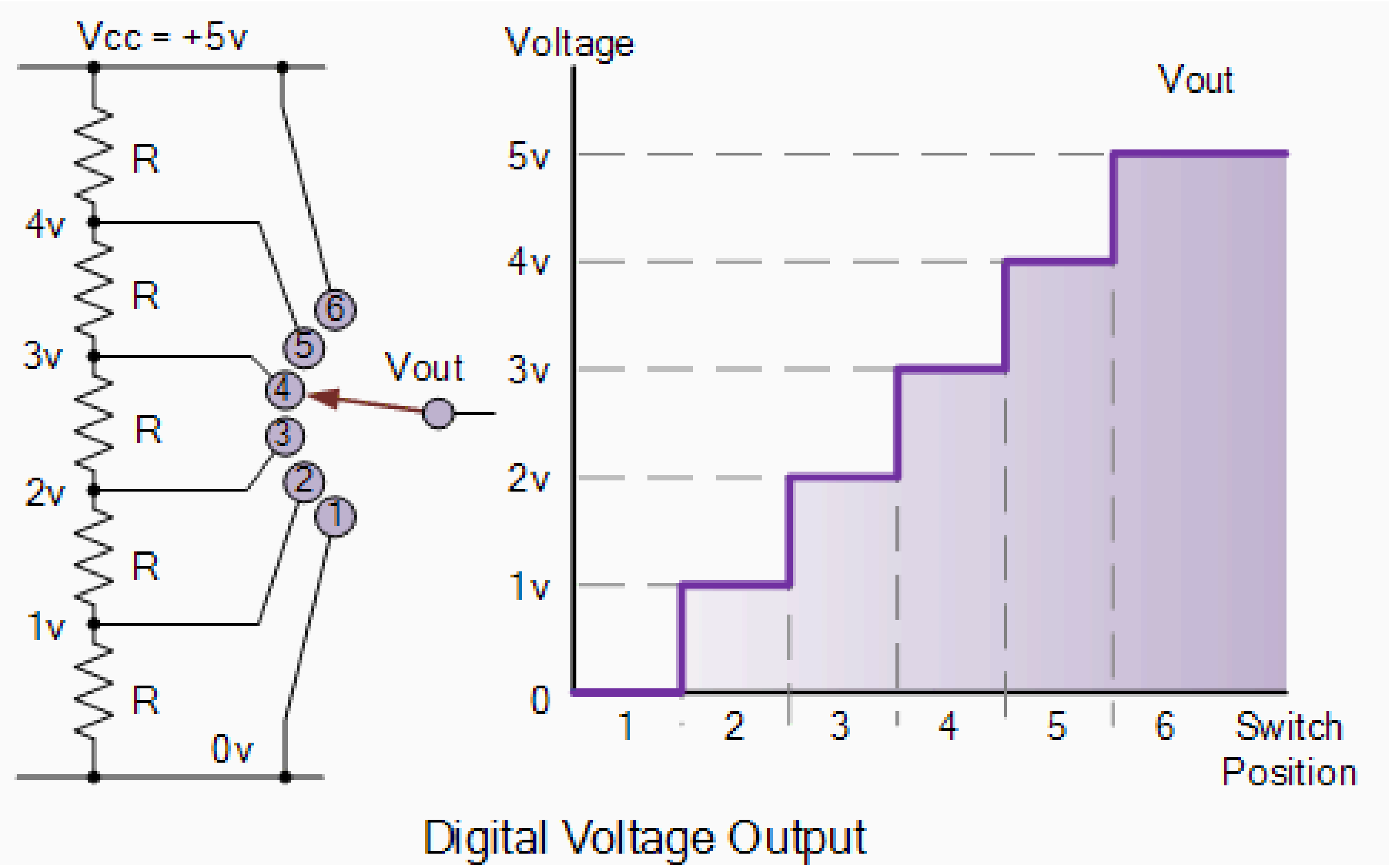
Darlington Transistor Switch

When large currents or voltages need to be controlled, Darlington Transistors can be used.

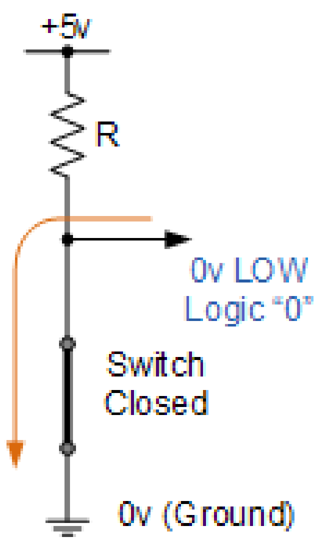
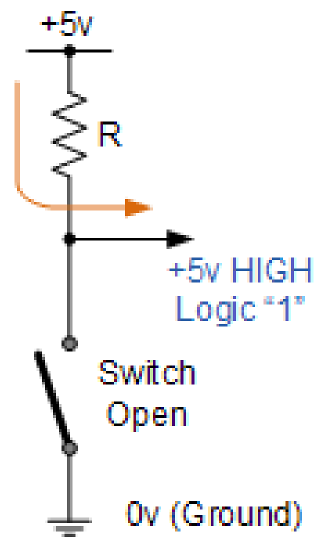
$$\beta_{TOTAL} = \beta_1 \times \beta_2$$



Digital Voltage Output Representation



Binary Logic Levels

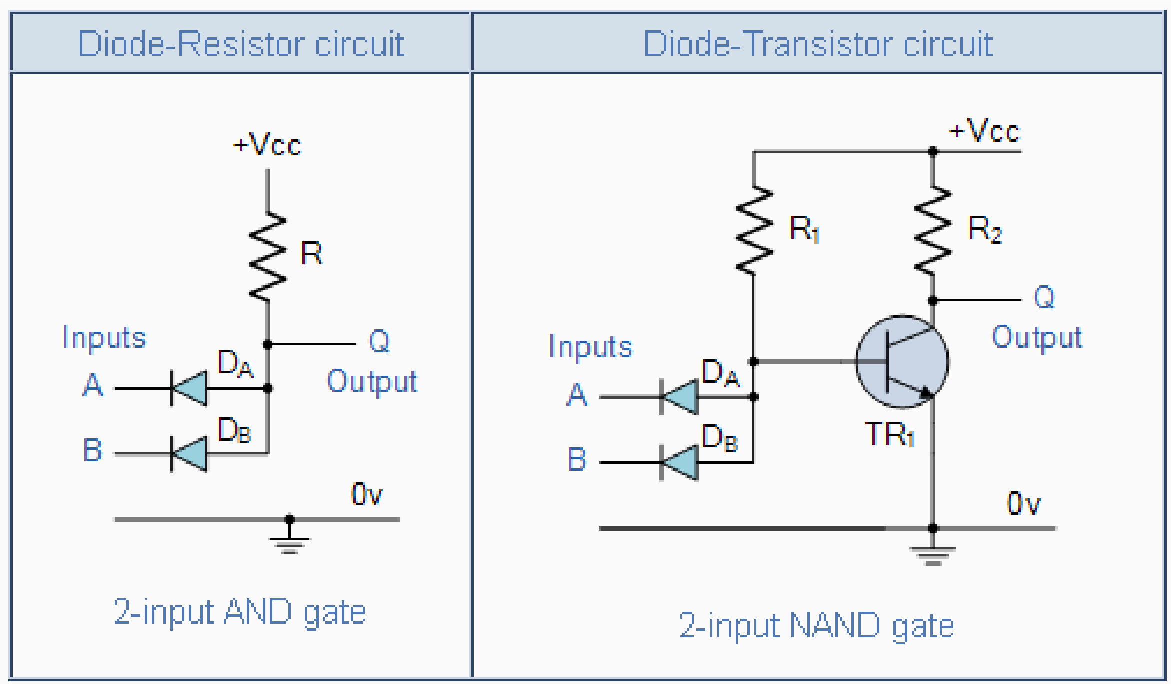
First State	Second State
Logic "0"	Logic "1"
LOW	HIGH
FALSE	TRUE
Low Level Voltage	High Level Voltage
0V or Ground	+5 Volts
	

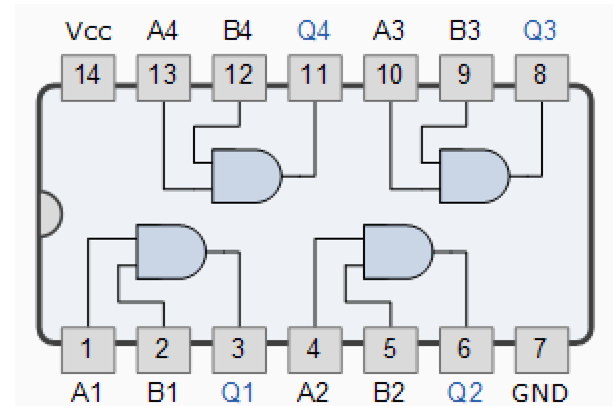
Digital Electronics

- A Digital Logic Gate is an electronic device that makes logical decisions based on the different combinations of digital signals present on its inputs.

- A digital logic gate may have more than one input but only has one digital output.

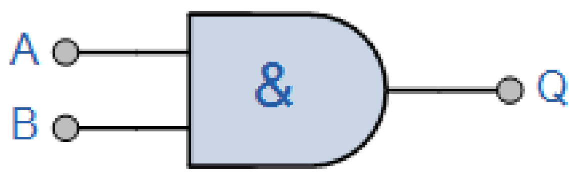
AND Gate





7408

Symbol



2-input AND Gate

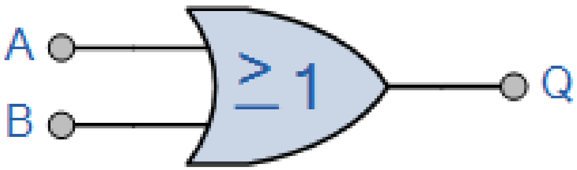
Boolean Expression **Q = A.B**

Truth Table

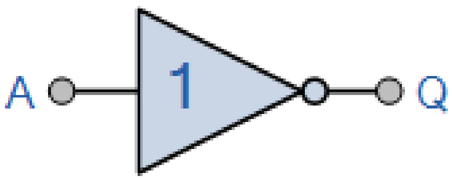
B	A	Q
0	0	0
0	1	0
1	0	0
1	1	1

Read as A **AND** B gives Q

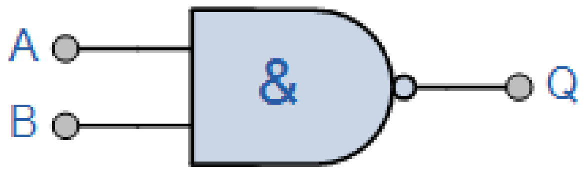
OR Gate

Symbol	Truth Table		
 2-input OR Gate	B	A	Q
	0	0	0
	0	1	1
	1	0	1
	1	1	1
Boolean Expression **Q = A+B**	Read as A **OR** B gives Q		

NOT Gate

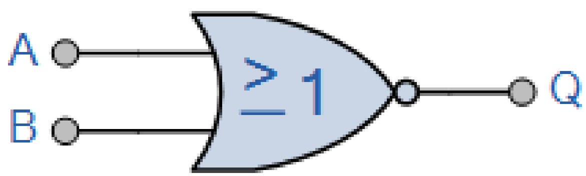
Symbol	Truth Table	
 Inverter or NOT Gate	A	Q
	0	1
	1	0
Boolean Expression **Q = not A or $\bar{A}$**	Read as inverse of **A** gives Q	

- ## NAND Gate



Symbol	Truth Table		
2-input NAND Gate	B	A	Q
	0	0	1
	0	1	1
	1	0	1
	1	1	0
Boolean Expression **Q = $\overline{A.B}$**	Read as A **AND** B gives **NOT** Q		

- ## NOR Gate



Symbol	Truth Table		
2-input NOR Gate	B	A	Q
	0	0	1
	0	1	0
	1	0	0
	1	1	0
Boolean Expression **Q = $\overline{A+B}$**	Read as A **OR** B gives **NOT** Q		

Some Sensors

- Optoelectronics is the branch of physics that deals with the interaction of light with electronic devices, or the production of light from such devices.
- Optoelectronic devices are
  - electrical-to-optical or optical-to-electrical transducers (converters).
- Optoelectronics is based on the *quantum mechanical* effects of light on *semiconducting* materials.

Common Light sources:

- LED
- Laser
- LCD
- …

Common Light Detectors:

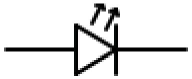
- Photodiodes
- Phototransistors
- Photoresistors (LDR)
- Photomultiplier Tube (PMT)
- Charge coupled device (CCD)
- Optocouplers
- …

In this chapter, we'll see some of above

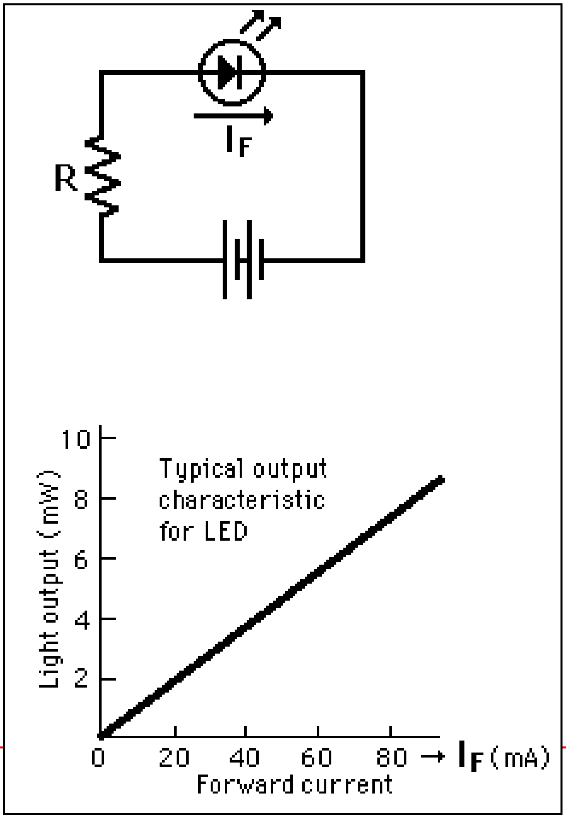
LED

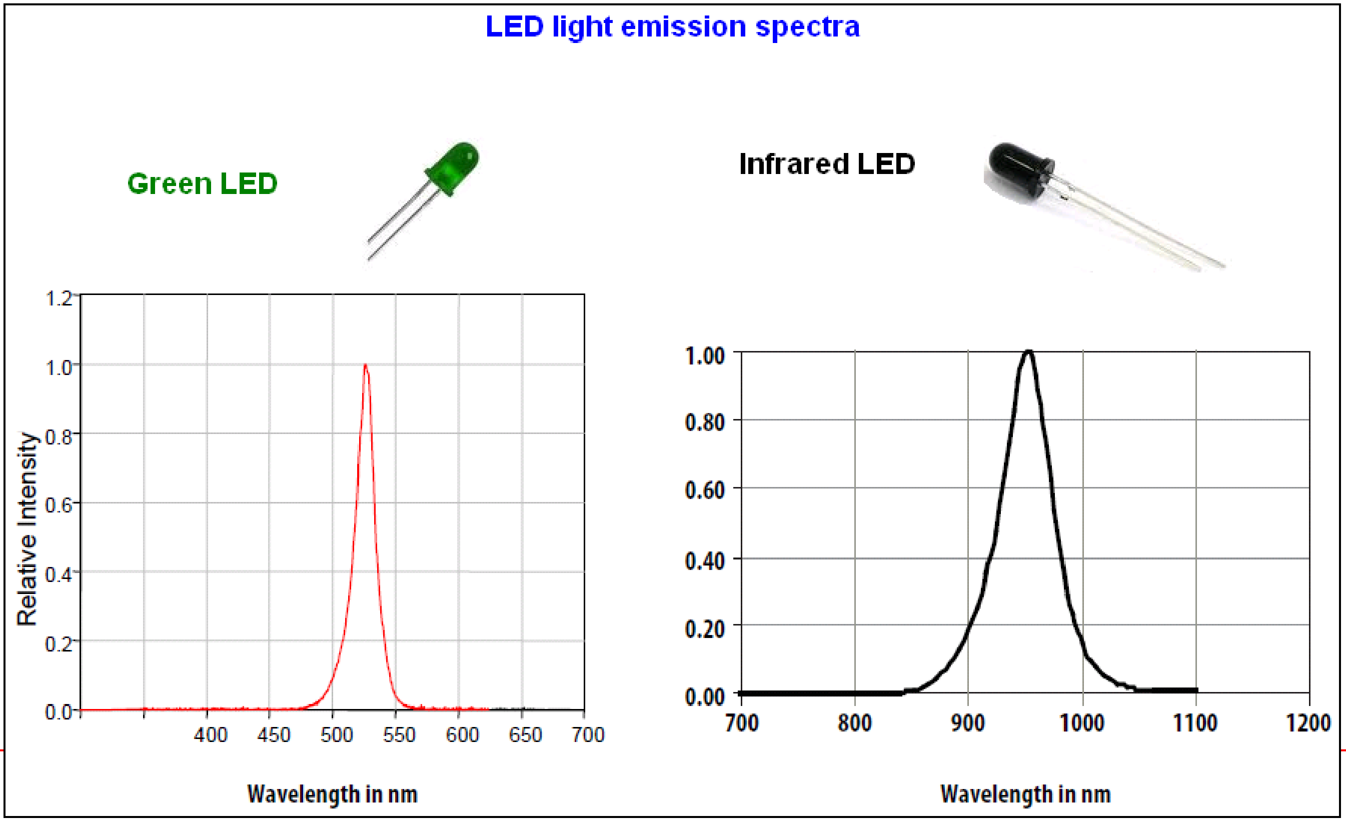
- A light-emitting diode (LED) is a semiconductor light source.

- Circuit Symbol:



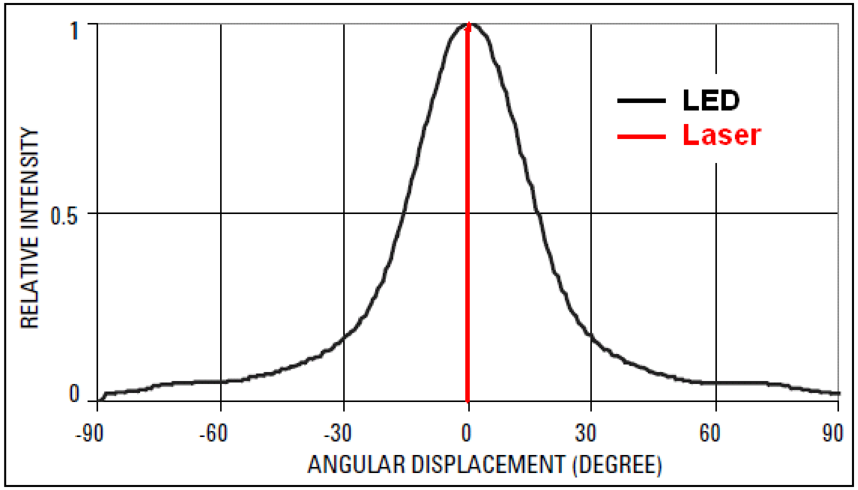
- A LED can produce the visible, ultraviolet and infrared wavelengths, with very high brightness.





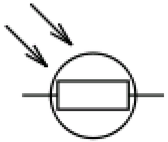
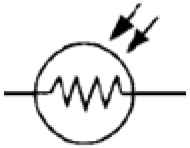
Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V_F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaInN	450nm	White	4.0v

Beam Divergence of LED and Laser



3D LED Cube

Photo-resistor (LDR)

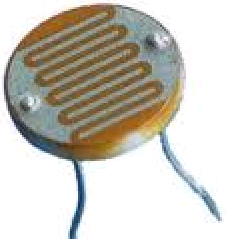
- A photoresistor or Light Dependent Resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. It can also be referred to as a **photoconductor**.
- Circuit symbol:  or 
- A LDR is made of a high resistance *semiconductor*.
  - If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the *conduction band*.
  - The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.
- LDR come in many different types. Inexpensive cadmium sulfide (CdS) cells can be found in many consumer items such as *camera light meters* and *street lights*.

Some Properties of LDR (Extracted from http://www.sunrom.com/files/3190-datasheet.pdf)

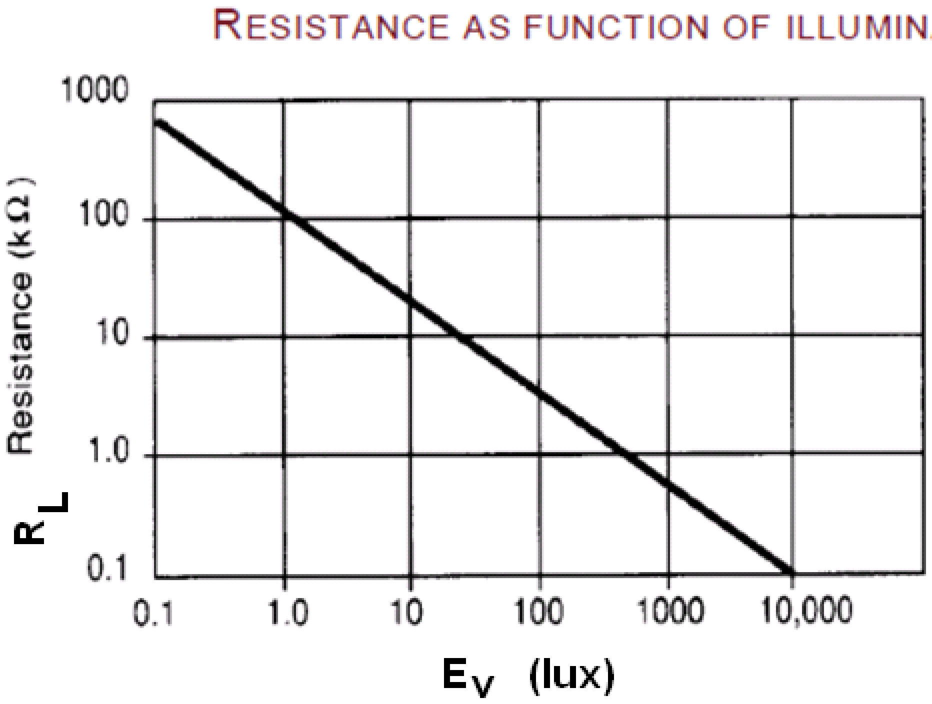
- *Typical Characteristics*

Parameter	Conditions	Min	Typ	Max	Unit
Cell resistance	1000 LUX 10 LUX	- -	400 9	- -	Ohm K Ohm
Dark Resistance	-	-	1	-	M Ohm
Dark Capacitance	-	-	3.5	-	pF
Rise Time	1000 LUX 10 LUX	- -	2.8 18	- -	ms ms
Fall Time	1000 LUX 10 LUX	- -	48 120	- -	ms ms
Voltage AC/DC Peak		-	-	320	V max
Current		-	-	75	mA max
Power Dissipation				100	mW max
Operating Temperature		-60	-	+75	Deg. C

(Extracted from http://www.sunrom.com/files/3190-datasheet.pdf)



- *Sensitivity*
  The sensitivity of a LDR is the relationship between the light falling on the device and the resulting output signal (resistance).



Equation of line is

$$\log(R_L) \approx 2 - 0.75\log(E_v)$$

LDR resistance in kΩ

illuminance in lux

(Extracted from http://www.sunrom.com/files/3190-datasheet.pdf)

- *Spectral Response*
  Like the human eye, the relative response of a LDR cell is dependent on the wavelength (color) of the incident light. Each photoconductor material type has its own unique spectral response curve.

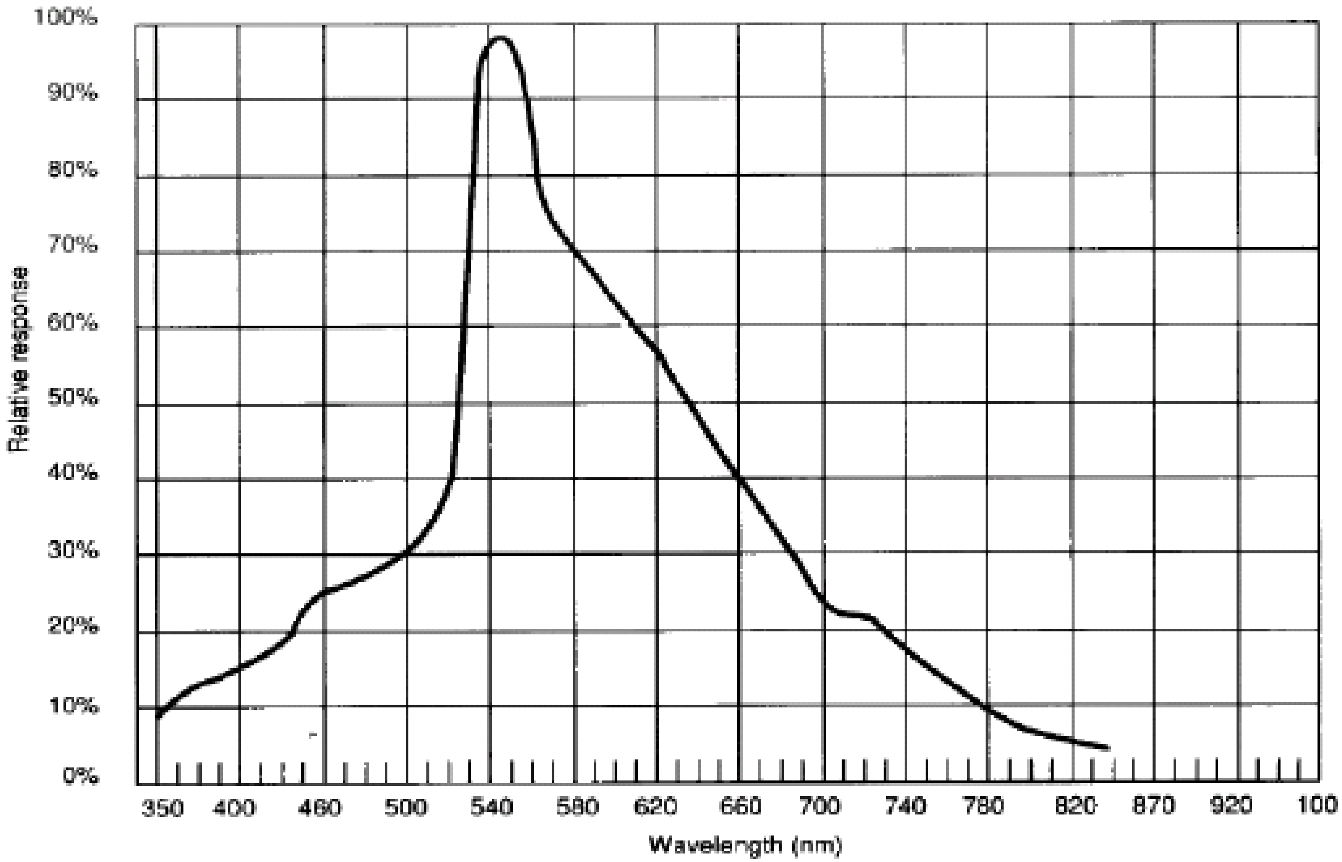
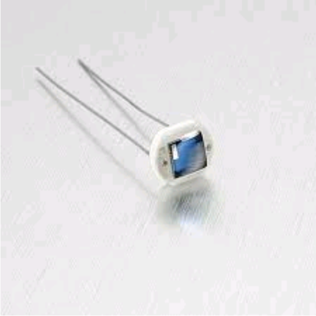
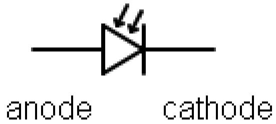


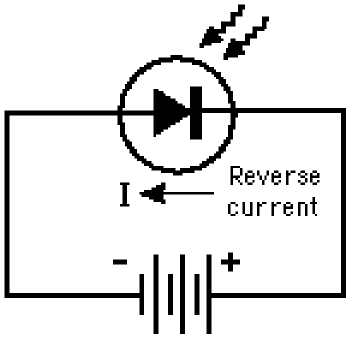
Photo-diode

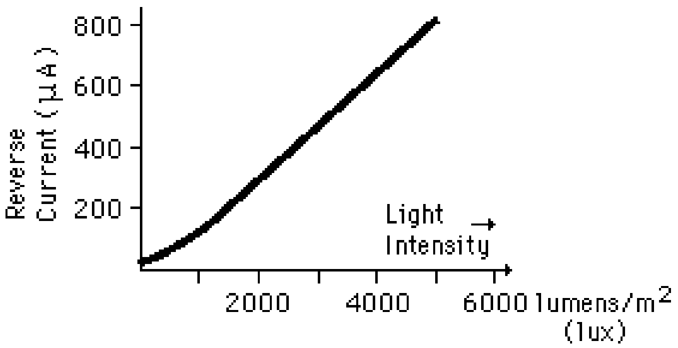


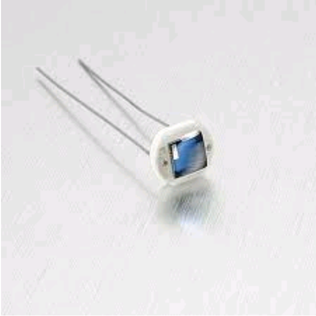
- A photodiode is capable of converting light into either current or voltage, depending upon the mode of operation.
- Circuit symbol: 

- A traditional *solar cell* is just a large area photodiode.
- When a photon of sufficient energy strikes the diode, it excites an electron, thereby creating a free electron and a (positively charged electron hole). Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced.
- Materials commonly used to produce photodiodes are:
  Silicon (Si)
  Germanium (Ge)
  Indium Gallium Arsenide (InGaAr)

- When light falls on the photodiode, a reverse current flows which is proportional to the illuminance.



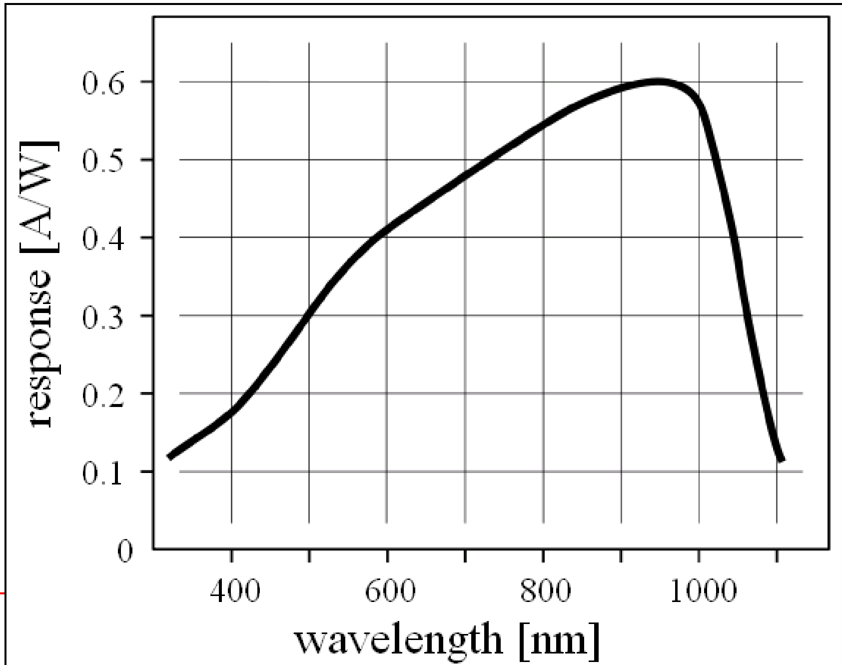




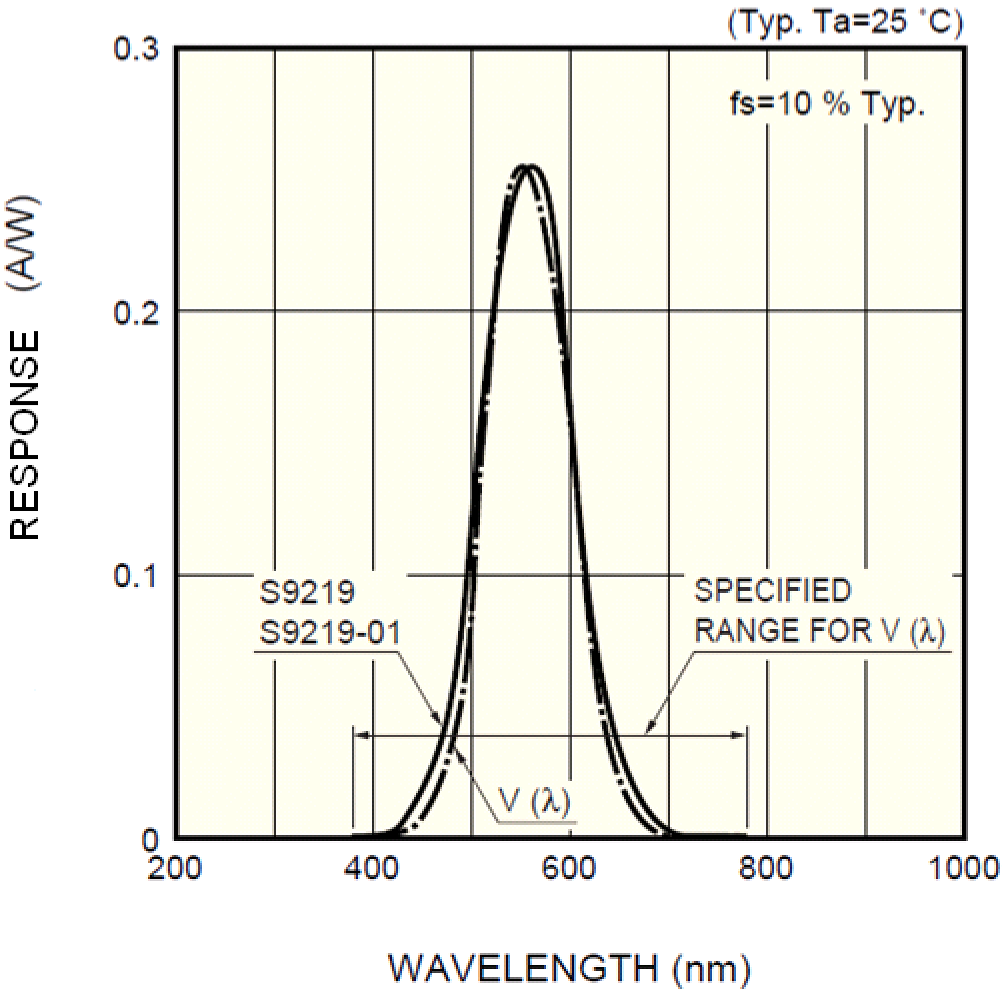
- Responsivity of a an electronic device is measure of the
electrical output per optical input.

SI Unit: Ampere/Watt

Response of a silicon photo diode vs wavelength of the incident light

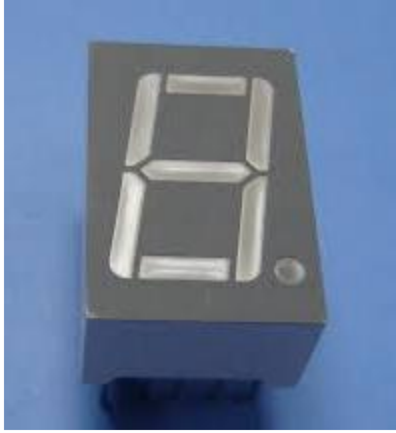


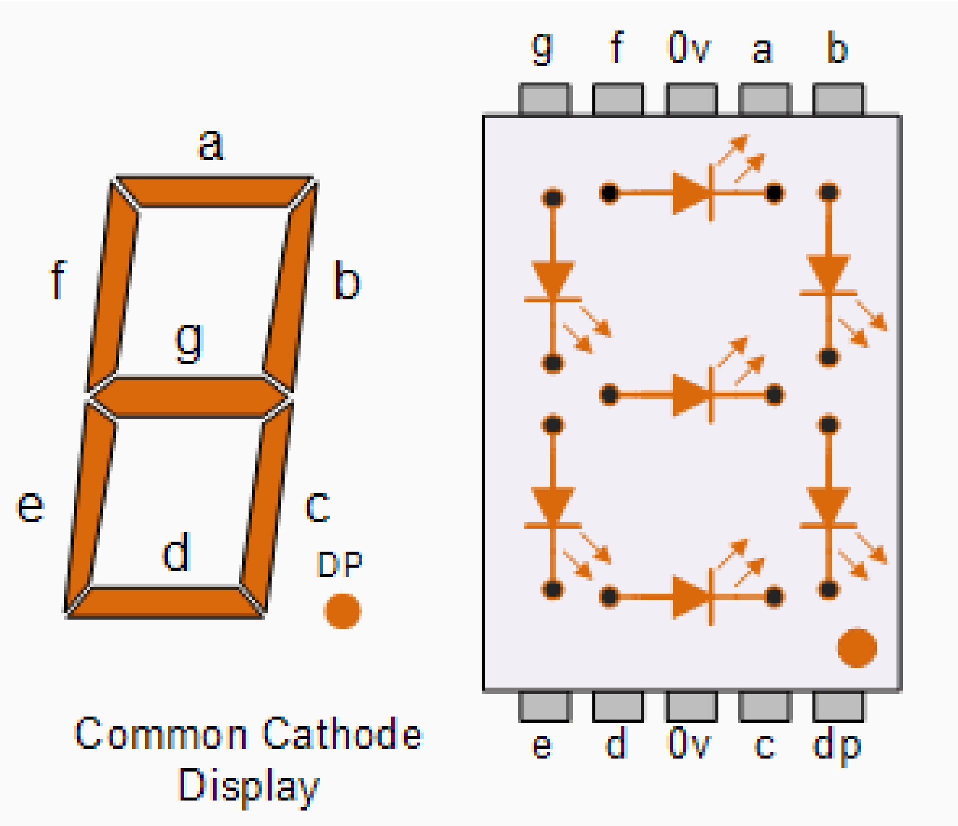
- An example Si photodiode (S9219 series) whose spectral response is like *human eye*!



See: http://www.datasheetdir.com/S9219+download

7 Segment Display





Opto-Coupler

OptoCoupler is a single electronic device that consists of a light emitting diode combined with
either a photo-diode or photo-transistor.