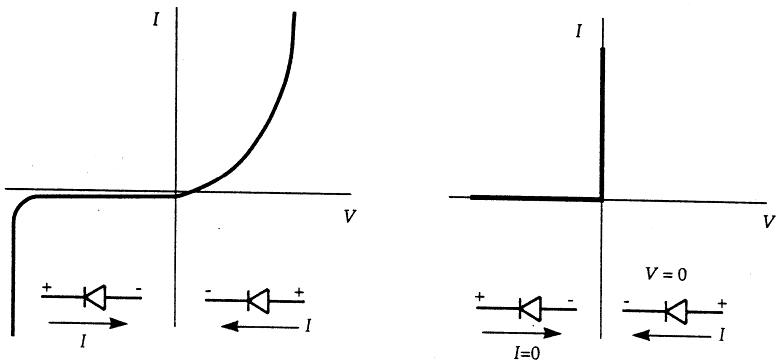
Diode Characteristics

Source: James Brophy, Basic Electronics for Scientists, 5th Edition



a) Actual diode

b) Ideal diode

Figure 6.18 Characteristics of a diode.

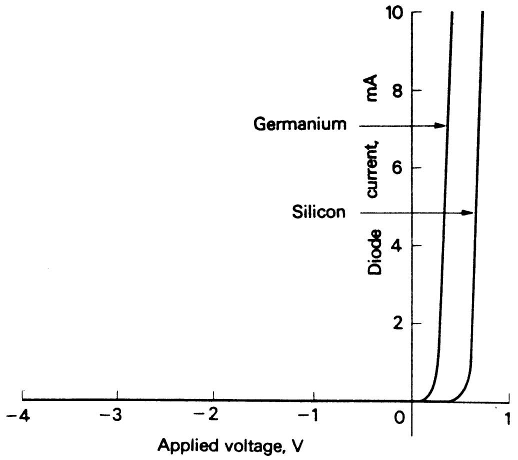


Figure 3-2 Current-voltage characteristics of germanium and silicon junction diodes.

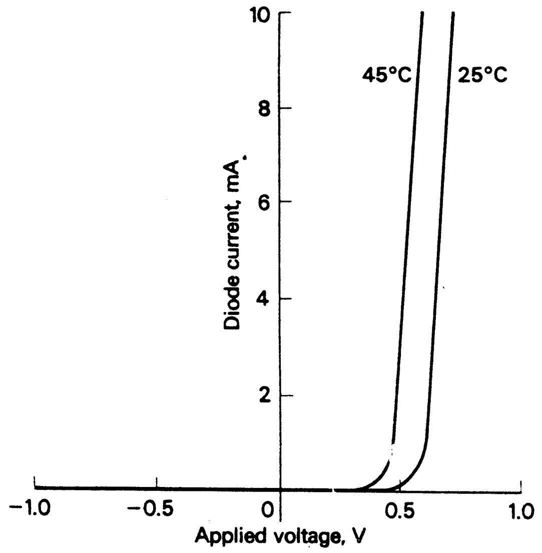


Figure 3-3 Effect of temperature on current-voltage characteristics of silicon junction diode.

Forward and Reverse Biasing of the PN Junction

Reference: Aminian and Kazimierczuk, Electronic Devices: A Design Approach, 2004

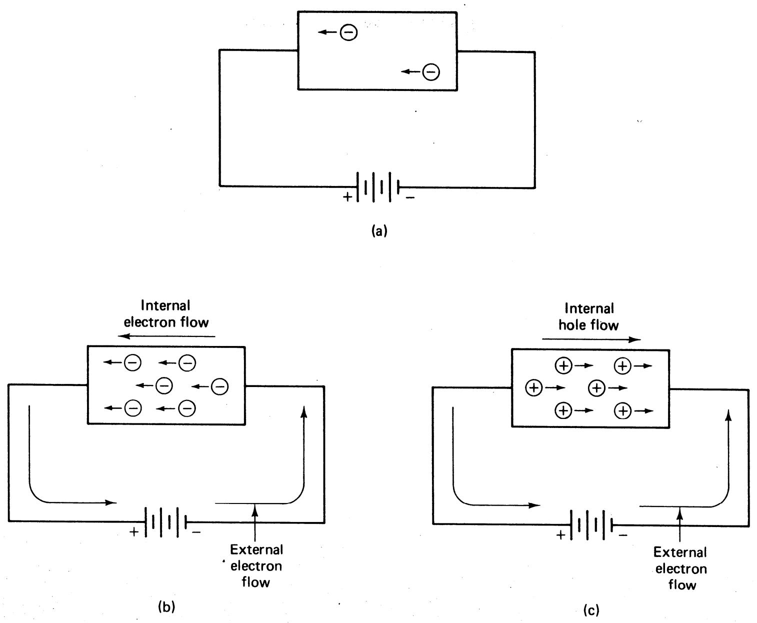
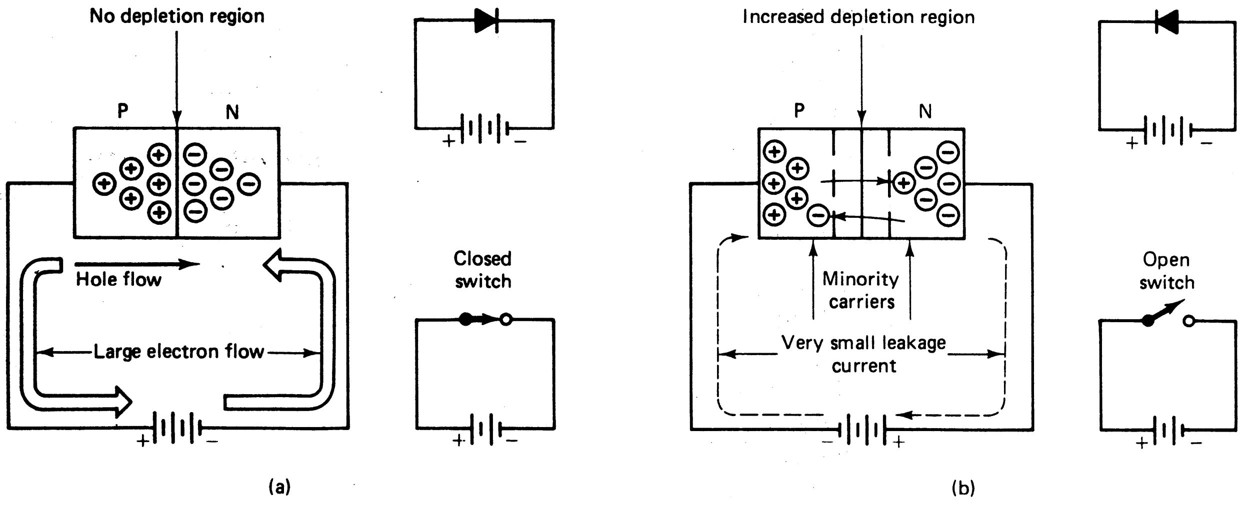


Figure 1–6 Conduction in semiconductor materials: (a) very little current flow in pure silicon; (b) electron flow in *n*-type material; (c) hole flow in *p*-type material.



Biasing the diode: (a) forward bias; (b) reverse bias.

Forward and Reverse Biasing of the PN Junction - continued

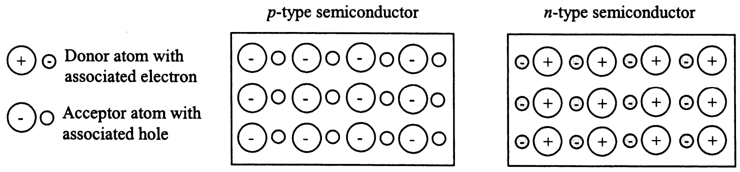


Figure 1-9: Blocks of *p*-type and *n*-type semiconductors before they are joined

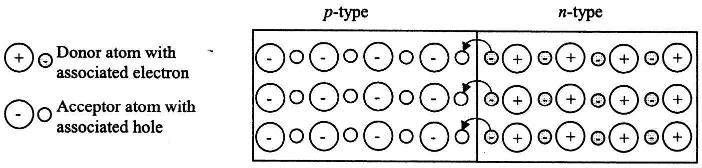


Figure 1-10: Blocks of *p*-type and *n*-type semiconductors at the instant they are joined

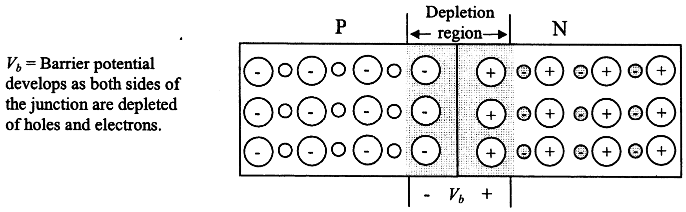


Figure 1-11: The *p-n* junction after recombination of electron-hole pairs

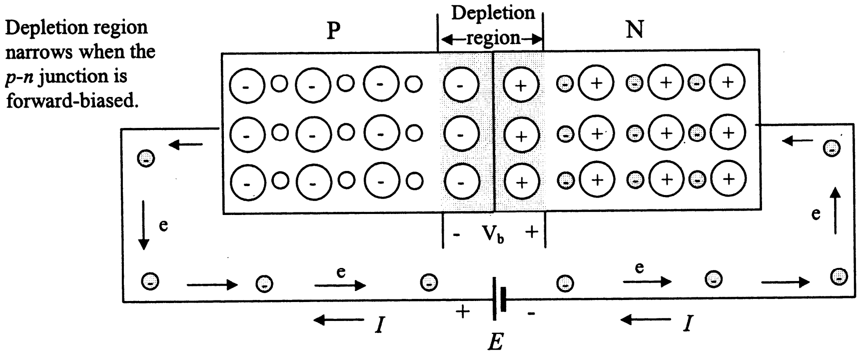


Figure 1-12: Forward biasing the *p-n* junction with an external source

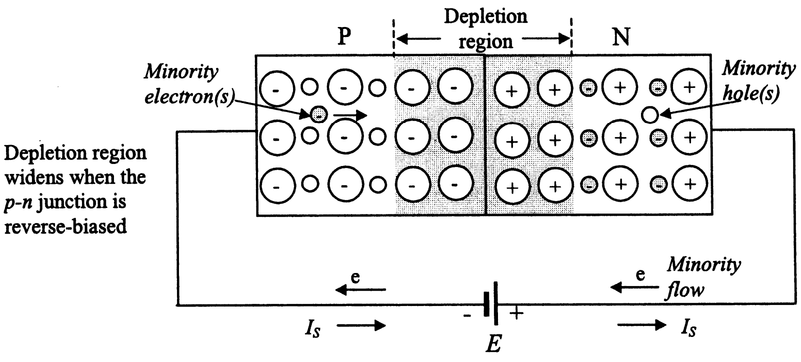
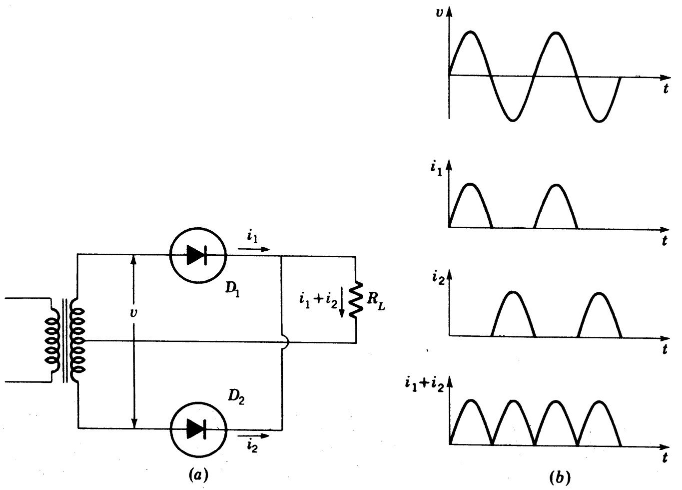


Figure 1-13: Reverse biasing the *p-n* junction with an external source

Diode Rectifiers, Clippers, and Clamps

Source: James Brophy, Basic Electronics for Scientists, 5th Edition



(a) (b)

Figure 3-8 (a) Full-wave rectifier and (b) waveforms.

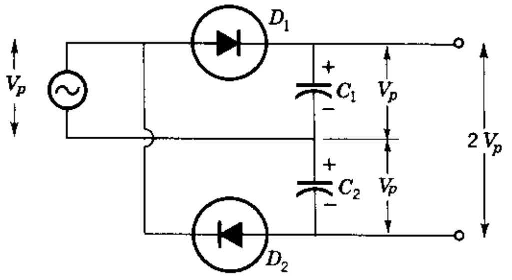


Figure 3-10 Voltage-doubler rectifier yields dc output voltage equal to twice peak input voltage.

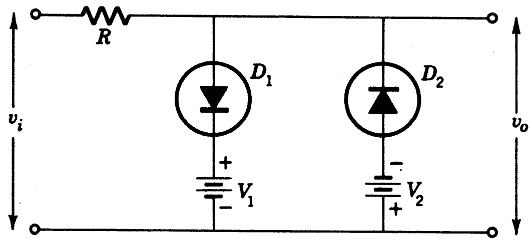


Figure 3-22 Diode clipper.

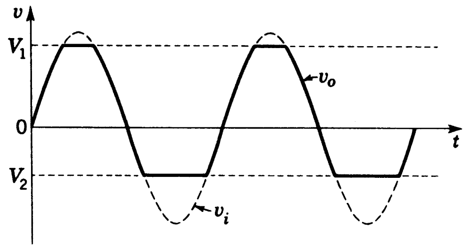


Figure 3-23 Maximum amplitudes in output waveform of diode clipper are limited to values of bias voltage.

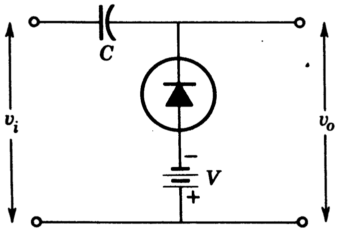


Figure 3-24 Diode clamp.

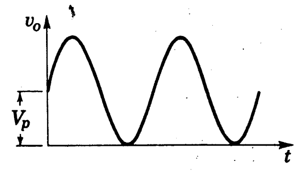
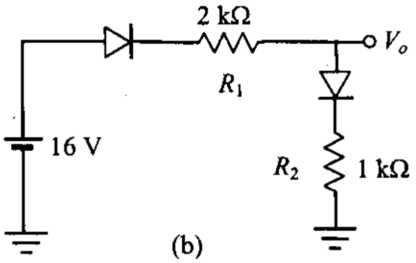


Figure 3-25 Negative peak of output waveform is clamped at zero when $V = 0$ in diode clamp circuit of Fig. 3-24.

Diode Circuits

Example



Calculate V_0

$V = 0.7 + I_D R_1 + 0.7 + I_D R_2$

$V - 0.7 - 0.7 = I_D(R_1 + R_2)$

$I_D = [V - (0.7 + 0.7)] / (R_1 + R_2)$

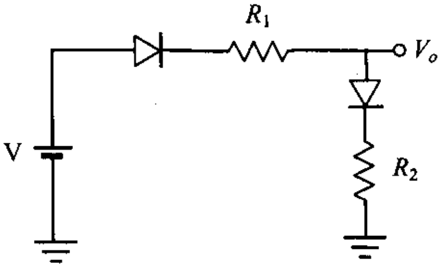
$I_D = 14.6 / (2000 + 1000)$

$I_D = 4.9$ mA

$V_0 = 0.7 + I_D R_2$

$V_0 = 0.7 + 0.0049 \times 1000 = 0.7 + 4.9 = 5.6$ V

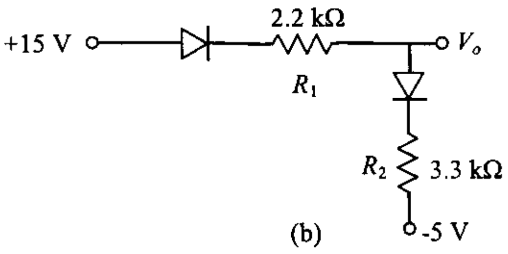
Exercise



Calculate V_0 for V = 15 V, R1 = 2200 Ω, R2 = 3300 Ω

Answer: $I_D = 2.5$ mA $V_0 = 8.9$ V

Example



Calculate V_0

$+15 = 0.7 + I_D R_1 + 0.7 + I_D R_2 - 5$

$20 - 0.7 - 0.7 = I_D(R_1 + R_2)$

$I_D = 18.6 / (R_1 + R_2)$

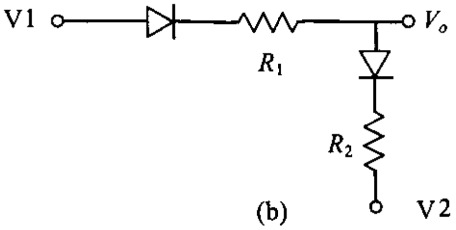
$I_D = 18.6 / (2200 + 3300)$

$I_D = 3.38$ mA

$V_0 = 0.7 + I_D R_2 - 5.0$

$V_0 = 0.7 + 0.00338 \times 3300 - 5.0 = 0.7 + 11.2 - 5.0 = 6.9$ V

Exercise

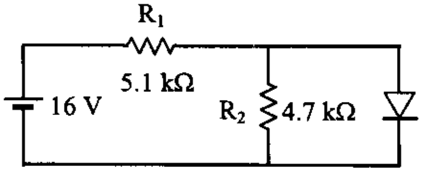


Calculate V_0 for V1 = +10 V V2 = -5 V
R1 = 1100 Ω R2 = 2200 Ω

Answer: $I_D = 4.1$ mA $V_0 = 4.8$ V

Diode Circuits - continued

Example (Refer to the Diode Circuit Lecture Notes)



Calculate the Current I_D

1. Remove Diode (Replace by V_{TH})

   For Voltage Divider $V_{TH} = V\ [\ R_2 / (R_1 + R_2)\ ]$

   $V_{TH} = 16\ [\ 4700 / (5100 + 4700)\ ] = 7.67\ V$

2. Short V_{source} (R_1 in parallel with R_2)

   $R_{EQ} = (R_1 \times R_2) / (R_1 + R_2)$

   $R_{EQ} = (5100 \times 4700) / (5100 + 4700) = 2446\ \Omega$

3. Redraw with V_{TH}, R_{EQ}, Diode

   $V_{TH} = I_D R_{EQ} + V_D$ $\qquad$ $I_D = (V_{TH} - V_D) / R_{EQ}$

   $I_D = (7.67 - 0.7) / 2446 = 2.85\ mA$

Alternative Solution Method

$V_{R2} = V_D = 0.7\ V$

$I_{R2} = V_{R2} / R_2 = 0.7 / 4700 = 0.15\ mA$

$I_{R1} = (V - V_{R2}) / R_1 = (16.0 - 0.7) / 5100 = 3.0\ mA$

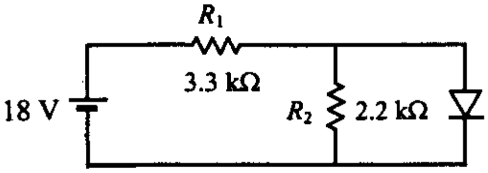
$I_{Total} = I_{R1}$

$I_D = I_{Total} - I_{R2} = 3.00 - 0.15 = 2.85\ mA$

Exercise

Calculate the Current I_D

Answer: $I_D = 4.9\ mA$ $\quad$ $V_D = 0.7\ V$

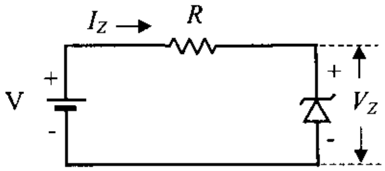


Scanned Images: Electronic Devices, Ali Aminian & Marian Kazimierczuk, Pearson-Prentice Hall, 2004

Zener Diodes

Note: Zener diodes operate in the reverse biased mode.

Example ($V = 12$ V, $R = 1000\ \Omega$, $V_Z = 3.3$ V)



$V = I_ZR + V_Z$

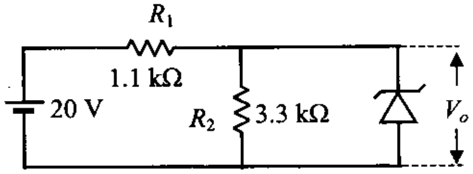
$12 = I_Z \times 1000 + 3.3$

$I_Z = (12.0 - 3.3) / 1000 = 8.7$ mA

If $V_{Source} > V_Z$ then V_0 maintained at V_Z, else $V_0 = 0$

Example (Refer to the Diode Circuit Notes and Zener Diode Lecture Notes)

For $V_Z = 5.1$ V, Calculate I_{Total} and I_{R2} and I_Z



1. Calculate V_{TH}

   $V_{TH} = 20\ (\ 3300 / (1100 + 3300)$
   $V_{TH} = 15$ V

2. Calculate R_{EQ}

   $R_{EQ} = (1100 \times 3300) / (1100 + 3300)$
   $R_{EQ} = 825\ \Omega$

3. Calculate I_{Total} and I_{R2} and I_Z

   $V_{TH} = I_{Total}R_{EQ} + V_Z$

   $I_Z = (V_{TH} - V_Z) / R_{EQ}$

   $I_Z = (15 - 5.1) / 825 = 12$ mA

   $I_{R2} = V_{R2} / R_2 = V_D / R_2 = 5.1 / 3300 = 1.55$ mA

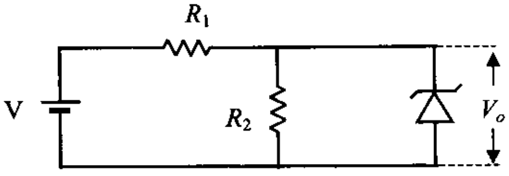
   $I_{Total} = I_Z + I_2 = 12 + 1.6 = 13.55$ mA

Alternative Solution Method

$V_{R2} = V_Z = 5.1$ V
$I_{R2} = V_{R2} / R_2 = 5.1 / 3300 = 1.55$ mA
$I_{R1} = (V - V_{R2}) / R_1 = (20.0 - 5.1) / 1100 = 13.55$ mA
$I_{Total} = I_{R1} = 13.55$ mA
$I_Z = I_{Total} - I_{R2} = 13.55 - 1.55 = 12$ mA

Exercise

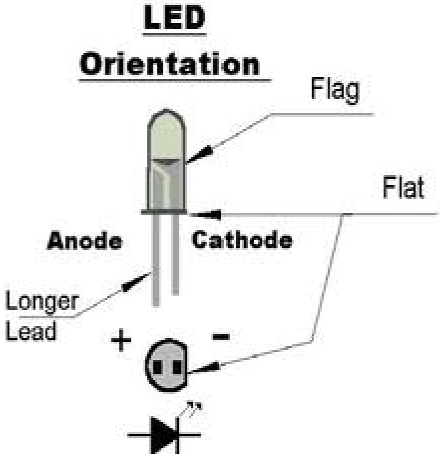
For $V = 21$, $R1 = 1000$, $R2 = 2000$, $V_Z = 7.5$ V
Calculate I_Z and I_{R2} and I_{Total}

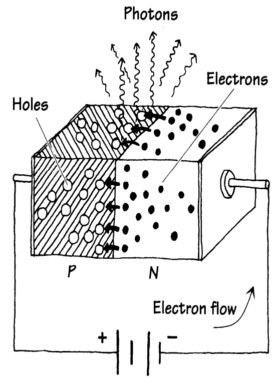


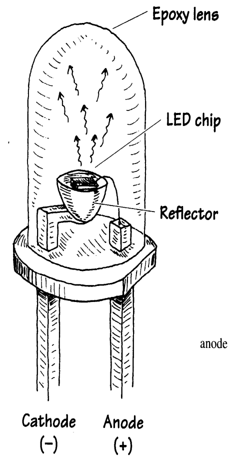
Answers:
$V_{TH} = 14$ V, $R_{EQ} = 666\ \Omega$, $V_0 = V_Z = 7.5$ V
$I_Z = 9.75$ mA, $I_{R2} = 3.75$, $I_{Total} = 13.5$ mA

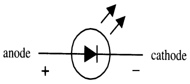
Scanned Images: Electronic Devices, Ali Aminian & Marian Kazimierczuk, Pearson-Prentice Hall, 2004

Light Emitting Diode LED

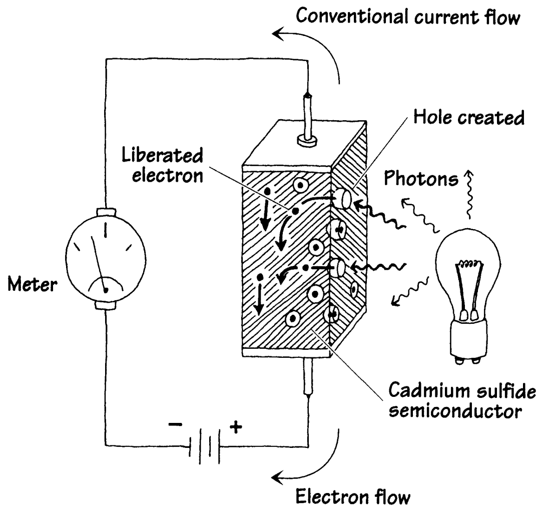


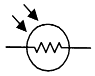


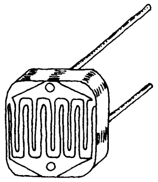




PhotoResistor

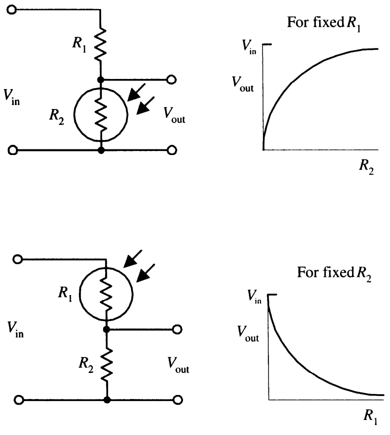






Actual package

Light-Sensitive Voltage Divider

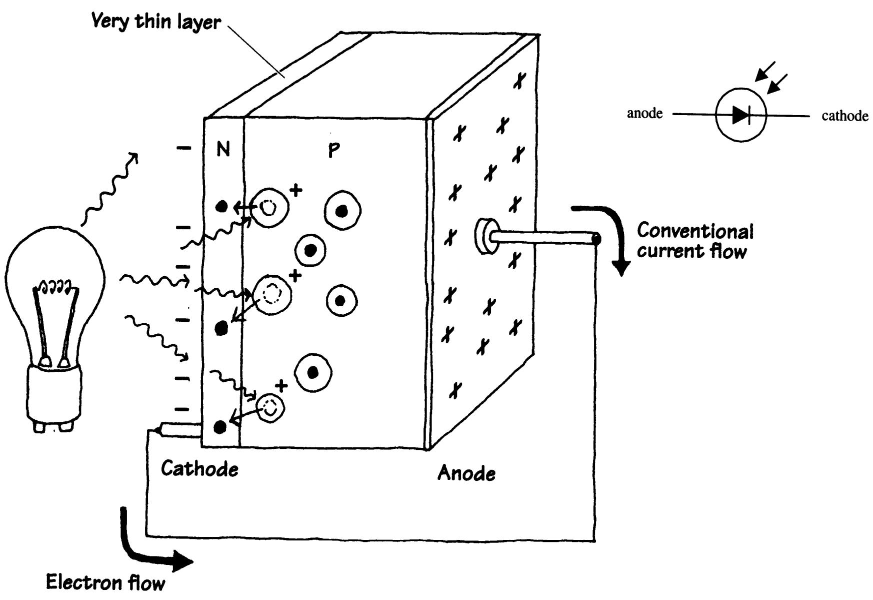


$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

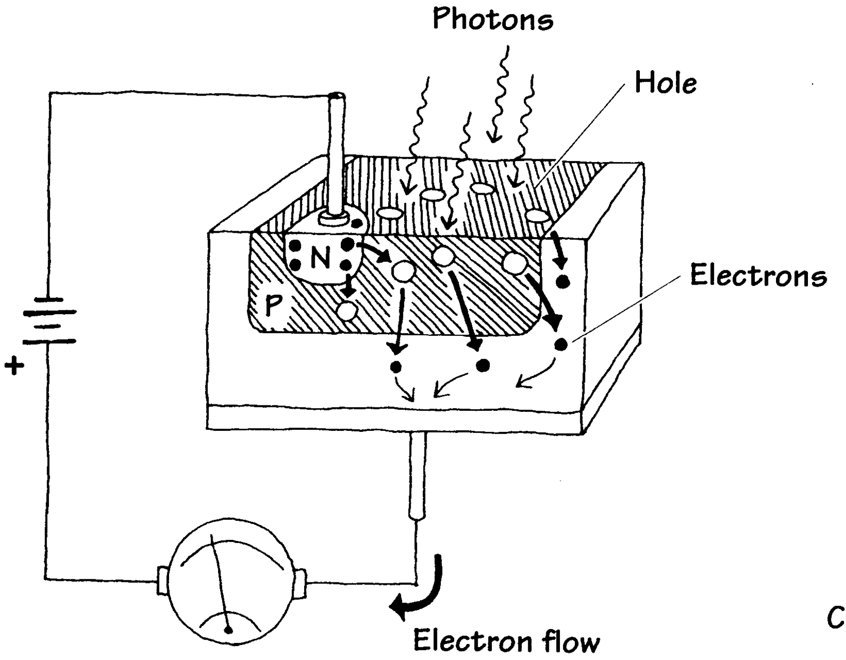
As the intensity of light increases, the resistance of the photoresistor decreases, so V_{out} in the top circuit gets smaller as more light hits it, whereas V_{out} in the lower circuit gets larger.

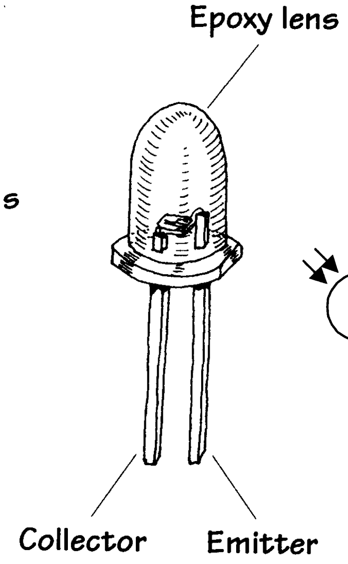
Scherz, Practical Electronics for Inventors, 2nd & 3rd Editions

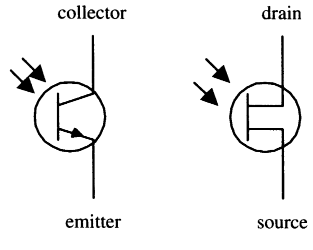
PhotoDiode



PhotoTransistors

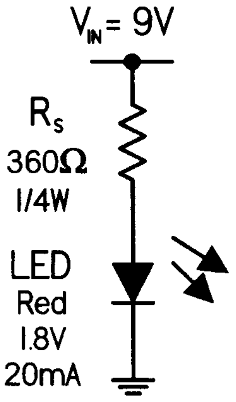






Source: Scherz, Practical Electronics for Inventors, 2nd & 3rd Editions

LED Current Limiting

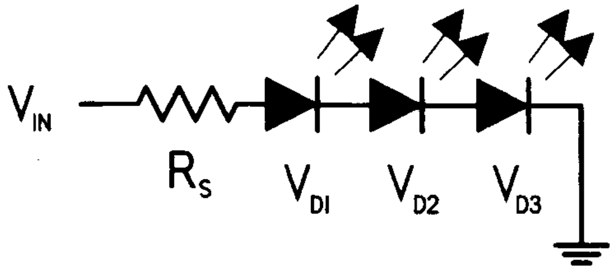


$$R_S = \frac{V_{IN} - V_{LED}}{I_{LED}}$$

V_{LED} = LED forward voltage

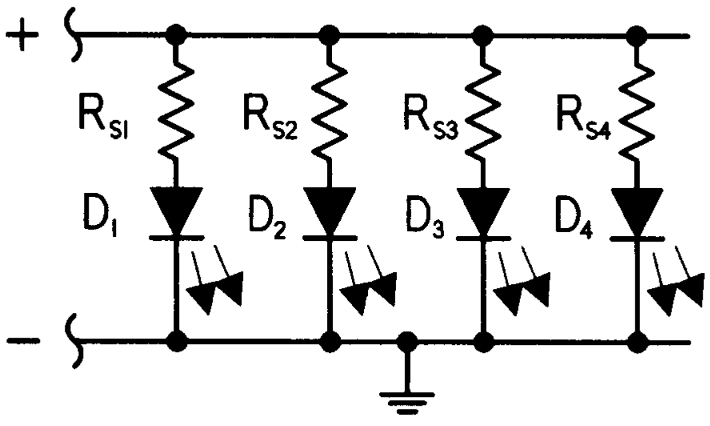
I_{LED} = LED forward current

LEDs in Series



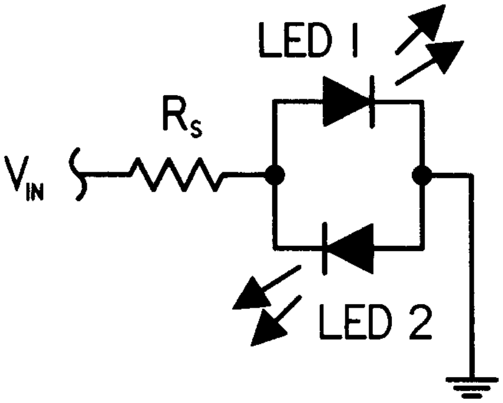
$$R_S = \frac{V_{IN} - (V_{D1} + V_{D2} + V_{D3})}{I_{D,\max}}$$

LEDs in Parallel



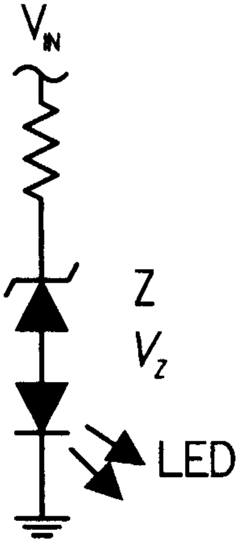
Reference: Scherz, Practical Electronics for Inventors, 2nd & 3rd Editions

AC-DC Polarity Indicator



V_{IN}	LED 1	LED 2
+	On	Off
−	Off	On
AC	On	On

Voltage-Level Indicator

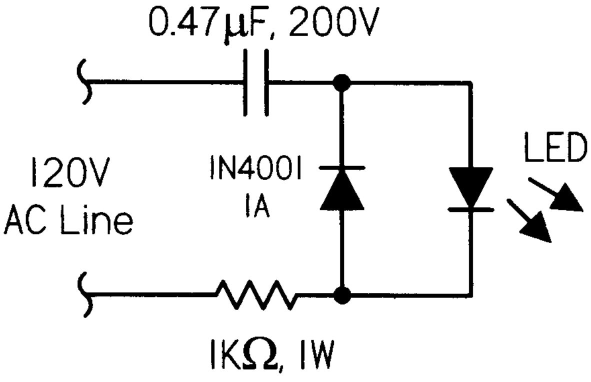


LED lights when V_z is exceeded

$$R_S = \frac{V_{In} - [V_Z + V_{LED}]}{I_{LED}}$$

$$V_{In(Minimum)} = R_S I_{LED} + V_Z + V_{LED}$$

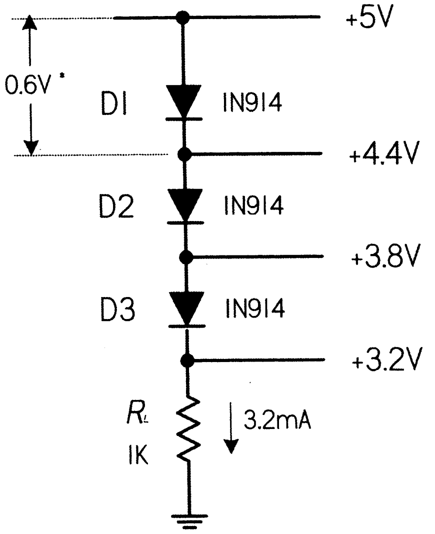
Driving LEDs from 120VAC



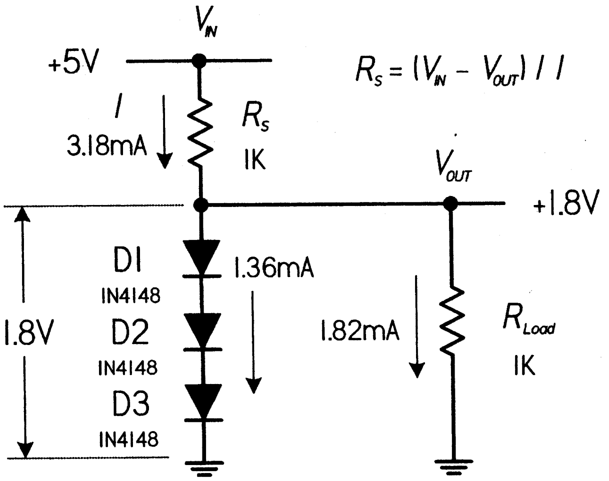
Reference: Scherz, Practical Electronics for Inventors, 2nd & 3rd Editions

Voltage Dropper

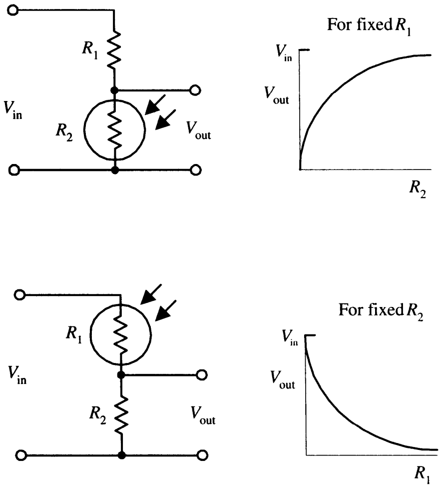
DC application



Voltage Regulator



Light-Sensitive Voltage Divider



$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

As the intensity of light increases, the resistance of the photoresistor decreases, so V_{out} in the top circuit gets smaller as more light hits it, whereas V_{out} in the lower circuit gets larger.