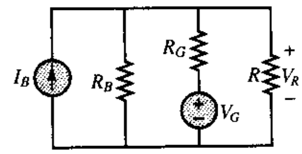
Principle of Superposition

Problem

Determine the voltage across resistor R in the circuit of Figure 3.30.



(a)

Figure 3.30 (a) Circuit used to demonstrate the principle of superposition

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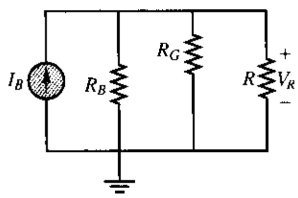
Solution

Known Quantities: The values of the voltage sources and of the resistors in the circuit of Figure 3.30 are $I_B = 12$ A; $V_G = 12$ V; $R_B = 1\ \Omega$; $R_G = 0.3\ \Omega$; $R = 0.23\ \Omega$.

Find: The voltage across R.



(b)

Figure 3.30 (b) Circuit obtained by suppressing the voltage source

Analysis: Specify a ground node and the polarity of the voltage across R. Suppress the voltage source by replacing it with a short circuit. Redraw the circuit, as shown in Figure 3.30(b), and apply KCL:

$$-I_B + \frac{V_{R-I}}{R_B} + \frac{V_{R-I}}{R_G} + \frac{V_{R-I}}{R} = 0$$

$$V_{R-I} = \frac{I_B}{1/R_B + 1/R_G + 1/R} = \frac{12}{1/1 + 1/0.3 + 1/0.23} = 1.38 \text{ V}$$

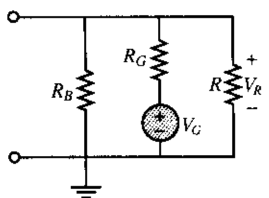
Suppress the current source by replacing it with an open circuit, draw the resulting circuit, as shown in Figure 3.30(c), and apply KCL:

$$\frac{V_{R-V}}{R_B} + \frac{V_{R-V} - V_G}{R_G} + \frac{V_{R-V}}{R} = 0$$

$$V_{R-V} = \frac{V_G/R_G}{1/R_B + 1/R_G + 1/R} = \frac{12/0.3}{1/1 + 1/0.3 + 1/0.23} = 4.61 \text{ V}$$

Finally, we compute the voltage across R as the sum of its two components:

$$V_R = V_{R-I} + V_{R-V} = 5.99 \text{ V}$$



(c)

Figure 3.30 (c) Circuit obtained by suppressing the current source

Fundamental of Electrical Engineering, Giorgio Rizzoni, McGraw-Hill, 2009

Ideal Transformer Relations (Equations)

Definitions:

Primary Winding (input - subscript $_1$)
Secondary Winding (output - subscript $_2$)

Turns Ratio = n_1 / n_2 (number of turns on primary winding / number of turns on secondary winding)

Voltage Ratio: $V_1 / V_2 = n1 / n_2$ (Directly Proportional)

Current Ratio: $I_1 / I_2 = n_2 / n_1$ (Inversely Proportional)

Power Ratio: 1 to 1 (Power Out = Power In) Ideal
Power Out = *e* x Power In where *e* is the Efficiency Factor ($e < 1$)

Impedance Ratio: $Z_1 / Z_2 = (n_1 / n_2)^2$

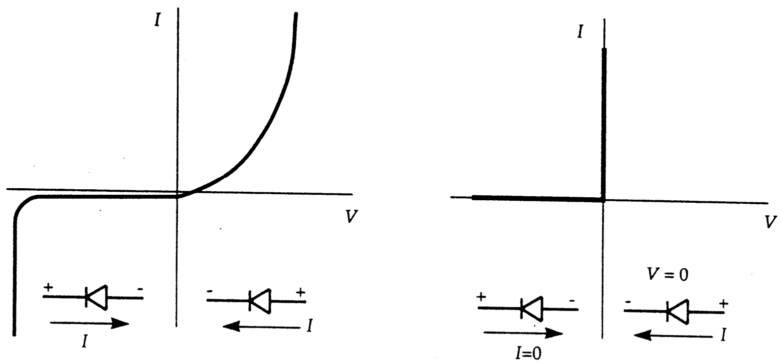
For additional information, refer to
Practical Electronics for Inventors, 2ed pp 386 - 392
Practical Electronics for Inventors, 3ed pp 374 - 402

Transformer Problems and Questions

1. Given an ideal transformer with primary turns = 9600 and secondary turns = 480, assume 100% efficiency. For input voltage = 120 VAC and output impedance = 16 ohms;
   a. Calculate output voltage
   b. Calculate output current
   c. Calculate output power
   b. Calculate input current
   c. Calculate input power
   b. Calculate input impedance

Diode Characteristics

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



a) Actual diode   b) Ideal diode

Figure 6.18 Characteristics of a diode.

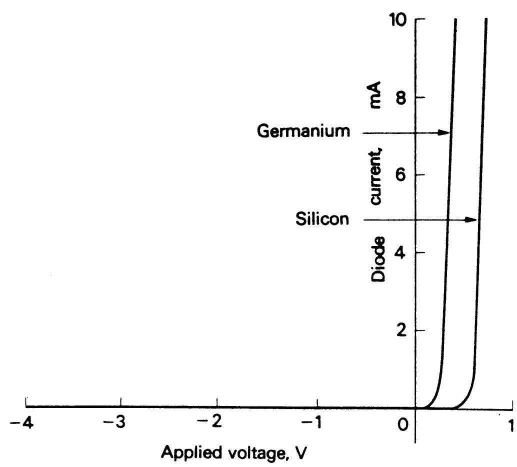


Figure 3-2 Current-voltage characteristics of germanium and silicon junction diodes.

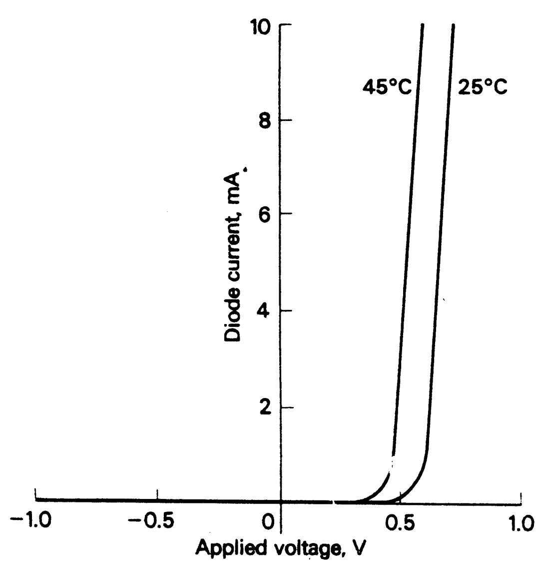


Figure 3-3 Effect of temperature on current-voltage characteristics of silicon junction diode.

Diode Rectifiers, Clippers, and Clamps

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

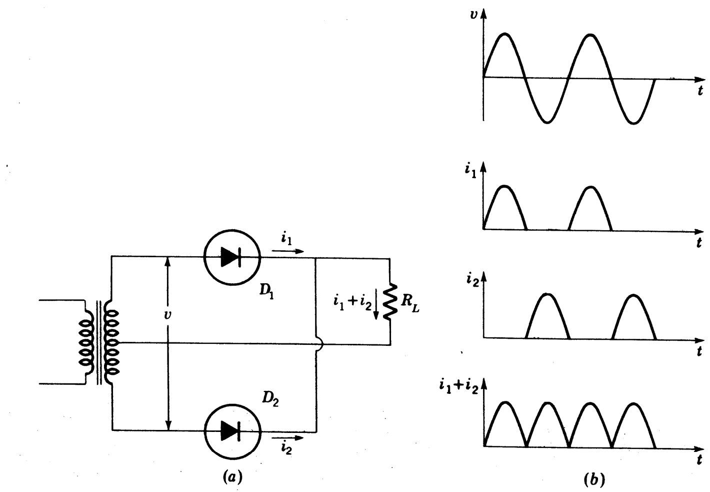


Figure 3-8 (*a*) Full-wave rectifier and (*b*) waveforms.

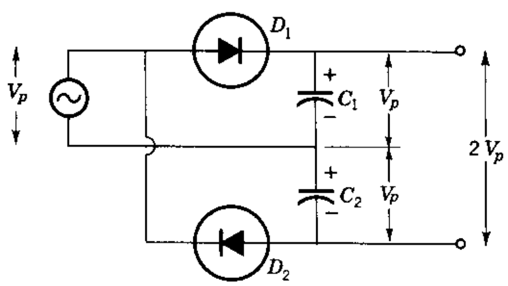


Figure 3-10 Voltage-doubler rectifier yields dc output voltage equal to twice peak input voltage.

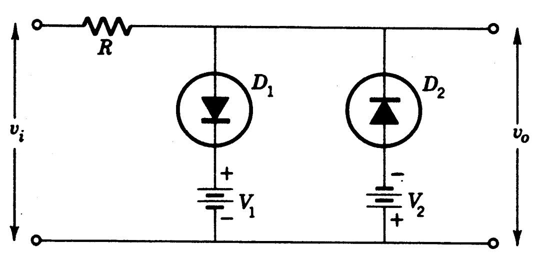


Figure 3-22 Diode clipper.

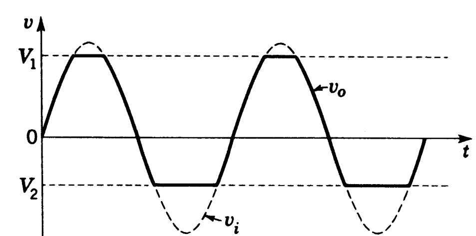


Figure 3-23 Maximum amplitudes in output waveform of diode clipper are limited to values of bias voltage.

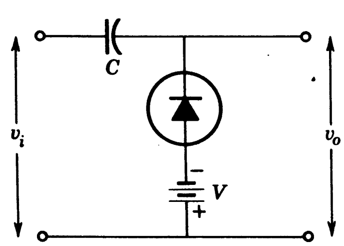


Figure 3-24 Diode clamp.

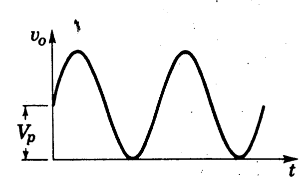
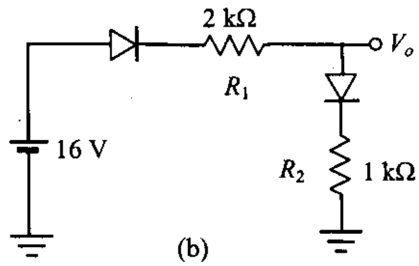


Figure 3-25 Negative peak of output waveform is clamped at zero when $V = 0$ in diode clamp circuit of Fig. 3-24.

Diode Circuits

Example

Calculate V_0



$V = 0.7 + I_DR_1 + 0.7 + I_DR_2$

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

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

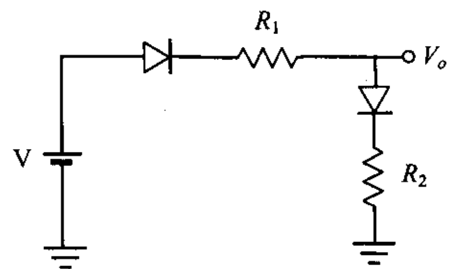
$I_D = 14.6 / (2000 + 1000)$

$I_D = 4.9$ mA

$V_0 = 0.7 + I_DR_2$

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

Exercise

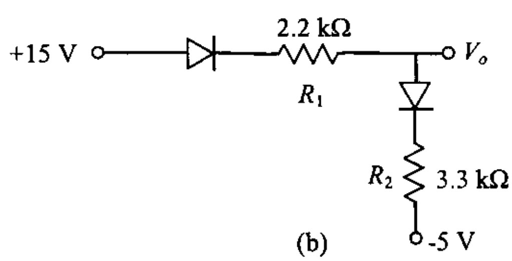


Calculate V_0 for V = 15 V, R1 = 2200 Ω, R2 = 3300 Ω

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

Example

Calculate V_0



$+15 = 0.7 + I_DR_1 + 0.7 + I_DR_2 - 5$

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

$I_D = 18.6 / (R_1 + R_2)$

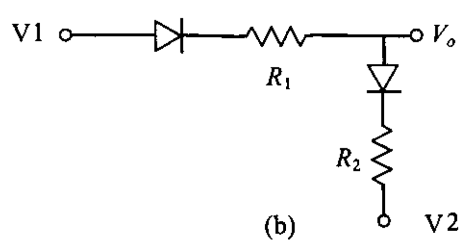
$I_D = 18.6 / (2200 + 3300)$

$I_D = 3.38$ mA

$V_0 = 0.7 + I_DR_2 - 5.0$

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

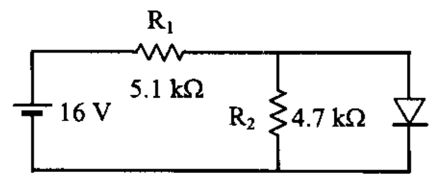
Exercise



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

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)

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

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

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