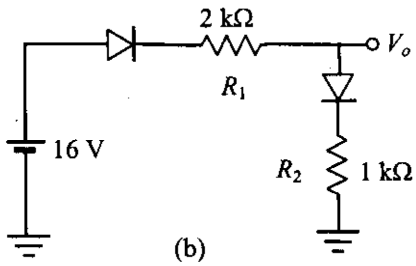
Diode Circuits

Example

Calculate V_0



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

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

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

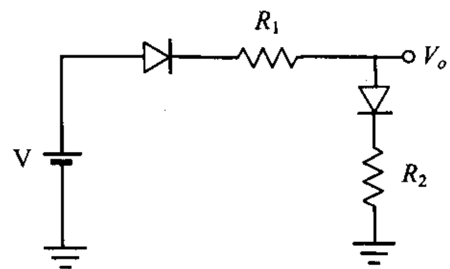
$I_D = 14.6 / (2000 + 1000)$

$I_D = 4.9$ mA

$V_0 = 0.7 + I_D R_2$

$V_0 = 0.7 + 0.0049 \text{ x } 1000 = 0.7 + 4.9 = 5.6$ V

Exercise

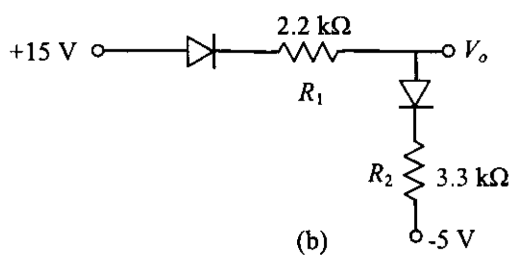


Calculate V_0 for V = 15 V, R1 = 2200 Ω, R2 = 3300 Ω

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

Example

Calculate V_0



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

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

$I_D = 18.6 / (R_1 + R_2)$

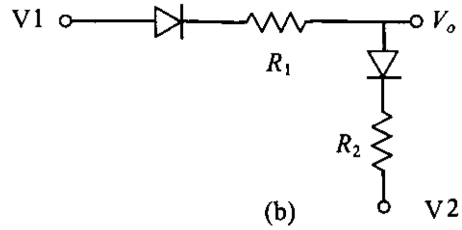
$I_D = 18.6 / (2200 + 3300)$

$I_D = 3.38$ mA

$V_0 = 0.7 + I_D R_2 - 5.0$

$V_0 = 0.7 + 0.00338 \text{ x } 3300 - 5.0 = 0.7 + 11.2 - 5.0 = 6.9$ V

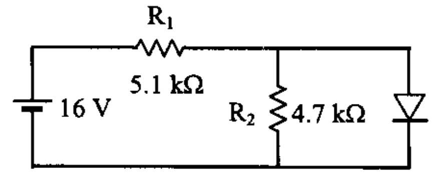
Exercise



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)

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

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

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

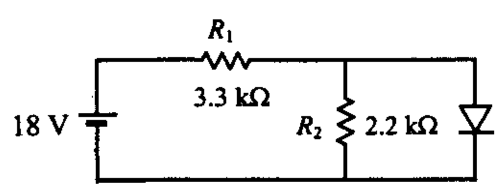
$I_{Total} = I_{R1}$

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

Exercise

Calculate the Current I_D

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

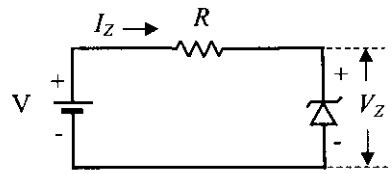


Zener Diodes

Note: Zener diodes operate in the reverse biased mode.

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

$V = I_Z R + V_Z$



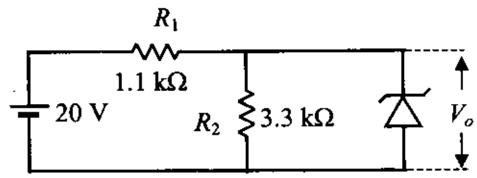
$12 = I_Z \times 1000 + 3.3$

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

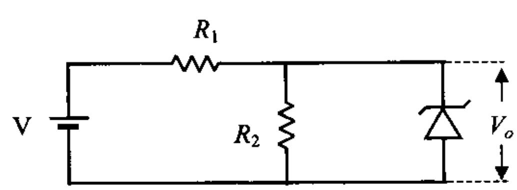
   $I_{Total} = I_Z + I_2 = 12 + 1.6 = 13.55$ mA

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

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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, 3ed & 4ed, pp 374 - 396.

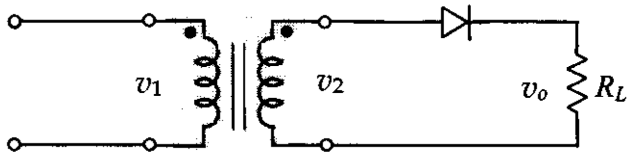
Transformer Problems and Questions

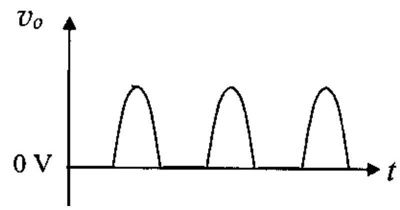
1. Given an ideal transformer with primary turns = 9600 and secondary turns = 480, assume 100% efficiency. For input voltage = 120 VAC and output impedance = 16 ohms;
   a. Calculate output voltage
   b. Calculate output current
   c. Calculate output power
   b. Calculate input current
   c. Calculate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

2. Determine the turns ratio for an impedance matching transformer where the first stage input impedance is 50 ohms and the second stage output impedance is 8 ohms.

Half-Wave &Full Wave Rectifiers, Filtering, Regulated Power Supply

Half-Wave Rectifier Equivalent DC Output Voltage





Example

Given:

v_{in}(RMS) = 110 V (60 HZ)

Turns Ratio 10:1

Find: v_{out}(DC Effective)

v_{in}(Peak) = 1.414 v_{in}(RMS) = 1.414 x 110 = 155.5 V

v_{out}(Peak) = 1/10 v_{in}(Peak) = 1/10 x 155.5 = 15.6 V

v_{Diode} = 15.6 - 0.7 = 14.9 V

V_{out}(DC Effective) = 0.318 v_{Diode} = 0.318 x 14.9 ≈ 4.7 VDC

Exercise #1

Given: v_{in}(RMS) = 110 V (60 HZ) Turns Ratio 5:1

Find: V_{out}(DC Effective)

Answer: 9.7 VDC

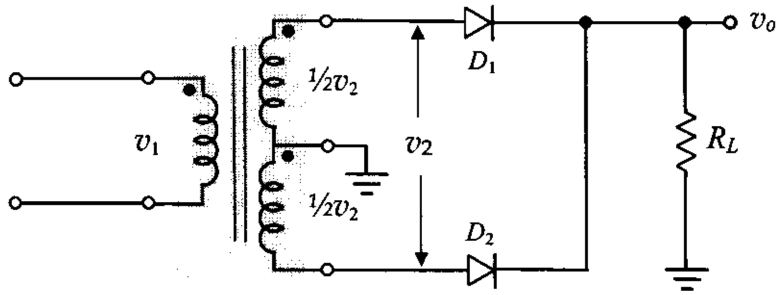
Exercise #2

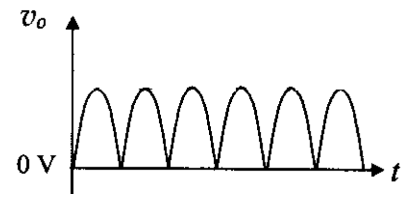
Given: v_{in}(RMS) = 120 V (60 HZ) Turns Ratio 5:1

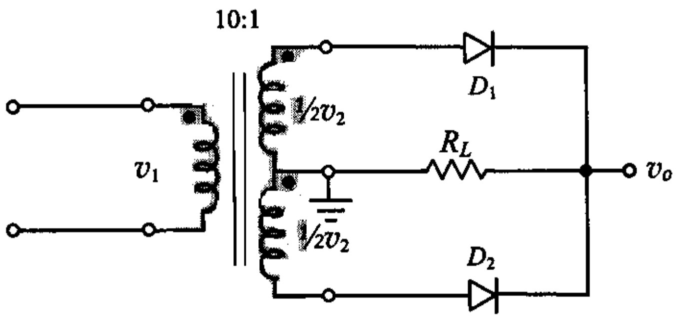
Find: V_{out}(DC Effective)

Answer: 10.6 VDC

Full-Wave Center-Tapped Rectifier Equivalent DC Output Voltage







Example

Given:
v_{in}(RMS) = 110 V (60 HZ)
Turns Ratio 10:1

Find: V_{out}(DC Effective)

v_{in}(Peak Center) = 1.414 v_{in}(RMS) = 1.414 x 110 = 155.5 V

v_{out}(Peak) = (1/2) (1/10) v_{in}(Peak) = 1/20 x 155.5 = 7.8 V

v_{Diode} = 7.8 - 0.7 = 7.1 V

V_{out}(DC Effective) = 0.636 v_{Diode} = 0.636 x 7.1 ≈ 4.5 VDC

Exercise #1

Given: v_{in}(RMS) = 110 V (60 HZ) Turns Ratio 5:1

Find: V_{out}(DC Effective)

Answer: 9.5 VDC

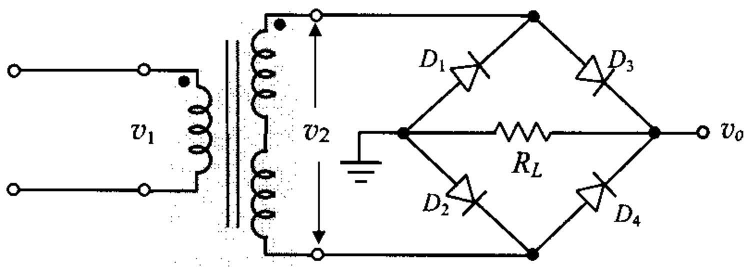
Exercise #2

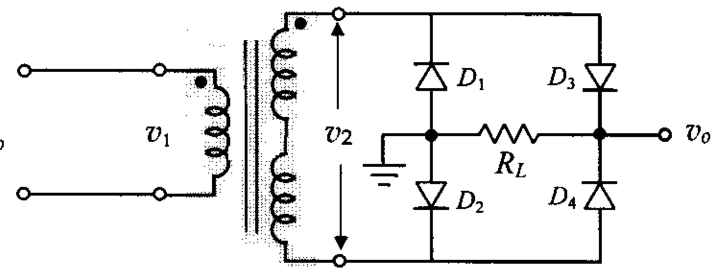
Given: v_{in}(RMS) = 120 V (60 HZ) Turns Ratio 5:1

Find: V_{out}(DC Effective)

Answer: 10.4 VDC

Full-Wave Bridge Rectifier Equivalent DC Output Voltage





Example

Given:
v_{in}(RMS) = 110 V (60 HZ)
Turns Ratio 10:1

Find: V_{out}(DC Effective)

v_{in}(Peak) = 1.414 v_{in}(RMS) = 1.414 x 110 = 155.5 V

v_{out}(Peak) = 1/10 v_{in}(Peak) = 1/10 x 155.5 = 15.6 V

v_{Diode} = 15.6 - 2(0.7) = 14.2 V

v_{out}(DC Effective) = 0.636 v_{Diode} = 0.636 x 14.2 ≈ 9 VDC

Exercise #1

Given: v_{in}(RMS) = 110 V (60 HZ) Turns Ratio 5:1

Find: V_{out}(DC Effective)

Answer: 18.9 VDC

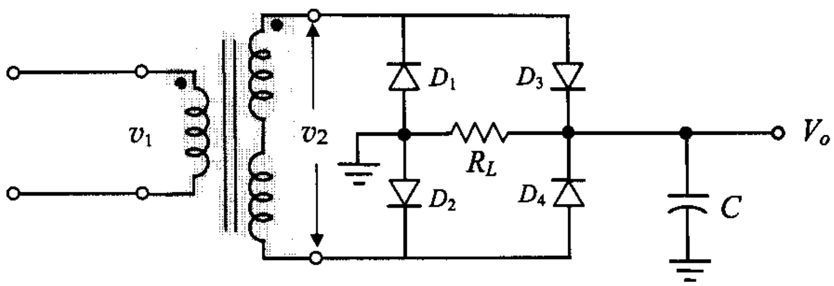
Exercise #2

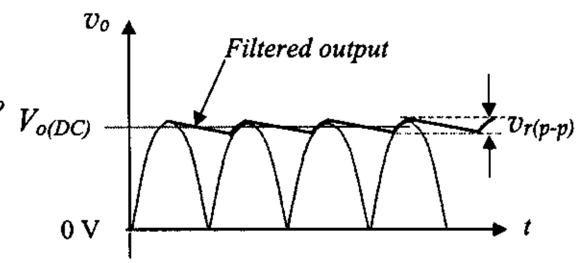
Given: v_{in}(RMS) = 120 V (60 HZ) Turns Ratio 5:1

Find: V_{out}(DC Effective)

Answer: 20.7 VDC

Filtering





$v_{ripple(peak-\ peak)} = I_{out(DC)} / 2fC$

$I_{out(DC)} = V_{out}(DC) / R_{Load}$

Two Steps

1. Assume V_{out}(DC) (Without filtering, i.e., use peak of the rectified wave , **NOT** the DC average value.)
2. Solve for $I_{out(DC)}$ and $v_{ripple(peak-\ peak)}$
3. Recalculate V_{out}(DC) Load = V_{out}(DC) (without filtering) - [$v_{ripple(peak-\ peak)}$] / 2

Example

Given:
v_{in}(RMS) = 110 V (60 HZ)
Turns Ratio 10:1
R_{Load} = 100 Ω C = 1000 μF f = 60 Hz

Find: V_{out}(DC) Load

From Full-Wave Bridge Rectifier (from Example page 3, above) V_{out}(DC) (without filtering) = 14.2 VDC

$I_{out(DC)}$ = V_{out}(DC) / R_{Load} = 14.2/100 = 0.142A = 142 mA

$v_{ripple(peak-\ peak)}$ = $I_{out(DC)} / 2fC$ = $0.142 / (2 \times 60 \times 1000 \times 10^{-6})$ = 1.18 V

V_{out}(DC) Load = V_{out}(DC) (without filtering) - [$v_{ripple(peak-\ peak)}$] / 2 = 14.2 - (1.18) / 2 = 13.6 VDC

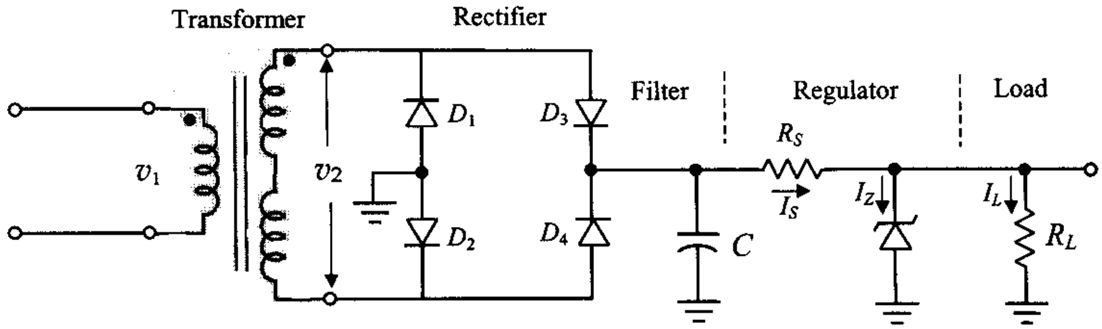
Exercise

Given:
v_{in}(RMS) = 120 V (60 HZ) Turns Ratio 5:1
R_{Load} = 240 Ω C = 470 μF f = 60 Hz
V_{out}(DC) (without filtering) = 32.5 VDC (from Problem, page 3, above. Note 32.5 not 32.5 x .636 = 20.7)

Find: V_{out}(DC) Load

Answer: $I_{out(DC)}$ = 136 mA $v_{ripple(peak-\ peak)}$ = 2.4 V V_{out}(DC) Load = 31.3 VDC

Regulated Power Supply



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