Tishk International University
Mechatronics Engineering Department
Electronics Principles and Devices ME 227
Lecture 2: 12/10/2022

Rectifier Circuits

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Previous lecture

- Introduction to Semiconductor
- PN Diode

Outline

- AC and DC
- Transformer
- Rectifier circuit
- Half wave rectifier
- Examples
- Full wave rectifier
- Bridge Rectifier
- Homework

AC and DC

- All active electronic devices require a source of constant dc that can be supplied by a battery or a dc power supply.
- The dc power supply will be provided by convert the standard **220 V, 50 Hz** ac voltage available at wall outlets into a constant dc voltage using ***Rectifier.***

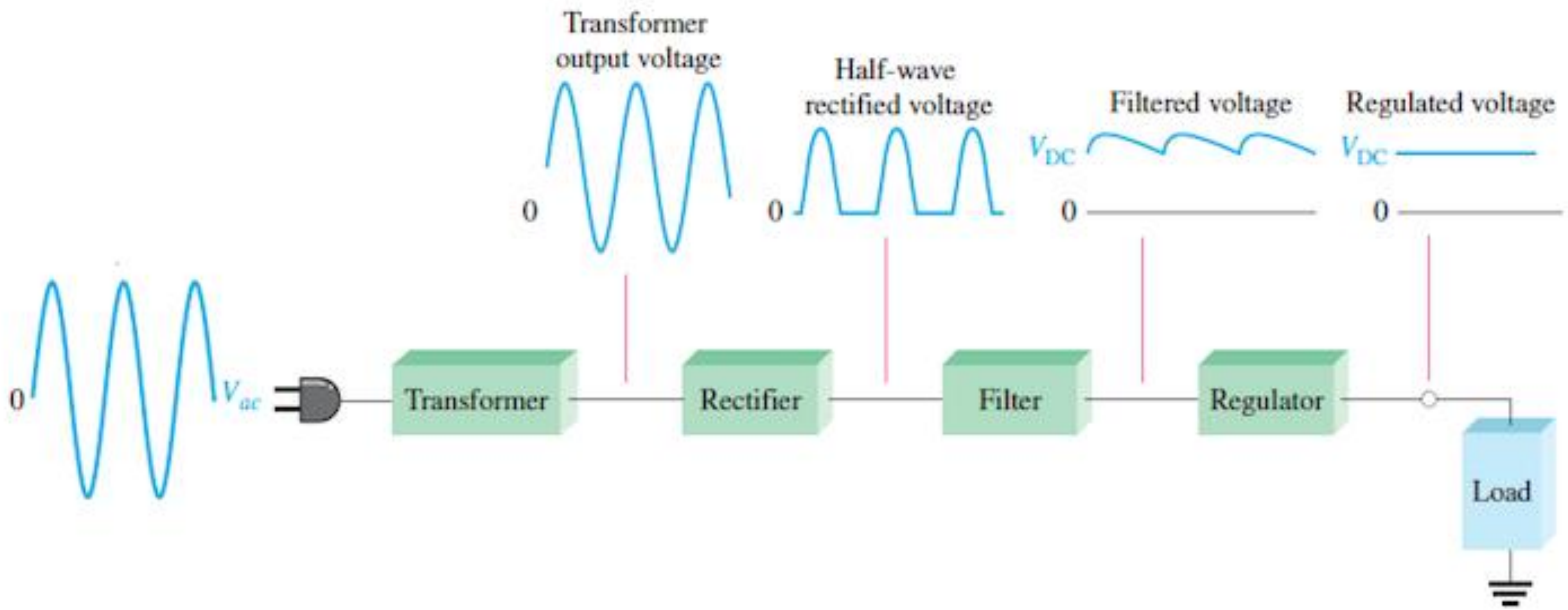


Fig. 1: Full processor to Convert AC to DC

Transformer

- The transformer is often used to couple the ac input voltage from the source to the rectifier, as shown in Figure (1). Transformer coupling provides two advantages.
  - ➢First, it allows the source voltage to be stepped down as needed.
  - ➢Second, the ac source is electrically isolated from the rectifier, thus preventing a shock hazard in the secondary circuit.
- The amount that the voltage is stepped down is determined by the turns ratio of the transformer.

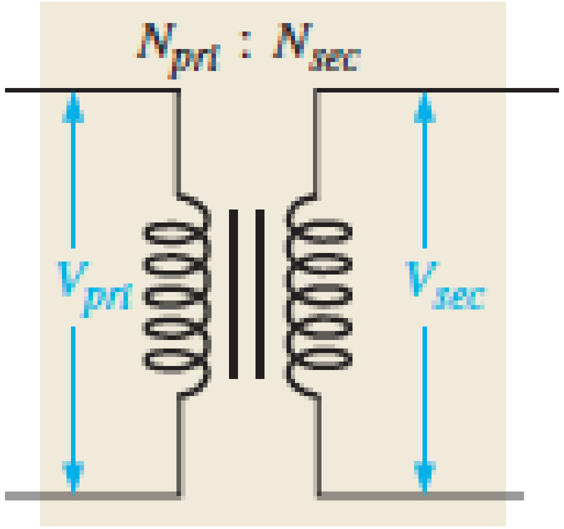


Fig. 2: Transformer

Transformer

- Turn ratio is equal to the number of turns in the secondary (Nsec) divided by the number of turns in the primary (Npri). n = Nsec / Npri.
- Thus, a transformer with a turns ratio less than 1 is a step-down type and one with a turns ratio greater than 1 is a step-up type.
- The secondary voltage of a transformer equals the turns ratio, n times the primary voltage. VSec = n Vpri.
    - ➢ If n > 1, the secondary voltage is greater than the primary voltage.
    - ➢ If n < 1 the secondary voltage is less than the primary voltage.
    - ➢ If n = 1, then Vsec = Vpri.

Rectifier circuit

- The Rectifier is convert the alternating current (AC) to direct current (DC).
- The dc voltage level required depends on the application, but most applications require relatively low voltages.
- The dc power supply is one of the most common circuits you will find. The voltage produced is used to power all types of electronic circuits including consumer electronics (televisions, DVDs, etc.), computers, industrial controllers, and most laboratory instrumentation systems and equipment.
- Rectifier circuit has two types: Half-wave rectifier and Full-wave rectifier.

Half Wave Rectifier

- A diode is connected to an ac source and to a load resistor, RL, forming a half-wave rectifier.
- When the sinusoidal input voltage (Vin) goes positive, the diode is forward-biased and conducts current through the load resistor, as shown in Figure (3).
- The current produces an output voltage across the load RL, which has the same shape as the positive half-cycle of the input voltage.

Half Wave Rectifier

- When the input voltage goes negative during the second half of its cycle, the diode is reverse-biased. There is no current, so the voltage across the load resistor is 0 V, as shown in Figure (3).

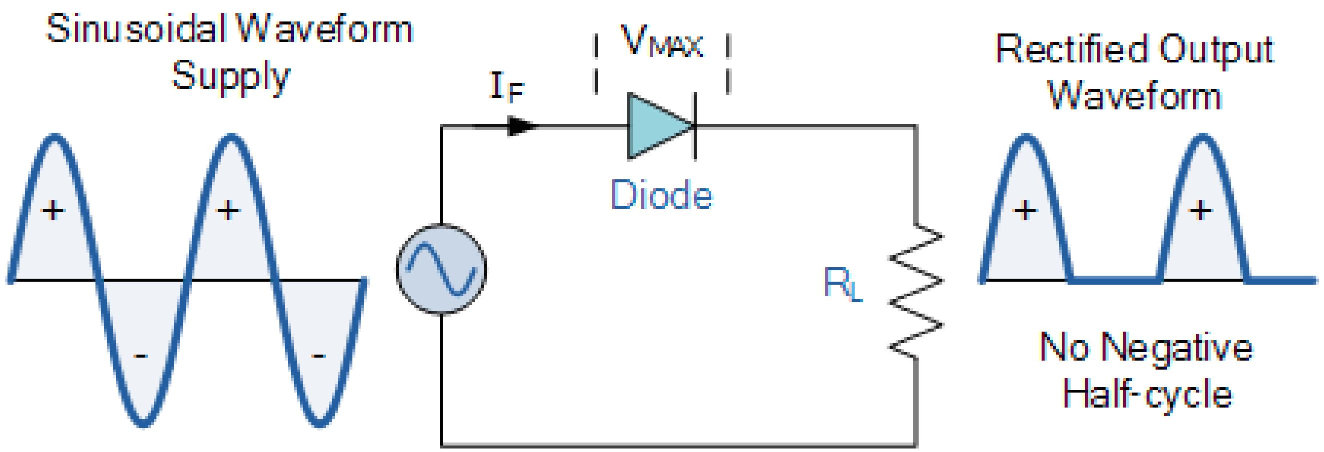


Fig.3: Half Wave Rectifier

Half Wave Rectifier

- During the positive half-cycle, the input voltage must overcome the barrier potential (which is 0.7 V) before the diode becomes forward-biased.
- The half-wave output with a peak value that is 0.7 V less than the peak value of the input, as shown in Figure (4). The expression for the peak output voltage is **Vp (out) = Vp(in) - 0.7 V**

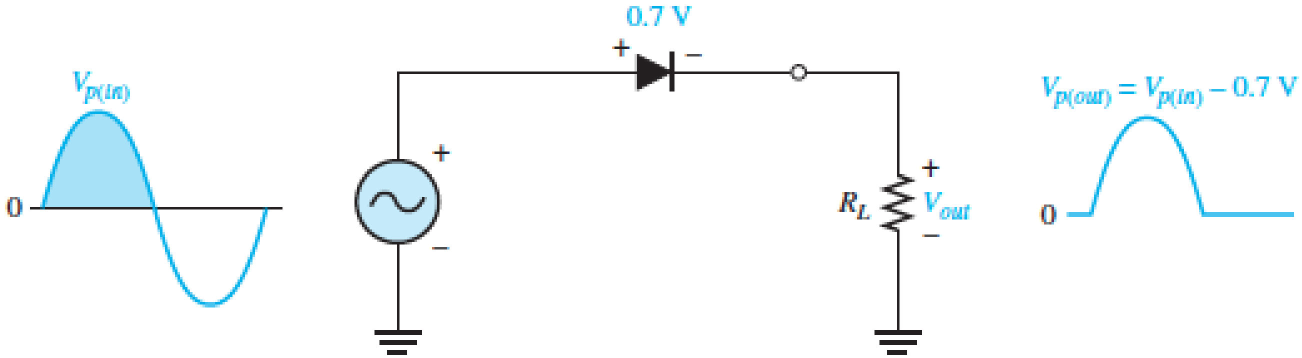
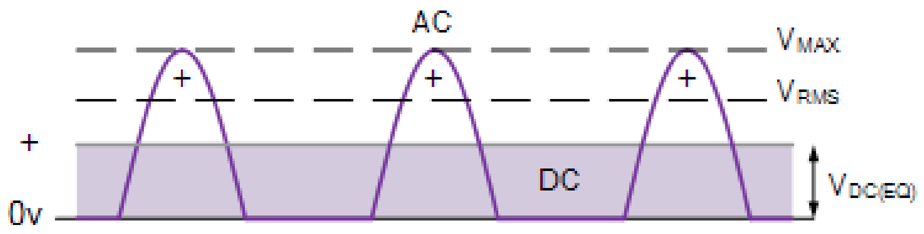


Fig. 4: Output Voltage at Half wave rectifier

Half Wave Rectifier

- The average value of the half-wave rectified output voltage is the value you would measure on a dc voltmeter.
- Mathematically, it is determined by finding the area under the curve over a full cycle, and then dividing by 2π, the number of radians in a full cycle.
- The result of this is expressed in the equation below, where Vp is the peak value of the voltage. This equation shows that VAVG is approximately 31.8% of Vp for a half-wave rectified voltage.

$$V_{AVG} = V_{d.c.} = V_p/\pi$$



Example1

Draw the output voltage of the rectifier circuit in Figure 5 then find the peak output voltage and the average voltage:

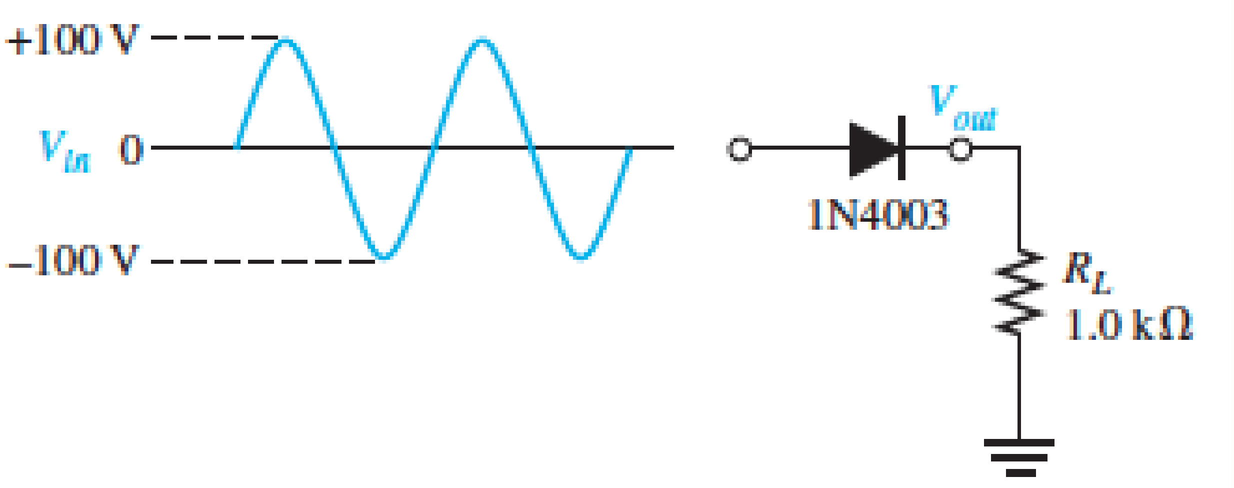


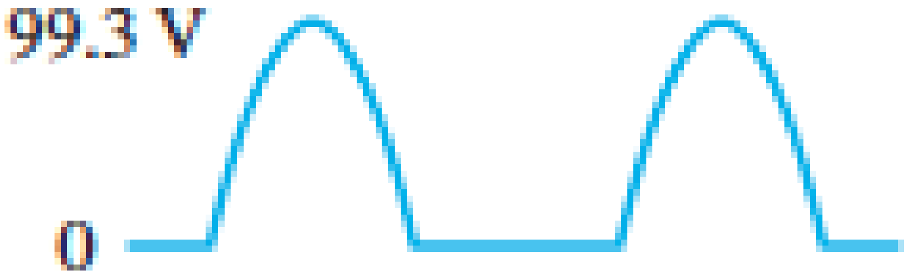
Fig. 5: Half Wave Rectifier Example

Solution of Example1

$V_{p(out)} = 100 – 0.7 = 99.3V$

$V_{AVG} = V_{p(out)}/\pi = 31.6V$

The shape of the output voltage is:



Half Wave Rectifier with Transformer

- When the half-wave rectifier connects to the Ac supply through a transformer, the VP(out) will be affected by the turns ratio of the transformer, the value of the Vin and the potential voltage for the diode which is equal to 0.7V. as seen in the following example:

Example2

Determine the output peak value and the average voltage for the following circuit in Figure 6:

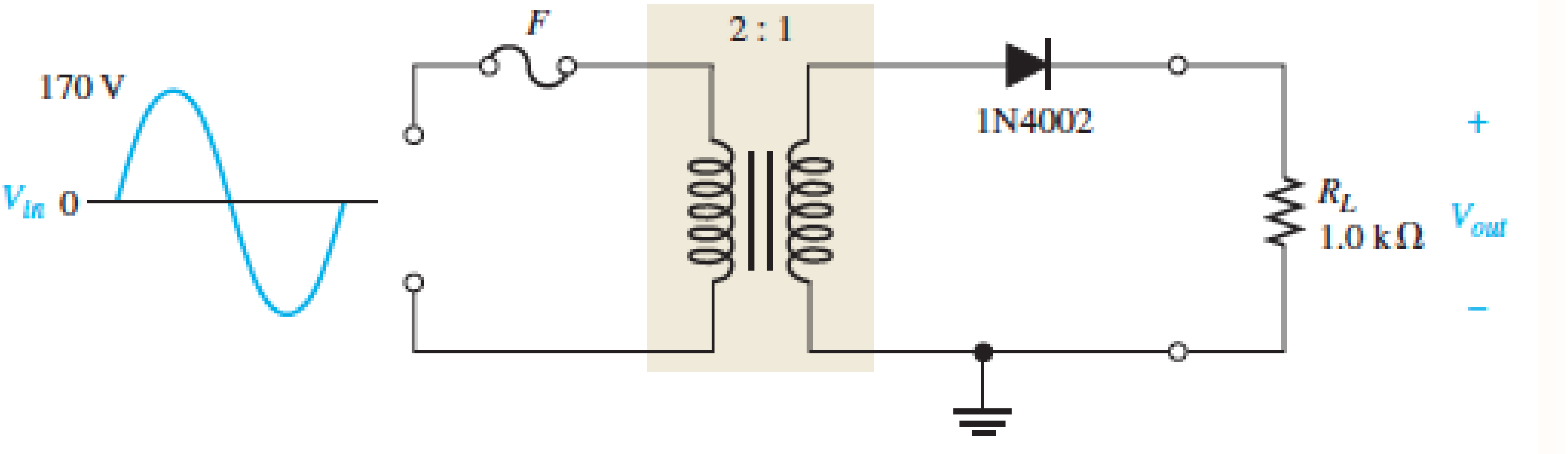


Fig. 6: Half Wave Rectifier with Transformer

Solution of Example2

Peak value for the primary voltage Vp(pri) is:

$$Vp\ (pri) = V(in) = 170\ V$$

Peak value for the secondary voltage Vp(sec) is:

$$Vp\ (sec) = n * Vp(pri) = 0.5 * 170\ V = 85\ V$$

The rectified peak output voltage Vp(out) is:

$$Vp(out) = Vp(sec) - 0.7\ V = 85 - 0.7 = 84.3\ V$$

The Average voltage (VAVG) is:

$$VAVG = Vdc = Vp(out)/\pi = 26.833V$$

Full Wave Rectifier

- The full-wave rectifier is the most commonly used type in dc power supplies, there is two types of full-wave rectifiers: center-tapped and bridge.
- A full-wave rectifier allows unidirectional (one-way) current through the load during the entire of the input cycle, whereas a half-wave rectifier allows current through the load only during one-half of the cycle. The result of full-wave rectification is an output voltage with a frequency twice the input frequency and that pulsates every half-cycle of the input, as shown in Figure 7.

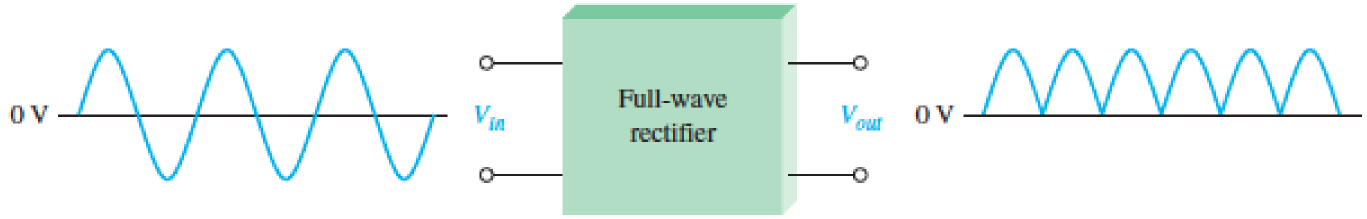


Fig.7: Full Wave Rectifier

Full Wave Rectifier

- The number of positive alternations that make up the full-wave rectified voltage is twice that of the half-wave voltage for the same time interval. The average value, which is the value measured on a dc voltmeter, for a full-wave rectified sinusoidal voltage is twice that of the half-wave, as shown in the following formula: $V_{AVG} = 2V_p / \pi$

Center-Tapped Full Wave Rectifier

A center-tapped rectifier is a type of full-wave rectifier that uses two diodes connected to the secondary of a center-tapped transformer, as shown in Figure (8). The input voltage is coupled through the transformer to the center-tapped secondary. Half of the total secondary voltage appears between the center tap and each end of the secondary winding.

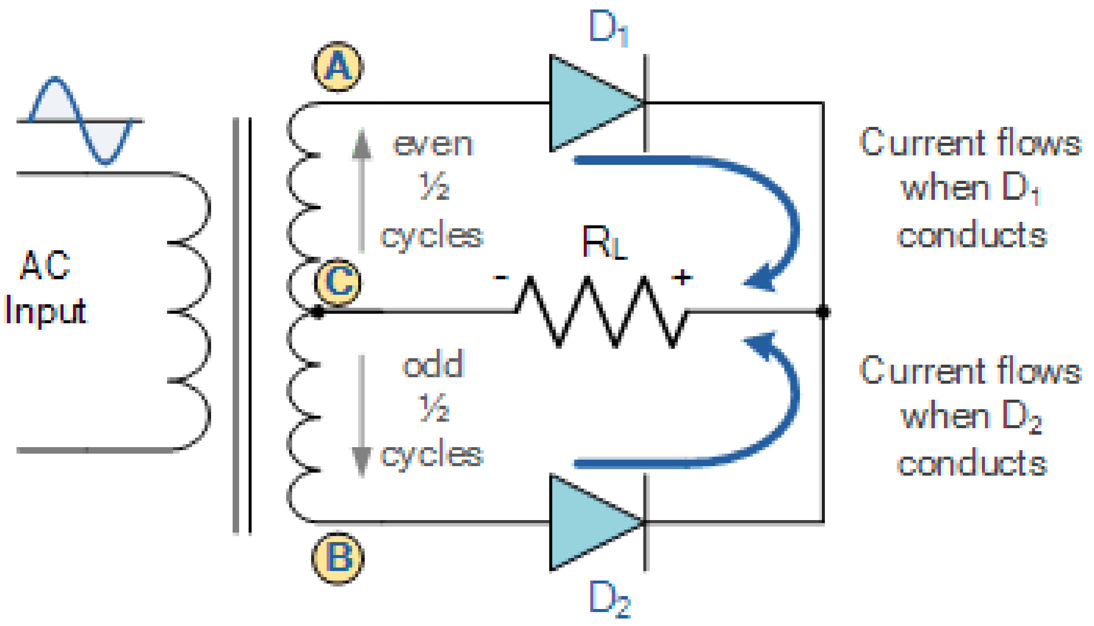


Fig. 8: Center-tapped Full Wave Rectifier

Center-Tapped Full Wave Rectifier

- For a positive half-cycle of the input voltage. The D1 will be forward-biased diode and D2 will be reverse-biases. The current path is through D1 and the load resistor RL.
- For a negative half-cycle of the input voltage. The D1 will be reverse-biases and D2 will be forward-biases. The current path is through D2 and RL.
- Because the output current during both the positive and negative portions of the input cycle is in the same direction through the load, the output voltage developed across the load resistor is a full-wave rectified dc voltage.

Center-Tapped Full Wave Rectifier

The effect of the Turns Ratio on the Output Voltage If the transformer turns ratio is 1, the peak value of the rectified output voltage equals *half* the peak value of the primary input voltage less the barrier potential, as illustrated in Figure 9. Half of the primary voltage appears across each half of the secondary winding (Vp(sec) = Vp(pri)). We will begin referring to the forward voltage due to the barrier potential as the diode drop.

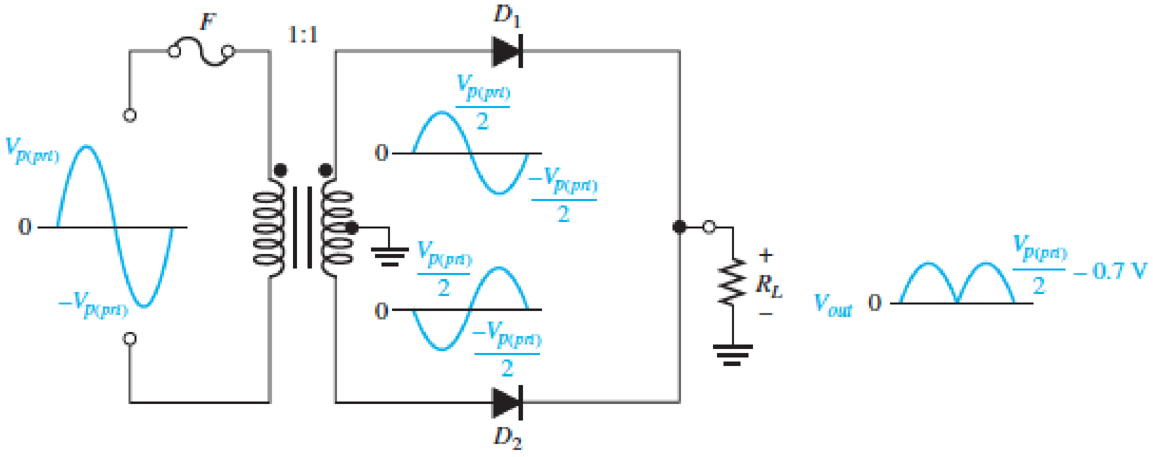


Fig. 9

Center-Tapped Full Wave Rectifier

In order to obtain an output voltage with a peak equal to the input peak (less the diode drop), a step-up transformer with a turns ratio of n = 2 must be used, as shown in Figure 10. In this case, the total secondary voltage (Vsec) is twice the primary voltage (2Vpri), so the voltage across each half of the secondary is equal to Vpri.

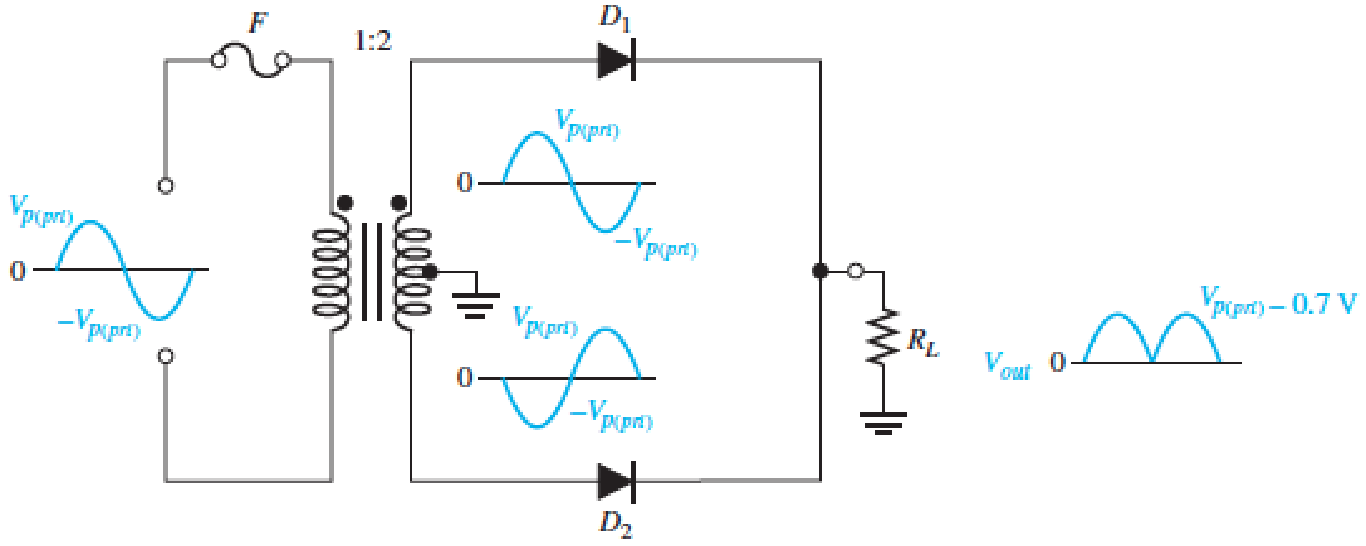


Fig. 10

Bridge Rectifier

The bridge rectifier uses four diodes connected as shown in Figure 11. When the input cycle is positive, diodes D1 and D2 are forward-biased and conduct current in the direction shown. A voltage is developed across RL that looks like the positive half of the input cycle. During this time, diodes D3 and D4 are reverse-biased.

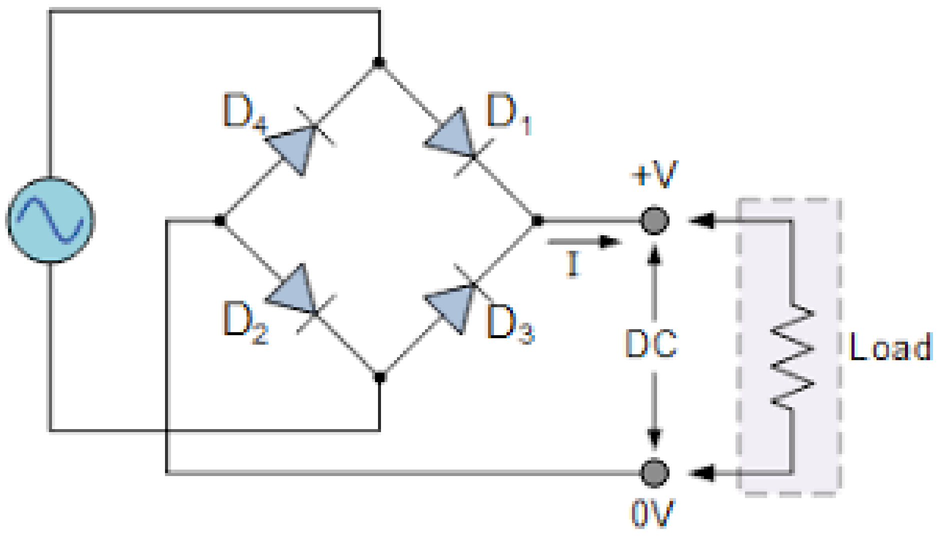


Fig. 11: Bridge Rectifier

Bridge Rectifier

- When the input cycle is negative, diodes D3 and D4 are forward biased and conduct current in the same direction through RL as during the positive half-cycle. During the negative half-cycle, D1 and D2 are reverse-biased. A full-wave rectified output voltage appears across RL as a result of this action.
- Because there are two diodes two diodes are always in series with the load resistor during both the positive and negative half-cycles. The output voltage is: $V_{p(out)} = V_{p(in)} - 1.4\ V$

Bridge Rectifier with Transformer

- A bridge rectifier with a transformer-coupled input is shown in Figure 12. During the positive half-cycle of the total secondary voltage, diodes D1 and D2 are forward-biased while diodes D3 and D4 are forward-biased during the negative half-cycle.
- The output voltage across the load is: Vp(out) = Vp(sec) - 1.4 V

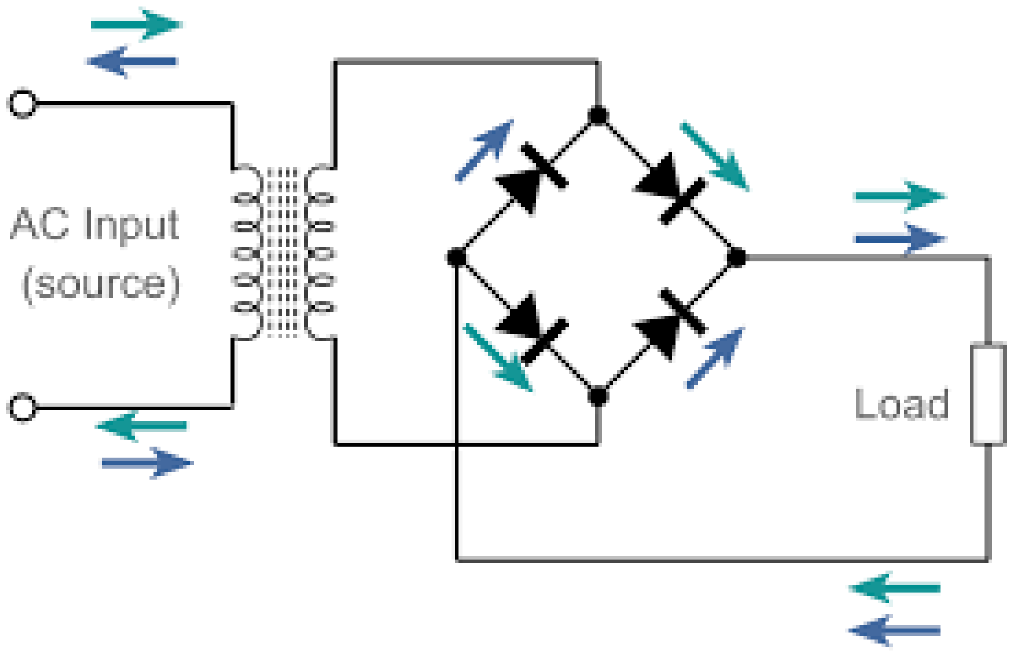


Fig. 12: Bridge rectifier with Transformer

Peak Inverse Voltage (PIV)

- The peak inverse voltage (PIV) equals the peak value of the input voltage, and the diode must be capable of withstanding this amount of repetitive reverse voltage.
- For the diode in the Half-Wave rectifier circuit, the maximum value of reverse voltage, designated as PIV, occurs at the peak of each negative alternation of the input voltage when the diode is reverse-biased.
- A diode should be rated at least 20% higher than the PIV.

PIV for Half Wave Rectifier Circuit

$Vp(sec) = n * Vp(pri)$

$Vp(out) = Vp(sec) - 0.7v$

$PIV = Vp(sec)$

PIV for Full Wave Rectifier Circuit

- Vp(out) = (Vp(sec) / 2) - 0.7 V then Vp(sec) = (Vp(out) + 0.7) * 2

- PIV = Voltage at D1 Cathode – Voltage at D2 Cathode

  = (Vp(sec) / 2) - 0.7 V - (-Vp(sec) / 2)

  = Vp(sec) - 0.7

  = 2 * (Vp(out) + 0.7) - 0.7

PIV = 2* Vp(out) + 0.7

PIV for Bridge Rectifier Circuit

- Vp(out) = Vp(sec) - 1.4V   then Vp(sec) = Vp(out) + 1.4 V
- Vp(sec) = Vp(pri) * n
- PIV = Vp(sec) - 0.7V

  = Vp(out) + 1.4V - 0.7V

PIV = Vp(out) + 0.7V

Advantages of Bridge Rectifier

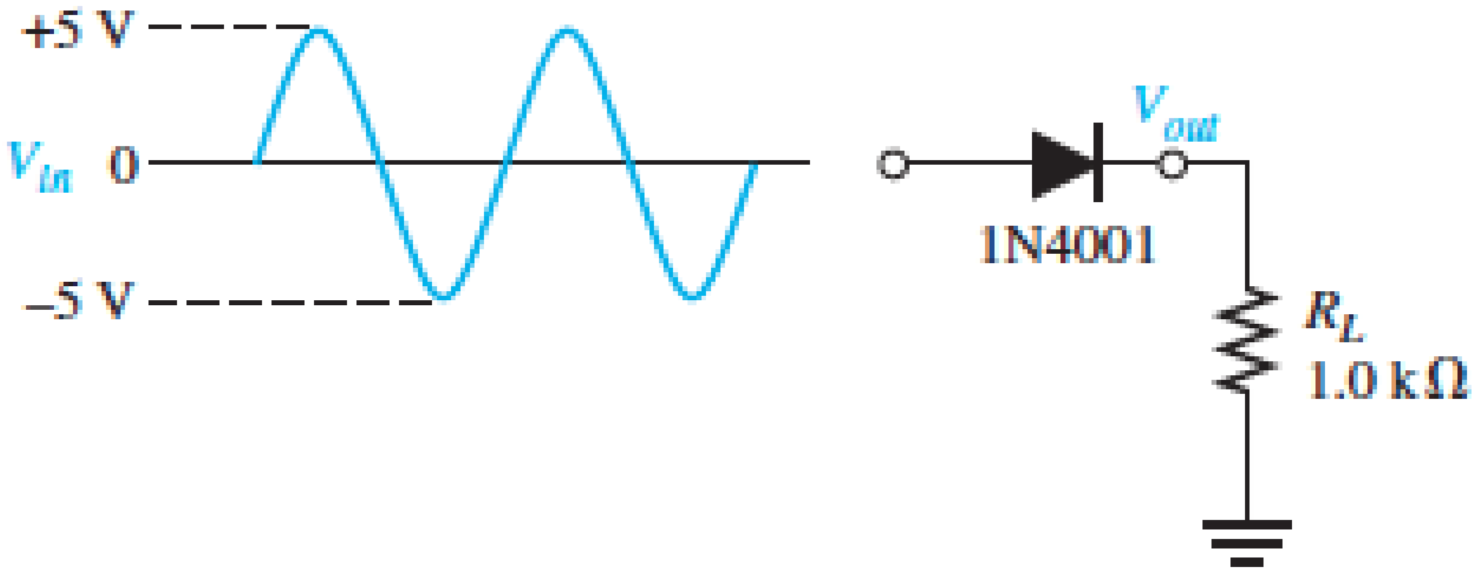
- The rectification efficiency of full-wave rectifier is double of that of a half-wave rectifier.
- Higher output voltage.
- No center tap is required in the transformer secondary so in case of a bridge rectifier the transformer required is simpler. If stepping up or stepping down of voltage is not required, transformer can be eliminated even.
- For a given power output, power transformer of smaller size can be used in case of the bridge rectifier because current in both primary and secondary windings of the supply transformer flow for the entire ac cycle.

Disadvantages of Bridge Rectifier

- It requires four diodes.
- The use of two extra diodes cause an additional voltage drop thereby reducing the output voltage.

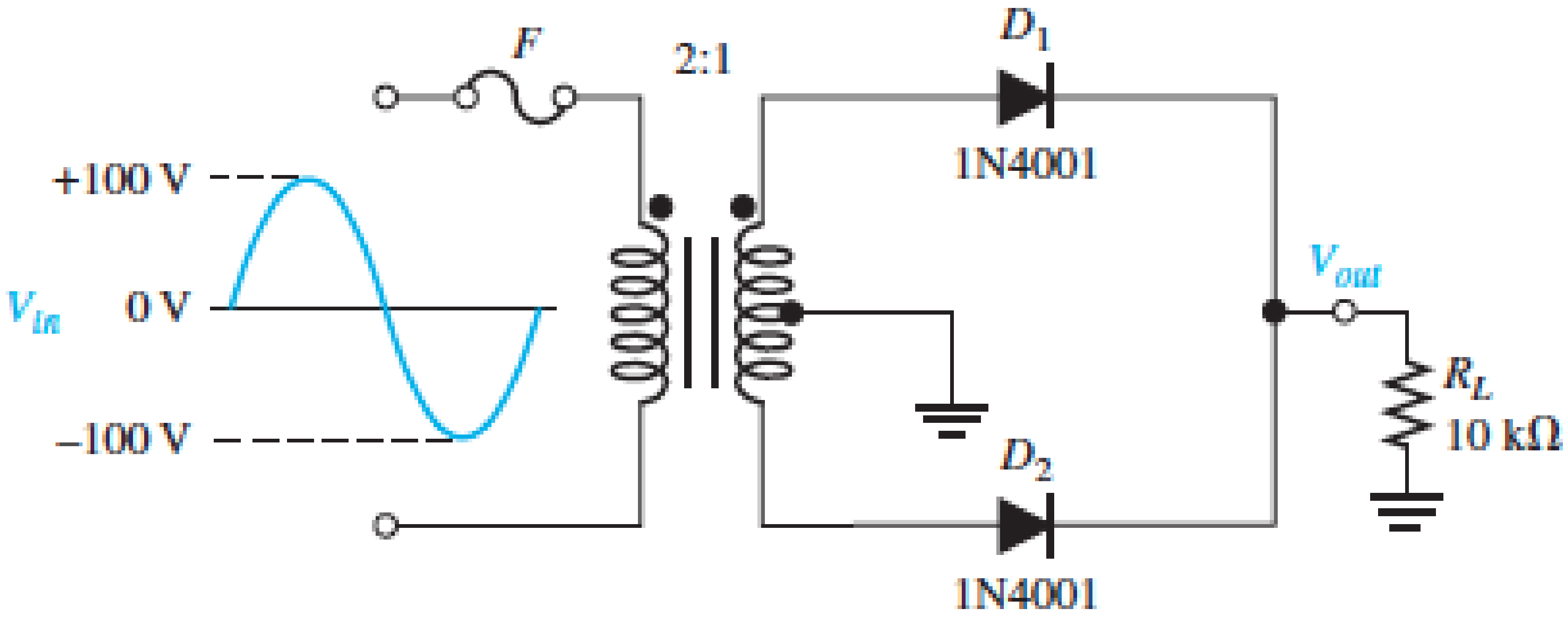
Homework 1

1. Draw the output voltage of the rectifier circuit in the following figure, then find the peak output voltage and the average voltage:



Homework 2

2. Find the peak secondary voltage across each half of the secondary winding and across RL when a 100 V peak sine wave is applied to the primary winding in the following Figure.



Next Lecture

- Root Mean Square and Average Values for Rectifier Circuits
- Filters

Reference:

- Thomas L. Floyed, 2012, Electronic Devices: Electron Flow Version, 9th Edition. Retrieved from: https://hristotrifonov.files.wordpress.com/2012/10/electronic-devices-9th-edition-by-floyd.pdf