Lab 2: Rectifiers

Objectives

1. **Design of three different types of rectifiers in LTSpice.**
2. **Explore ways to reduce the ripple in the output voltage.**

Reading exercise

Please read about rectifier circuits in https://www.electronics-tutorials.ws/diode/diode_6.html

Viva questions will be based on the lab and reading exercise

Limiting Circuit / Diode Clipping Circuit

A diode is a device that conducts current from its anode to its cathode (forward direction), but not in the reverse direction. Diodes are designed to have a forward "ON" resistance of fractions of an Ohm while their reverse blocking resistance is in the mega-Ohms range. There are two types of diodes – signal and power diodes. Signal diodes are generally designed for handling low currents (up to 100mA) and high speeds (greater than 1MHz). Power diodes, on the other hand, can handle current ratings from 1A to 25A or more and breakdown voltages going from 100 volts to 1000 volts. However, their speeds are much lower (limited usually to below 1MHz). These are the diodes typically used in DC power supply circuits.

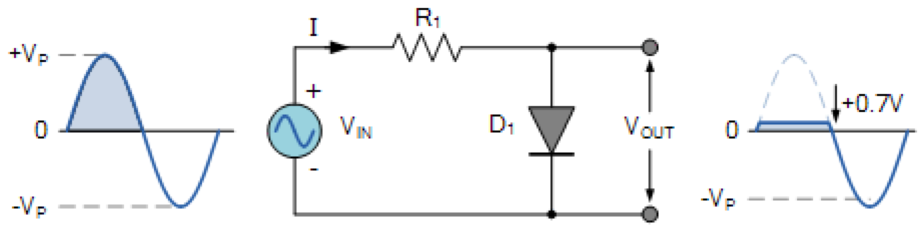

Fig. 1 Basic Limiting Circuit

In the diode clipping circuit shown above, the diode is forward biased (anode more positive than cathode) during the positive half cycle of the sinusoidal input waveform. For the diode to become forward biased, it must have an input voltage magnitude greater than +0.7 volts (0.3 volts for a germanium diode). When this happens the diode begins to conduct and holds the voltage across itself constant at 0.7V until the sinusoidal waveform falls below this value. Thus the output voltage which is taken across the diode can never exceed 0.7 volts during the positive half cycle. During the negative half cycle, the diode is reverse biased (cathode more positive than anode) blocking current flow through itself and as a result has no effect on the negative half of the sinusoidal voltage which passes to the load unaltered. Thus the diode limits the positive half of the input waveform and is known as a positive clipper circuit. By reversing the polarity of the diode or the source, we obtain the negative clipper circuit.

Lab exercise

1. For the circuit shown in Fig.1 (Limiting circuit), first use a DC source excitation with V_{IN} = 15V, using the assumption V_f = 0.7V, find the R_1 resistor value you need to set the diode current to 5mA. The resistor value will be used for the following steps.
2. Enter the circuit schematics into LTSpice,
3. Use a DC sweep in LTSpice to plot the I-V characteristic of the diode (voltage and current across the diode).
4. Use a DC sweep in LTSpice to plot the transfer function (V_{OUT} divided by V_{IN}) of the circuit. Note that the diode voltage is the output voltage.
5. Use LTSpice to run a transient simulation for the circuit keeping V_{IN} as 15V, 50Hz sinusoidal wave.

Rectifier

The rectifier is a device used to change AC power into pulsating DC. A pulsating DC voltage means a unidirectional voltage containing large varying components called ripples in it. The basic component of a rectifier is a diode.

Half-wave rectifier

The figure below shows the operation of a power diode as a half wave rectifier. Note that the term half-wave is because the circuit passes just one half of each complete sine wave of the AC supply in order to convert it into a DC supply.

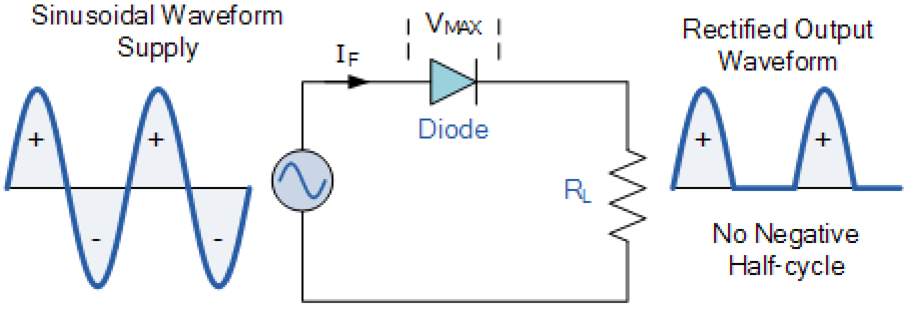

Fig 2. Half-wave rectifier with resistive load

A single phase, half-wave rectifier circuit is very inefficient (since the negative cycle produces no output). A more practical option is to use a full wave rectifier instead.

Lab exercise

1. Using LTSpice, consider a 15V DC source instead of AC source in the circuit in Fig. 2 and R_L = 3.3k. Find the diode voltage and diode current.
2. Use DC sweep in LTSpice to plot the transfer function ($V_{OUT,}$ divided by V_{IN}) of the circuit. Note that the resistor voltage is the output voltage in this circuit.
3. Now replace the DC source with an AC source excitation with an amplitude of 15V and a frequency of 50Hz. Use LTSpice to plot the resistor's voltage across several time cycles using transient simulation.
4. Find the time-averaged output voltage, $V_{OUT,}$, across three time cycles.

Center Tapped Full wave rectifier

A center tapped full wave rectifier circuit consists of two *power diodes* connected to a single load resistance (R_L) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D_1 conducts in the forward direction as indicated by the arrows. When point B is positive (in the negative half of the cycle) with respect to point C, diode D_2 conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles. As the output voltage across the resistor R_L is the phasor sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a “bi-phase” circuit.

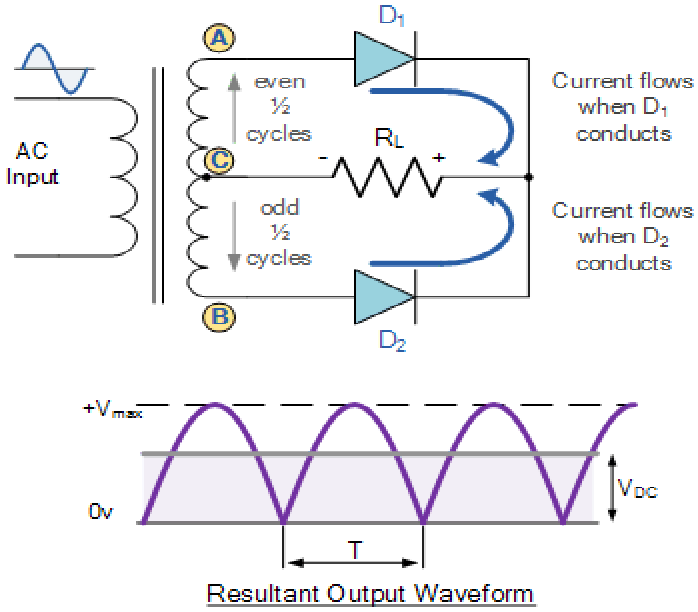

Fig 3. Center tapped full wave rectifier

The main disadvantage of this type of full wave rectifier circuit is that a larger transformer for a given power output is required with two separate but identical secondary windings (which is the design of a center tap) making this type of full wave rectifying circuit costly compared to the "Full Wave Bridge Rectifier" circuit equivalent.

Lab exercise

1. Use an AC source excitation with an amplitude of 230Vrms and a frequency of 50Hz as the input to the primary of an ideal step down transformer (15:1). Use LTSpice to plot the resistor's voltage across several time cycles using transient simulation.
2. Find the time-averaged output voltage across three time cycles.

Full Wave Bridge Rectifier

A full wave bridge rectifier circuit utilizes four diodes connected in a bridge form so as to produce the output during the full cycle of input. Two of the diodes (D_1 and D_3) conduct for one half cycle and two (D_2 and D_4) conduct for the other half cycle of the input supply. The circuit eliminates the need of any center-tapping of the transformer in this circuit. The circuit of a bridge full wave rectifier is as shown in the following figure.

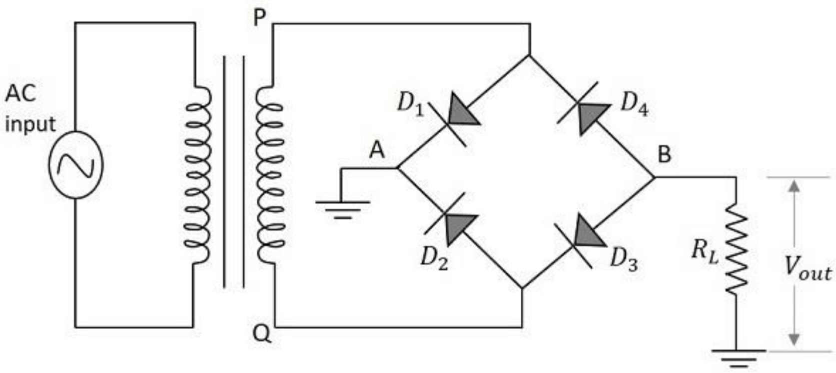

Fig.4. Full wave bridge rectifier circuit

Lab exercise

1. Use an AC source excitation with an amplitude of 230Vrms and a frequency of 50Hz in the primary of an ideal step down transformer (15:1). Use LTSpice to plot the resistor's voltage across several time cycles using transient simulation.
2. Find the time-averaged output voltage across three time cycles.

3. By comparing the performance of the half-wave, center tapped full wave and bridge rectifier circuits, choose an appropriate rectifier circuit for your power supply design and justify your choice.
4. Prepare an electronic lab report with results.