Electronic Devices and Circuits Lab
Experiment 4- Group 4

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Aim-

To design a battery charging circuit with AC input as $V_0 \sin(\omega t)$ (frequency of the input source is 50Hz). Also to determine the maximum possible charging time per AC cycle.

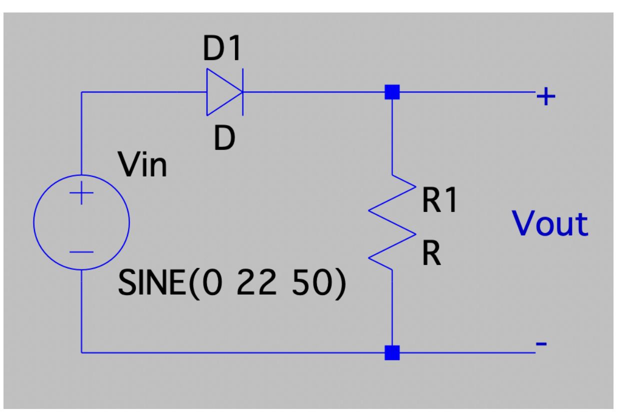
The given conditions are-
1) Voltage of the given battery, $V_B = 12V$.
2) Maximum current that can flow through the diode is 120mA.
3) Maximum reverse bias voltage of the diode, $V_{RB} = 34V$.

Theory-

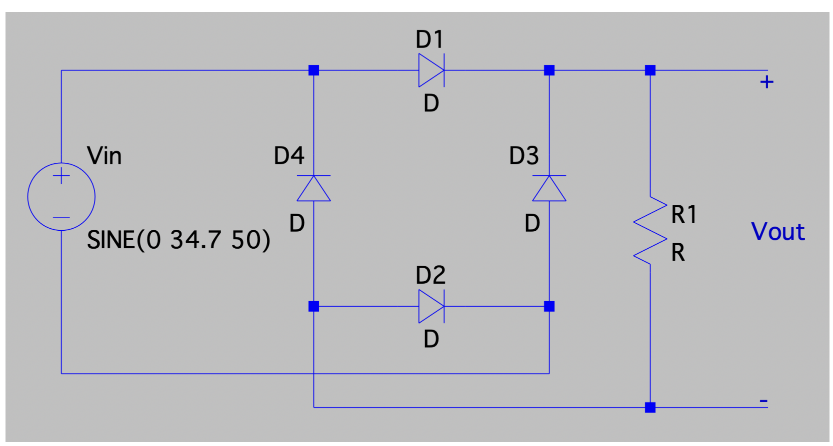
In a battery charging circuit, the current must flow into the battery for charging it. Here, we are given an AC source in which the voltage is positive for half cycle and negative for half cycle, so a correction is required. We can correct the voltage in such a way that the negative oscillation of the source is converted to a zero/positive voltage. Based on this idea there are two types of corrections - Half Wave Rectifier and Full Wave Rectifier. In both these rectifiers we can use a diode which allows current to flow only in one direction.

In a Half Wave Rectifier, we can use a diode in series with the input voltage. This is done so that when the source voltage, V_{in} is positive (and greater than $V_{Fwd\ Bias}$) the diode is in forward bias and there is a flow of current through the circuit and when V_{in} is negative the diode is in reverse bias and there is no flow of current through the circuit. So in one cycle of the input voltage, the polarity in the first half of the cycle is positive and is zero in the next half of the cycle.

In a Full Wave Rectifier, we use four diodes in a bridge configuration so that the polarity of the output voltage is positive in the whole cycle of the input voltage. So in this configuration, when V_{in} is positive (and greater than $2*V_{Fwd\ Bias}$) D_1 and D_2 are in forward bias and D_3 and D_4 are in reverse bias allowing current to flow only through D_1 and D_2. Similarly, when V_{in} is negative (and $|V_{in}|$ greater than $2*V_{Fwd\ Bias}$) D_3 and D_4 are in forward bias and D_1 and D_2 are in reverse bias allowing current to flow only through D_3 and D_4.



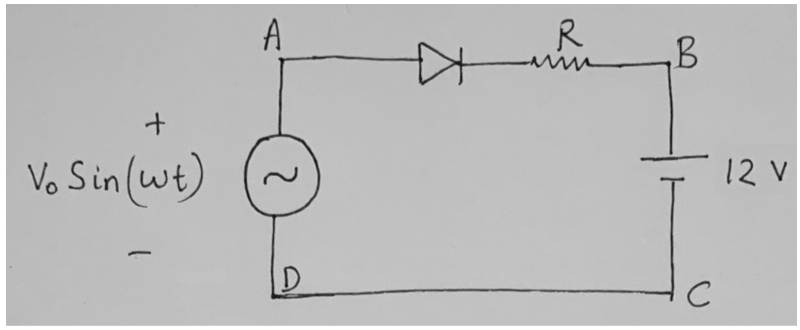
Half Wave Rectifier



Full Wave Rectifier

Procedure and Calculations-

Half Wave Rectifier-



To calculate V_0 we can apply KVL when the diode is in reverse bias, also we consider at the time when V_{in}=-V_0 as it uses the maximum reverse bias voltage condition that the diode can bear.

KVL through DCBAD-

$$V_0 + 12V + 0 - V_{RB} = 0$$

=> $V_0 = V_{RB} - 12V = 34V - 12V = 22V$

For R we can apply KVL through the loop when the diode is in forward bias as the maximum current it can handle is 120mA, so we can take $V_{in} = V_0$. Also the forward bias voltage of the diode is 0.7V.

KVL through ABCDA-

$$V_0 - 0.7V - iR - 12V = 0$$

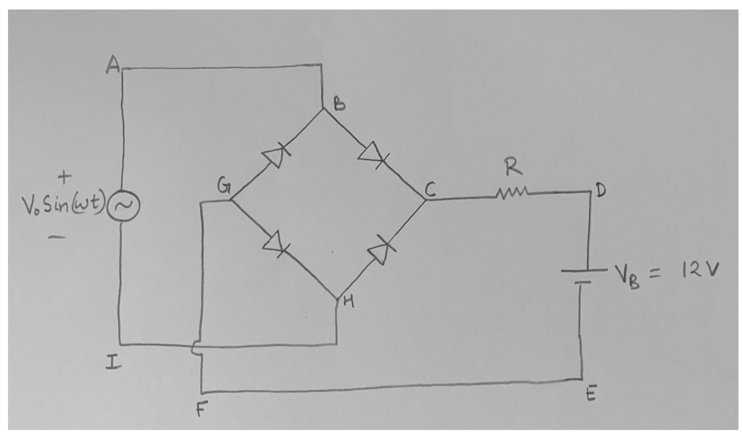
=> $R = (22V - 12.7V)/120mA = 77.5\ \Omega$

The battery charges only when there is an inflow of current into the battery, so V_{in} must be greater than 0.7V + 12V.

So $22\sin(\omega t) > 12.7$, putting $\omega=2\pi f=100\pi$ we get t=6.08ms out of a 20ms cycle of input voltage.

Therefore the battery charges for (6.08 / 20) * 100% = 30.4% of the time in a single cycle.

Full Wave Rectifier-



We consider the case when V_{in}=V_0 for calculation of V_0 and R as it gives the maximum current that the diodes can bear and also uses the maximum reverse bias voltage that the diode can bear. So the current i flows through the loop ABCDEFGHIA with i=120mA (as V_{in} is maximum)

KVL through ABCDEFGHIA-

$V_0 - 0.7V - iR - 12V - 0.7V = 0$

$V_0 - iR = 13.4V$ .... eq (1)

KVL through ABGFEDCBA-

(We are taking this loop because the two diodes in this loop are reverse biased)

$V_0 - V_{RB} + iR + 12V - V_{RB} = 0$, w.k.t. $V_{RB} = 34V$

$V_0 + iR = 56V$ .... eq (2)

Putting i=120mA and solving both linear equations for the variables V_0 and R, we get V_0=34.7V and R=177.5 Ω .

The battery charges only when there is an inflow of current into the battery, so V_{in} must be greater than 0.7V + 12V + 0.7V=13.4V (due to two diodes in series).

So $34.7\sin(\omega t) > 13.4$, putting $\omega=2\pi f=100\pi$ we get t=14.96ms out of a 20ms cycle of input voltage.

Therefore the battery charges for (14.96 / 20) * 100% = 74.8% of the time in a single cycle.

Full Wave Rectifier with same V_0 as the Half Wave Rectifier-

So, $V_0 = 22V$ and substituting it into eq(1) we get R=71.67 Ω. We are not substituting into eq(2) because $V_0 < 34V$, so the reverse bias of the diode can not be greater than 34V. To determine the charging time $22\sin(\omega t) > 13.4$ (from above).Putting $\omega=2\pi f=100\pi$ we get t=11.66ms out of a 20ms cycle of input voltage.

Therefore the battery charges for (11.66 / 20) * 100% = 58.3% of the time in a single cycle.

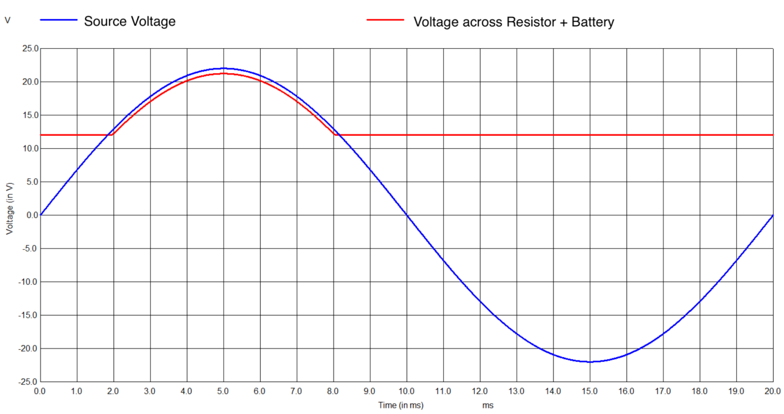
Conclusions-

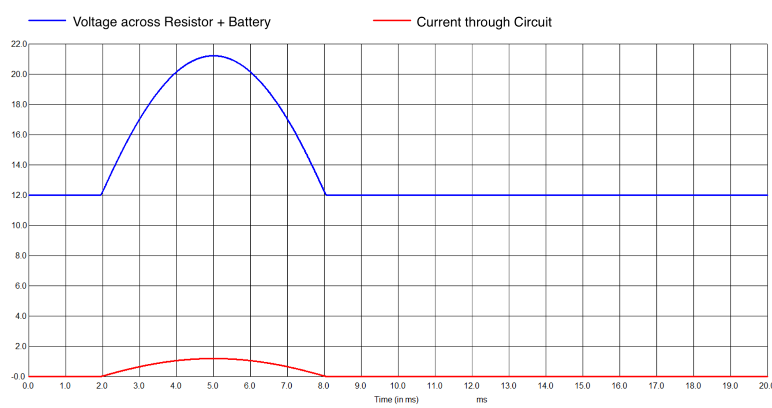
From the above experiments we can conclude that the Full Wave Rectifier is more efficient than the Half Wave Rectifier because the Full Wave Rectifier allows current to flow even when the polarity of the source is negative. Also in the Full Wave Rectifier there are two diodes in any path which allows for a higher source voltage and hence higher current for charging.

But if we use the same source voltage for Full Wave Rectifier as in Half Wave Rectifier the efficiency of the circuit is less than twice the efficiency of Half Wave Rectifier because of an extra diode in the path. This extra diode consumes 0.7V more than the previous case resulting in a lesser current flow.

Plots-

For Half Wave Rectifier-





For Full Wave Rectifier-