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MIT WORLD PEACE UNIVERSITY | PUNE

F. Y. B. Tech Academic Year 2021-22

Trimester: **Subject:** Basics of Electrical and Electronics Engineering

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Experiment No: 2

Name of the Experiment: Design of Rectifier using pn junction diode.

Performed on: 17th December 2021

Submitted on: 24th December 2021

Aim: Design of rectifier using pn junction diode.

Prerequisite:

- Basic knowledge of diode and rectifier, capacitor filter.

Objectives:

- To study the operation of Half- Wave Rectifier with and without filter and to find its ripple factor
- To measure voltages and observe waveforms at output of rectifier.

Components and equipment required:

S.No.	Name	Quantity
1	Bread board	1 (One) No.
2	Diodes (1N4007)	1 (One) No.
3	Resistor (1KΩ/2.2 KΩ)	1 (One) No.
4	Capacitor 100μF/4.7μF	1 (One) No.

Equipment:

Function generator, CRO, DMM, 1N4007 rectifier diode, capacitors, connecting wires etc.

Theory:

Components of DC Power Supply:

The DC power supply converts the standard ac voltage (230V, 50Hz) into a constant DC voltage. The DC voltage produced by a power supply is used to power all types of electronic circuits, such as television, VCRs, CD players and most of the laboratory equipment. The simplest and most common type of DC power supplies is a 'linear' system. The block diagram of typical linear power supply is shown schematically in Fig. 5.1. AC voltage is applied to a transformer, which steps it down to the level for the desired dc output. Output of the transformer is applied to a diode rectifier which provides a full-wave rectified voltage. This voltage is filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or AC voltage variation. To remove this ripple, a regulator circuit is used. This regulator provides a constant DC voltage at the output despite changes in the input or the load current.

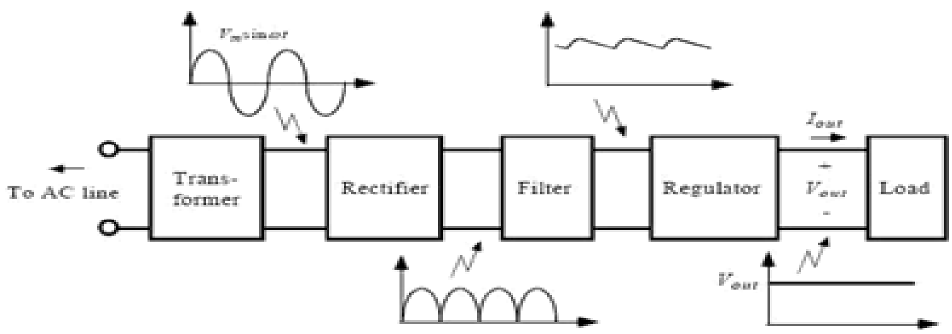


Fig 5.1: Components of a typical linear power supply

pn junction diode as a rectifier:

A rectifier is an electronic device that converts AC voltage into DC voltage. A rectifier is used in almost all the electronic devices. Mostly it is used to convert the main voltage into DC voltage in the power supply section. By using DC voltage supply electronic devices work. According to the period of conduction, rectifiers are classified into two categories: Half Wave Rectifier and Full Wave Rectifier.

Working of a Half-Wave Rectifier

During the positive half cycle, when the input is positive, the diode is under forward bias condition and it conducts current. During the positive half cycles, the input voltage is applied directly to the load resistance when the forward resistance of the diode is assumed to be zero. The wave forms of output voltage and output current are same as that of the AC input voltage. During the negative half cycle, the diode is under reverse bias condition and it does not conduct current. During the negative half cycle, the voltage and current across the load remains zero. The magnitude of the reverse current is very small and it is neglected. So, no power is delivered during the negative half cycle.

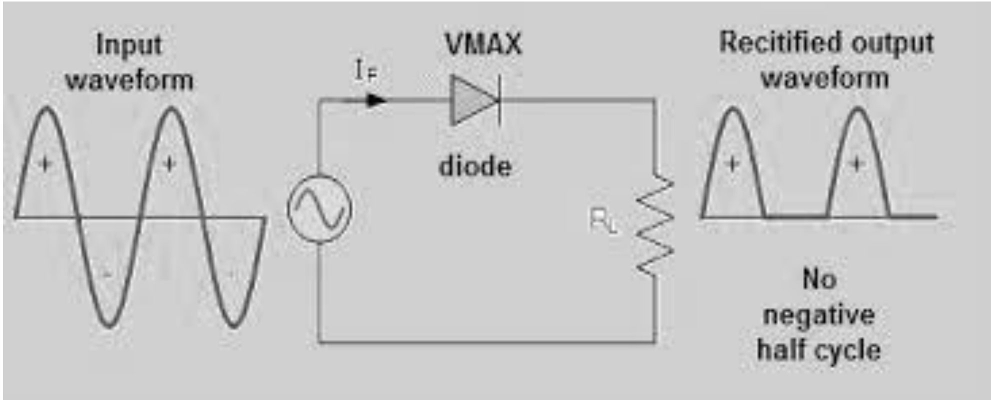


Fig 5.2 Half wave rectifier without filter

Since the diode conducts only in one half-cycle (0-π), it can be verified that the d.c. component in the output is $\boldsymbol{V_{max}/\pi}$, where $\boldsymbol{V_{max}}$ is the peak value of the voltage. Thus,

$$V_{LDC} \approx \frac{V_m}{\pi} \tag{5.1}$$

$$V_{LDC} = \frac{Vm}{\pi} = 0.318 \times Vm \tag{5.2}$$

AC or RMS LOAD CURRENT (I_{rms}):

$$Irms = \frac{Im}{2} \tag{5.3}$$

AC or RMS LOAD VOLTAGE (V_{Lrms}):

$$V_{Lrms} \approx Vm/2 \tag{5.4}$$

The current flowing through the resistor and power consumed by the load,

$$P_{Ldc} = I_{Ldc}{}^{2} * R \tag{5.5}$$

$$I_{Ldc} = V_{LDC}/R \tag{5.6}$$

Ripple factor:

As the voltage across the load resistor is only present during the positive half of the cycle, the resultant voltage is "ON" and "OFF" during every cycle resulting in a low average dc value. This variation on the rectified waveform is called "**Ripple**" and is an undesirable feature. The ripple factor is a measure of purity of the d.c. output of a rectifier and is defined as

The **ripple factor without** (theoretical) **filter**:

$$r = \frac{V_{ac(output)}}{V_{dc(output)}} = \sqrt{\frac{{V_{rms}}^2 - {V_{dc}}^2}{{V_{dc}}^2}} = \sqrt{\left[\frac{0.5}{0.318}\right]^2 - 1} = 1.21 \tag{5.7}$$

The ripple factor with (theoretical) filter:

$$r = \frac{1}{2fCR\sqrt{3}} \tag{5.8}$$

The ripple (practical) factor:

$$r = \frac{V_{ac}}{V_{dc}} \tag{5.9}$$

Rectification Efficiency:

Rectification efficiency, $\boldsymbol{\eta}$, is a measure of the percentage of total a.c. power input converted to useful dc power output. Here r_d is the forward resistance of diode. Under the assumption of no diode loss (r_d<<), the rectification efficiency in case of a half-wave rectifier is approximately 40.5%.

η = d .c. power delivered to load a.c. power at input

$$P_{dc} = \left(\frac{{I_m}^2}{\pi^2}\right) \times R_L \tag{5.10}$$

$$P_{ac} = \frac{{I_m}^2}{4} \times \left(R_L + R_S + R_f\right) \tag{5.11}$$

$$\boldsymbol{\eta = P_{dc} / P_{ac} = 0.406 \text{ ----- } R_L >> R_s + R_f} \tag{2.12}$$

% $\boldsymbol{\eta = 40.6\%}$

Peak Inverse Voltage (PIV):

PIV- the maximum value of reverse voltage,occurs at the peak of each negative alternation of the input voltage when the diode is reverse biased.

PIV for HWR is **Vp(in) or *Vm***

Determining the required PIV rating of HWR:

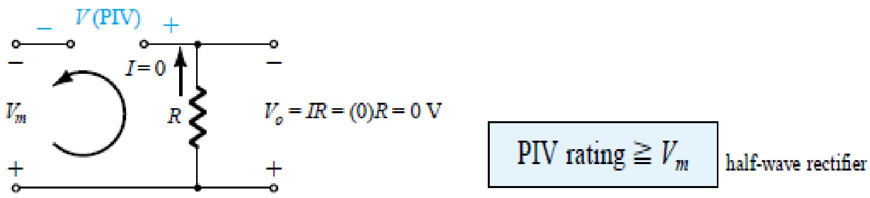


Fig.5.3 PIV of Half wave rectifier

Filters:

The output of a rectifier gives a pulsating d.c. signal (Fig.5.2) because of presence of some a.c. components whose frequency is equal to that of the a.c. supply frequency. Very often when rectifying an alternating voltage we wish to produce a "steady" direct voltage free from any voltage variations or ripple. Filter circuits are used to smoothen the output. Various filter circuits are available such as shunt capacitor, series inductor, choke input LC filter and π-filter etc. Here we will use a simple **shunt capacitor** filter circuit (Fig.5.4). Since a capacitor is open to d.c. and offers low impedance path to a.c. current, putting a capacitor across the output will make the d.c. component to pass through the load resulting in small ripple voltage.

The working of the capacitor can be understood in the following manner. When the rectifier output voltage is increasing, the capacitor charges to the peak voltage V_m. Just past the positive peak the rectifier output voltage tries to fall. As the source voltage decreases below V_m, the capacitor will try to send the current back to diode making it reverse biased. Thus the diode separates/disconnects the source from the load and hence the capacitor will discharge through the load until the source voltage becomes more than the capacitor voltage. The diode again starts conducting and the capacitor is again charged to the peak value V_m and the process continues. Although in the output waveform the discharging of capacitor is shown as a straight line for simplicity, the decay is actually the normal exponential decay of any capacitor discharging through a load resistor. The extent to which the capacitor voltage drops depends on the capacitance and the amount of current drawn by the load; these two factors effectively form the RC time constant for voltage decay. A proper combination of large capacitance and small load resistance can give out a steady output.

Circuit Diagram:

Half Wave Rectifier (without filter):

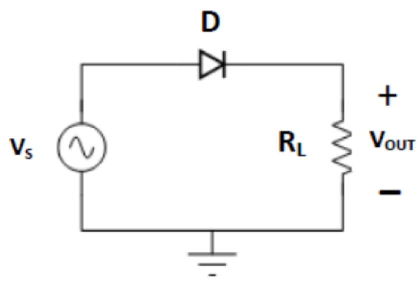


Fig.5.4 Half-wave rectifier circuit

Half Wave Rectifier (with filter):

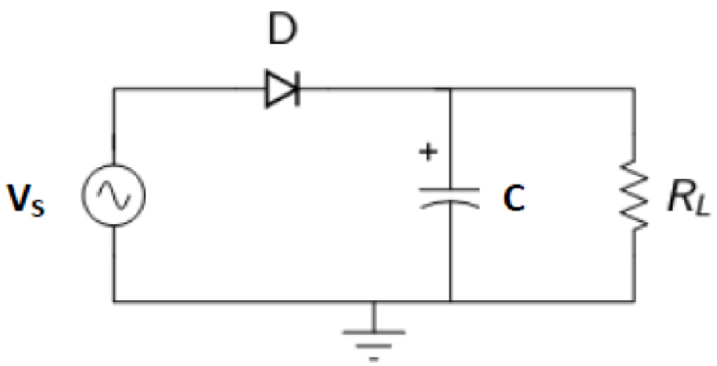


Fig.5.5 Half -wave rectifier circuit with capacitor filter

Procedure:

1. Make the connection as per the circuit diagram shown in fig. 5.4 & 5.5
2. Note down the voltage which is unregulated input voltage.
3. Observe unregulated output voltage at the output of rectifier and filter.
4. Observe the waveform at load resistor and capacitor filter.

Observations:

Input Voltage (***Vm***) ***= 5 V***

Specifications of components used:

i) **Diode Selection**

V_{Ldc} = ***1.59 V***

PIV = 5 V

I_{Ldc}***=IF=*** V_{Ldc}***/Rf+RL***= 1.59/10000 ***= 0.15 mA***

Therefore ***IN4001*** diode is selected.

ii) **Load resistance RL= *10000 Ω***

iii) **Filter Capacitor C= *10 µF***

Expected Waveforms:

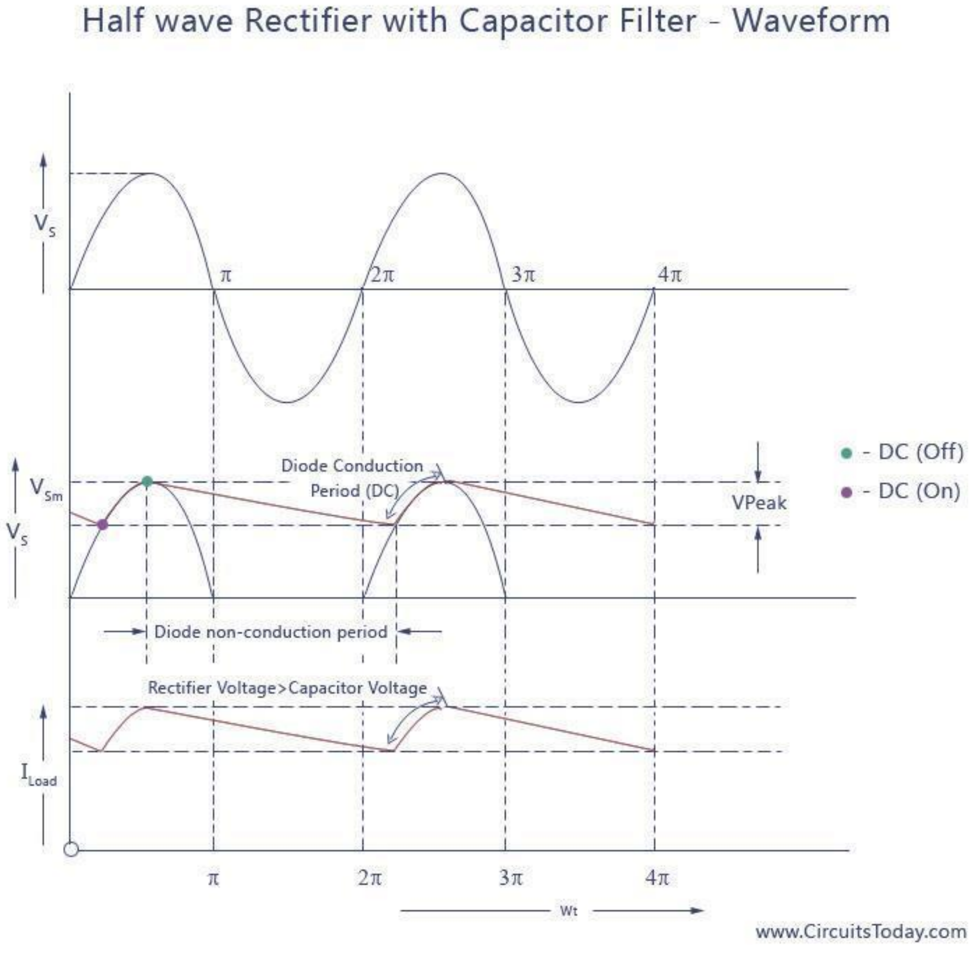


Fig.5.6 Waveform of Half wave rectifier and filter

Observation Table:

Half wave rectifier without filter

Sr. no.	V_m	V_{Ldc}	V_{rms}	I_{Ldc}
1	5	1.59	2.5	0.15 mA
2	10	3	5	0.3 mA

Half wave rectifier with filter

Sr. no.	C(μF)	V_{rpp}	V_{Ldc}	I_{Ldc}
1	10	0.8	4.03	0.4 mA
2	10	1	8.43	0.8 mA

Result:

Ripple factor without filter		Ripple factor with filter	
Theoretical	Practical	Theoretical	Practical
1.21	1.319	0.057	0.057

Note: Students are instructed to do all the necessary calculations on separate sheets.

Conclusion:

Half Wave Rectifier and Full Wave rectifiers were studied and their working was understood in detail. Their respective circuit diagrams were made and the resulting waveform was observed in an Oscilloscope. The ripple factor was found and noted theoretically and practically in both cases.

Post Lab Questions:

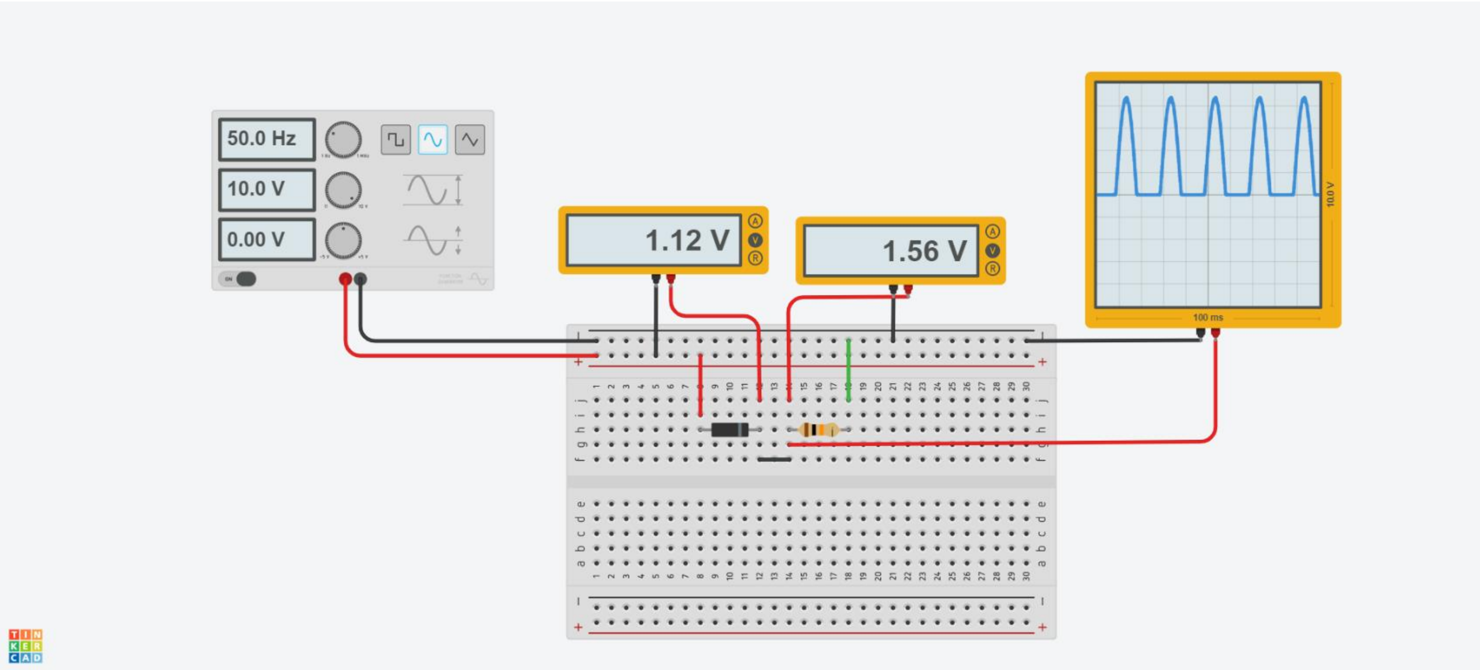
1. What is the purpose of rectifier?
2. What is the difference between half wave and full wave rectifier?
3. What is the use of filter in rectifier?
4. Explain how bridge rectifier is more advantages than conventional full wave rectifier.

Additional links for more information:

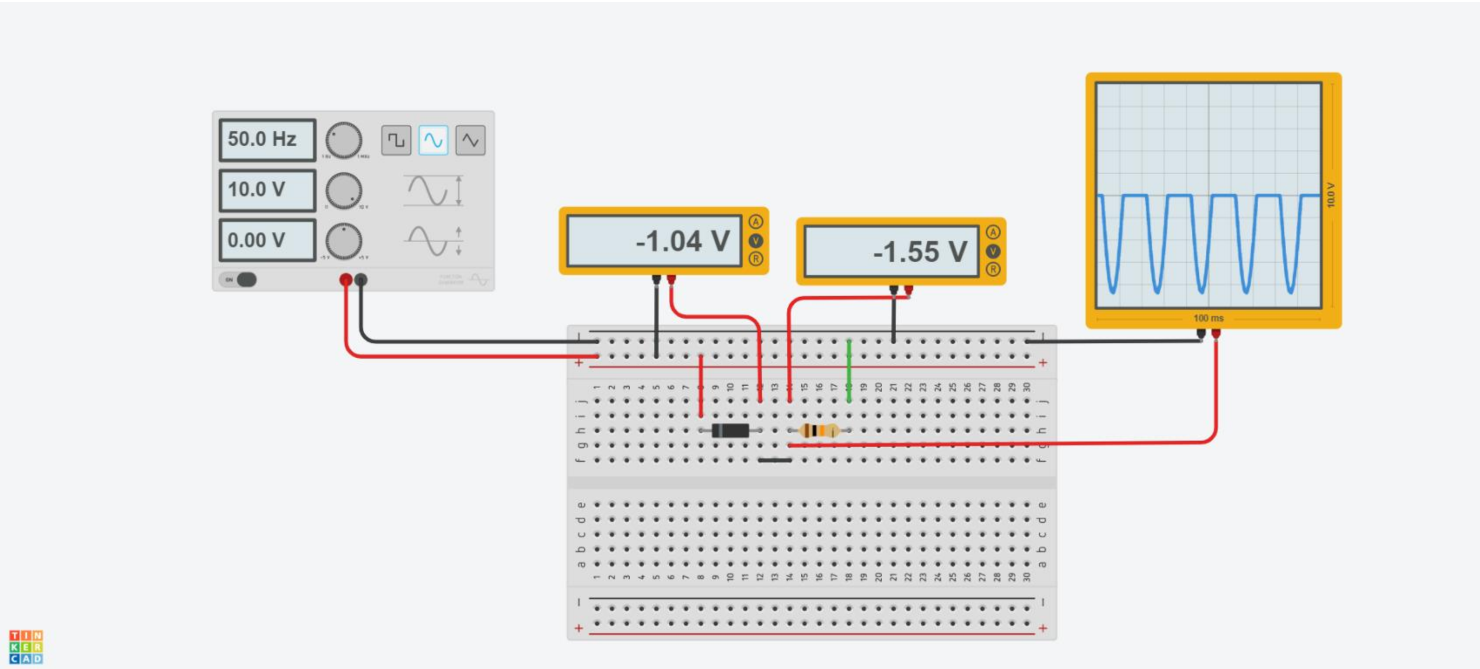
- http://vlabs.iitkgp.ernet.in/be/exp6/index.html
- http://vlabs.iitkgp.ernet.in/be/exp7/index.html

Circuits Made in Tinkercad:

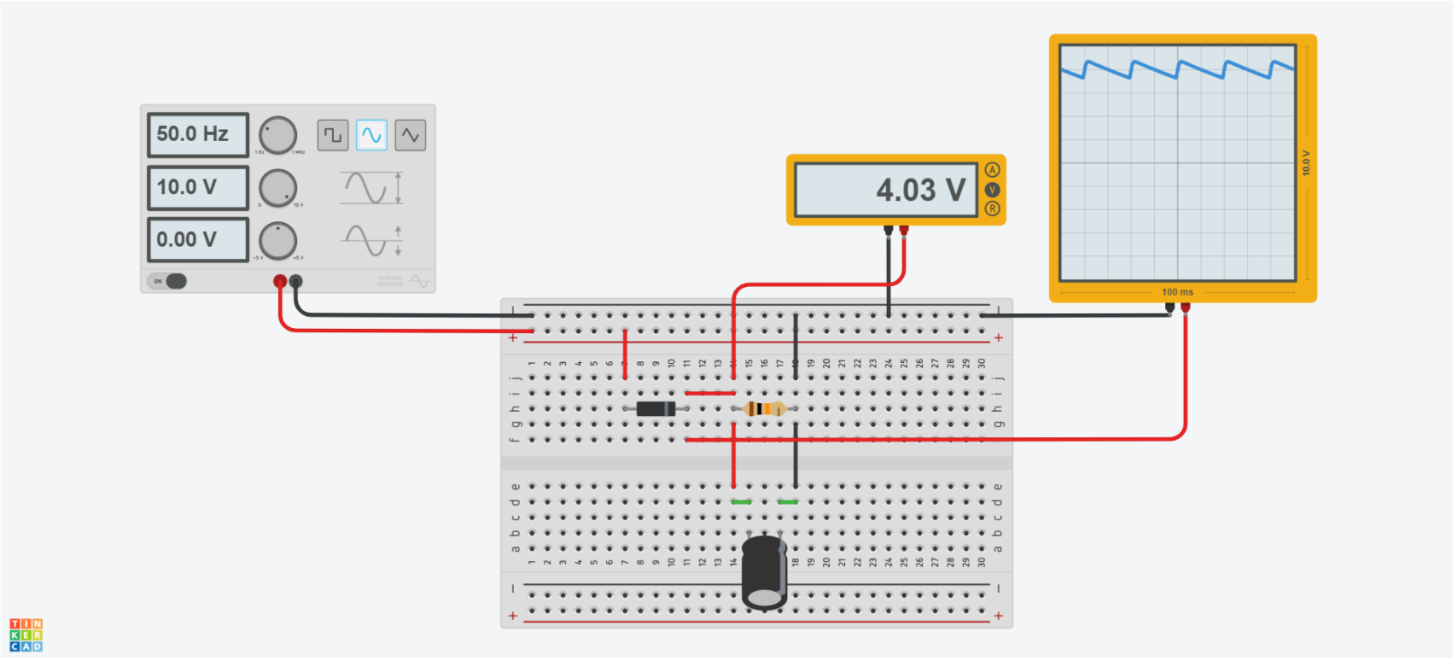
1. Half Wave Rectifier without Capacitor Filter (Positive output)



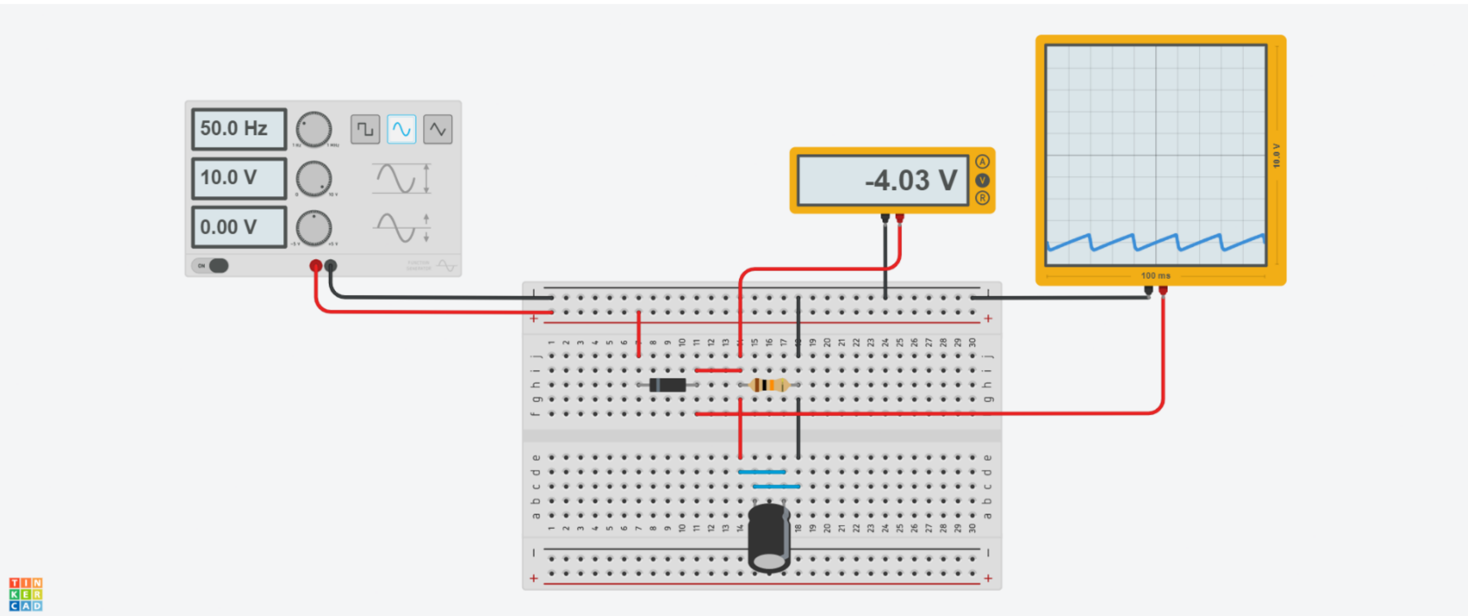
2. Half Wave Rectifier without Capacitor Filter (Negative output)



3. Half Wave Rectifier with Capacitor Filter (Positive output)



4. Half Wave Rectifier with Capacitor Filter (Negative output)



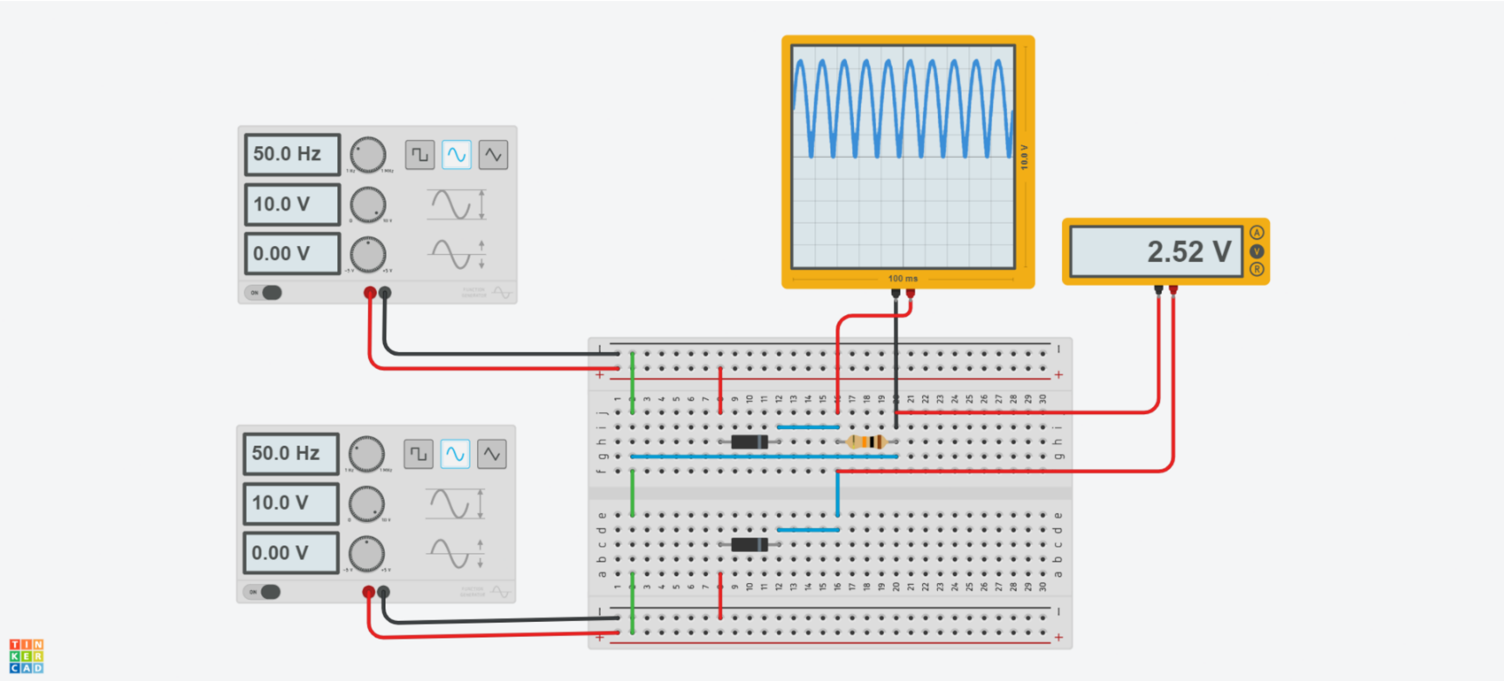
Component List for Half wave Rectifier with Capacitor filter

Name	Quantity	Component
R1	1	10 kΩ Resistor
FUNC1	1	50 Hz, 10 V, 0 V, Sine Function Generator
Meter1	1	Voltage Multimeter
C1	1	10 uF, 16 V Polarized Capacitor
U1	1	10 ms Oscilloscope
D1	1	Diode

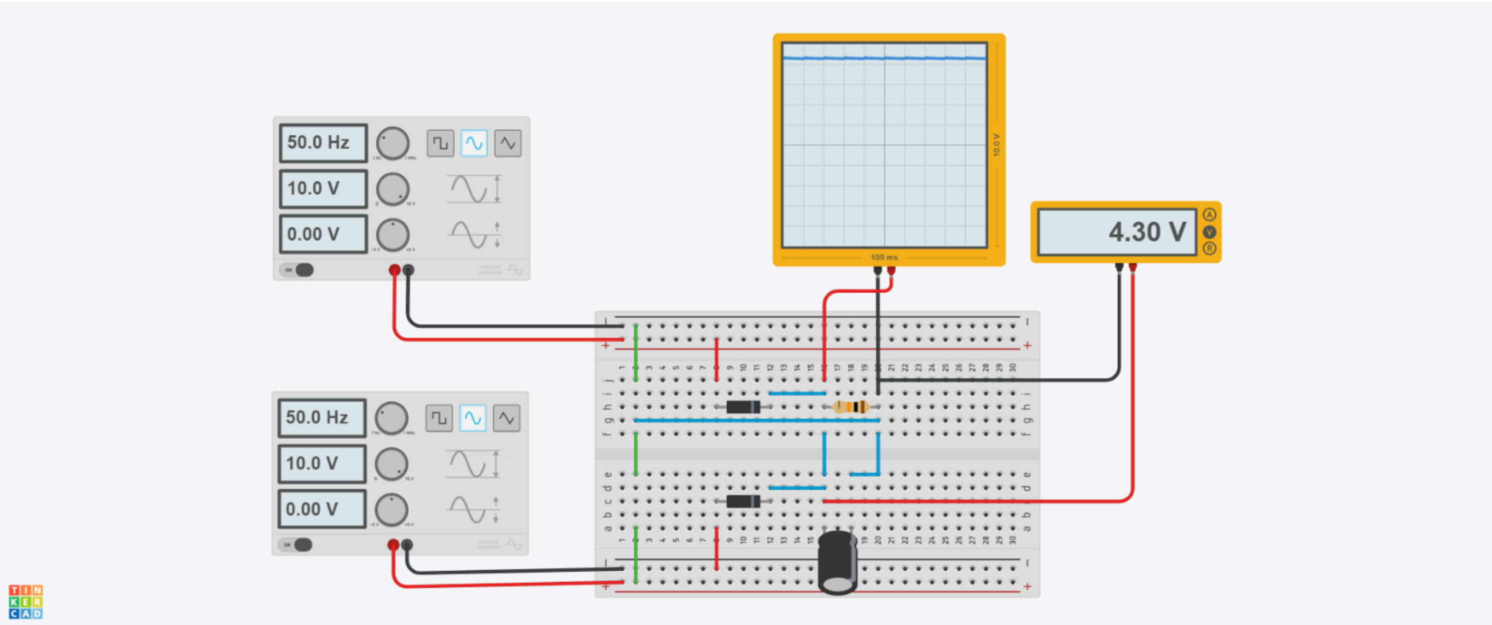
Component List for Half Wave Rectifier without Capacitor Filter:

Name	Quantity	Component
FUNC1	1	50 Hz, 10 V, 0 V, Sine Function Generator
U1	1	10 ms Oscilloscope
Meter1, Meter2	2	Voltage Multimeter
D1	1	Diode
R1	1	10 kΩ Resistor

5. Full Wave Rectifier without Capacitor Filter



6. Full Wave Rectifier with Capacitor Filter



Component List of Full Wave Rectifier without Capacitor Filter

Name	Quantity	Component
FUNC1, FUNC2	2	50 Hz, 10 V, 0 V, Sine Function Generator
U1	1	10 ms Oscilloscope
Meter1	1	Voltage Multimeter
D1, D3	2	Diode
R1	1	10 kΩ Resistor

Component List of Full Wave Rectifier with Capacitor Filter

Name	Quantity	Component
FUNC1, FUNC2	2	50 Hz, 10 V, 0 V, Sine Function Generator
U1	1	10 ms Oscilloscope
Meter1	1	Voltage Multimeter
D1, D3	2	Diode
R1	1	10 kΩ Resistor
C1	1	100 uF, 16 V Polarized Capacitor

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(*) Calculations

Basic Values for components :

① Function generator output = 50 Hz AC (~)

V_{PP} = 10 V

V_M = 5 V

R = 10 KΩ

C = 10 μF

Case - 1 : Half Wave Rectifier without Capacitive filter:

Formula : r_{th} = ripple factor = $\sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$

$V_{RMS} = \frac{V_m}{2}$ (for No filter circuit)

$= \frac{5}{2} = \underline{2.5\ V}$

$V_{DC} = \frac{V_m}{\pi} = \frac{5}{3.14159} = \underline{1.59\ V}$

So Theoritical value of ripple factor without filter

$r_{th} = \sqrt{\left(\frac{2.5}{1.59}\right)^2 - 1} = \underline{\underline{1.21}}$

But V_{DC} as measured on multimeter =

$V_{DC_{multimeter}} = \underline{\underline{1.51}}$.

So practical value of ripple factor without capacitor,

$$r_{practical} = \sqrt{\left(\frac{V_{rms}}{V_{DC_{multimeter}}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{2.5}{1.51}\right)^2 - 1}$$

$$= \underline{\underline{1.31}}.$$

∴ For Half wave rectifier,
Ripple factor, $r_{th} = 1.21$

$\underline{r_{practical} = 1.31}$

<u>Case - 2</u> : Half Wave Rectifier with filter

$V_{PP} = 10V$, $V_M = 5V$, $C = 10\mu F$,
$R = 10 k\Omega$, $f = 50$ Hz.

From Formula for Ripple factor r_{th},

$$r_{th} = \frac{1}{2fCR\sqrt{3}} = \frac{1}{2 \times 50 \times 10 \times 10^{-6} \times 10^4 \times \sqrt{3}}$$

$$r_{th} = \underline{\underline{0.057}}$$

→ Using readings in tinkercad experiments,

$$r_{practical} = \frac{V_{ac}}{V_{DC}} = \frac{V_{r\,RMS}}{V_{LDC}}$$

$$V_{R\,RMS} = \frac{V_{Rpp}}{2\sqrt{3}} = \frac{0.8}{2\sqrt{3}}$$ [From Oscilloscope Reading]

So $V_{R_{PP}} = \underline{0.8 \text{ V}}$

$$V_{R_{RMS}} = \frac{0.8}{2\sqrt{3}} = \underline{0.230 \text{ V}}$$

$V_{LDC} = \underline{4.03 \text{ V}}$ [From reading on multimeter]

So

$$r_{practical} = \frac{V_{R_{RMS}}}{V_{LDC}} = \frac{0.230}{4.03} = \underline{\underline{0.057}}$$

So for half wave rectifier, ~~fo~~ with capacitor,

ripple factor $r_{th} = \underline{0.057}$, and

ripple factor $r_{practical} = \underline{0.057}$.

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28/12/2021

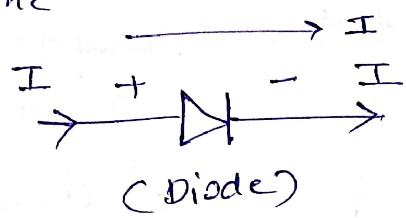
BEEE EXPERIMENT - 2

Post Lab Questions

Q.1 What is the purpose of rectifier?

→ A rectifier is an electronic device that converts alternating current (AC), which ~~per~~ periodically reverses direction into direct current (DC) which flows only in one direction.

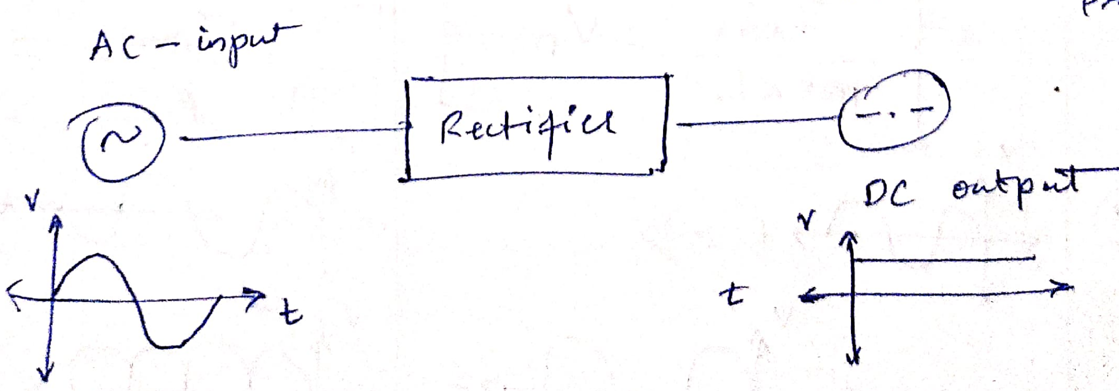
The process is known as rectification as it straightens the direction of current. It can be done with the help of diodes.



(current only passes in one direction)

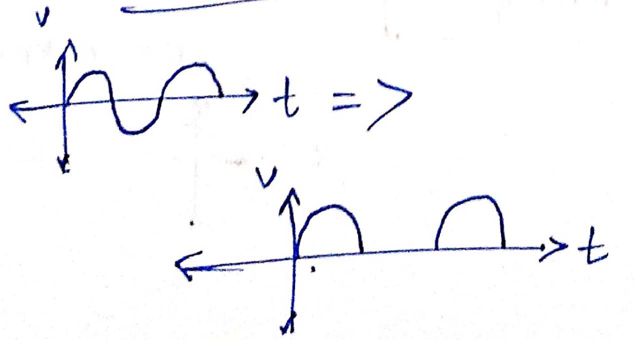
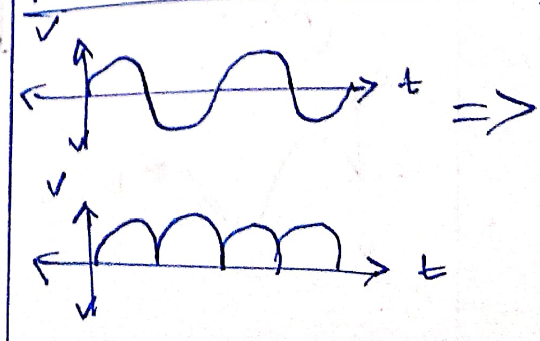
Rectifiers can be of 2 types

- Half wave
- Full wave Rectifier
  - Centre tap
  - Full Bridge



Q.2 What is the difference between half wave and full wave rectifier?

→

	Half wave Rectifier	Full Wave Rectifier
1	Consists of a step down transformer and 1 diodes	Consists of a step down transformer and 4 diodes or 2 diodes.
2	Rectification Efficiency = 40.6 %	Rectification Efficiency = 81.2 %.
3	Ripple factor $r = 1.21$	Ripple factor $r = 0.482$
4	Transformer utilization factor = 0.286	Transformer utilization factor = 0.692
5	Fundamental frequency of Ripple = Supply frequency = f	= Double of supply frequency = 2f.
6	Peak factor = 2	Peak factor = 1.414
7	Peak inverse voltage = V_s	Peak inverse voltage = $2V_s$
8	DC output voltage $= \boxed{\frac{I_{max}}{\pi R_L} = V_{DC}}$	DC output voltage $= \boxed{\frac{2 I_{max}}{\pi R_L} = V_{DC}}$
9		

Q.3. What is the use of filter in Rectifier?

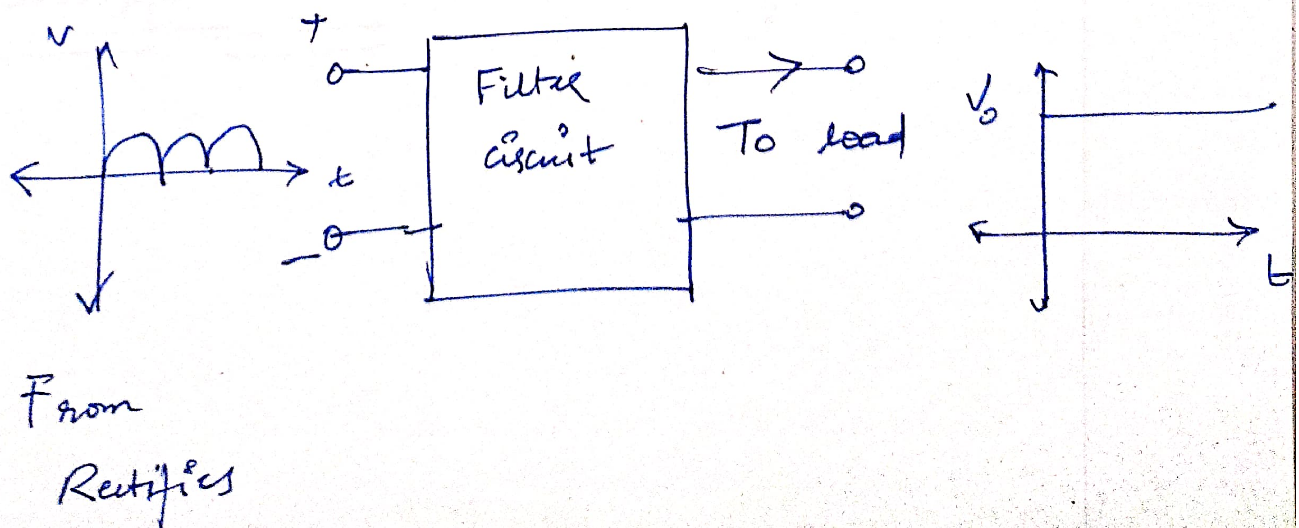
→ We know that rectifiers can convert AC to DC, but there is presence of a ripple. So conversion is not pure DC. This is undesirable as most sophisticated circuits need pure DC to power them correctly.

→ To do this, we need a filter to remove the ~~ripple~~ ripple or the AC factor.

→ This is done by shunting a capacitor to the load resistance. A capacitor does not allow voltage to change instantaneously in a circuit.

$$\boxed{I = C \cdot \frac{dv}{dt}}$$

If $\frac{dv}{dt} \uparrow$, $I \uparrow$. So a capacitor tends to reduce rapid changes in ~~a~~ the circuit voltage thereby reducing ripple.

→ 

Q.4. Explain how Bridge rectifier is more advantageous than conventional full wave rectifier.

→ ① In full Bridge rectifier, we do not need a centre-Tap transformer, that greatly reduces the cost.

② The Peak inverse voltage for conventional full wave rectifier is $(2 \cdot V_s)$. This means diodes have to be more ~~expens~~ expensive. For a Full Bridge rectifier, it is only (V_s). Thereby using cheaper and safer diodes.

③ Transformer utilization factor is (0.693) for center tap full wave rectifier.

It is (0.812) for Full Bridge rectifier and therefore it is more efficient.