BIRZEIT UNIVERSITY

Faculty of Engineering & Technology
Electrical & Computer Engineering Department

ENEE 3102 – Electronics Lab

Experiment #2

Diode characteristic and apllications

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Absract :

The aim of this experiment we were able to investingate the operation of PN junction , the VI characteristics of the silicon diode and some applications of the P-N junction like rectification , clamping – clipping .

Equipment's used in experiment :

- Diodes
- resistance and variable resistance
- DC source
- AC source
- capacitor
- variable voltage
- transformer
- Bridge Full wave rectifier
- Oscilloscope
- DVM
- Assembling board
- short circuit

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Theory

I. Diode chracteristics

The diode is a device formed from semi conductor material manufactured in a way so it will be a good conductor called doping process , it consist of two junction a junction of n-type and p-type .
The p-type material is called the anode and the the n-type material is the cathode. In general, the cathode of a diode is marked by a solid line on the diode. Shown Figrue 1

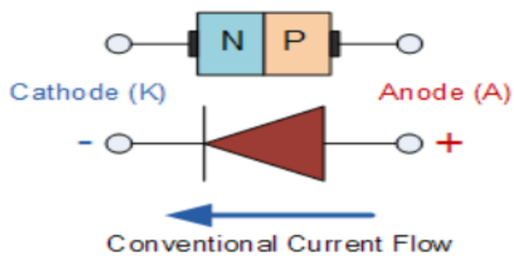

Figure 1   junction diode [1]

A diode is simply a PN junction, but its applications are extensive in electronic circuits. Three important characteristics of a diode are, first of all, the forward voltage drop. Under a forward bias condition, this should be about .7 volts. Then there is the reverse voltage drop. In the reverse, when we reverse bias the diode the depletion layer widens and usually, the applied voltages are felt across the diode. Then there is the reverse breakdown voltage. Reverse voltage drop that will reverse current flow and in most cases destroy the diode . [1]

The main function of the diode is the rectification. When it is forward biased (the higher potential is connected to the anode), it will pass current. When it is reverse biased (the higher potential is connected to the cathode lead), the current is blocked. The characteristic curves of an ideal diode and a real diode are shown in Figure 2

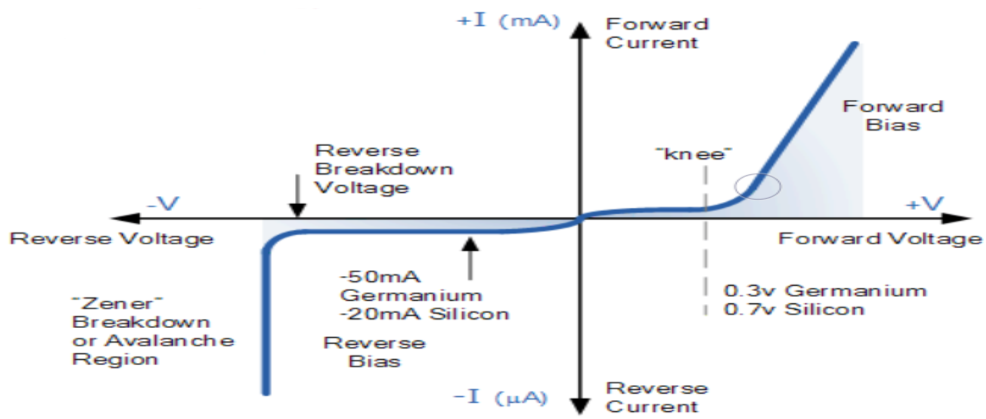

Figure 2 static I - V characteristics .[1]

II. RECTIFICATION .

A. The Half – Wave Rectifier

A half wave rectifier is defined as a type of rectifier that only allows one half-cycle of an AC volyage waveform to pass, blocking the other half-cycle. Half-wave rectifiers are used to convert AC voltage to DC voltage, and only require a single diode to construct.

The circuit of a half – wave rectifier shown in the Figure (3) . Using the more realistic constant – voltage – drop diode model, we obtain this equation :-

$$F = \begin{cases} V_0 = 0 , & V_S < V_D \\ V_O = V_S - V_D , & V_S \geq V_D \end{cases} \quad \ldots\ldots\ldots\ldots(1)$$

From this equation we can obtain the transfer characteristic is sketched in figure (3) , when V_D = 0.7V or 0.8V and in figure (3) has the output voltage obtained when the input V_S is a sinusoid .

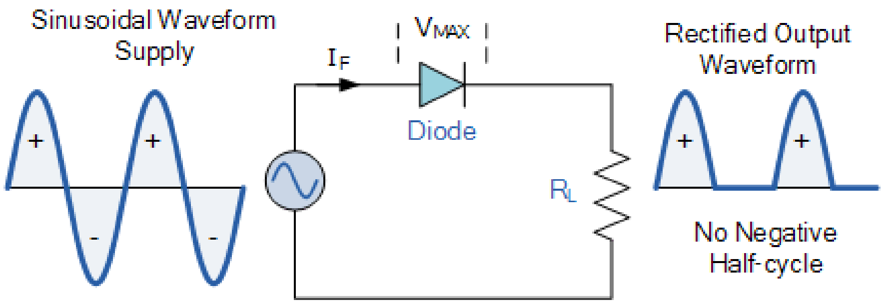

Figure 3 (a) Half-wave rectifier & input and output waveforms.[2]

As noted in Figure 3, the output voltage is lower than the input voltage and there is no output voltage when the input voltage is negative because the Diode does not pass the opposite current "negative" and the different between V_S & V_O produce V_D .

→ Conclusion :-

PIV = V_S …………………………………………………………..(2)

B. Full-wave rectification

The full-wave rectifier used both equity of the input sinusoid and it inverts the negative side of the sine wave so the output is unipolar . the input line voltage is positive, both of the signals labeled V_S will be positive. In this case D_1 will conduct and D_2 will be reverse biased. The current through D_1 will flow through R and back to the center tap of the secondary. The circuit then behaves like a half -wave rectifier, and the output during the positive half-cycles when D_1 conducts will be identical to that produced by the half-wave rectifier. But , the negative half-cycle of the AC line voltage, both of the voltages labeled V_S will be negative. Thus D_1 will be cut off while D_2 will conduct. The current conducted by D_2 will flow through R and back to the center tap. It follows that during the negative half-cycles while D_2 conducts, the circuit behaves again as a half-wave rectifier. The important point, however, is that the current through R always flows in the same direction . ..[3]

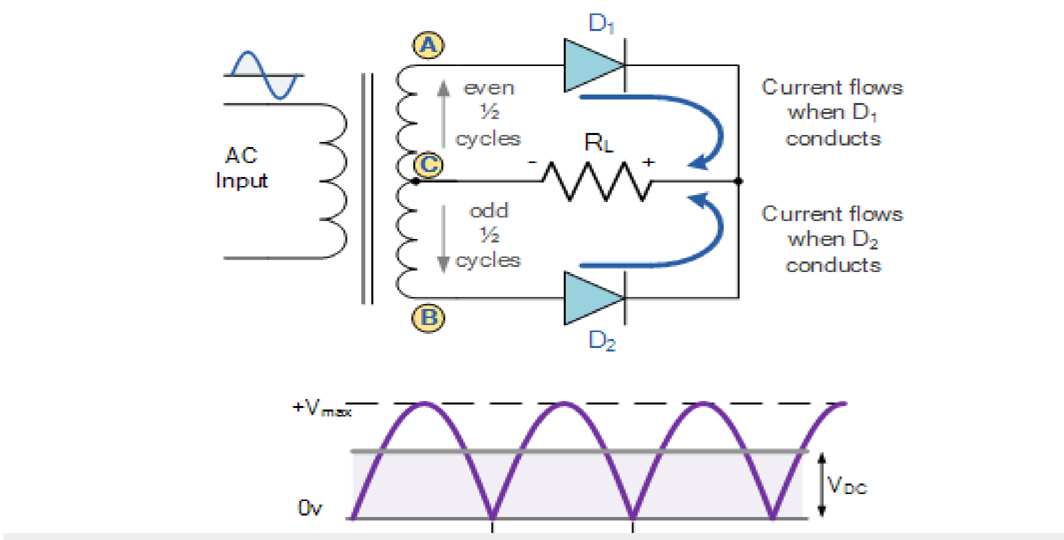

Figure 4:Full-wave rectifier used a transformer with a center-tapped secondary winding . [3]

To find the PIV of the diodes in the full-wave rectifier , consider the situation during the positive half-cycles. Diode D_1 is conducting, and D_2 is cut off. The voltage at the cathode of D_2 is V_O, and that at its anode is $-V_S$. Thus the reverse voltage across D_2 will be ($V_O + V_S$),which will reach its maximum when V_O is at its peak value of ($V_s - V_D$), and V_S is a peak value . thus :

$PIV = 2V_S - V_D$ ……………………………….(3)

III. OTHER APPLICATIONS

A. clippings

In this diode clipping circuit, 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 the input voltage magnitude greater than +0.7 volts (0.3 volts for a germanium diode).

When this happens the diodes 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.[4]

To produce diode clipping circuits for voltage waveforms at different levels, a bias voltage, VBIAS is added in series with the diode to produce a combination clipper as shown. The voltage across the series combination must be greater than VBIAS + 0.7V before the diode becomes sufficiently forward biased to conduct. For example, if the VBIAS level is set at 4.0 volts, then the sinusoidal voltage at the diode's anode terminal must be greater than 4.0 + 0.7 = 4.7 volts for it to become forward biased. Any anode voltage levels above this bias point are clipped off. [4]

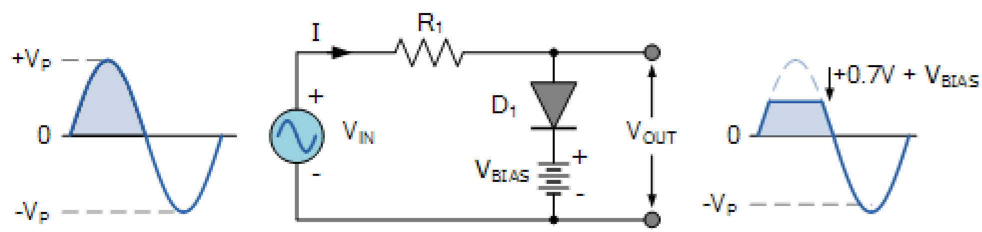

Figure 5 :the positive biased clipper circuit .[4]

Likewise, by reversing the diode and the battery bias voltage, when a diode conducts the negative half cycle of the output waveform is held to a level –VBIAS – 0.7V as shown.[4]

B. Clampings

A clamper is an electronic circuit that fixes either the positive or the negative peak excursions of a signal to a defined value by shifting its DC value . The clamper does not restrict the peak-to-peak excursion of the signal, it moves the whole signal up or down so as to place the peaks at the reference level.   There are several types of name we will talk about negative biased . A negative biased voltage clamp is likewise identical to an equivalent unbiased clamp but with the output voltage offset in the negative direction by the bias amount V_{BIAS}. Thus, $V_{OUT} = V_{IN} - (V_{INpeak} + V_{BIAS})$.   …………[5]

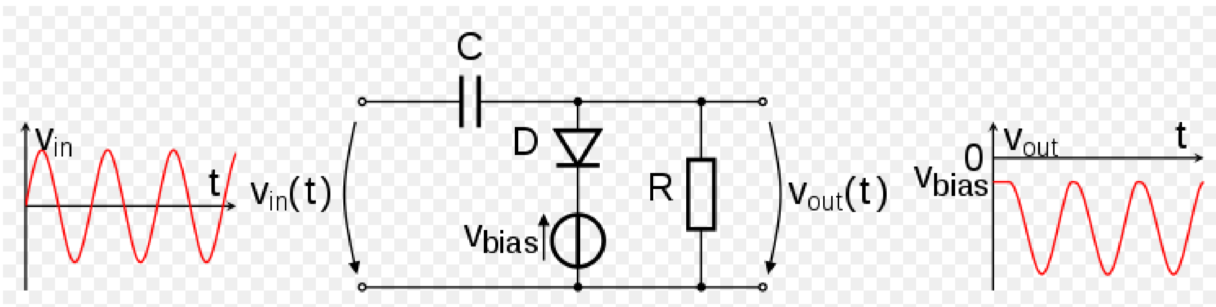

Figure 6:Negative biased circuit .[5]

C. Voltage multiplier circuits

The voltage multiplier is an electronic circuit that delivers the output voltage whose amplitude (peak value) is two, three, or more times greater than the amplitude (peak value) of the input voltage.[6]

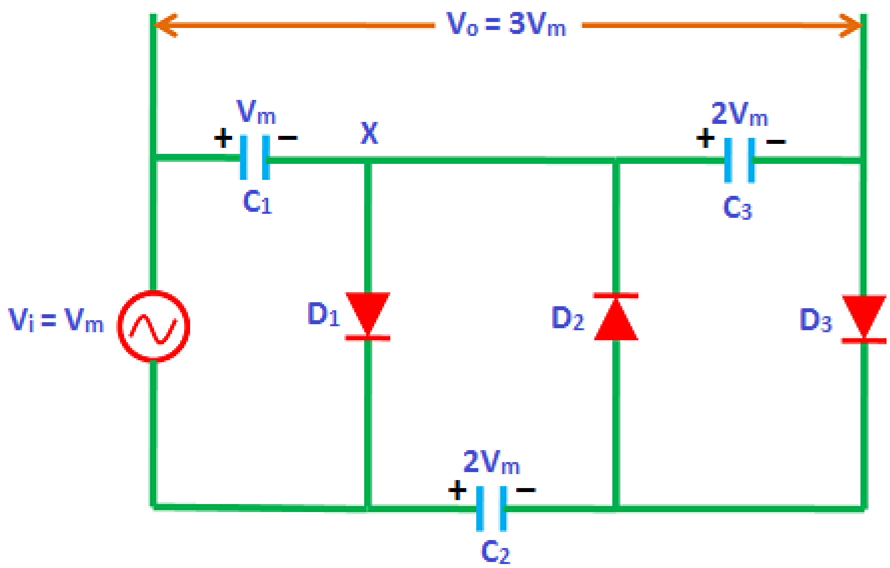

Figure 7 :voltage multiplier.[6]

The voltage multiplier is an electronic circuit that converts the low AC voltage into high DC voltage. Or The voltage multiplier is an AC-to-DC converter, made up of diodes and capacitors that produce a high voltage DC output from a low voltage AC input…….[6]

Types of voltage multipliers

Voltage multipliers are classified into four types:

- Half-wave voltage doubler
- .Full-wave voltage doubler
- Voltage tripler
- Voltage quadrupler

Generally, the DC output voltage (Vdc) of a rectifier circuit is limited by the peak value of its sinusoidal input voltage. But by using combinations of rectifier diodes and capacitors together we can effectively multiply this input peak voltage to give a DC output equal to some odd o

even multiple of the peak voltage value of the AC input voltage.

Procedure:-

I. DIODE CHARACTERISTICS

The circuit shown in the figure(1.1) below was connected, the potentiometer was turned to zero

the power supply was Switched on and adjusted to 5 volt.

By Using potentiometer the value of Vs was changed from zero to 1 volt in 0.1V steps and in 0.5 steps from 1V to 3V.

For each setting the value of VR was measured and recorded in table(1.1)

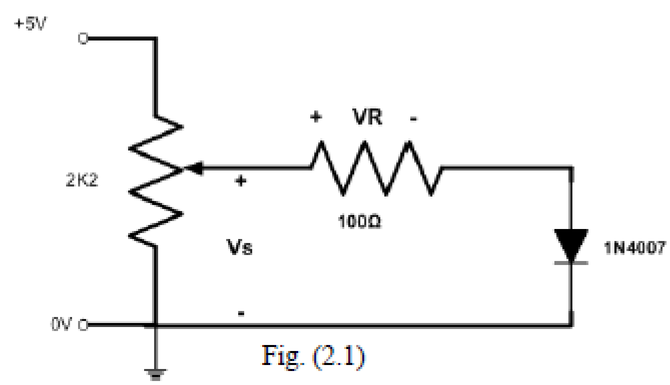

Fig. (2.1)

Figure 8: the diode circuit with resistance

II. RECTIFICATION

A. HALF - WAVE RECTIFICATION.

The circuit in the figure(1.2) which shown below was connected, the oscilloscope and the sinusoidal supply were Switched on. the period (time T) and peak voltage Vpk for the output voltage were measured

The dc and ac components of the output voltage was measured by using DVM. The dc value was compared with the theoretical value.

The values which measured were recorded in table(2.1)

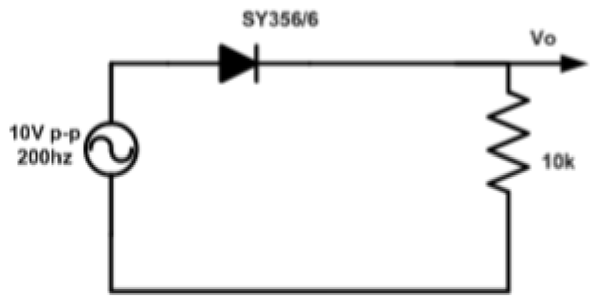

Figure 9 : the half-wave rectification circuit

Then a capacitor of 2.2μF was added to the circuit ,the circuit became as shown in Fig.(2.2) below

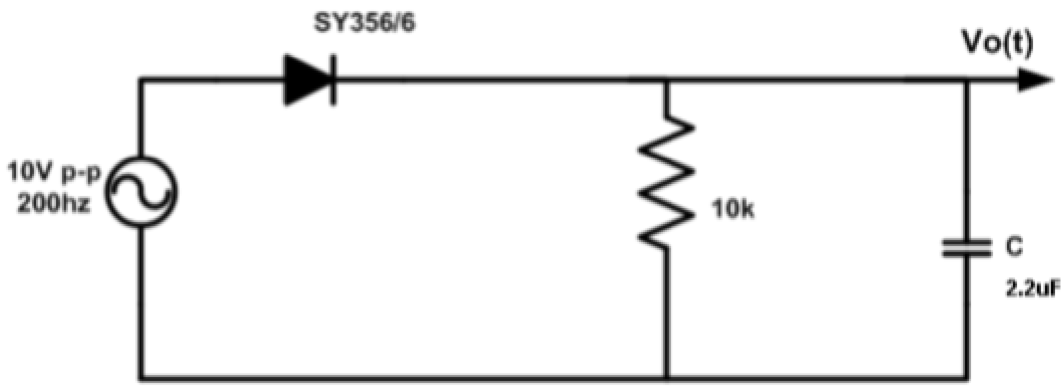

Figure 10 :the half-wave rectification circuit with capacitor

the output waveform on the oscilloscope was observed, the peak-to-peak ripple and rms ripple voltage were measured using ac coupling.
The mean value of Vo(t) was measured using dc coupling, then the ripple factor was calculated.
The 2.2 μF capacitor was replaced by a much larger value of 47μF the + side of the capacitor was connected to the diode cathode (the capacitor is electrolytic and MUST be connected in the correct polarity).

B. FULL-WAVE RECTIFICATION

The circuit shown in the figure below(Fig(2.3)) was connected, the oscilloscope was connected to the output, a picture of the output waveform as seen on the oscilloscope was taken, the dc and ac components of the voltage across the load were measured using DVM

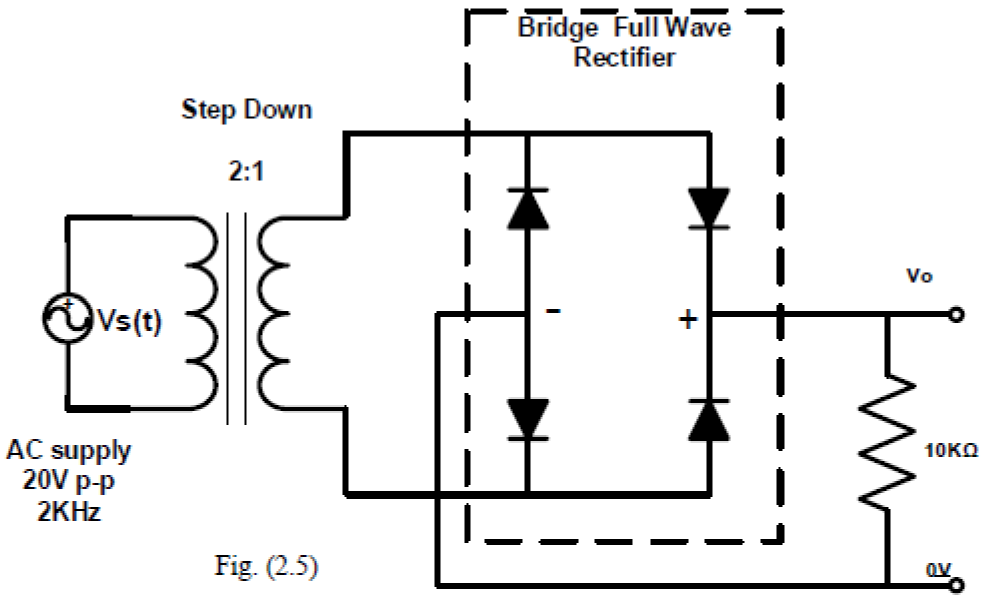

Figure 11:.the full-wave rectification circuit

Then a capacitor of 2.2µF was added to the circuit, and the output was observed on the oscilloscope.

III. other applications:

A. clipping:

The circuit which shown in Fig.(3.1) below was connected, the oscilloscope was connected to the output of the circuit, the power supply variable control was sat to zero (fully anti-clockwise) and the output waveform was sketched. The dc source was increased slightly and noticed what happend to the output waveform.

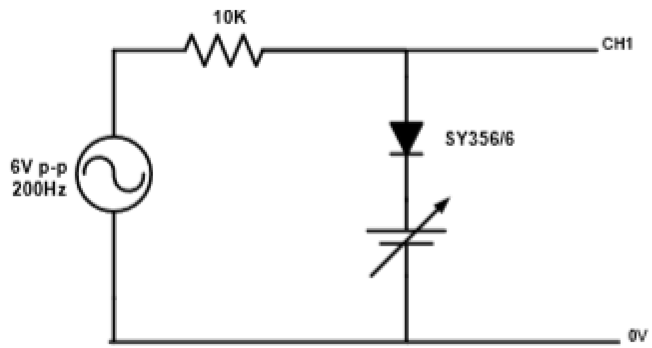

Figure 12: the positive baised clipper circuit

B. Clamping:

The circuit shown in Fig.(3.2) was connected, the same steps which done in the previous part A (clipping) were followed And done again.

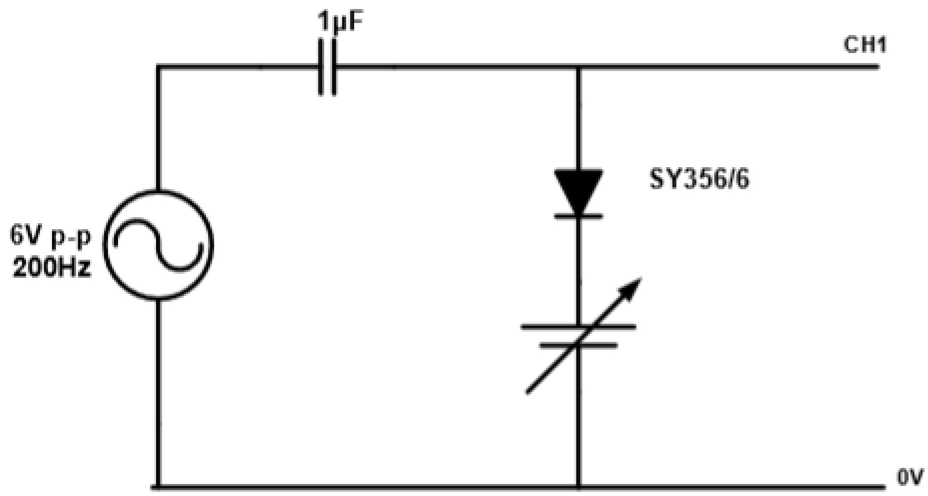

Figure 13: the clamper negative baised circuit

C. VOLTAGE MULTIPLIER CIRCUITS

the circuit shown in Figure below was connected,

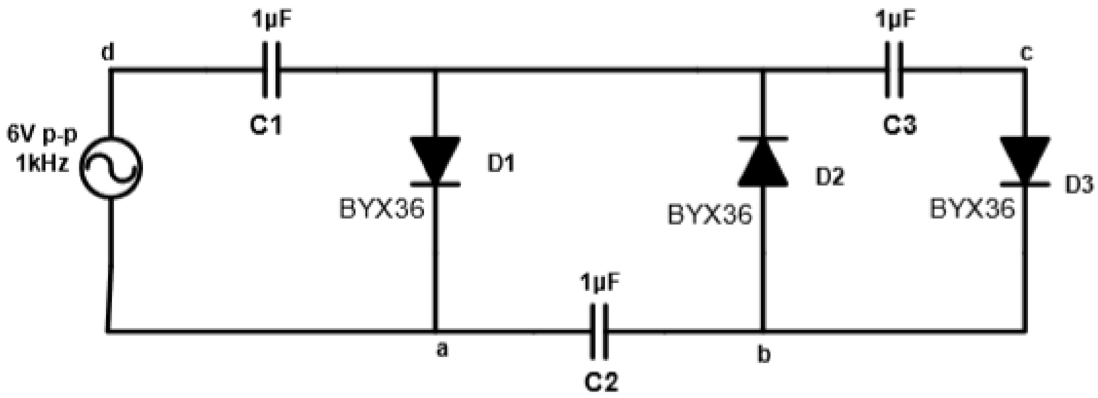

Figure 14:. the voltage multiplier circuits

The dc voltage was measured between points a and b using DVM To see how the circuit works as a doubler

The dc voltage was measured between points c and d.To see how the circuit works as a Tripler

The voltage across each capacitor was measured.

Data and Calculation:

I. Diode Characteristics

Table 1: Data of diode characteristics

Vs	VR	VD = (Vs-VR)	ID =IR=(VR/R)
0	0	0v	0
0.1	0	0.1v	0
0.2	0	0.2v	0
0.3	0.0020v	0.298v	.02mA
0.4	0.0024v	0.3976v	0.024mA
0.5	0.0152v	0.4848v	0.152mA
0.6	0.08v	0.52v	0.8mA
0.7	0.09v	0.61v	0.9mA
0.8	0.22v	0.58v	2.2mA
0.9	0.27v	0.63v	2.7mA
1.0	0.42v	0.58v	4.2mA
1.5	0.6v	0.9v	6mA
2	1.44v	0.56v	0.0144A
2.5	1.80v	0.7v	0.018A
3	2.24v	0.76v	0.024A

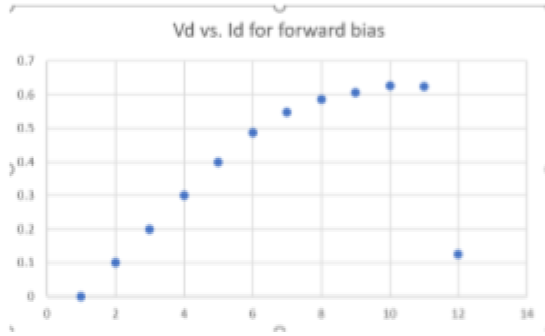

Figure2.1.2: Vd vs. Id for forward bias

Questions:

- **At what approximate value of VD does the current ID begin to rise noticeably?**
  - The current start to pass through the circuit when the Vs value = 0.6 volt.

- **Does VD rise much above this value for larger values of ID?**
  - By increasing the value of Vs, the value of Vr increases exponentially.

- **What happens if the diode is reversed?**
  - When the diode was reversed, no current passed through the circuit since the diode was open.

II. RECTIFICATION

A. HALF - WAVE RECTIFICATION.

T(the period) = 4.73 ms

Peak to Peak voltage = 4.98 volt

Vac = 1.82 volt

Vdc = 1.41 volt

The dc and ac component of the output voltage were measured using the oscilloscope by determine the value of the mean for dc and the value of RMS for ac.

ripple factor =(Vac/Vdc) *100%

ripple factor(experimentally)=1.82/1.41 *100%=129.07%

The output waveform

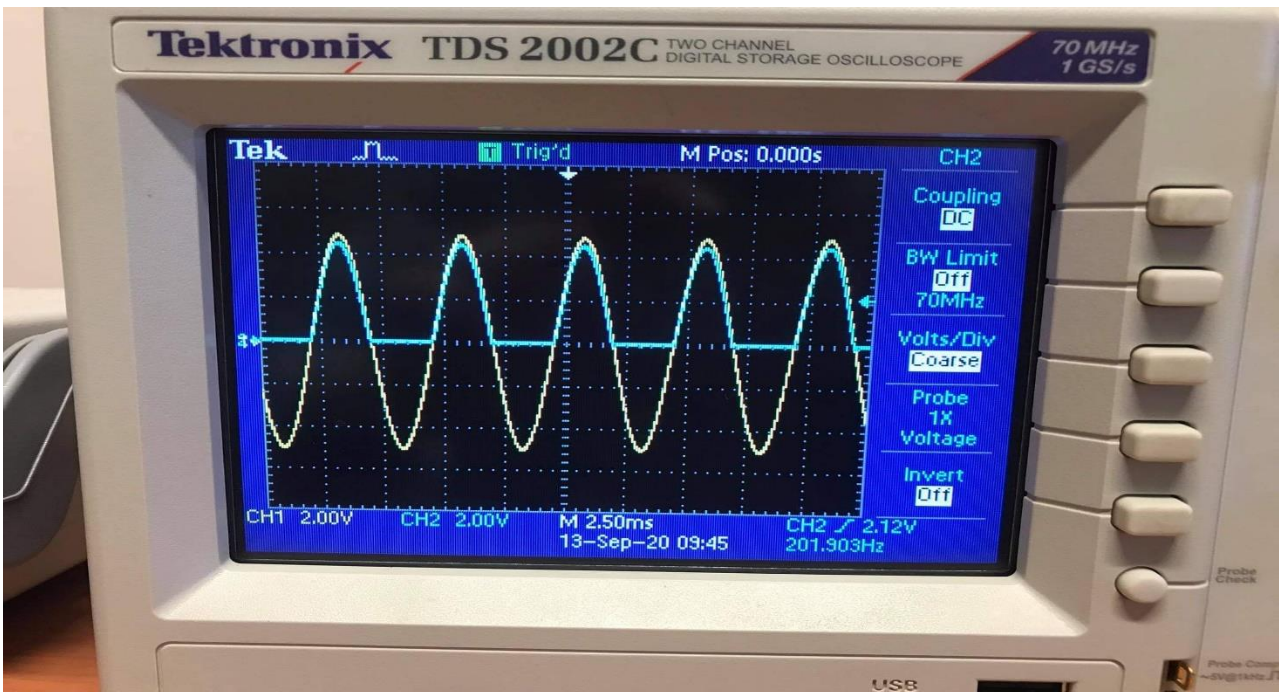

Figure 15 : the output voltage of half-wave rectifier

When the diode was reversed, the output waveform:

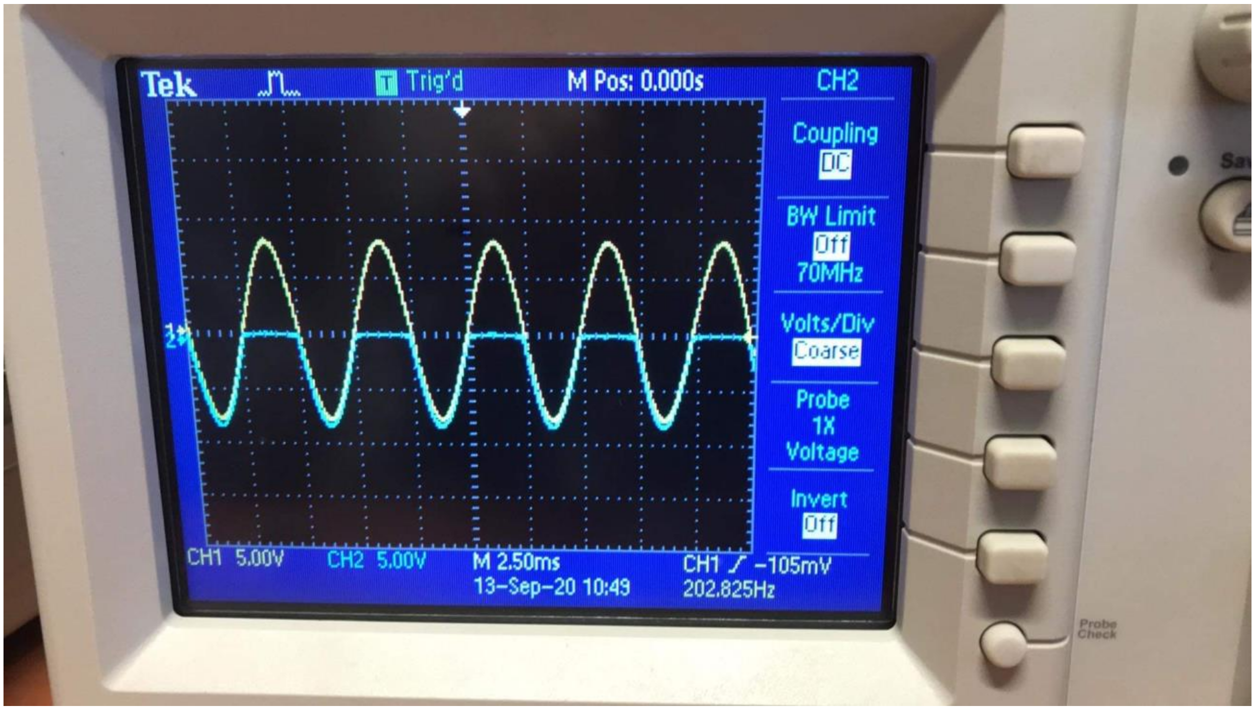

Figure 16 :the output voltage of hal-wave rectifier when reverse the diode

Questions:

- **Is Vpk nearly equal to the peak voltage of the supply.**
  - The output voltage of the half wave rectifier has a peak voltage which is nearly equal to the peak voltage of the input

- **Why will Vpk not be exactly equal to the source peak voltage ?**
  - There is a voltage drop across the diode that doesn't make Vpk equal the source peak voltage.

- **How much will it differ?**
  - The difference between the two values (the input and output voltage peak) is the voltage drop across the diode which is equal to 0.7 volt.

- **How could you obtain a negative voltage relative to zero?**
  - Reversed the diode obtained a negative voltage since the negative wave of the input will cause the diode to be on.

After that an external capacitor equal to 2.2µF was added to the circuit

Vp-p= 880 mV

Vmean = 4.34 volt

VRms = 250 mV

ripple factor= 5.76%

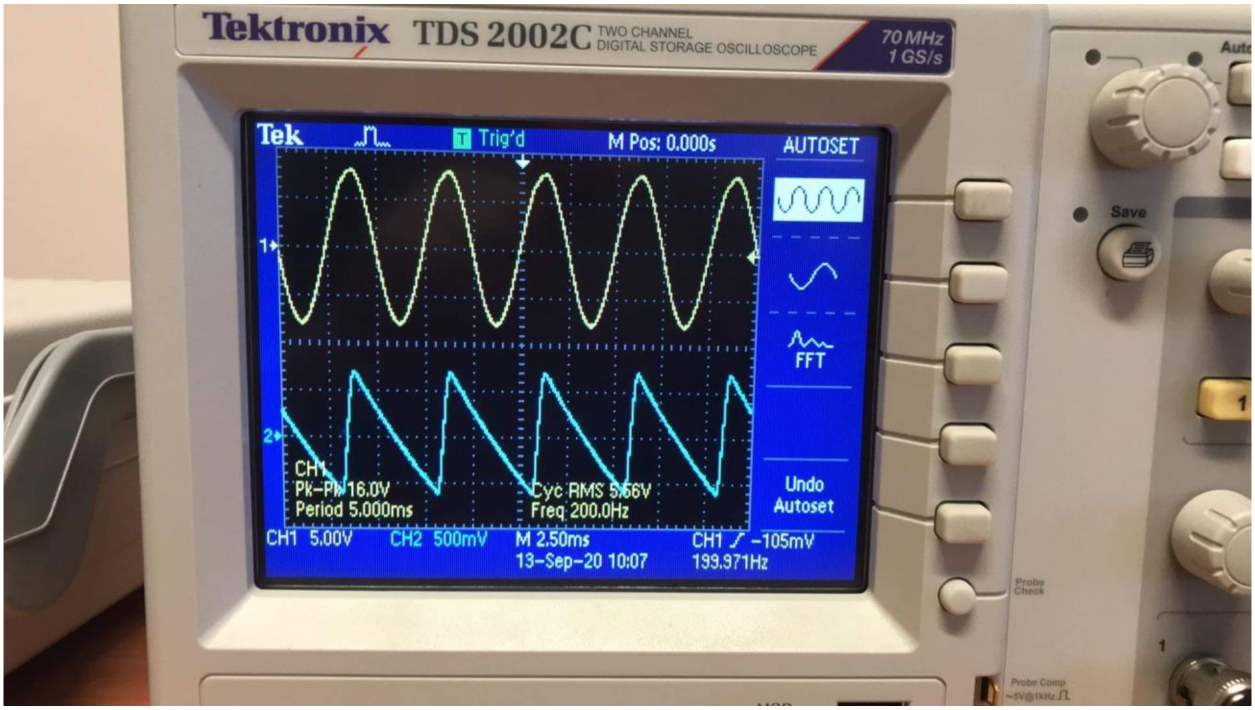

Figure 17:the output voltage of half-wave rectifier with capacitor (2.2µF)

Questions

- **Is the ripple now less than or more than it was with the lower value of the capacitor?**

- The ripple is less than it was with the lower value of the capacitor.

- **Is the mean rectified voltage now greater or less?**

- The ripple is less than it was with the lower value of the capacitor.

- **From measurements above, the following were noticed:**

According to the relation of the ripple factor r=1/3^0.5(2*f*R*C-1)*100%

B. FULL-WAVE RECTIFICATION

Vdc =1.08 volts

Vac = 0.741 volts

ripple =Vac/Vdc*100%=68 .6%

The waveform of the output:

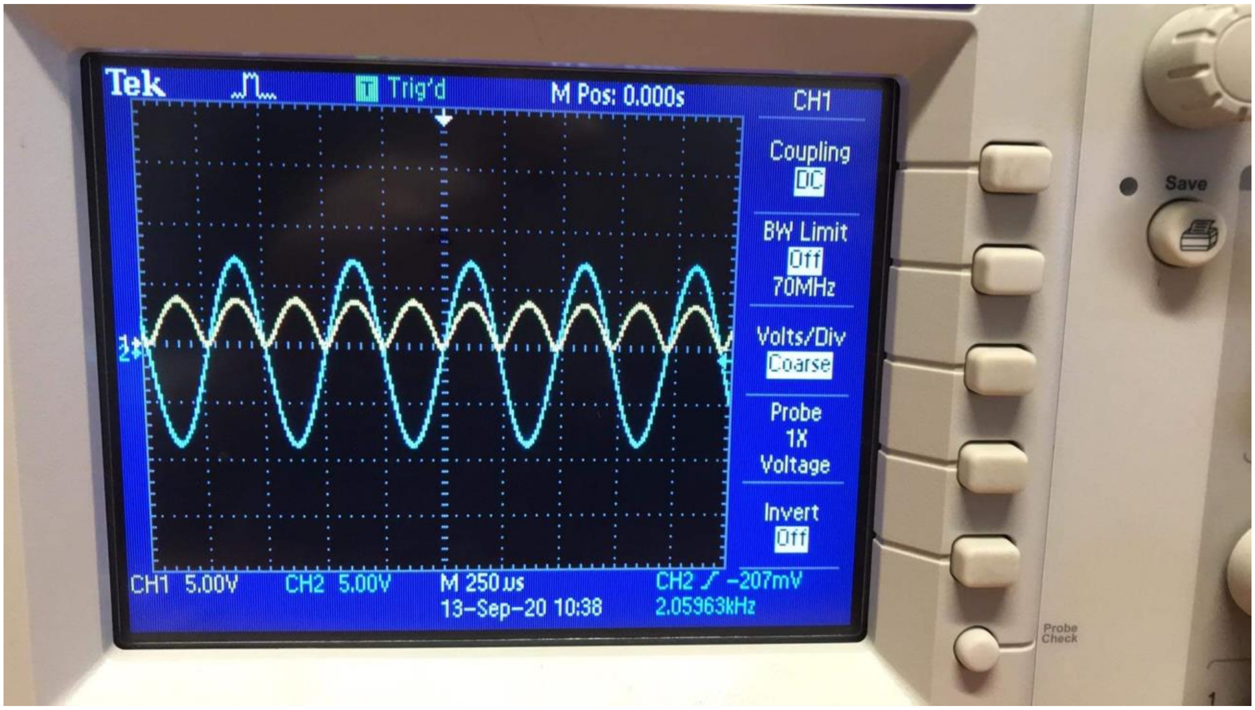

Figure 18: the output voltage of full-wave rectification

When a capacitor (2.2µF) was added to the circuit, the output waveform:

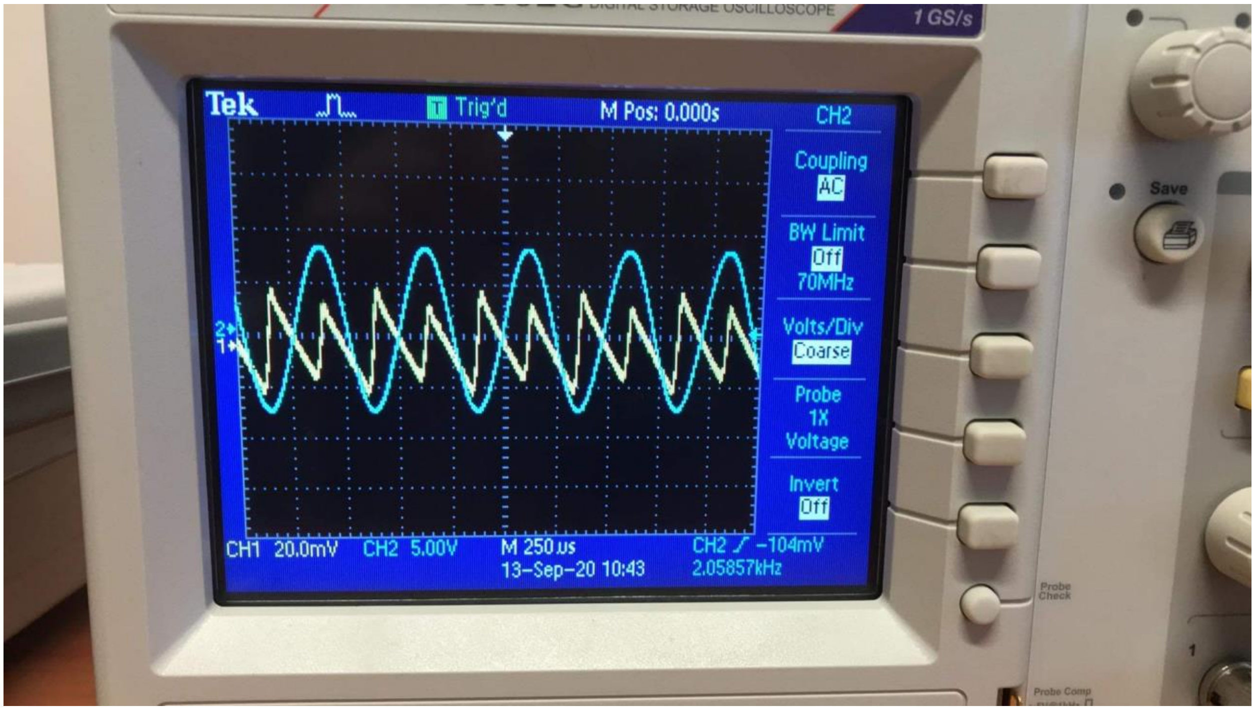

Figure 19: the output voltage of full-wave rectification with capacitor

Questions

- **When the capacitor connected, what is the change on the waveform, why?**

- Adding capacitor will smooth the signal so it is nearly a dc value by the rule of charging and discharging of the capacitor.

- **Does the ripple voltage change with frequency?**

- The ripple voltage depends on the frequency with negative relationship such as: $ripple\ Factor$ = 1 √3 [4 fRC−1].

- **If the input frequency is low do you need a larger or a smaller capacitor to achieve the same smoothing as when the frequency is higher?**

- The frequency was rapidly changed after adding the capacitor, so a larger capacitor.

III. other applications:

A. clipping:

When VDC=0

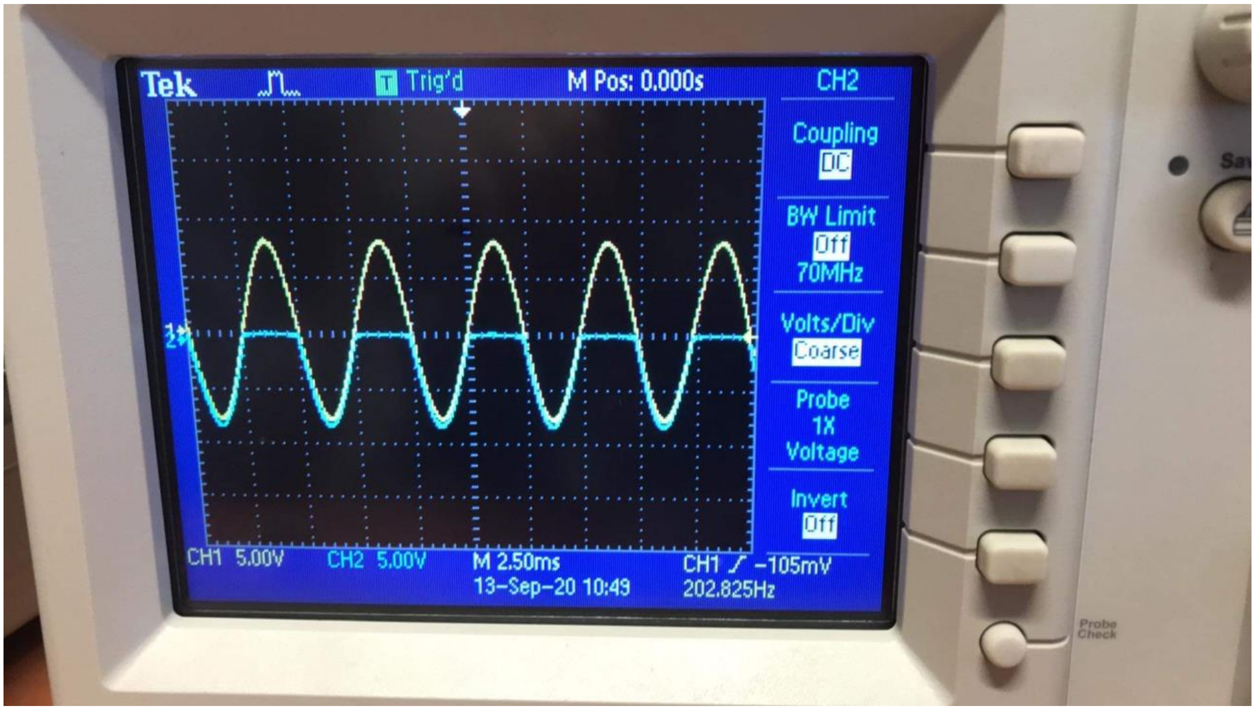

Figure 20 : the output voltage of clipping circuit when Vdc=0.

Questions:

- **What difference is there between the input and output wave?**
  - The output was nearly equal to the input in some regions, and it clipped in some other region and this difference between the input and output is clipped at specific value depending on Vdc. During the positive half cycle, the circuit maintains the output voltage at a constant value

B. Clamping:

When VDC=0

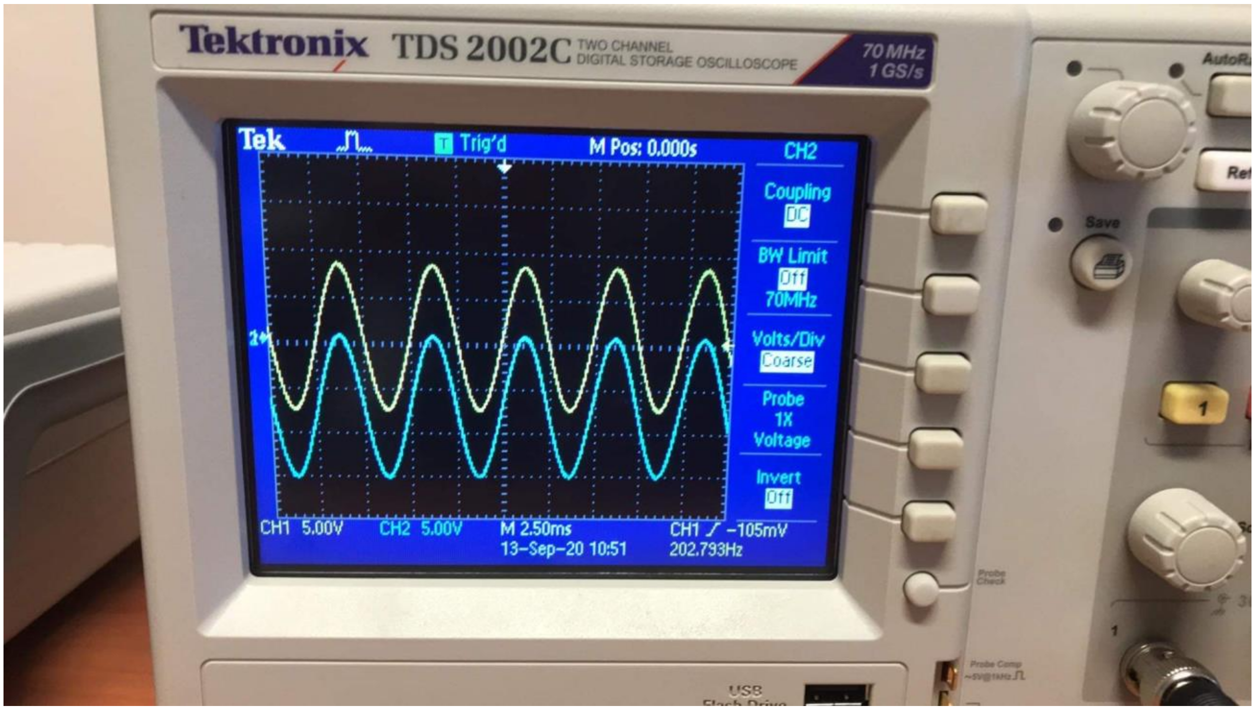

Figure 21: theoutput and input voltage of clamping when Vdc = min.

Questions:

- **Does the output wave form alternate about the same dc level as the input waveform?**
  - The output waveform alternated about the same DC level as the input.

- **To what value is the positive peak of the output waveform clamped, if the ac input signal is 5VPK?**
- The difference between 2 waves was the amplitude value such that the output voltage just shifted up or down, so that $V_c = V_i - 0.7$.
  -
- **Does the positive peak still stay clamped to the same level?**
  - The positive peak doesn't still stay to the same level.

- **Can you see any relation between the reference voltage setting and the clamping level.**
  - The Relation between VDC and the clamping level, that is $V_o = V_i - [V_p - V_D - V_{DC}]$.

C. VOLTAGE MULTIPLIER CIRCUITS

Vab = 5.0v

Vcd = 7.5 v

Vc1 =2.5v

Vc2 = 5v

VC3 = 5.1v

Questions

- **Is the output voltage between a,b twice the input voltage.**
- The voltage between a and b is double the voltage across the input, and the voltage across d and c is triple the voltage across the input.

- **Is the output voltage between c,d three times the input voltage.**
  - the voltage across d and c is triple the voltage across the input.

- **What is the peak inverse voltage across each diode?**
  - the peak inverse voltage across each diode is -Vp

- **Compare the results of the above questions with the theoretical values.**
  - The values of this part were very closer to the theoretical values.

Conclusion

In this experiment the following were achieved:

The desired aims of investigating the operation of PN junction, the VI characteristics of the silicon diode and some applications of the P-N junction like Rectification, Clamping and Clipping.

The diode characteristic of forward and reverse bias was learned.

The process of the rectification, the half wave and full wave rectification.

Applications of the diode such as clipping, clamping and voltage multiplier were known.

Some comparison between the values was measured during the practical part with our theoretical one.

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