Power Electronics Laboratory

MANUAL

Part – B Hardware

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EXPERIMENT–1

AIM: - To study V-I characteristics of SCR and find the Latching and Holding current

Apparatus: SCR (TYN616)
Regulated Power Supply (0-30 V)
Resistors 1k, 10k
Voltmeters (0-30 V),
Ammeters (0-15 mA, 0-50 mA),
Breadboard, Connecting wires

Theory:-

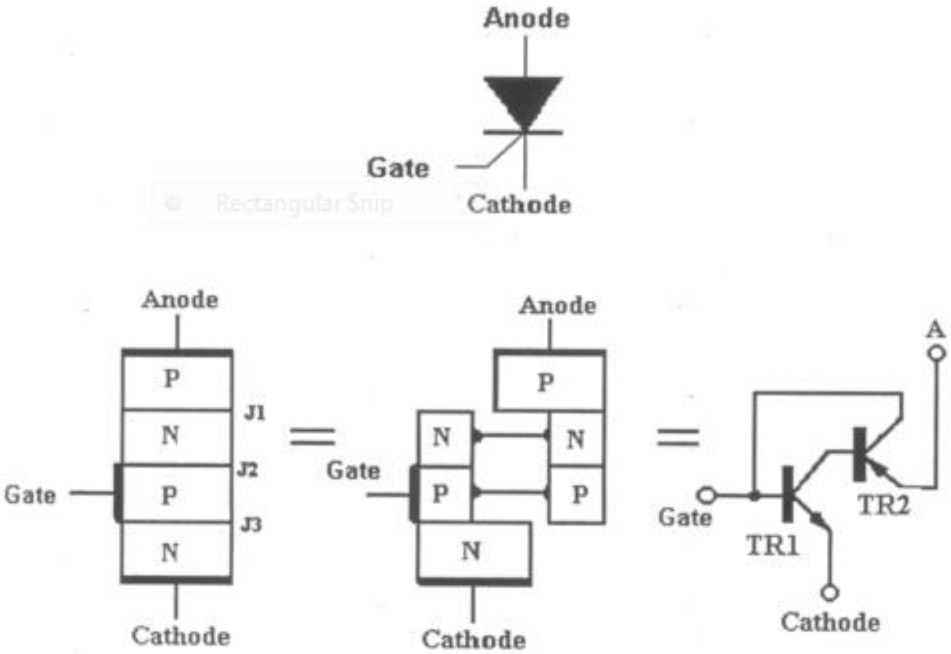
The Silicon Controlled Rectifier (SCR) is a semiconductor device that is a member ofa family of control devices known as Thyristors. The SCR has become the workhouse of the industrial control industry. Its evolution over the year has yielded adevice that is less expensive, more reliable and smaller in size than ever before.

Typical applications include: DC motor control , generator field regulation ,variablefrequency drive (VFD) DC bus voltage control, solid state Relays and lighting systemcontrol.

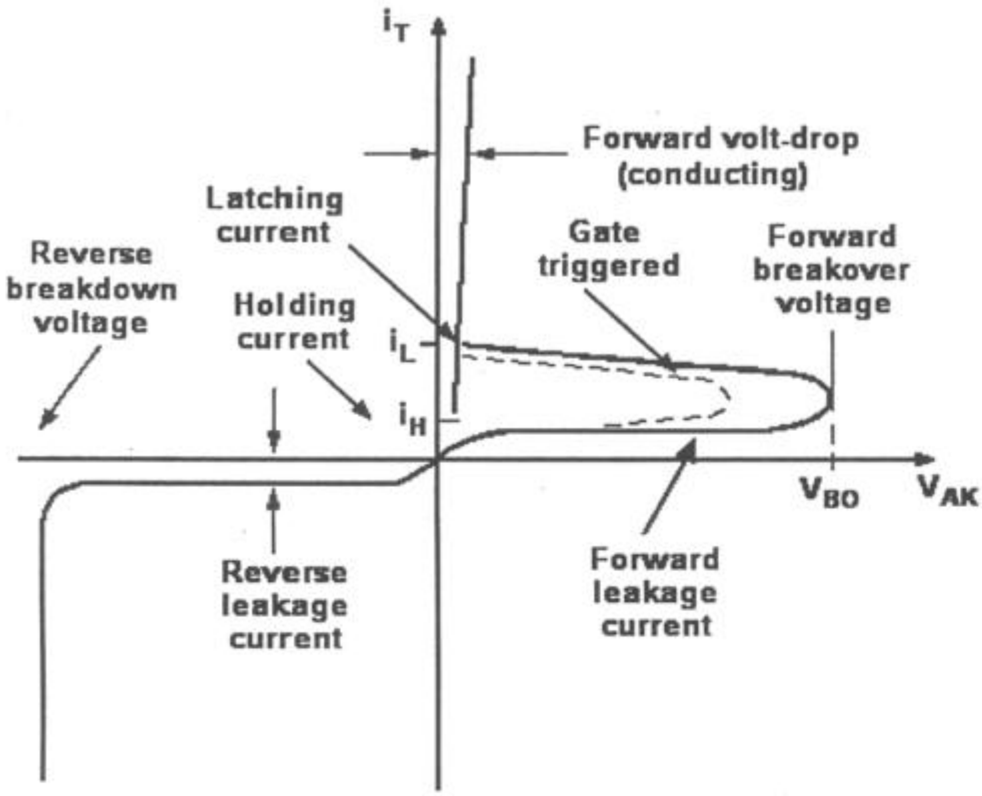
The SCR is a three – lead device with an anode and a cathode (as with astandard diode) plus a third control lead or gate. As the name implies, it is arectifier which can be controlled – or more correctly one that can be triggeredto the “ON” state by applying a small positive voltage (VTM) to the gate lead.Once gated ON, the trigger signal may be removed and the SCR will remainconducting as long as current flows through the device.The load to be controlled by the SCR is normally placed in the anode circuit.

For the SCR to turn OFF current flow through the device must be interrupted, or dropbelow the maximum holding current(I_H) , for a short period of time (typically 10-20microseconds) which is known as the commutated turn – off time (t_q).When applied to alternating current circuits or pulsating DC system, thedevice will self – commutate at the end of every half – cycle when the currentgoes through zero.When applied to pure DC circuits, in applications such as alarm or trip circuitlatching, the SCR can be reset manually by interrupting the current with apush button. When used in VFD's or inverters,SCRs are electronically forcedOFF using additional Commutating circuitry, Such as smaller SCRs andcapacitors, which momentarily apply an opposing reverse bias voltage acrossthe SCR.

SCR is one of the most important types of power semiconductor device. They areoperated as bi-stable switches, operating from non conducting state to conducting state.

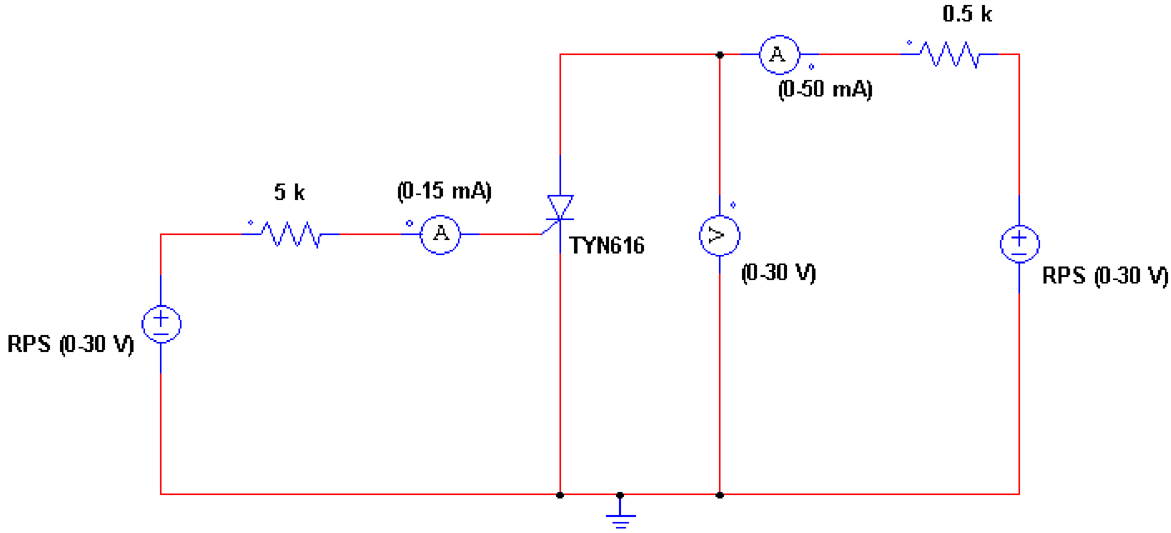


Symbol and Internal Layer



V-1 Characteristics

Circuit Diagram:



Procedure:

V-I characteristic:

1. Make the connections as per the circuit diagram.
2. Keep both the DC supplies at zero initially.
3. Apply some Gate current initially by varying the Gate voltage.
4. Now increase Anode-Cathode voltage gradually and observe whether the SCR conducts. When SCR will conduct, the I_{Ak}will increase and V_{AK} will drop.
5. If no conduction, increase the gate current little more and check; by this way find the minimum gate current for which the SCR conducts.
6. Note down the minimum Gate current and the corresponding Forward voltage.
7. Once into conduction, take the readings of $I_{Ak}$by slowly varying $V_{AK.}$
8. Plot the graph of I_{Ak}vs$V_{AK.}$
9. Repeat the steps for another value of Gate current.

Latching Current:

1. Once into conduction, remove the Gate wire and check whether SCR continue to conduct. Apply the Gate, and reduce Gate current and check for Conduction after removal of Gate wire.
2. The minimum Gate current, the removal of which causes the SCR to stop conduction is nothing but the Latching current $I_{L.}$

Holding Current:

1. While the SCR is conducting, reduce the $I_{Ak,}$ by reducing V_{AK} and observe the current. The minimum current, below which the conduction stops, is the holding current $I_{H.}$

Observation:

Gate Current: ____________

V_{AK} (V)	I_{AK} (mA)

EXPERIMENT–2

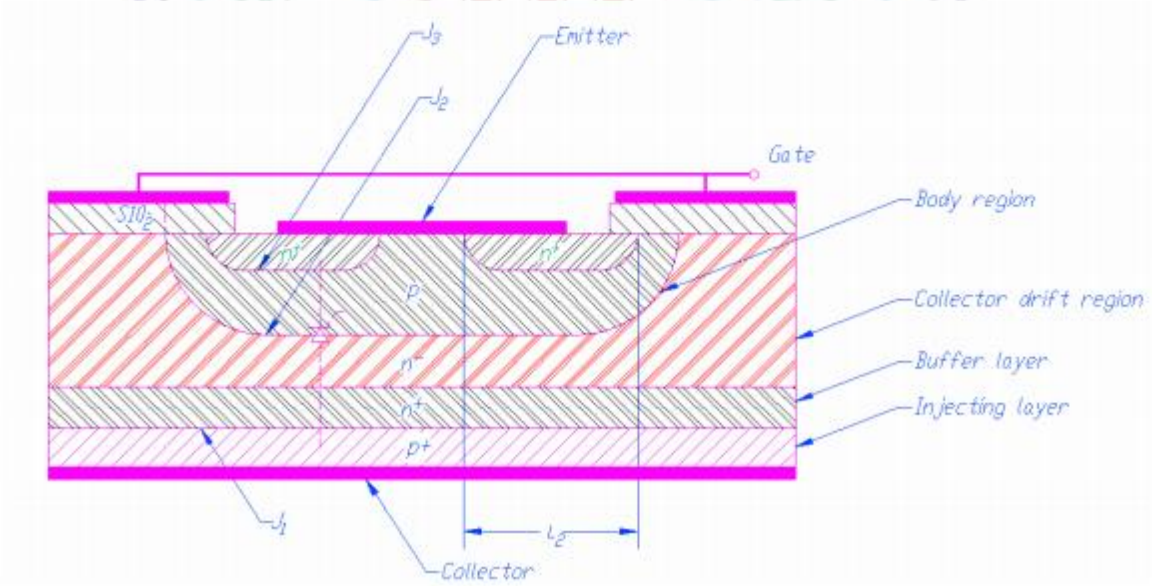
AIM: - To study V-I characteristics of IGBT

Apparatus: IGBT
Regulated Power Supply (0-30 V)
Resistors
Voltmeters (0-30 V),
Ammeters (0-15 mA, 0-50 mA),
Breadboard, Connecting wires

Theory:-

The Insulated Gate Bipolar Transistor (IGBT) is a minority-carrier device with high input impedance and large bipolar current-carrying capability. Many designers view IGBT as a device with MOS input characteristics and bipolar output characteristic that is a voltage-controlled bipolar device. To make use of the advantages of both Power MOSFET and BJT, the IGBT has been introduced. It's a functional integration of Power MOSFET and BJT devices in monolithic form. It combines the best attributes of both to achieve optimal device characteristics.

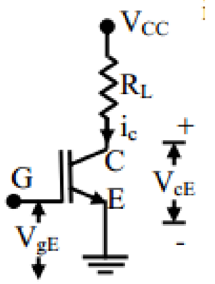
The IGBT is suitable for many applications in power electronics, especially in Pulse Width Modulated (PWM) servo and three-phase drives requiring high dynamic range control and low noise. It also can be used in Uninterruptible Power Supplies (UPS), Switched-Mode Power Supplies (SMPS), and other power circuits requiring high switch repetition rates. IGBT improves dynamic performance and efficiency and reduced the level of audible noise. It is equally suitable in resonant-mode converter circuits. Optimized IGBT is available for both low conduction loss and low switching loss.



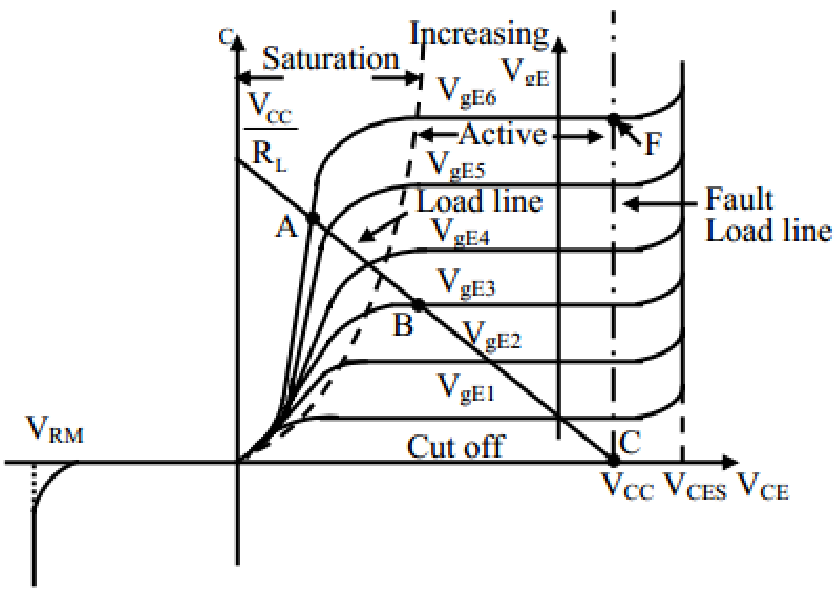
Schematic view of a generic N-channel IGBT

Output Characteristics

It has a family of curves, each of which corresponds to a different gate-to-emitter voltage (V_{GE}). The collector current (I_C) is measured as a function of collector-emitter voltage (V_{CE}) with the gate-emitter voltage (V_{GE}) constant.

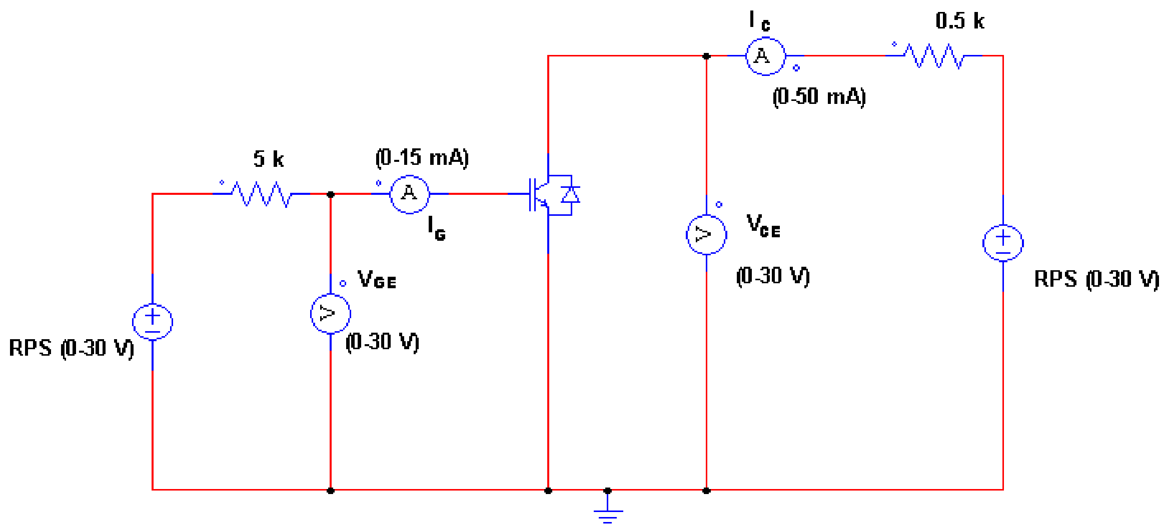


IGBT symbol and parameters



Output Characteristics

Circuit Diagram:



(Note: The resistance values may differ depending upon device rating)

Procedure:

1. Make the connections as per the circuit diagram.
2. Keep both the DC supplies at zero initially.
3. Adjust V_{GE}=5 V (say) and then vary V_{CE} in steps and note down the variation of I_C.
4. Now change the value of V_{GE} to different values (8 V, 12 V…) and repeat the process.
5. Plot the graph of I_C v/s V_{CE} for different values of V_{GE}.

Observation:

V_{GE} = 5V		V_{GE} = 8V		V_{GE} = 12V	
V_{CE}	I_C	V_{CE}	I_C	V_{CE}	I_C

EXPERIMENT–3

AIM: - To study V-I characteristics of MOSFET

Apparatus: MOSFET

Regulated Power Supply (0-30 V)

Resistors

Voltmeters (0-30 V),

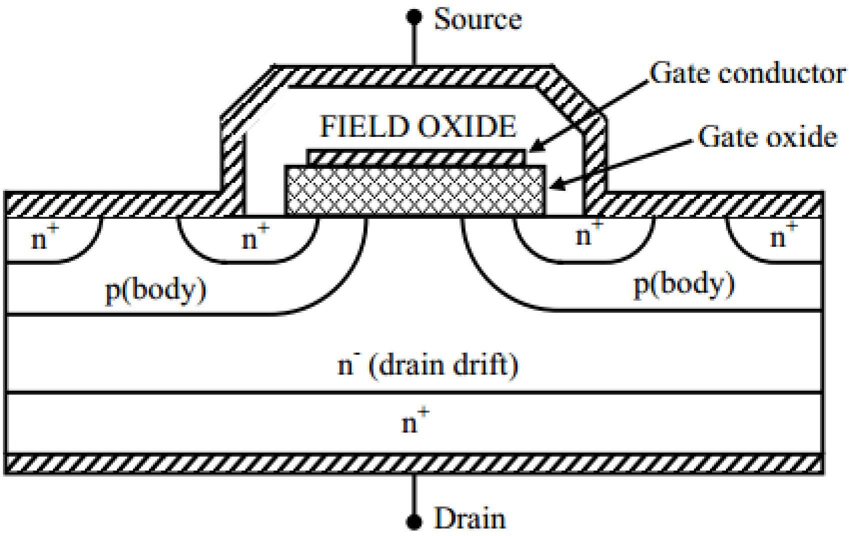
Ammeters (0-15 mA, 0-50 mA),

Breadboard, Connecting wires

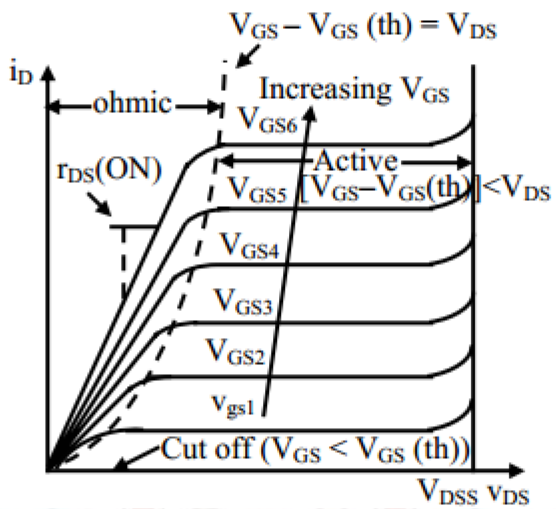
Theory:-

The reliance of the power electronics industry upon bipolar devices was challenged by the introduction of a new MOS gate controlled power device technology in the 1980s. The power MOS field effect transistor (MOSFET) evolved from the MOS integrated circuit technology. The new device promised extremely low input power levels and no inherent limitation to theswitching speed. Thus, it opened up the possibility of increasing the operating frequency inpower electronic systems resulting in reduction in size and weight. The initial claims of infinite current gain for the power MOSFET were, however, diluted by the need to design the gate drive circuit to account for the pulse currents required to charge and discharge the high input capacitance of these devices. At high frequency of operation the required gate drive power becomes substantial. MOSFETs also have comparatively higher on state resistance per unit area of the device cross section which increases with the blocking voltage rating of the device. Consequently, the use of MOSFET has been restricted to low voltage (less than about 500 volts) applications where the ON state resistance reaches acceptable values. Inherently fast switching speed of these devices can be effectively utilized to increase the switching frequency beyond several hundred kHz.

From the point of view of the operating principle a MOSFET is a voltage controlled majority carrier device. As the name suggests, movement of majority carriers in a MOSFET is controlled by the voltage applied on the control electrode (called gate) which is insulated by athin metal oxide layer from the bulk semiconductor body. The electric field produced by the gate voltage modulates the conductivity of the semiconductor material in the region between the main current carrying terminals called the Drain (D) and the Source (S). Power MOSFETs, just like their integrated circuit counterpart, can be of two types (i) depletion type and (ii) enhancement type. Both of these can be either n- channel type or p-channel type depending on the nature of the bulk semiconductor.

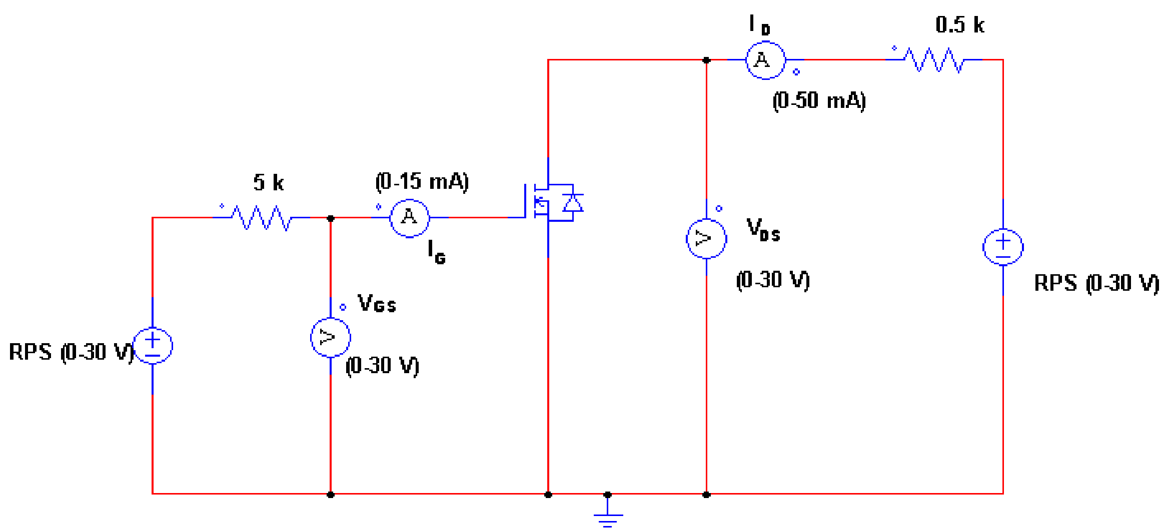


Structure of a Power MOSFET



Output Characteristics

Circuit Diagram:



(Note: The resistance values may differ depending upon device rating)

Procedure:

1. Make the connections as per the circuit diagram.
2. Keep both the DC supplies at zero initially.
3. Adjust V_{GS}=0.5 V (say) and then vary V_{DS} in steps and note down the variation of I_D.
4. Now change the value of V_{GS} to different values (1 V, 1.5 V…) and repeat the process.
5. Plot the graph of I_D v/s V_{DS} for different values of V_{GS}.

Observation:

V_{GS} = 0.5V		V_{GS} = 1V		V_{GS} = 1.5V	
V_{DS}	I_D	V_{DS}	I_D	V_{DS}	I_D

EXPERIMENT–4

AIM: - To study V-I characteristics of DIAC

Apparatus: DIAC

Regulated Power Supply (0-50 V)

Resistance

Voltmeters (0-50 V),

Ammeter (0-100 mA),

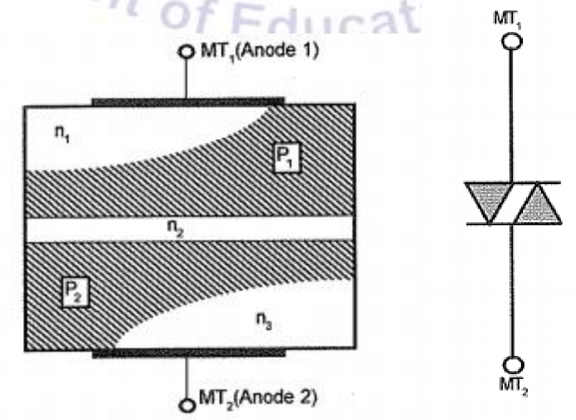
Breadboard, Connecting wires

Theory:-

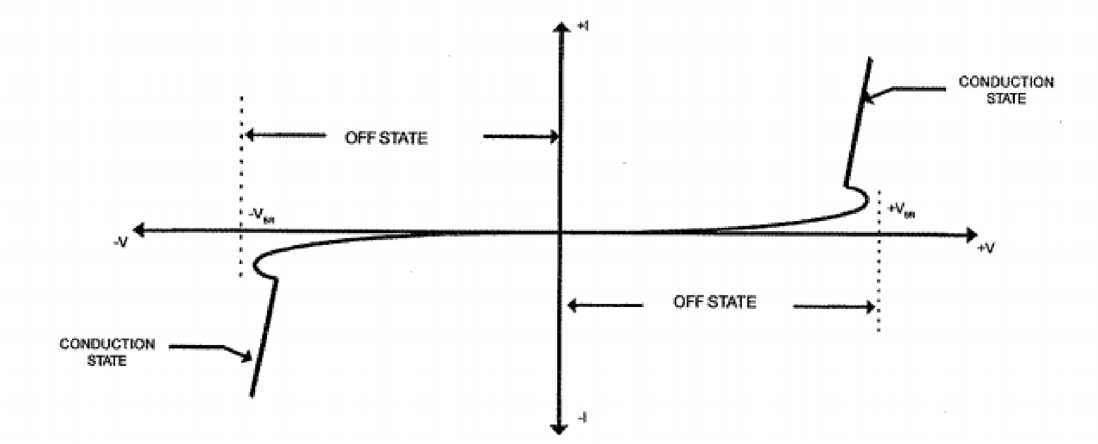
A DIAC is equivalent to two diodes connected back to back. Also, it is a bidirectional device, in contrast to the diode, which is a unidirectional device, having reverse blocking characteristic, preventing the flow of current from Cathode to Anode. So, when it (DIAC) is in conduction mode, current flows in both directions (forward and reverse). The DIAC, or diode for alternating current, is a trigger diode that conducts currentonly after its breakdown voltage has been exceeded momentarily. When this occurs,the resistance of the DIAC abruptly decreases, leading to a sharp decrease in thevoltage drop across the DIAC and, usually, a sharp increase in current flow throughtheDIAC. The DIAC remains "in conduction" until the current flow through it dropsbelow a value characteristic for the device, called the holding current. Below thisvalue, the DIAC switches back to its high-resistance (non-conducting) state. Thisbehavior is bidirectional, meaning typically the same for both directions of currentflow.

Most DIACs have a breakdown voltage around 30 V. DIACs have no gate electrode, unlike some other thyristors they are commonly usedto trigger, such as TRIACs. Some TRIACs contain a built-in DIAC in series with theTRIAC's "gate" terminal for this purpose.

DIACs are also called symmetrical trigger diodes due to the symmetry of theircharacteristic curve. Because DIACs are bidirectional devices, their terminals are notlabeled as anode and cathode but as A1 and A2 or MT1 ("Main Terminal") and MT2.

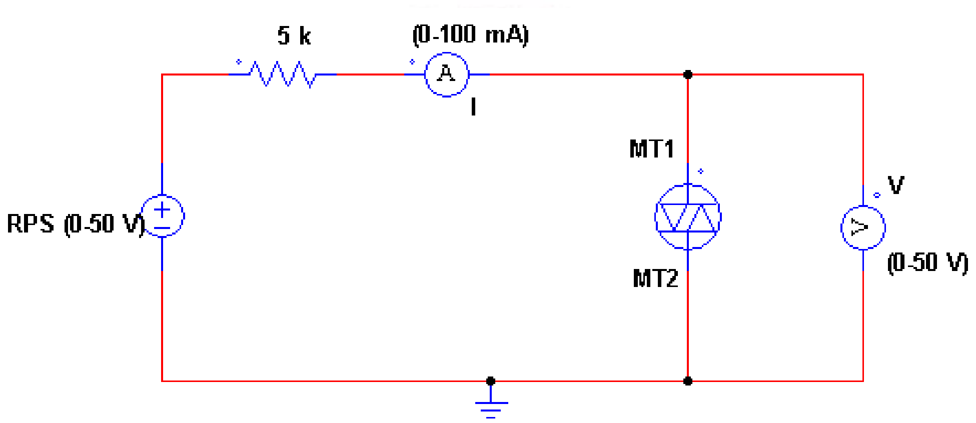


Schematic and Symbol



Characteristics

Circuit Diagram:



Procedure:

1. Make the connections as per circuit diagram.
2. Initially keep the input voltage to zero.
3. Then increase the input voltage in small steps and note down value of the voltage across the DIAC and corresponding current through the DIAC in the observation table.
4. Initially the value of current through the DIAC will be in micro- ampere until the DIAC starts conducting. After that, the value of the current will be determined by the value of the load connected in the circuit.
5. Take 8 to 10 readings for DIAC voltage and current.
6. Now bring input voltage back to zero.
7. Reverse the terminal MT_1 and MT_2 of the DIAC and take another set of the reading by repeating the above steps.
8. Plot the V-I characteristic of the DIAC on the graph paper.

Observation:

Sr no.	With MT1 +ve		With MT2 +ve	
	V	I	V	I

Continue the table

EXPERIMENT–5

AIM: - To study Full Wave Fully Controlled SCR Converter

Apparatus: Trainer Kit

Patch Chords

Oscilloscope

Theory:-

Single phase uncontrolled rectifiers are extensively used in a number of power electronic based converters. In most cases they are used to provide an intermediate unregulated dc voltage source which is further processed to obtain a regulated dc or ac output. They have, in general, been proved to be efficient and robust power stages.

However, they suffer from a few disadvantages. The main among them is their inability to control the output dc voltage / current magnitude when the input ac voltage and load parameters remain fixed. They are also unidirectional in the sense that they allow electrical power to flow from the ac side to the dc side only.

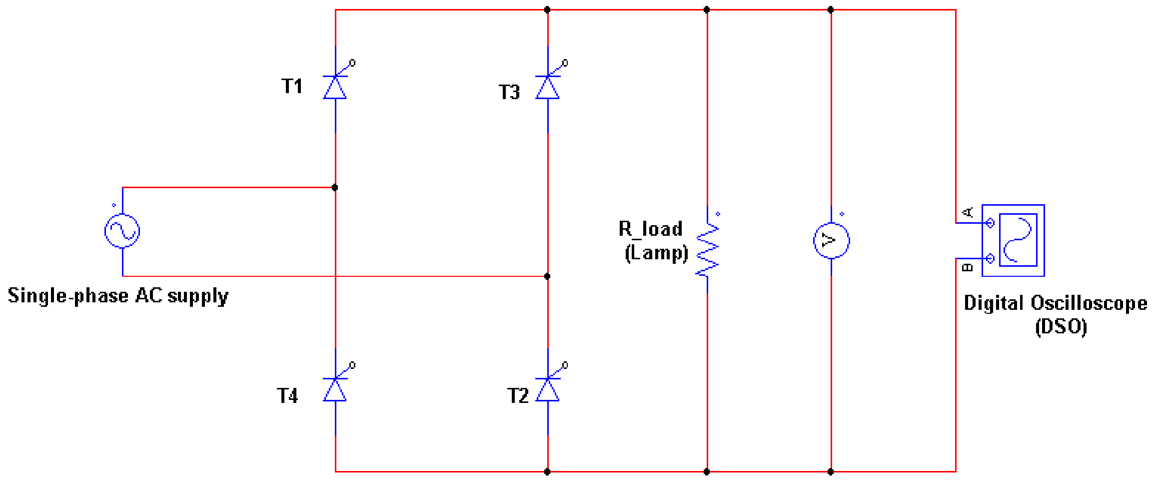
These two disadvantages are the direct consequences of using power diodes in these converters which can block voltage only in one direction. These two disadvantages are overcome if the diodes are replaced by thyristors; the resulting converters are called fully controlled converters.

Thyristors are semi-controlled devices which can be turned ON by applying a current pulse at its gate terminal at a desired instance. However, they cannot be turned off from the gate terminals. Therefore, the fully controlled converter continues to exhibit load dependent output voltage / current waveforms as in the case of their uncontrolled counterpart. However, since the thyristor can block forward voltage, the output voltage / current magnitude can be controlled by controlling the turn on instants of the thyristors.

Full bridge is the most popular configuration used with single phase fully controlled rectifiers.

From the circuit diagram of below, it is clear that for any load current to flow at least one thyristor from the top group (T1, T3) and one thyristor from the bottom group (T2, T4) must conduct. It can also be argued that neither T1-T3nor T2-T4 can conduct simultaneously. For example whenever T3 and T4 are in the forward blocking state and a gate pulse is applied to them, they turn ON and at the same time a negative voltage is applied across T1 and T2 commutating them immediately. Similar argument holds for T1 and T2. For the same reason T1-T4 or T2-T3 cannot conduct simultaneously. Therefore, the only possible conduction modes when the current i_0 can flow are T1-T2 and T3-T4. Of course it is possible that at a given moment none of the thyristors conduct. This situation will typically occur when the load current becomes zero in between the firings of T1-T2 and T3-T4. Once the load current becomes zero all thyristors remain off. In this mode the load current remains zero. Consequently the converter is said to be operating in the discontinuous conduction mode.

Circuit Diagram:



Procedure:

1. Make the connections as per the circuit diagram.
2. Keeping the firing angle controlling pot at maximum position, switch-on the kit supply.
3. Now vary the firing angle pot in steps and at each step note down the value of firing angle form the output voltage waveform in DSO. Also note the output voltage from voltmeter/multi-meter.
4. Plot the sample graph of Input and Output voltage for minimum two values of firing angle.

Caution:

The DSO plug must be connected to isolated power supply.

Observation:

SL. No.	Firing Angle	Peak input voltage	Average DC output	
			Calculated	Measured

Formula:

$$V_o = \frac{1}{\Pi}\int_{\alpha}^{\pi} V_m Sin\omega t d(\omega t) = \frac{V_m}{\Pi}(1 + Cos\alpha)$$

Sample Waveform:

Compiled by: Md Aftab Alam, EEN, AU

EXPERIMENT–6

AIM: - To study Full Wave Fully Controlled SCR Converter with R-L load and effect of Freewheeling diode.

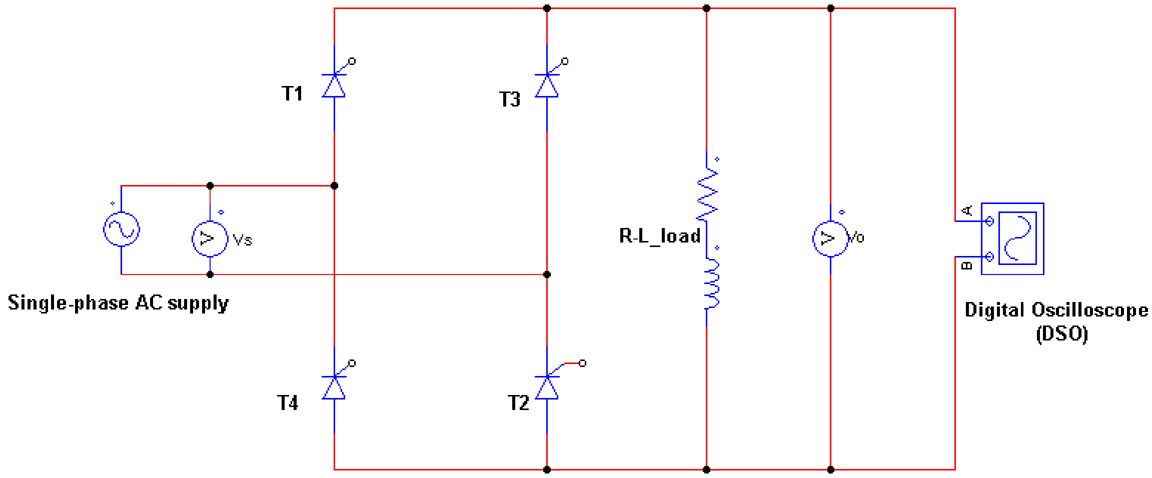
Apparatus: Trainer Kit
Patch Chords
Oscilloscope

Theory:-

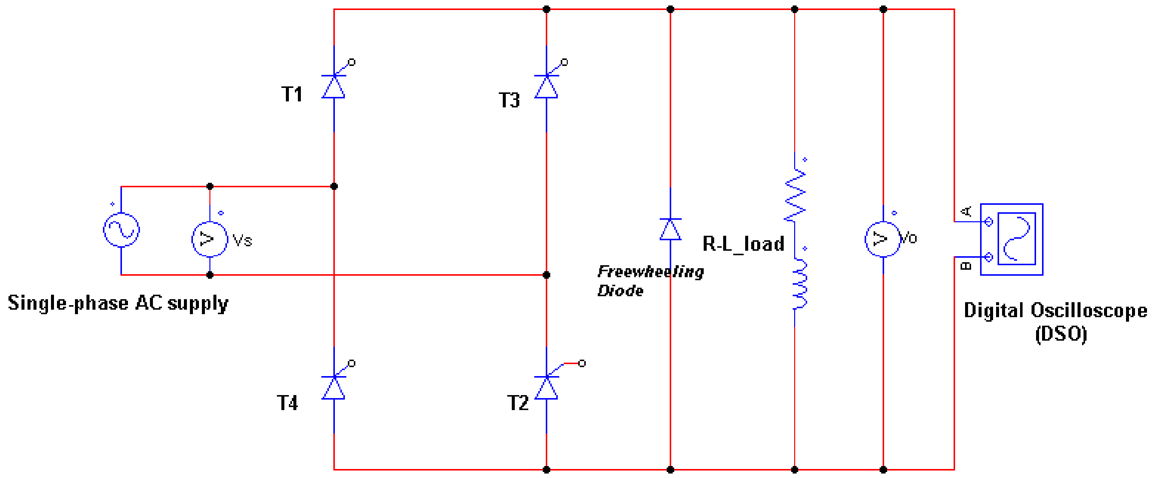
Due the presence of inductance in load, the output current cannot follow the output voltage instantly and lags behind. So, while at the end of positive half cycle the thyristors T1,T2 are reverse biased but the energy in the inductor continues to force the current in the same direction. This makes the thyristors T1-T2 pair to conduct the negative part of the input voltage also, as T3-T4 pair cannot conduct current in positive direction. After the inductor is de-energized at the extinction angle β, the T1-T2 pair starts conducting as they are already reverse biased. The pair T3-T4 is then fired at (π+α) and conducts in the negative half cycle of source voltage. Again at the end of negative half cycle the inductor is energized and forces the T3-T4 pair to carry the current beyond 2π and the process repeats.

Now if a freewheeling diode is connected across the output terminals, the thyristors are relieved of carrying the negative current. As soon as the thyristors are reverse biased, and next pair of thyristors are not fired, the diode gets forward biased due to inductor energy and the output current circulates through load and freewheeling diode. The inductor thus gets discharged and diode stops conducting.

Circuit Diagram:



Without Freewheeling Diode



With Freewheeling Diode

Procedure:

1. Make the connections as per the circuit diagram.
2. Keeping the firing angle controlling pot at maximum position, switch-on the kit supply.
3. Now vary the firing angle pot in steps and at each step note down the value of firing angle and extinction angle (for case without freewheeling diode) form the output voltage waveform in DSO. Also note the output voltage from voltmeter/multi-meter.
4. Plot the sample graph of Input and Output voltage for minimum two values of firing angle.

Caution:

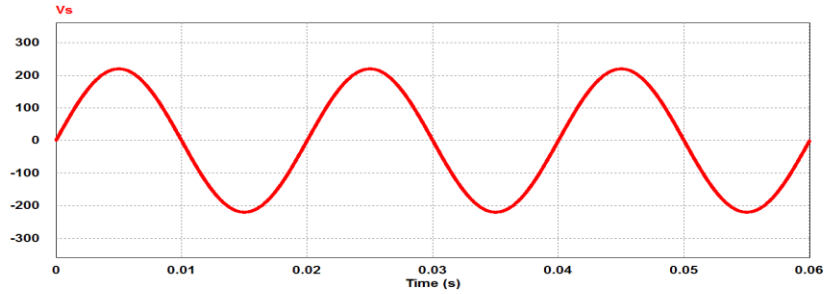
The DSO plug must be connected to isolated power supply.

Observation:

SL. No.	Firing Angle (α)	Extinction Angle (β)	Average DC output

For second case i.e. with freewheeling diode, the extinction angle β will not be there.

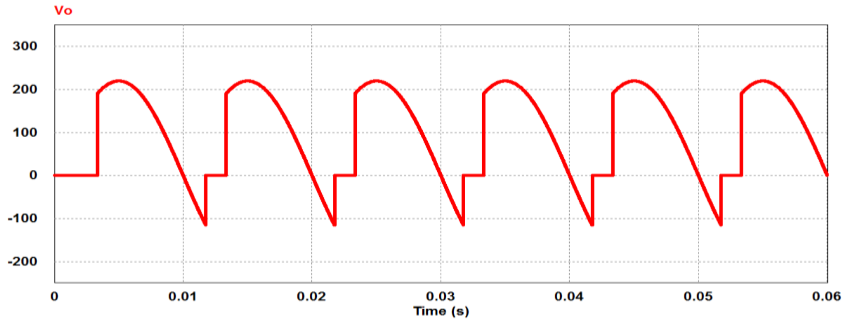
Sample Waveform:



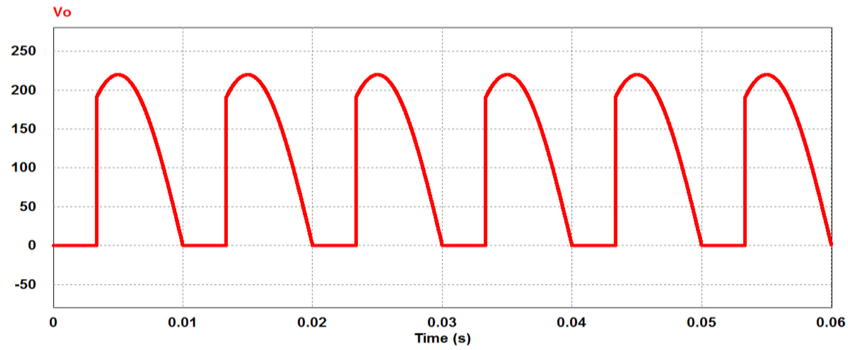
Vs

Ig1,2

Ig3,4



Vo without freewheeling diode



Vo with freewheeling diode

EXPERIMENT–7

AIM: - To study Full Wave Fully Controlled AC Voltage Regulator

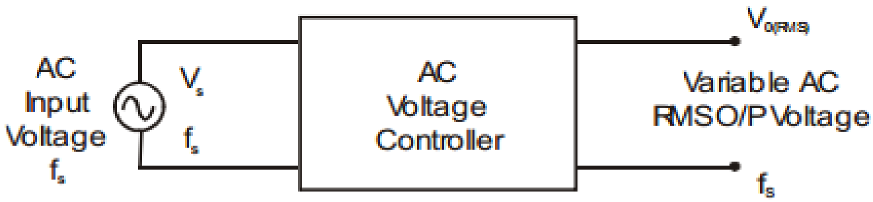
Apparatus: Trainer Kit

Patch Chords

Oscilloscope

Theory:-

AC voltage controllers (ac line voltage controllers) are employed to vary the RMS value of the alternating voltage applied to a load circuit by introducing Thyristors between the load and a constant voltage ac source. The RMS value of alternating voltage applied to a load circuit is controlled by controlling the triggering angle of the Thyristors in the ac voltage controller circuits. In brief, an ac voltage controller is a type of thyristor power converter which is used to convert a fixed voltage, fixed frequency ac input supply to obtain a variable voltage ac output. The RMS value of the ac output voltage and the ac power flow to the load is controlled by varying (adjusting) the trigger angle 'α'.



There are two different types of thyristor control used in practice to control the ac power flow

- On-Off control
- Phase control

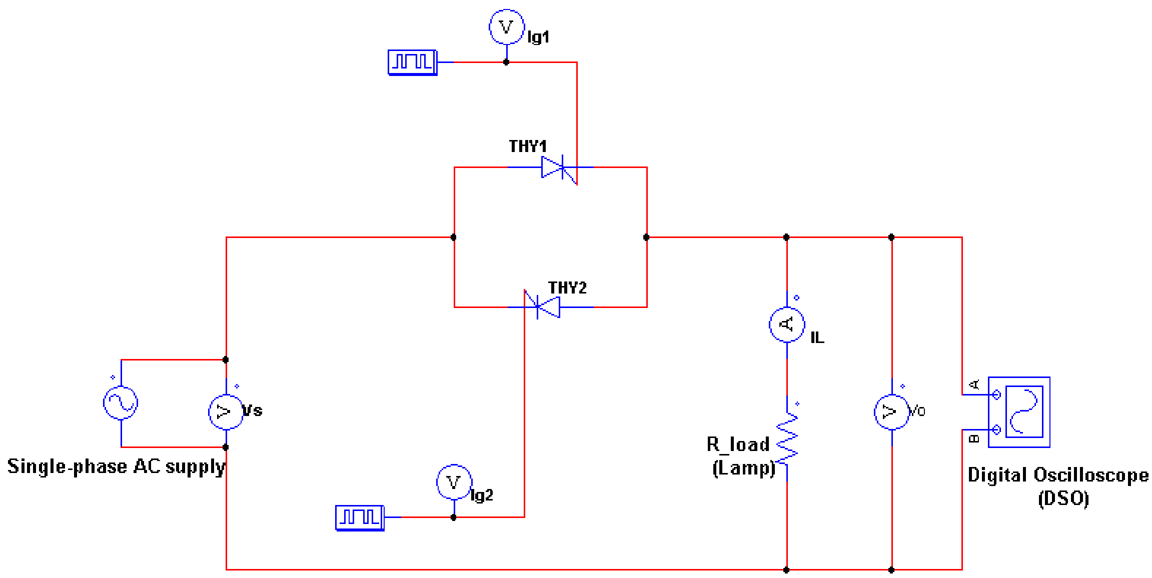
These are the two ac output voltage control techniques.

In On-Off control technique Thyristors are used as switches to connect the load circuit to the ac supply (source) for a few cycles of the input ac supply and then to disconnect it for few input cycles. The Thyristors thus act as a high speed contactor (or high speed ac switch).

In phase control the Thyristors are used as switches to connect the load circuit to the input ac supply, for a part of every input cycle. That is the ac supply voltage is chopped using Thyristors during a part of each input cycle. The thyristor switch is turned on for a part of every half cycle, so that input supply voltage appears across the load and then turned off during the remaining part of input half cycle to disconnect the ac supply from the load.

By controlling the phase angle or the trigger angle 'α' (delay angle), the output RMS voltage across the load can be controlled. The trigger delay angle 'α' is defined as the phase angle (the value of ωt) at which the thyristor turns on and the load current begins to flow.

Circuit Diagram:



Procedure:

5. Make the connections as per the circuit diagram.
6. Keeping the firing angle controlling pot at maximum position, switch-on the kit supply.
7. Now vary the firing angle pot in steps and at each step note down the value of firing angle and form the output voltage waveform in DSO. Also note the output voltage from voltmeter/multi-meter.
8. Plot the sample graph of Input and Output voltage for minimum two values of firing angle.

Formula:

$$V_{o,\mathrm{rms}} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} [V_m \sin(\omega t)]^2 \, d(\omega t)} = \frac{V_m}{\sqrt{2}}\sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin(2\alpha)}{2\pi}}$$

Caution:

The DSO plug must be connected to isolated power supply.

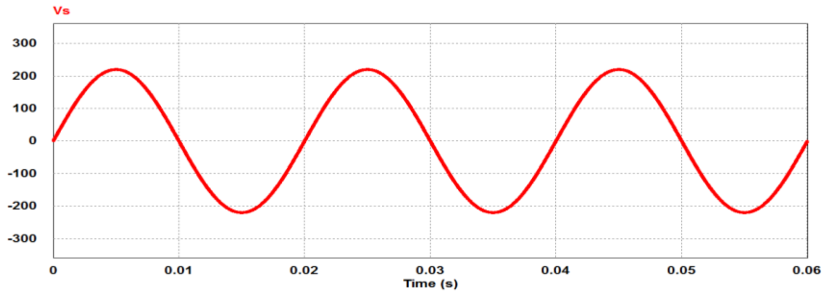
In the above formula, π and α (other than inside sin) must be in radians. The α inside sin should be put depending upon mode of calculator (degree or radian).

Observation:

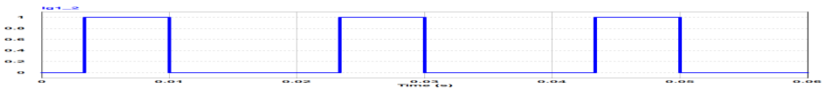
Vm=_______

SL. No.	Firing Angle (α) (in radians)	Firing Angle (α) (in degrees)	RMS Output voltage	
			Measured	Calculated

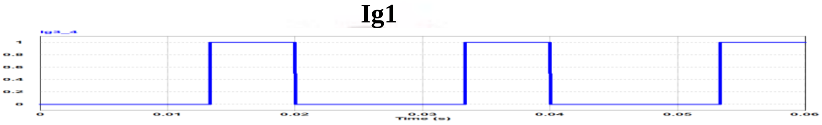
Sample Waveform:



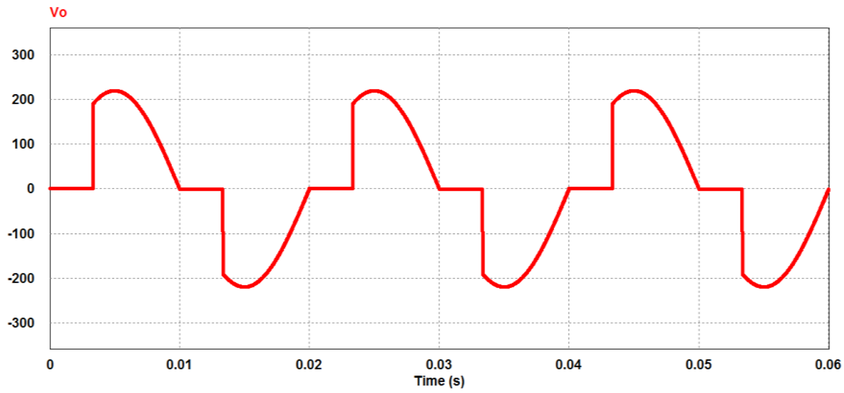
Vs



Ig1



Ig2



Vo

EXPERIMENT–8

AIM: - To study Mid-Point Cycloconverter

Apparatus: Trainer Kit

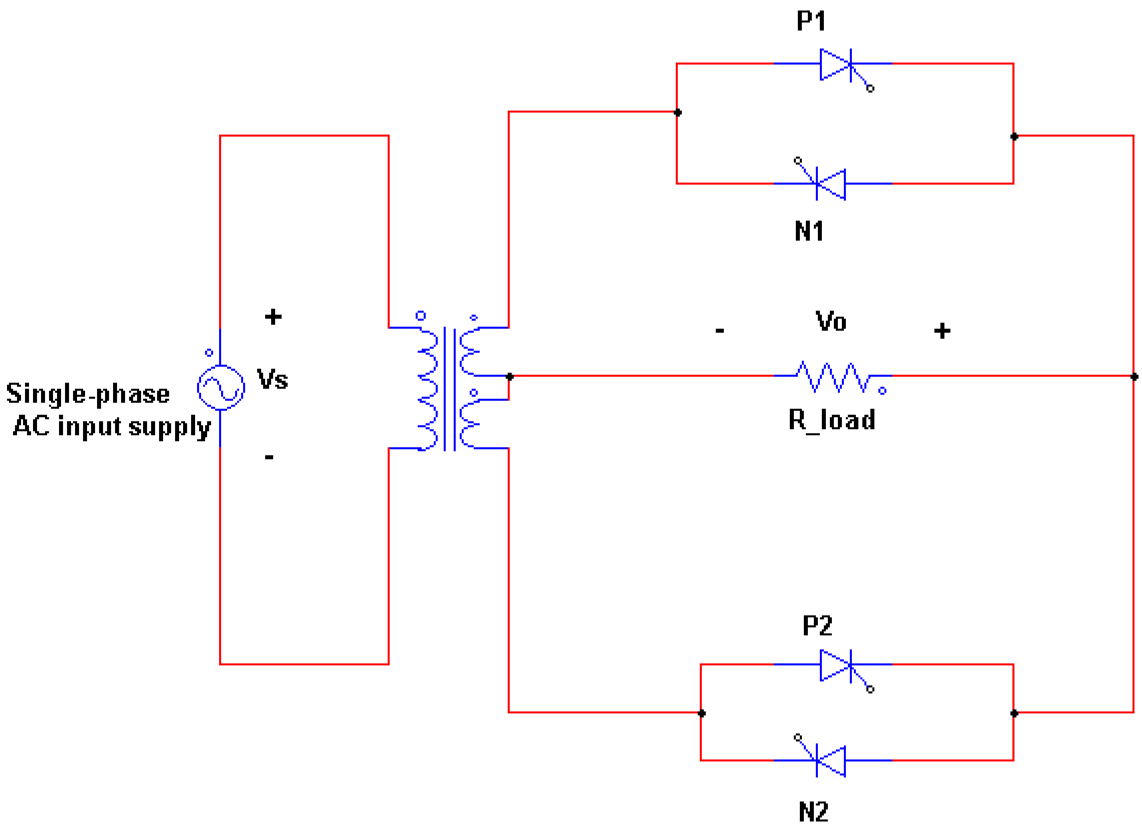
Patch Chords

Oscilloscope

Theory:-

Cycloconverter is the single stage AC frequency divider circuit. The input and output both are AC but the output frequency is usually the fraction of input frequency. (Output frequency higher than input frequency is also possible, but standard use of Cycloconverter is to obtain an AC output that is having the frequency which is fraction of input frequency, say 1/3 or 1/4). The output voltage magnitude too can be controlled through control of firing pulses of the switching device, usually line commutated thyristors. Thus a Cycloconverter has the facility for continuous and independent control over both its output frequency and voltage.

Circuit Diagram:



Procedure:

1. Make the connections as per the circuit diagram.
2. Keep firing mode selector switch such that the firing frequency is 25 Hz.
3. Switch on the supply to the trainer kit.
4. Observe the voltage waveform across the load.
5. Switch off the supply and change the firing mode to 12.5 Hz with the help of selector switch.
6. Again switch on the supply and observe the output voltage waveform.

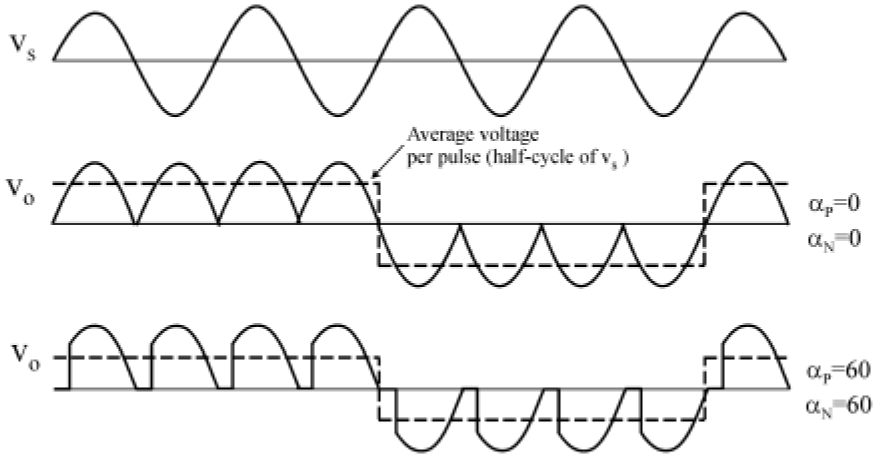
Caution:

The DSO plug must be connected to isolated power supply.

Observation:

The output voltage frequency is the fraction of input supply frequency.

Sample Waveform:



Experiment 9: Study of Uninterruptible Power Supply (UPS)

A UPS system is an alternate or backup source of power with the electric utility company being the primary source. The UPS provides protection of load against line frequency variations, elimination of power line noise and voltage transients, voltage regulation, and uninterruptible power for critical loads during failures of normal utility source. A UPS can be considered a source of standby power or emergency power depending on the nature of the critical loads. The amount of power that the UPS must supply also depends on these specific needs. These needs can include emergency lighting for evacuation, emergency perimeter lighting for security, orderly shutdown of manufacturing or computer operations, continued operation of life support or critical medical equipment, safe operation of equipment during sags and brownouts, and a combination of the preceding needs.

Put simply, a UPS is a device that:

- Provides backup power when utility power fails, either long enough for critical equipment to shut down gracefully so that no data is lost, or long enough to keep required loads operational until a generator comes online.
- Conditions incoming power so that all-too-common sags and surges don't damage sensitive electronic gear.

UPSs come in three major varieties, which are also known as topologies:

1. **Single-conversion systems**

In normal operation, these feed incoming utility AC power to IT equipment. If the AC input supply falls out of predefined limits, the UPS utilizes its inverter to draw current from the battery, and also disconnects the AC input supply to prevent back feed from the inverter to the utility. The UPS stays on battery power until the AC input returns to normal tolerances or the battery runs out of power, whichever happens first. Two of the most popular single-conversion designs are standby and line-interactive:

• Standby UPSs allow critical equipments to run off utility power until the UPS detects a problem, at which point it switches to battery power. Some standby UPS designs incorporate transformers or other devices to provide limited power conditioning as well.

• Line-interactive UPSs regulate input utility voltage up or down as necessary before allowing it to pass through to protected equipments. However, like standby UPSs, they use their battery to guard against frequency abnormalities.

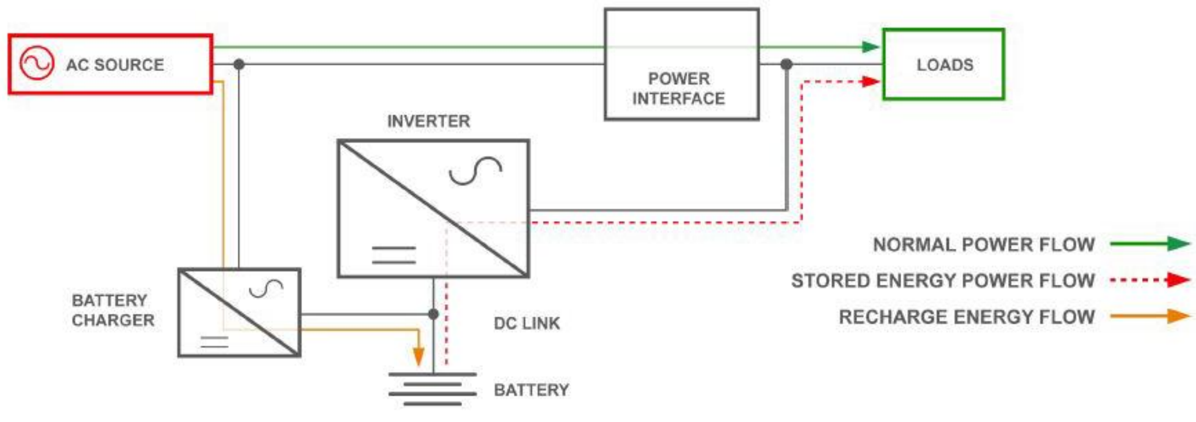


Figure: Internal design of a line-interactive UPS.

2. **Double-conversion systems**

As the name suggests, these devices convert power twice. First, an input rectifier converts AC power into DC and feeds it to an output inverter. The output inverter then processes the power back to AC before sending it on to critical equipments. This double-conversion process isolates critical loads from raw utility power completely, ensuring that critical equipment receives only clean, reliable electricity.

In normal operation, a double-conversion UPS continually processes power twice. If the AC input supply falls out of predefined limits, however, the input rectifier shuts off and the output inverter begins drawing power from the battery instead. The UPS continues to utilize battery power until the AC input returns to normal tolerances or the battery runs out of power, whichever occurs sooner. In case of a severe overload of the inverter, or a failure of the rectifier or inverter, the static switch bypass path is turned on quickly, to support the output loads.

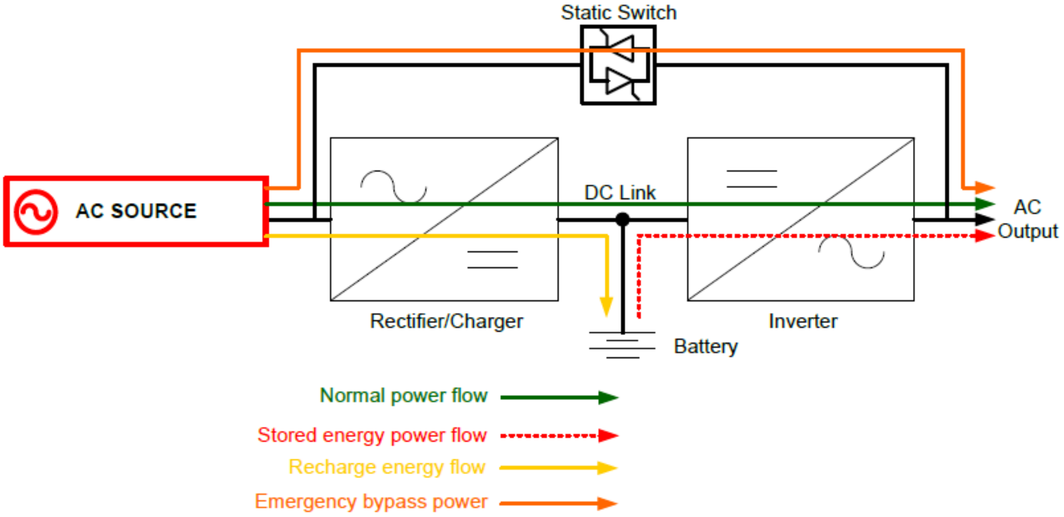


Figure: Internal design of a double-conversion UPS

3. Multi-mode systems

These combine features of both single- and double-conversion technologies while providing substantial improvements in both efficiency and reliability:

• Under normal conditions, the system operates in line-interactive mode, saving energy and money while also keeping voltage within safe tolerances and resolving common anomalies found in utility power.

• If AC input power falls outside of preset tolerances for line-interactive mode, the system automatically switches to double-conversion mode, completely isolating critical equipments from the incoming AC source.

• If AC input power falls outside the tolerances of the double-conversion rectifier, or goes out altogether, the UPS uses the battery to keep supported loads up and running. When the generator comes online, the UPS switches to double-conversion mode until input power stabilizes. Then it transitions back to high-efficiency line-interactive mode.

Multi-mode UPSs are designed to dynamically strike an ideal balance between efficiency and protection. Under normal conditions, they provide maximum efficiency. When problems occur, however, they automatically sacrifice some efficiency to deliver maximum levels of protection.

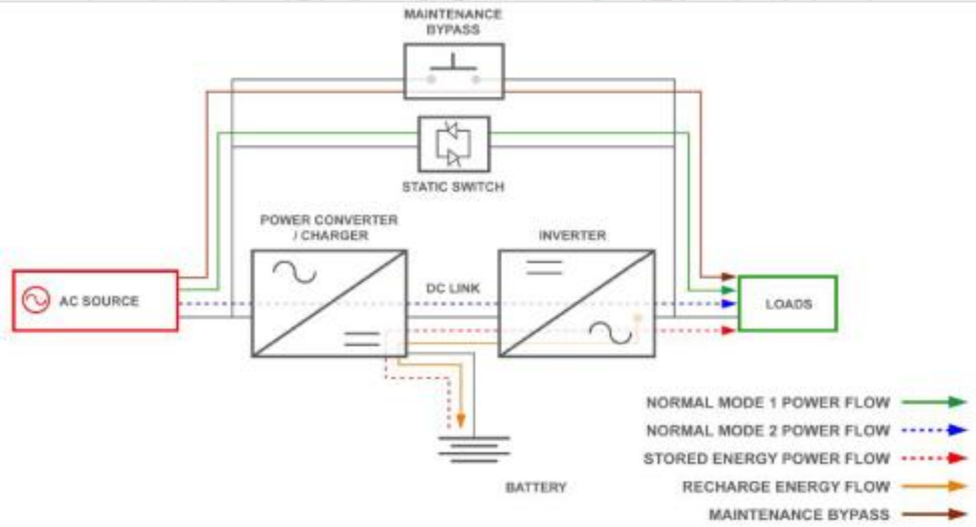


Figure: Internal design of a multi-mode UPS