QMP 7.1 D/F

Channabasaveshwara Institute of Technology
(Affiliated to VTU, Belgaum & Approved by AICTE, New Delhi)
(**NAAC Accredited & ISO 9001:2015 Certified Institution)**
NH 206 (B.H. Road), Gubbi, Tumkur – 572 216. Karnataka.

Department of Electrical & Electronics Engineering

POWER ELECTRONICS LABORATORY

LAB MANUAL

BEEL504

(2024 – 25′)

Bachelor of Engineering

V Semester

NAME: ________________________________

USN: __________________________________

SECTION:__________BATCH:__________

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Department of Electrical & Electronics Engineering

POWER ELECTRONICS LAB

Version 1.1

Prepared by:
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Reviewed by:
Prof. V C Kumar
Associate Professor

Approved by:
Prof. V C Kumar
Professor & Head,
Dept. of EEE

OUR VISION

To create centers of excellence in education and to serve the society by enhancing the quality of life through value based professional leadership.

OUR MISSION

- To provide high quality technical and professionally relevant education in a diverse learning environment.
- To provide the values that prepare students to lead their lives with personal integrity, professional ethics and civic responsibility in a global society.
- To prepare the next generation of skilled professionals to successfully compete in the diverse global market.
- To promote a campus environment that welcomes and honors women and men of all races, creeds and cultures, values and intellectual curiosity, pursuit of knowledge and academic integrity and freedom.
- To offer a wide variety of off-campus education and training programmes to individuals and groups.
- To stimulate collaborative efforts with industry, universities, government and professional societies.
- To facilitate public understanding of technical issues and achieve excellence in the operations of the institute.

QUALITY POLICY

Our organization delights customers (students, parents and society) by providing value added quality education to meet the national and international requirements. We also provide necessary steps to train the students for placement and continue to improve our methods of education to the students through effective quality management system, quality policy and quality objectives.

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

DEPARTMENT VISION
To establish a centre of excellence in Electrical and Electronics Engineering education and to foster the development of technically proficient professionals in Electrical Science and related fields while instilling a strong sense of ethics to serve the society efficiently.

DEPARTMENT MISSION	
M1	To provide competent human resources, and to ensure that our students receive top-notch education and mentorship, enabling them to excel in electrical and electronics engineering and allied fields.
M2	To provide quality infrastructure, and to create an environment conducive to innovative learning and research, empowering our students to explore the frontiers of Electrical Sciences and related disciplines.
M3	To foster strong collaborations with industry and research institutions, and to facilitate the exchange of knowledge and ideas, allowing our students and faculty to remain at the cutting edge of technological advancements and practical applications in the field..
M4	To emphasize social responsibility and professional ethics in our curriculum and community engagement, and to prepare our graduates to be conscientious leaders who use their expertise to benefit society, making a positive impact through their work in Electrical Sciences and allied fields..

‘Instructions to the Candidates’

1. Students should come with thorough preparation for the experiment to be conducted.

2. Students should come with proper dress code.

3. Students will not be permitted to attend the laboratory unless they bring the practical record fully completed in all respects pertaining to the experiment conducted in the previous class.

4. Experiment should be started only after the staff-in-charge has checked the circuit diagram.

5. All the calculations should be made in the observation / Manual / Work book. Specimen calculations for one set of readings have to be shown in the practical record.

6. Wherever graphs to be drawn, A-4 size graphs only should be used and the same should be firmly attached to the practical record.

7. Practical record should be neatly maintained.

8. They should obtain the signature of the staff-in-charge in the observation book after completing each experiment.

9. Theory regarding each experiment should be written in the practical record before procedure in your own words.

Instructions to the students’

1. Come prepared to the lab with relevant theory about the experiment you are conducting.
2. Before switching on the power supply, make sure that the voltage knobs are in minimum position and current knobs are in maximum position.
3. While using electrolytic capacitors, connect them in the right polarity.
4. Before doing the circuit connection, check the active components, CRO probes, equipment etc., for their good working condition.
5. Do not use the multimeter, if the low battery indication comes
6. While using function generators make sure that DC offset is off

Caution

1. **Don’t play with electricity.**
2. **Carelessness not only destroys the valuable equipment in the lab but also costs your life.**
3. **Mere conduction of the experiment without a clear knowledge of the theory is of no value.**
4. **Before you close the switch, think consequences.**
5. **Don’t close the switch until the faculty-in0charge checks the circuit.**

Course objectives & outcomes

Course objectives:

- To conduct experiments on semiconductor devices to obtain their static characteristics.
- To study different methods of triggering the SCR
- To study the performance of single phase controlled full wave rectifier and AC voltage controller with R and RL loads.
- To control the speed of a dc motor, universal motor and stepper motors.
- To study single phase full bridge inverter connected to resistive load.

Course outcomes:

At the end of the course the student will be able to:

- Obtain static characteristics of semiconductor devices to discuss their performance.
- Trigger the SCR by different methods
- Verify the performance of single phase controlled full wave rectifier and AC voltage controller with R and RL loads.
- Control the speed of a dc motor, universal motor and stepper motors
- Verify the performance of single phase full bridge inverter connected to resistive load.

Syllabus

POWER ELECTRONICS LAB

Course Code: BEEL504 **CIE Marks: 50**
Hrs/ Week: 03 **SEE Marks: 50**
Exam Hours: 03

1. Static characteristics of SCR.

2. Static characteristics of MOSFET & IGBT

3. Static characteristics of TRIAC.

4. SCR turn-on circuit using synchronized UJT relaxation oscillator.

5. SCR Digital triggering circuit for a single-phase controlled rectifier and AC voltage Regulator

6. Single-phase controlled full-wave rectifier with R, R-L and RLE Loads with and without Freewheeling diode.

7. A.C. voltage controller using TRIAC and DIAC combination connected to *R* and *RL* loads.

8. Speed control of a DC Motor Using single semi converter

9. Speed control of a stepper motor.

10. Speed control of universal motor using A.C. voltage regulator.

11. Speed control of a separately excited D.C. motor using an IGBT or MOSFET chopper.

12. Single phase MOSFET/IGBT Based PWM Inverter

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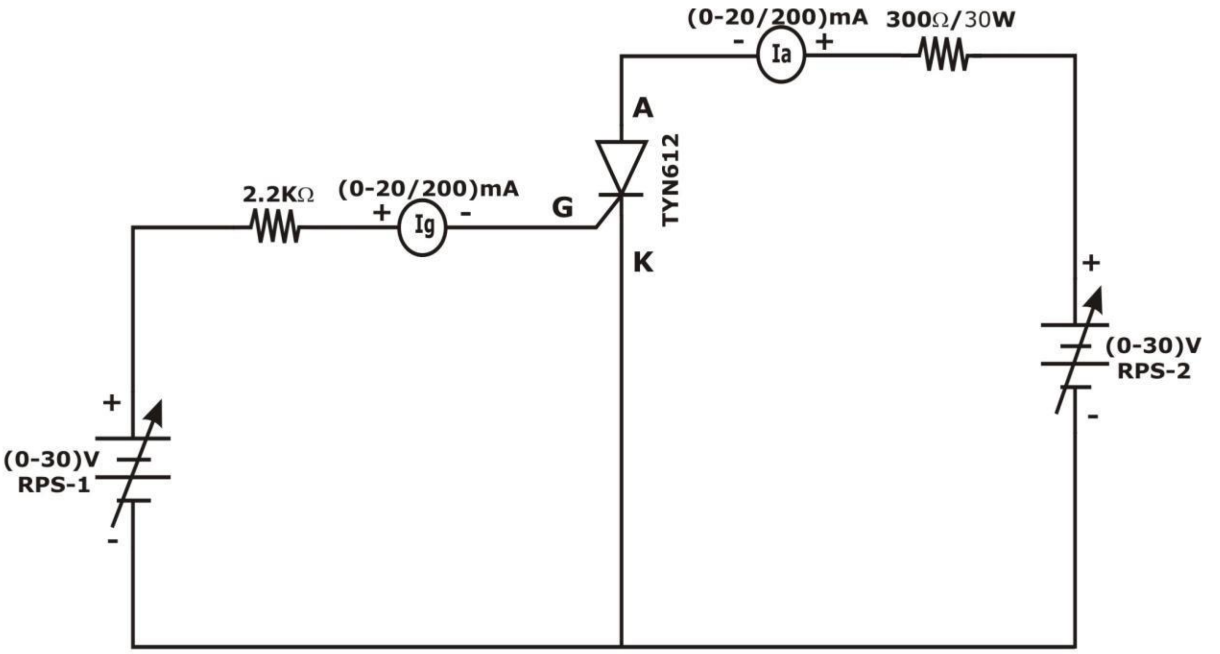
Note:

Sl. No.	Name of the Experiment	Date			Observation Marks (Max . 20)	Record Marks (Max. 10)	Signature (Student)	Signature (Faculty)
		Conduction	Repetition	Submission of Record				
Average								

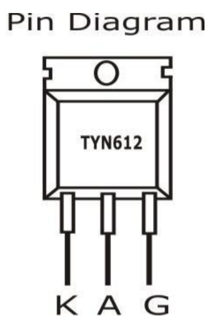
- **If the student fails to attend the regular lab, the experiment has to be completed in the same week. Then the manual/observation and record will be evaluated for 50% of maximum marks.**

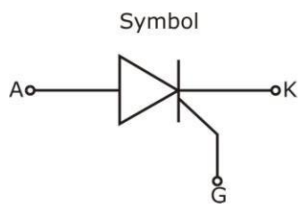
CONTENTS

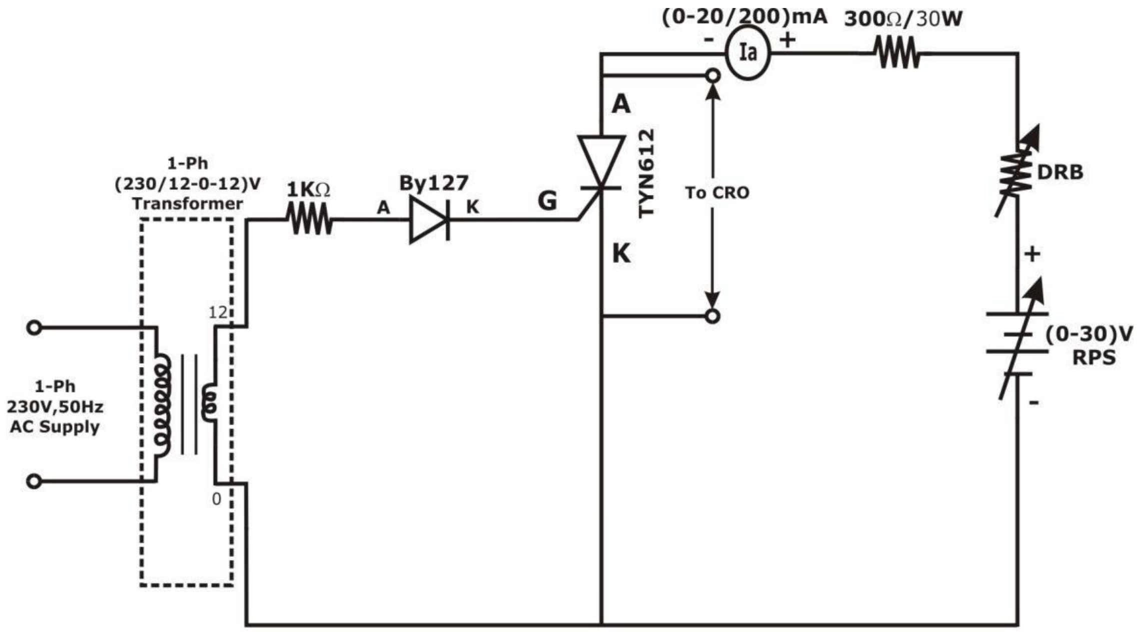
First Cycle Experiments



Circuit Diagram(1.1)
V-I Characteristics of SCR & its Holding current







Circuit Diagram(1.2)
To find the Latching current

Experiment No. 1 **Date:___/___/ _____**

Static Characteristics of Silicon Controlled Rectifier

Aim: To conduct an experiment to plot the static characteristics of an SCR and to find the Latching current, holding current and its on state resistance.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	SCR TYN612	-	1
2.	Resistors	As per design	1
3.	Milliammeter	0-20/200mA	2
4.	Multimeter	-	1
5.	Diode BY127	-	1
6.	Transformer	12 – 0 – 12	1
7.	DRB	-	1
8.	CRO with Probes	-	1
9.	Regulated power Supply (RPS)	0-30V	2

Procedure:

For V-I Characteristics:

1. Check the components/equipments of their correctness
2. Connection are made as shown in fig. 1.1
3. Both RPS-1 and RPS-2 should be in zero position and the supply switch is ON
4. <u>To find Gate current require to trigger the SCR:</u>
   Fix the anode voltage V_{AK} around 20V (by using the RPS-2). Increase the gate current gradually by using RPS-1 until the SCR turn on (V_{AK} meter becomes approximately 0.7V). Note down the gate current required to turn on the SCR.
5. Switch OFF RPS-1 & RPS-2 (Don't vary RPS-1 and bring RPS-2 to zero).
6. Increase the RPS-2 gradually until V_{AK} jumps to 0.7V , note down RPS-2 reading i.e., V_{BO}
7. Now gradually vary the RPS-2 and note down the corresponding readings of V_{AK} and I_A .
8. Repeat the steps 6 and 7 for some other gate current value
9. Graph between V_{AK} and I_A is plotted.

Design:

$V_{AK} = V_{AA} - I_A R_A$

$R_A = (V_{AA} - V_{AK}) / I_A$

Assume $V_{AAmax} = 30$ V, $V_{AKon} = 0.7$ V, and $I_A = 100$ mA

Then $R_A = 293\ \Omega$ choose $R_A = 300\ \Omega$

and $P_{RA} = (V_{AAmax} - V_{AKon})^2 / R_A = 2.86$ W

Therefore $R_A = 300\ \Omega$ / 10 W

Tabular Column:

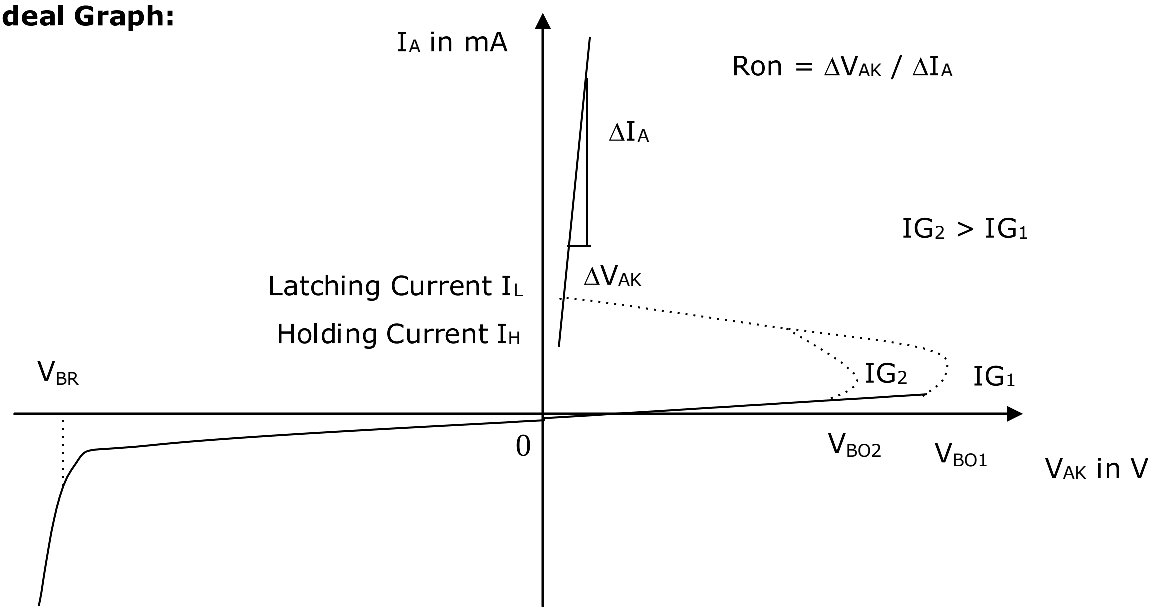
IG_1 =________mA V_{BO1} =________V

V_{AK} (V)	I_A (mA)

IG_2 =________mA V_{BO2} =________V

V_{AK} (V)	I_A (mA)

Ideal Graph:



For Holding Current:

1. Connections are made as shown in fig.1.1.
2. Keep V_{AK} around 20V by using RPS-2 and turn on the SCR by applying the required gate current by using RPS-1 (Now V_{AK} will be 0.7).
3. Bring back RPS-1 to zero position and switch off (i.e., remove gate current).
4. Gradually reduce the anode voltage by using RPS-2. Anode current also decreases slowly, at certain value, the anode current will jumps to zero suddenly. Note down this current value. (This is Holding Current).

For Latching Current:

1. Connections are made as shown in fig.1.2
2. Keep DRB in maximum resistance position.
3. Apply the V_{AK} around 20V by using RPS-2.
4. Observe the square waveform across the anode and cathode of SCR (now SCR is operating in Gate dependent mode).
5. Now reduce the DRB (from higher range to lower) gradually till the square wave disappears (now SCR is operating in Gate independent mode).
6. Note down the anode current at which the square wave disappear (This is Latching Current).

Calculation:

On state resistance $R_{on} = \Delta V_{AK} / \Delta I_A$ =___________Ω

Result:

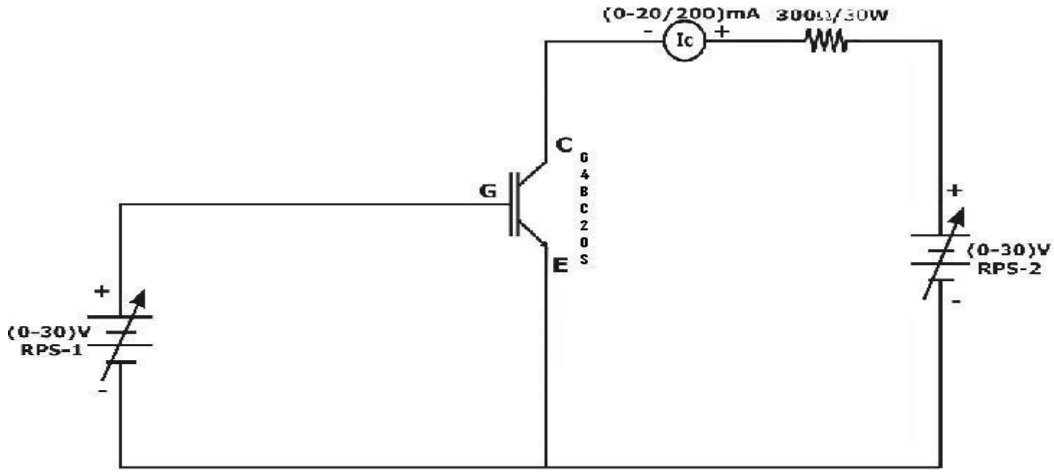
The on state resistance of SCR R_{on} =_________Ω

The holding current I_H =_________________mA

The latching current I_L =_________________mA

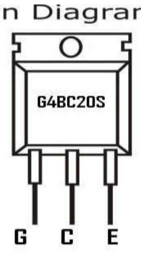
At gate current IG_1 =__________ma the break over voltage V_{BO1} =_________V

IG_2 =__________ma the break over voltage V_{BO2} =_________V

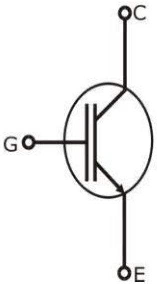


Circuit Diagram(2.1)
To find the Transfer and Output characteristics of IGBT

Pin Diagram

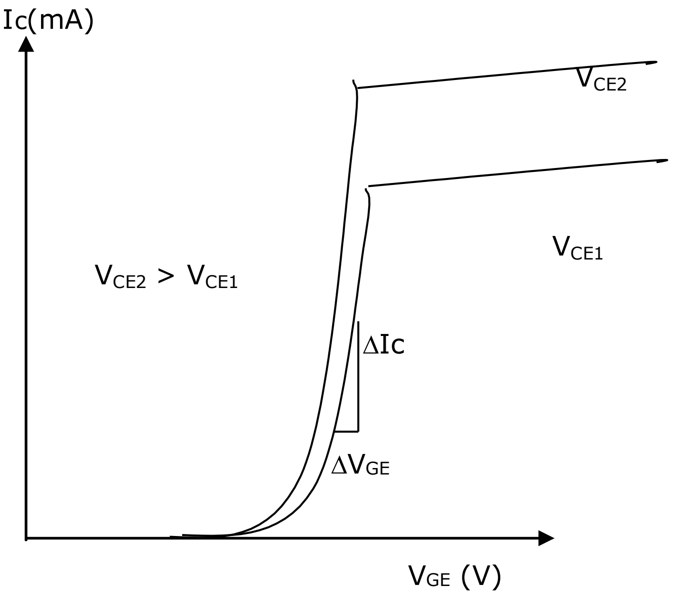


Symbol

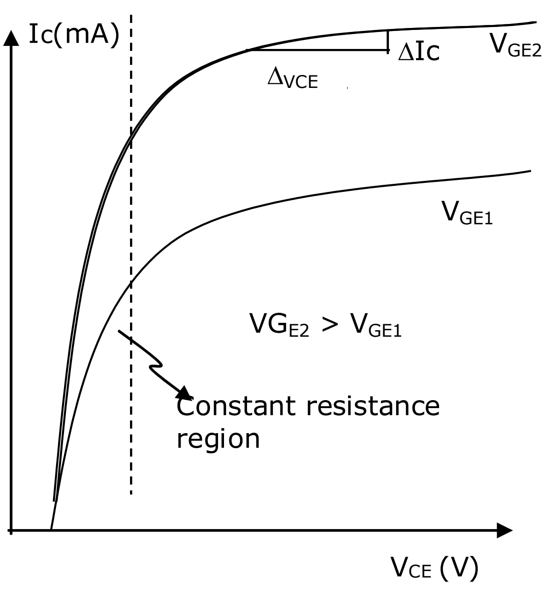


Ideal Graph:

Transfer Characteristics:



Output Characteristics:



Experiment No. 2 **Date:___/___/ ______**

Static Characteristics of MOSFET & IGBT

Aim: To conduct an experiment on IGBT to plot the transfer characteristics and output characteristics and to find the transconductance and output resistance.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	IGBT-G4BC20S	-	1
2.	Milliammeter	0-20/200mA	1
3.	Multimeter	-	1
4.	Resistor	300Ω	1
4.	Regulated power Supply	0-30V	2

Procedure:

Transfer Characteristics

1. Check the components/equipments of their correctness
2. Connections are made as shown in fig.2.1
3. Initially both RPS-1 and RPS-2 are kept at zero output position.
4. By varying the RPS-2, set V_{CE} around 1V
5. Now increase V_{GE} by varying the RPS-1 gradually and note down the corresponding collector current.
6. Repeat the steps 4 and 5 for some other V_{CE} value
7. Draw the graph between V_{GE} and I_c

Output Characteristics

1. Check the components/equipments of their correctness
2. Connections are made as shown in fig.2.1
3. Both RPS-1 and RPS-2 should be in zero output position and supply switch is ON
4. By varying RPS-1, set V_{GE} to some value (slightly greater than the Threshold voltage determined from the transfer characteristics)
5. Now increase the V_{CE} by varying the RPS-2 gradually and note down the corresponding collector current
6. Repeat the steps 4 and 5 for some other V_{GE} value
7. Graph between V_{CE} Vs I_c is plotted

Tabular Columns:

Transfer Characteristics

V_{CE1} =________________V

V_{GE} (V)	I_C (mA)

V_{CE2} =________________V

V_{GE} (V)	I_C (mA)

Output Characteristics

V_{GE1} =________________V

V_{CE} (V)	I_C (mA)

V_{GE2} =________________V

V_{CE} (V)	I_C (mA)

Calculations:

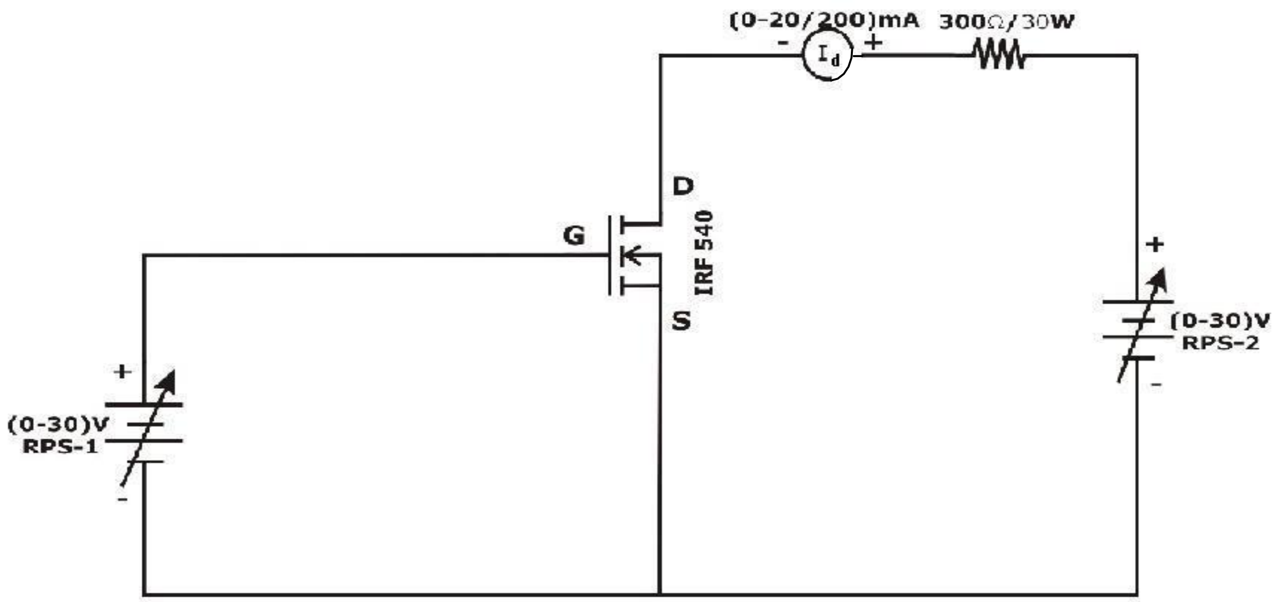
Trans conductance $g_m = \Delta I_c / \Delta V_{GE}$ mho

Output Resistance $R_o = \Delta V_{CE} / \Delta I_c$ Ω

Results:

The transconductance g_m =______________mho

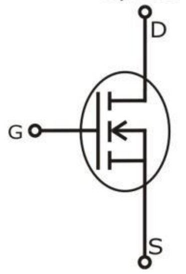
The output resistance R_o =_______________Ω



Circuit Diagram(3.1)
To find the Transfer and Drain characteristics of MOSFET

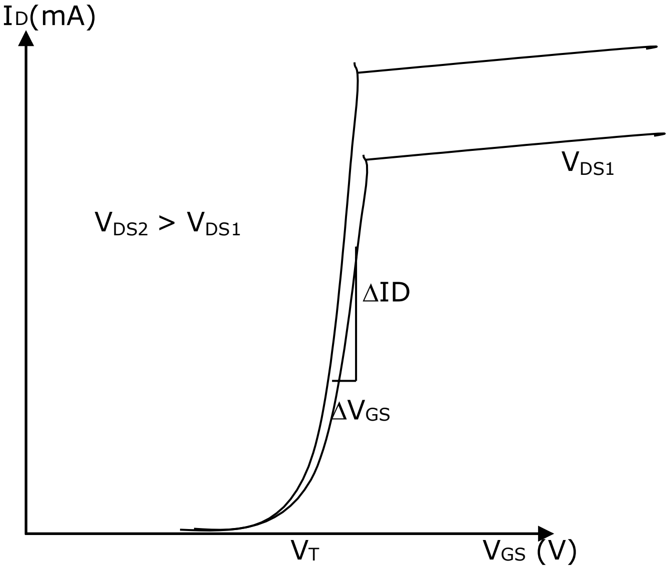
Pin Diagram

Symbol

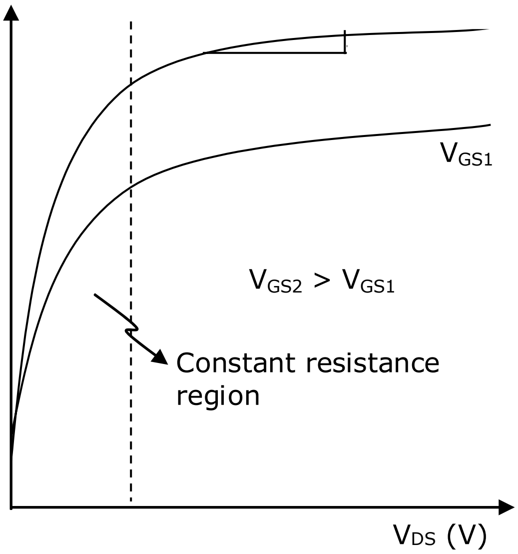


Ideal Graph:

Transfer Characteristics:



Drain Characteristics



Static Characteristics of MOSFET

Aim: To conduct an experiment to plot the transfer characteristics and output characteristics of an MOSFET and to find the transconductance and drain resistance.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	MOSFET (IRF 540)	-	1
2.	Milliammeter	0-20/200mA	1
3.	Multimeter	-	1
4.	Resistor	300Ω	1
5.	Regulated power supply	0-30V	2

Procedure:

Transfer Characteristics

1. Check the components/equipments of their correctness
2. Connection are made as shown in fig.3.1
3. Initially both RPS-1 and RPS-2 are kept at zero output position.
4. By varying the RPS-2, set V_{DS} around 3V
5. Now increase V_{GS} by varying the RPS-1 gradually and note down the corresponding drain current.
6. Repeat the steps 4 and 5 for some other V_{DS} value
7. Draw the graph between V_{GS} and I_D

Output Characteristics

1. Check the components/equipments of their correctness
2. Connection are made as shown in fig.3.1
3. Both RPS-1 and RPS-2 should be in zero output position and supply switch is ON
4. By varying RPS-1, set V_{GS} to some value (slightly greater than the Threshold voltage determined from the transfer characteristics)
5. Now increase the V_{DS} by varying the RPS-2 gradually and note down the corresponding drain current.
6. Repeat the steps 4 and 5 for some other V_{GS} value.
7. Graph between V_{DS} Vs I_D is plotted

Tabular Column:

Transfer Characteristics

V_{DS1} = ________________ V

V_{GS} (V)	I_D (mA)

V_{DS2} = ________________ V

V_{GS} (V)	I_D (mA)

Output/Drain Characteristics:

V_{GS1} = ________________ V

V_{DS} (V)	I_D (mA)

V_{GS2} = ________________ V

V_{DS} (V)	I_D (mA)

Calculations:

Trans conductance $g_m = \Delta I_D / \Delta V_{GS}$ mho

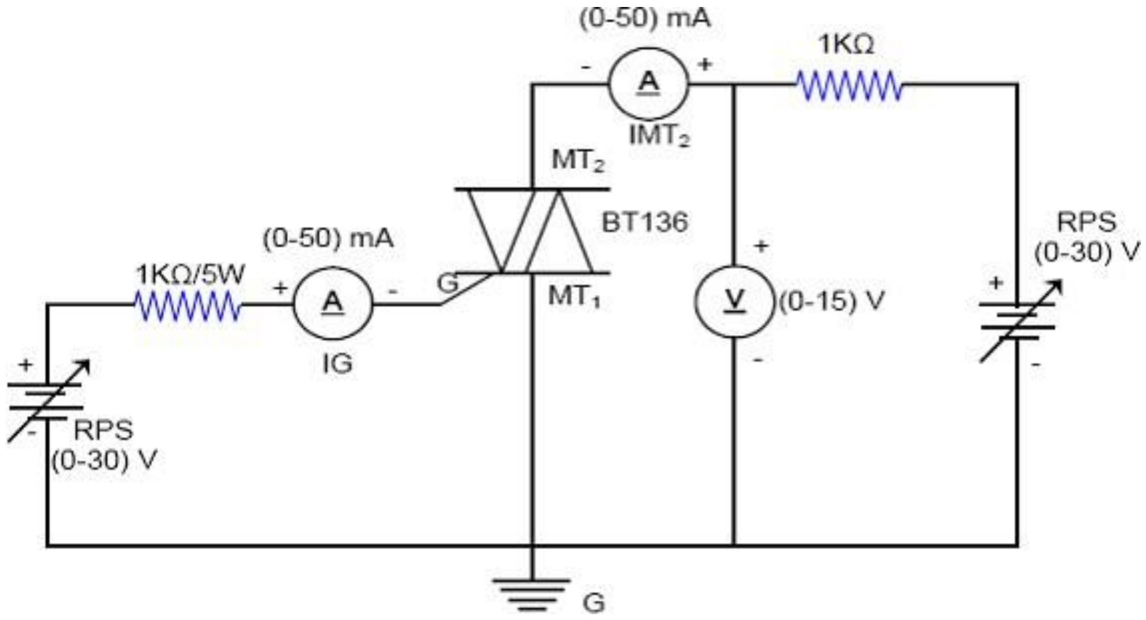
Drain Resistance $R_D = \Delta V_{DS} / \Delta I_D$ Ω

Results:

The transconductance g_m =_______________mho

The drain resistance R_D =_______________Ω

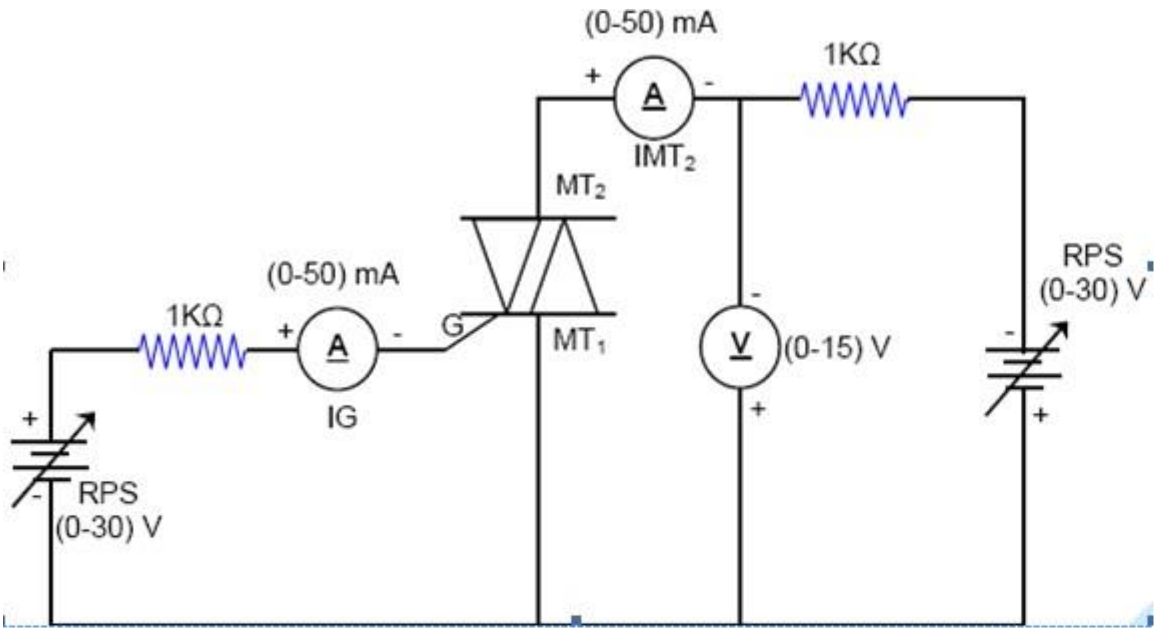
Forward direction



Circuit Diagram(12.1)

Characteristics of triac in forward direction

Reverse direction



Circuit Diagram(12.2)

Characteristics of triac in reverse direction

Experiment No. 3 **Date:___/___/ ______**

CHARACTERISTICS OF TRIAC

Aim: To draw the V-I characteristics of TRIAC and obtain the break over voltage (VBO).

Apparatus\ Components Required:

Sl. No.	**Particulars**	Range	**Quantity**
1	RPS	(0-30)V (0-300)V	1
2	VOLTMETER	(0–50)mA (0–30)mA (0–10)mA	1
3	AMMETER	(0–50)V (0-15)V	1
4	TRIAC	BTM36	1
5	RESISTOR	5K Ω, 1K Ω	1

Procedure:

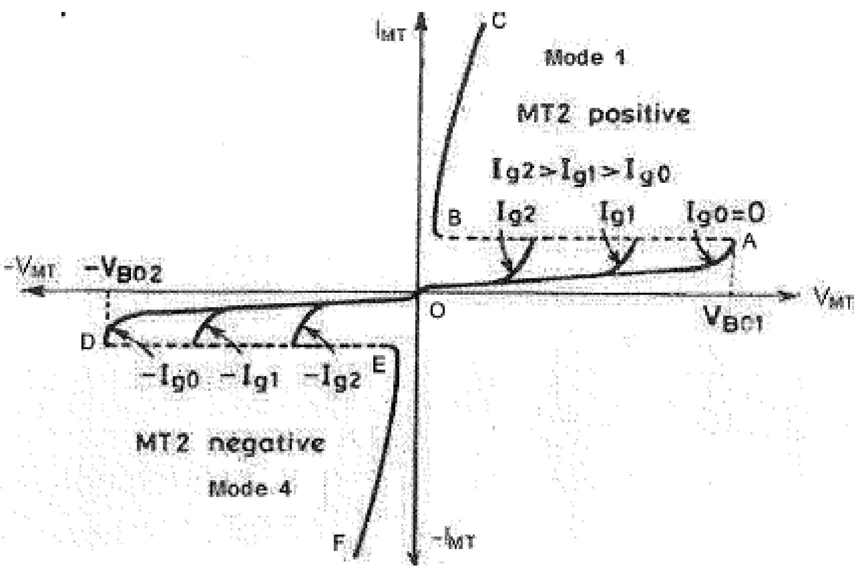
TRIAC Characteristics:

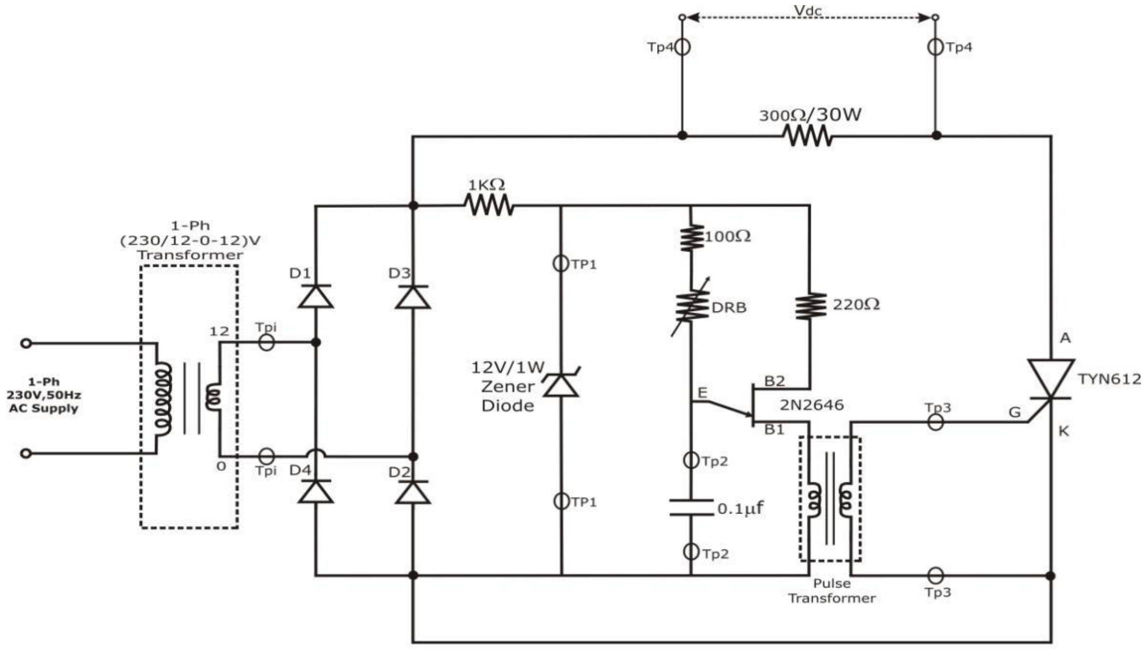
1. The connections are made as shown in the circuit diagram.
2. The TRIAC is connected in forward direction and supply is switched 'ON'.
3. VMT1MT2 is constant by varying RPS2 and then varying IG by varying RPS1.
4. The corresponding ammeter and voltmeter readings are noted and tabulated.
5. Next the TRIAC is connected in reverse direction.
6. The above process is repeated.

Tabular column:

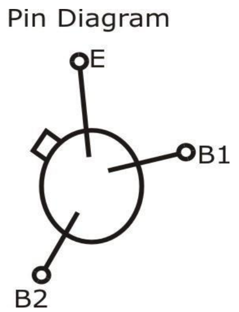
Sl.No.	Vmt1 & Vmt2 (V) When TRIAC in 'OFF'	Ig (mA)	Vmt1 & Vmt2 (V) When TRIAC in 'ON'	Imt1 (mA)

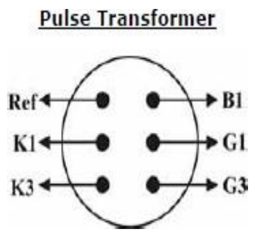
Model Graph:

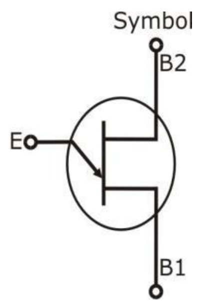




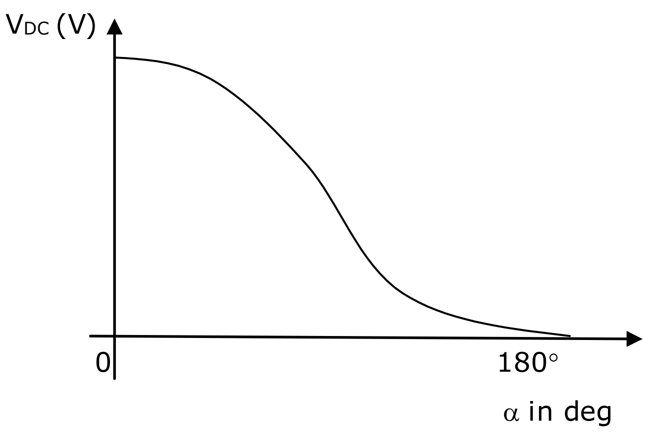
Circuit diagram(4.1)
SCR triggering by using UJT Relaxation Oscillator







Ideal Graph:



Experiment No. 4 **Date:___/___/ _____**

SCR turn on circuit using Synchronized UJT Relaxation Oscillator

Aim: To construct a firing/triggering circuit of a SCR using Synchronized UJT relaxation oscillator.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	SCR TYN612	-	1
2.	UJT 2N2646	-	1
3.	Resistors & Capacitor	As per design	1 each
4.	Zener Diode	12V / 1W	1
5.	Diode BY127	-	4
6.	Transformer	12 – 0 – 12	1
7.	Pulse Transformer	-	1
8.	DRB	-	1
9.	CRO with Probes	-	1
10.	Multimeter	-	1

Procedure:

1. Check the components/equipments of their correctness
2. Connection are made as shown in fig.4.1
3. Set the DRB value as 10k.
4. Now switch ON the supply.
5. By keeping the CRO probes across the Test-points Tpi, FWR o/p, TP1, Tp2, Tp3 and Tp4 the waveforms are observed.
6. Now vary the firing angle by increase the value of resistance in DRB in steps, observe the waveforms and note down the necessary values.
7. The graph between α Vs V_{DC} is plotted.

Tabular Column:

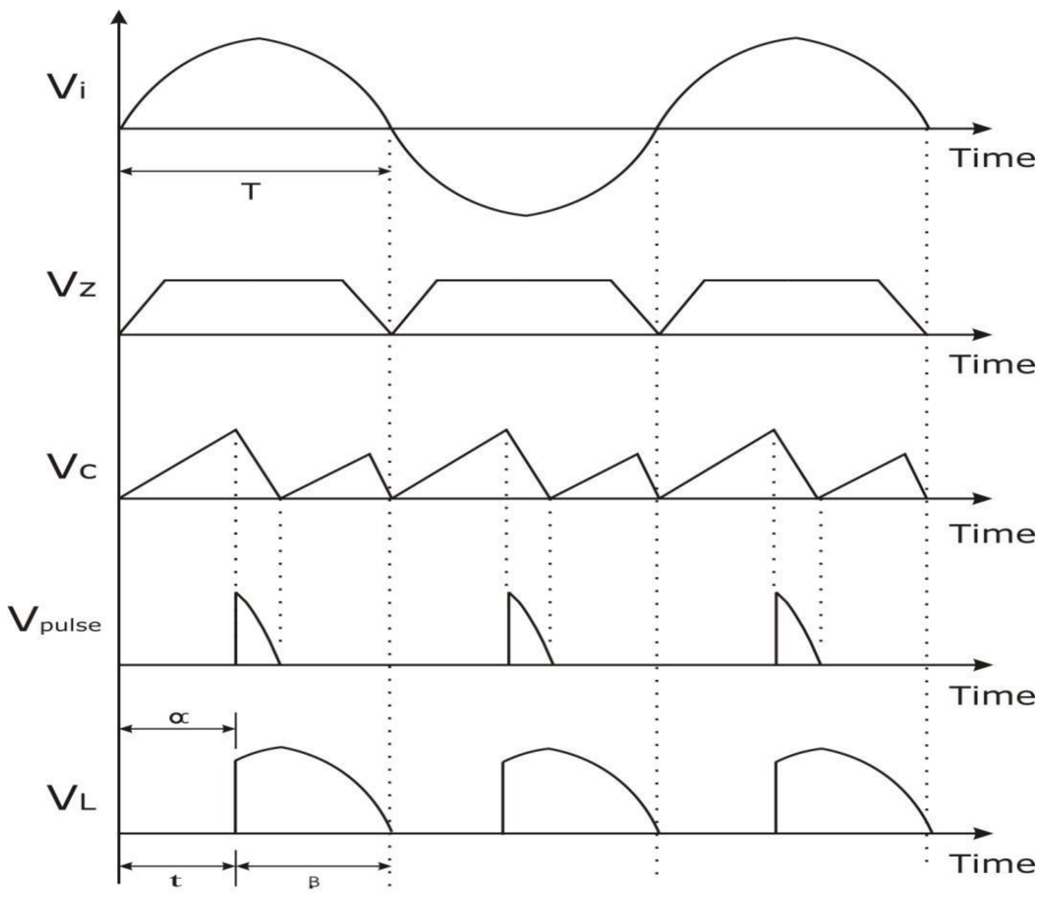
V_m =_______________V C = 0.1 μf

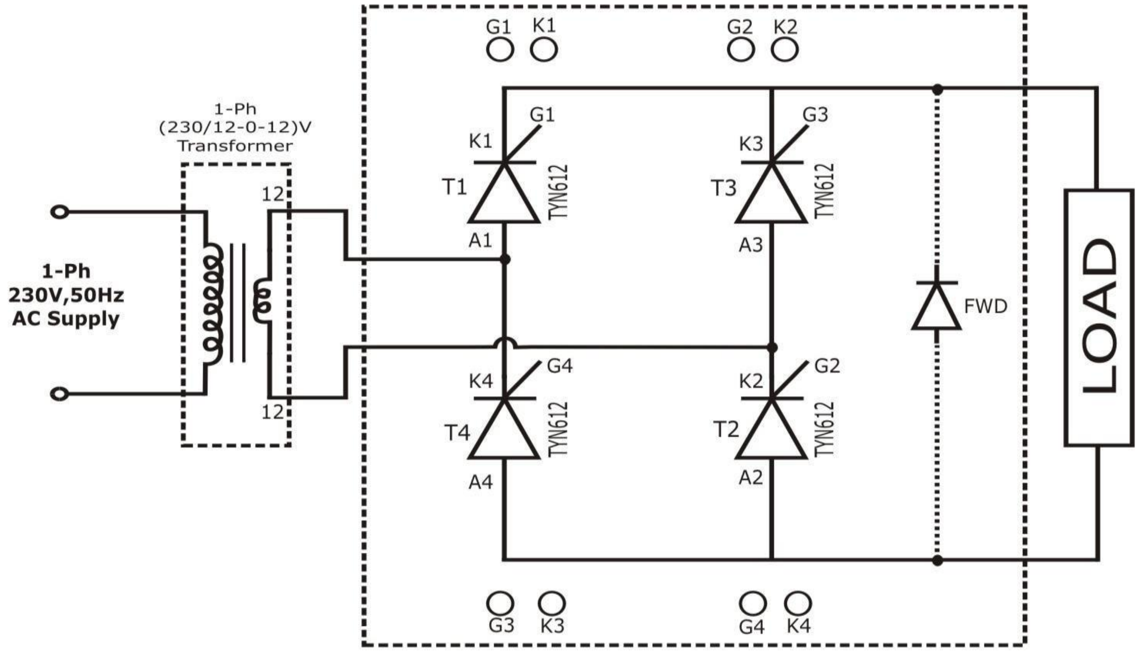
R (Ω)	T_{prac} (mSec)	t (mSec)	α (deg)	β (deg)	$V_{DC\ theo}$ (V)	$V_{DC\ prac}$ (V)

Note: $\alpha = \frac{t}{T} * 180°$:$\beta = 180° - \alpha$

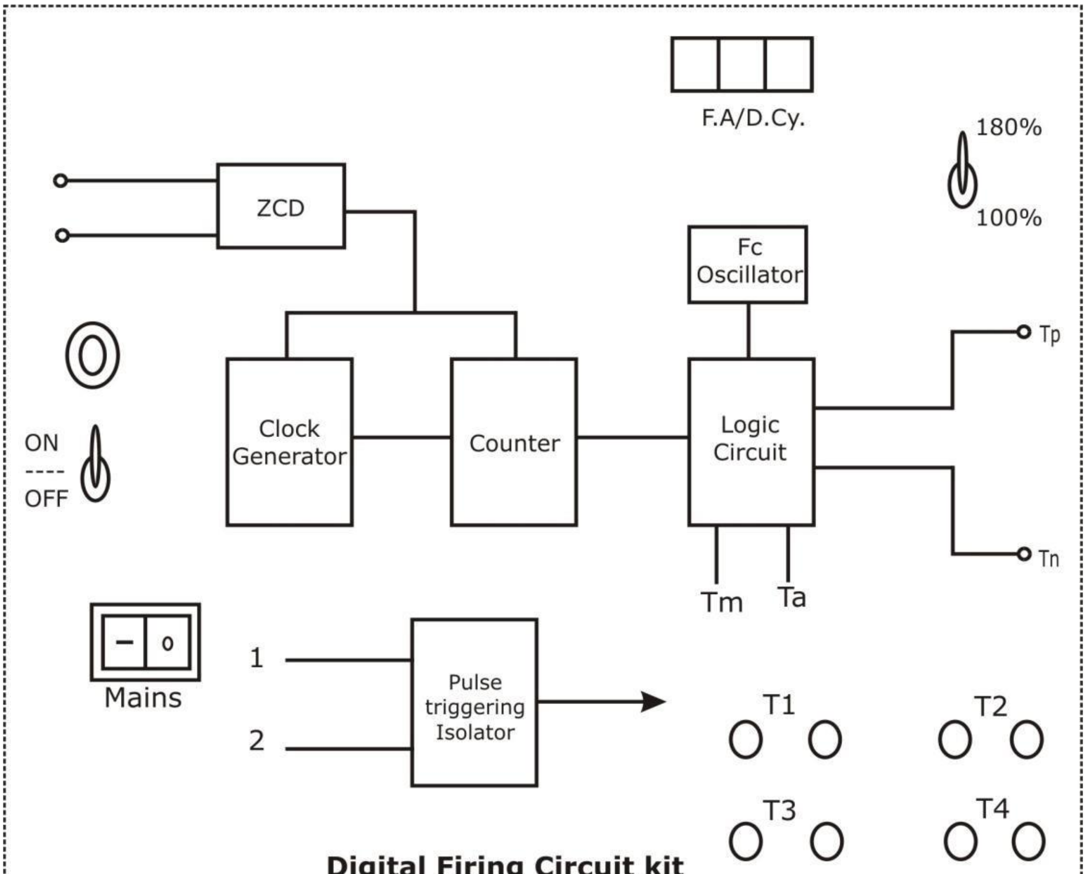
$$V_{DC(theoritcal)} = \frac{V_m}{\Pi}[1 + \cos\alpha]$$

Waveforms:





Circuit diagram(5.1)
Single phase Fully controlled Rectifier



Digital Firing Circuit kit

Experiment No. 5 **Date:___/___/ ______**

SCR Digital triggering circuit for Single phase controlled Rectifier and AC voltage regulator

Aim: To draw the output waveforms of fully controlled rectifier using digital triggering circuit

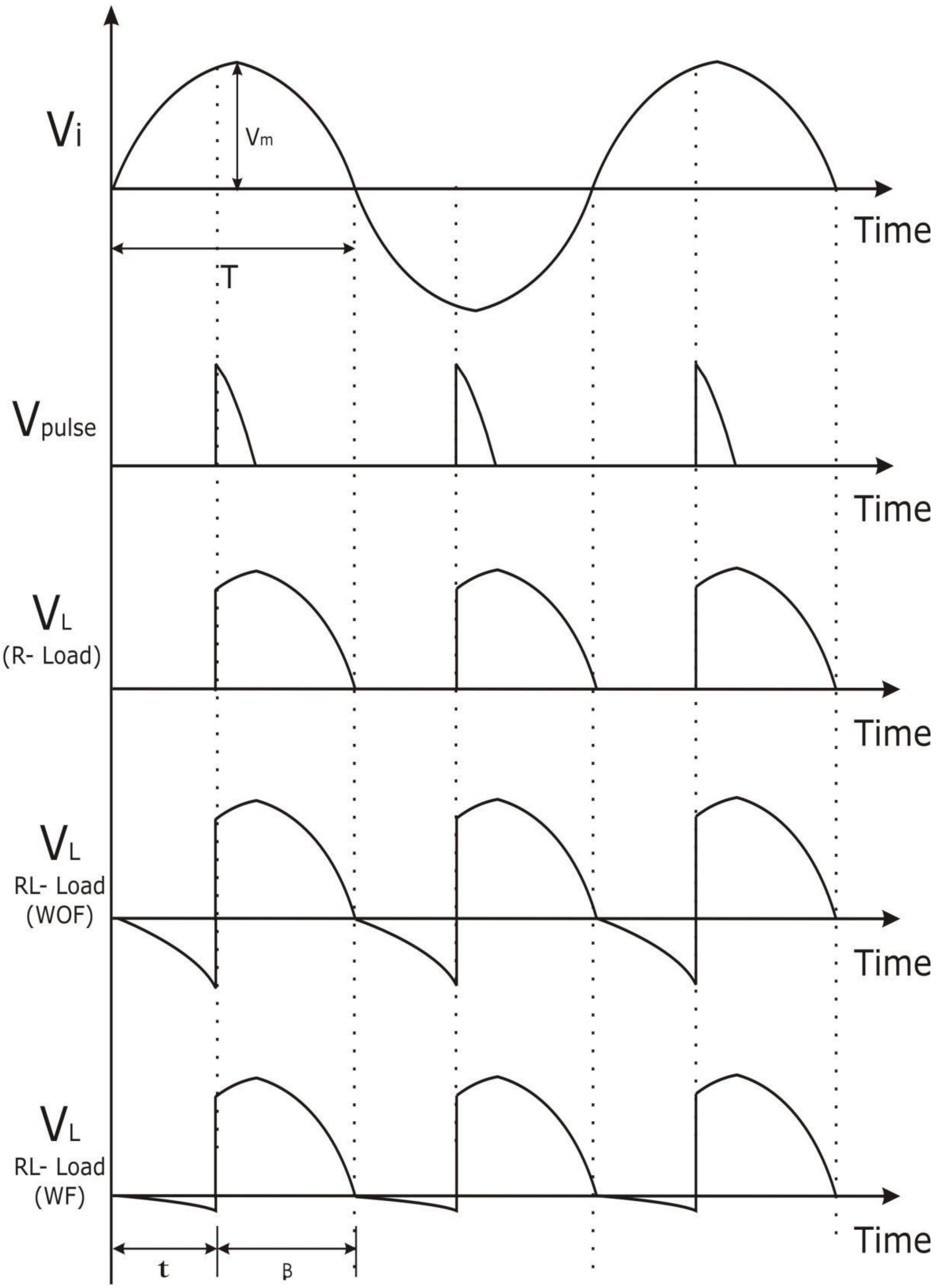
Apparatus Required:

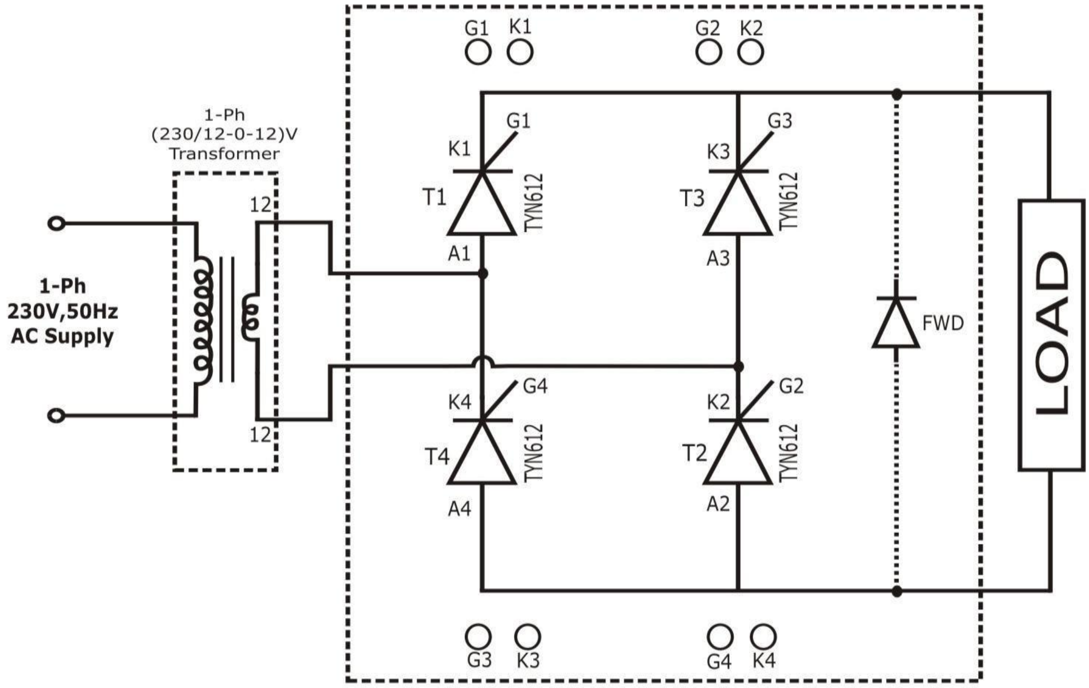
Sl. No.	Particulars	Range	Quantity
1.	1-Phase fully controlled rectifier unit	-	1
2.	Digital triggering circuit unit	-	1
3.	CRO with probes		1

Procedure:

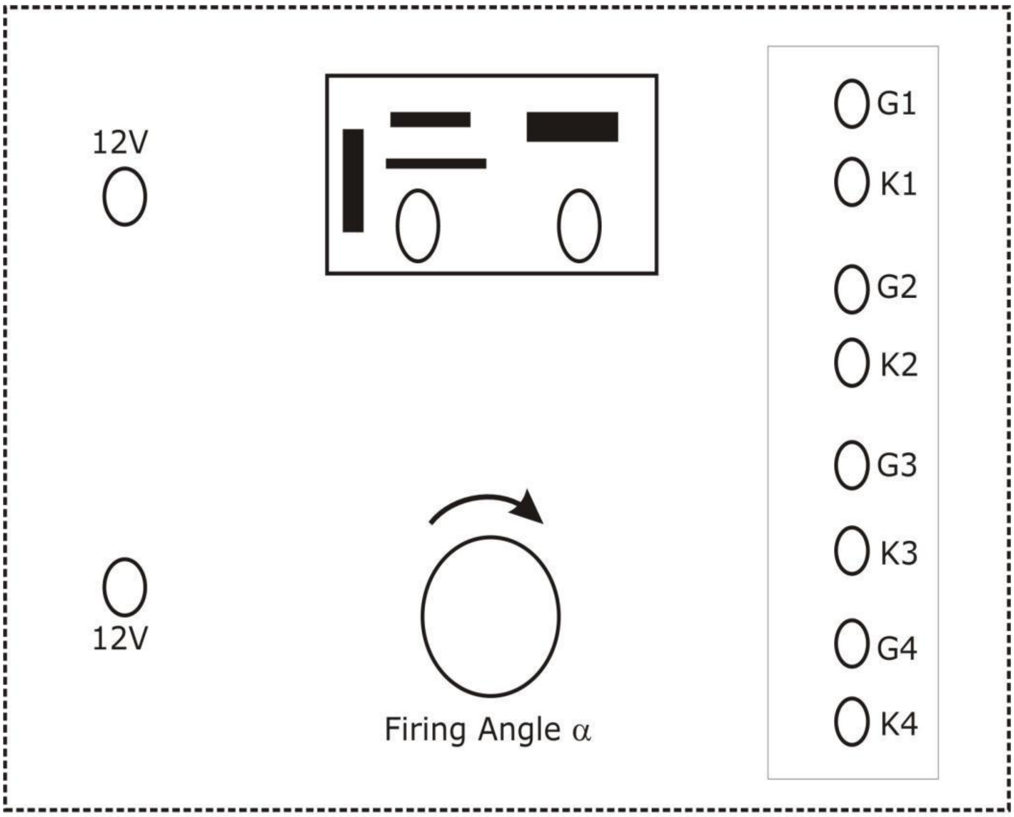
1. Digital firing circuit kit T1, T2, T3 and T4 terminals are connected with the corresponding SCR terminals in the rectifier unit.
2. Ensure the thumb wheel switch (F.A/D.cy) in the DFC kit should show '000' and the toggle switch in 180^{o} position.
3. Now switch ON rectifier unit then DFC kit.
4. Observe the output waveforms across the Load.
5. Vary the firing angle by varying the thumb wheel switch (F.A/D.cy) in the DFC kit in steps and observe the waveform.

Waveforms:


Vi
Vm
Time
T
Vpulse
Time
VL
(R- Load)
Time
VL
RL- Load
(WOF)
Time
VL
RL- Load
(WF)
Time
t
β



Circuit diagram(6.1)
Single phase Fully controlled Rectifier



Fully controlled bridge Firing Module
(UJT Relaxation oscillator based)

Experiment No. 6 **Date:___/___/ ______**

Single Phase Fully Controlled Converter with R, R-L load

Aim: To conduct an experiment on single phase fully controlled rectifier with R, R-L loads and vary the DC output voltage.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	1-Φ Fully Controlled Bridge converter Module	-	1
2.	Fully Controlled Bridge Firing Module	-	1
3.	Resistor	30 Ω / 30 W	1
4.	Diode BY127	-	1
5.	Transformer	12 – 0 – 12	1
6.	CRO with Probes	-	1
7.	Multimeter	-	1
8.	Resistive-Inductive Load	-	1

Procedure:

1. Firing module triggering pulses are connected with the corresponding SCR terminals in the rectifier unit.
2. Ensure the firing angle variation POT is in zero position.
3. Now switch ON rectifier unit then firing module.
4. By keeping the CRO probes across the Load (R, R-L) the waveforms are observed.
5. Now vary the firing angle by turning the POT in steps, observe the waveforms and note down the necessary values.
6. The graph between α Vs V_{DC} is plotted (for both R & R-L load)

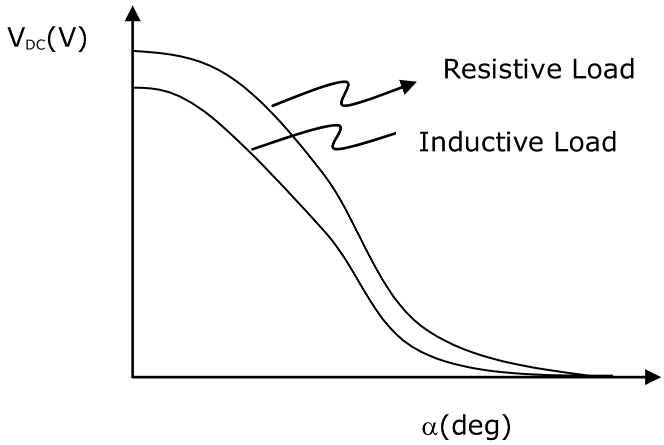
Tabular Column:

V_m =_______________V T =___________ms

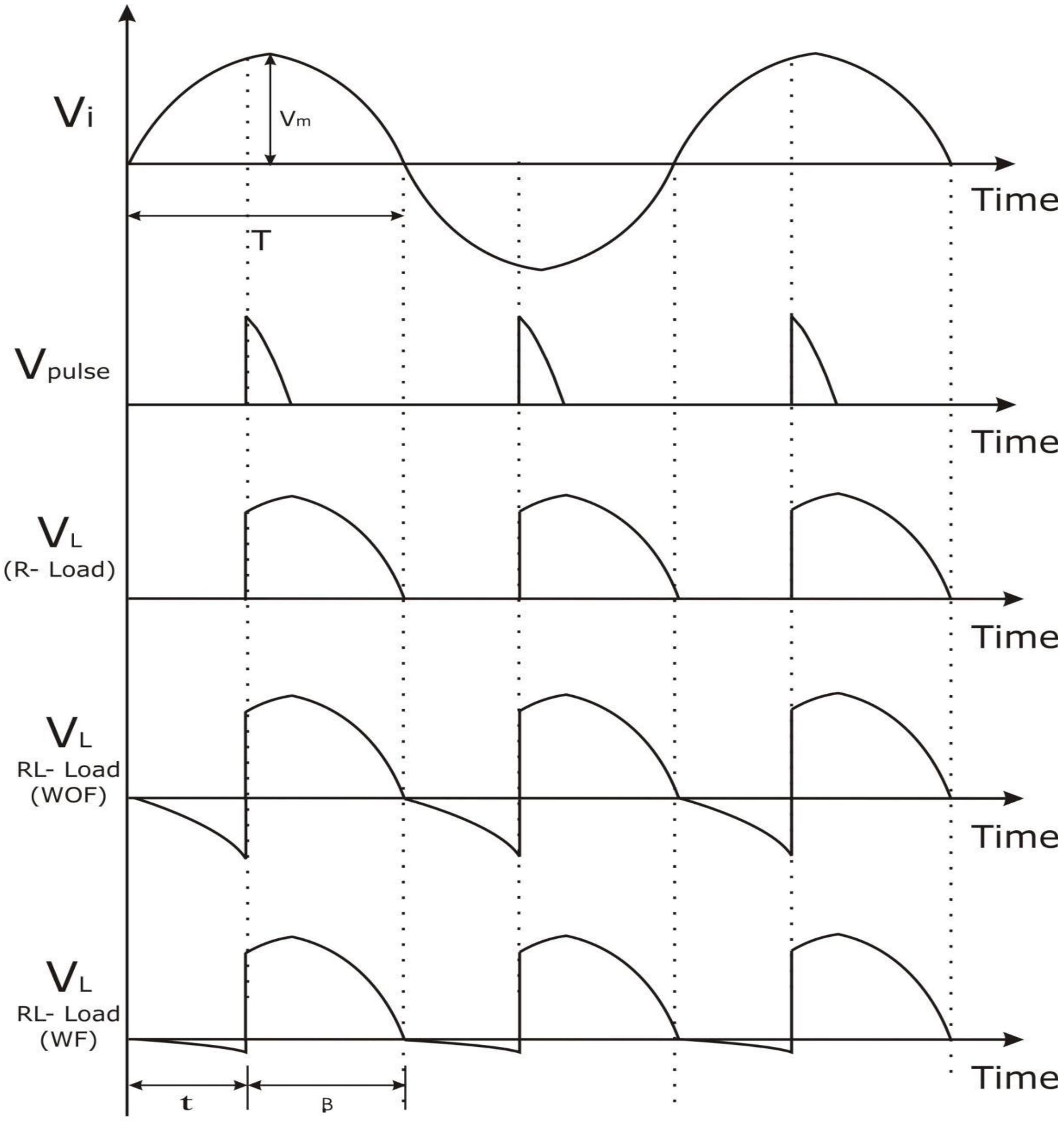
Sl. No.	t (mSec)	α (deg)	β (deg)	V_{DC}(V) (R - Load)	V_{DC}(V) (R-L Load)

Note: $\alpha = \frac{t}{T} * 180^\circ$: $\beta = 180^\circ - \alpha$

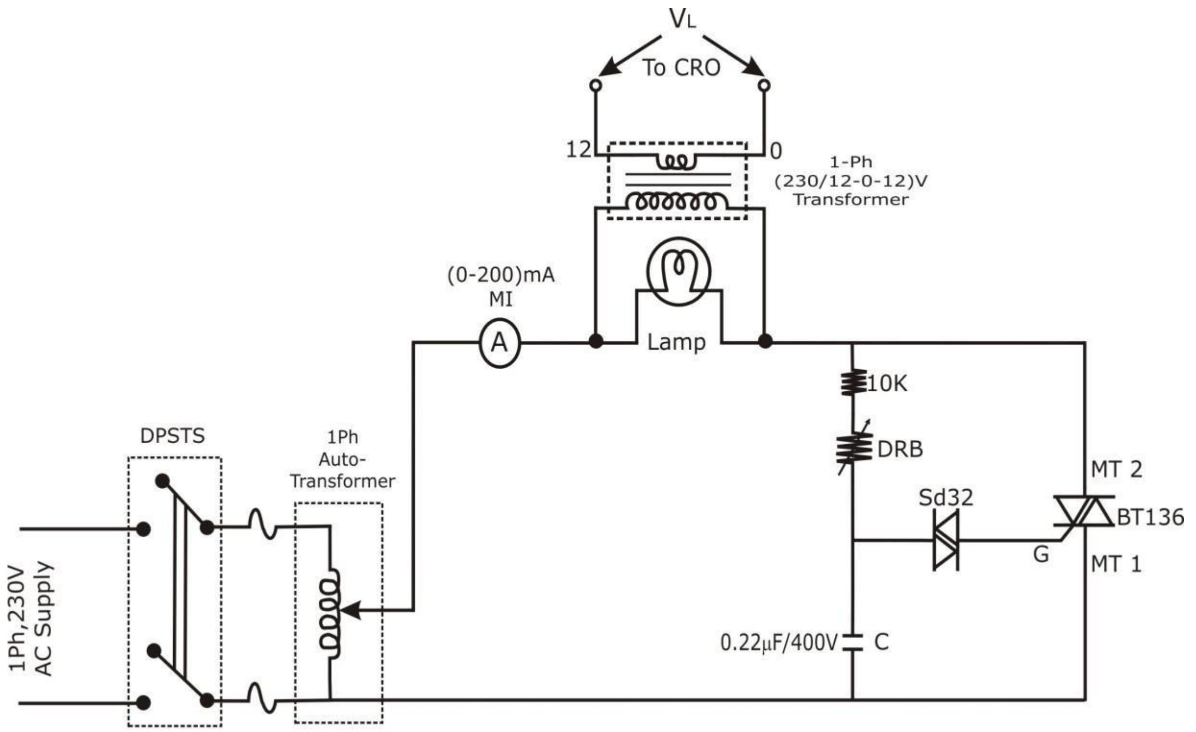
Ideal Graph:



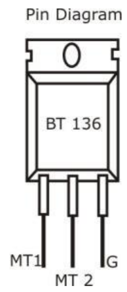
Waveforms:

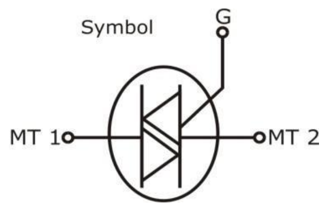


Calculations:

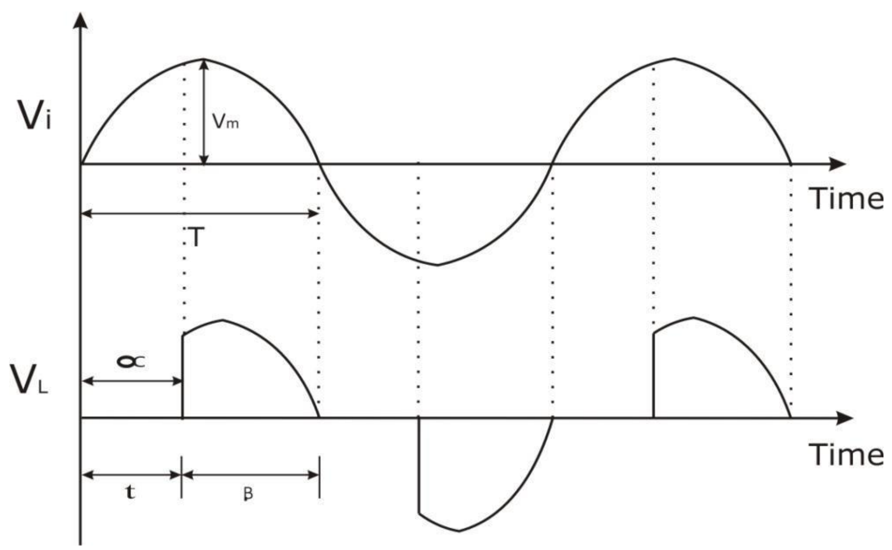


Circuit Diagram(7.1)
AC Voltage controller using TRIAC-DIAC combination for Illumination control





Waveforms:



Experiment No. 7 **Date:___/___/ _____**

AC Voltage Controller Using TRIAC-DIAC Combination connected to R and RL load

Aim: To conduct an experiment to control the AC voltage using TRIAC-DIAC combination.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	TRIAC BT136	-	1
2.	DIAC SD32	-	1
3.	Resistor & Capacitor	As per design	1 each
4.	Dimmerstat (1-ph Auto-Trans.)	-	1
5.	Transformer	12 – 0 – 12	1
6.	DRB	-	1
7.	CRO with Probes	-	1
8.	Incandescent Lamp	60W	1
9.	Multimeter	-	1
10.	AC Milliammeter	(0-200)mA (MI)	1

Procedure:

1. Check the components/equipments of their correctness
2. Connection are made as shown in fig.7.1
3. Set the DRB in minimum resistance position.
4. Keep the 1-Phase Auto-transformer in zero output position and the supply switch is ON.
5. Set the Auto-transformer output voltage around 150V (use Multimeter to measure).
6. Increase the DRB value in steps and observe I_{rms} and V_{rms} (measure across transformer primary) values and tabulate it.
7. Bring back the Auto-transformer output to Zero position and the supply switch is OFF.
8. The graph between α Vs V_{rms} and α Vs I_{rms} are plotted.

Note : Since 150V AC input is applied do not touch any components when supply is switched on

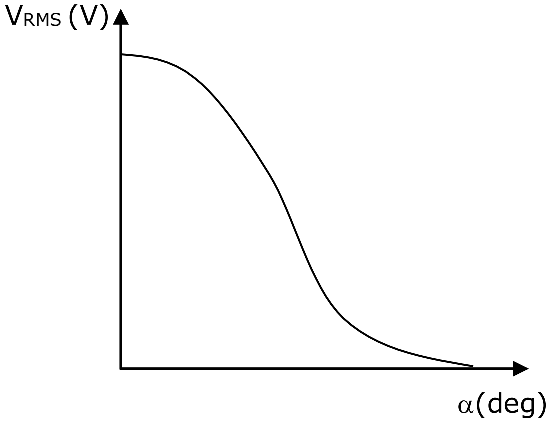
Tabular Column:

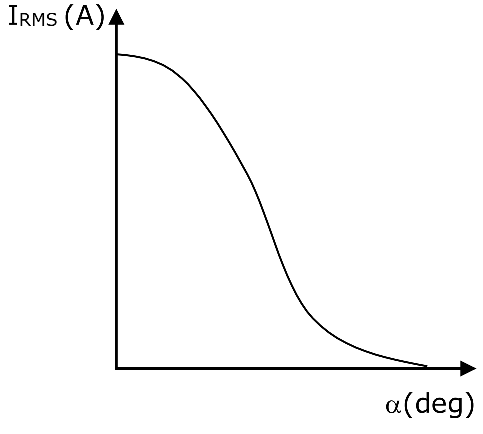
Vm =_______________V, C =_____________μf T =______________ms

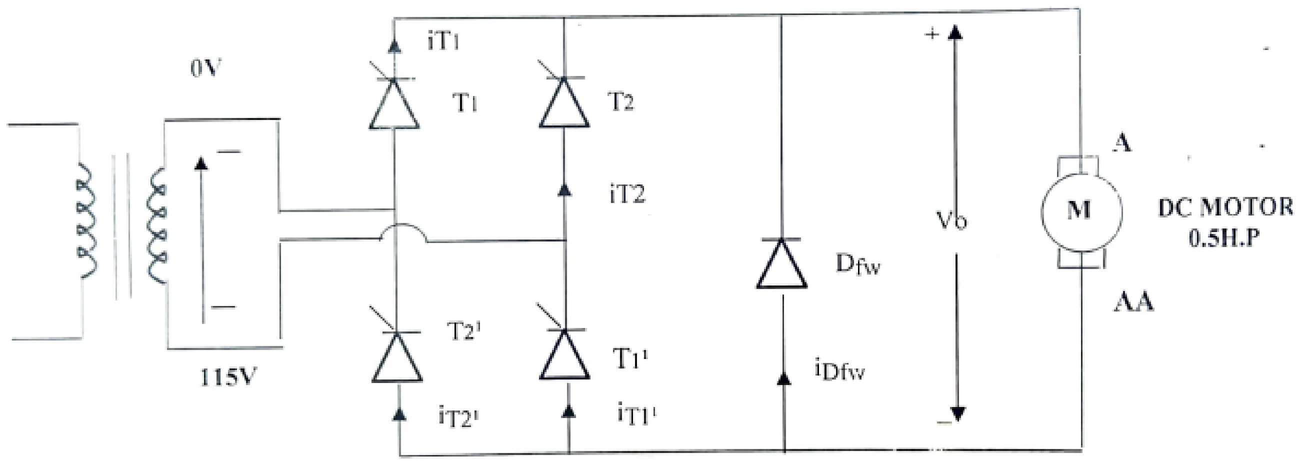
R (Ω)	**t** **(mSec)**	α **(deg)**	β **(deg)**	V_{rms} **(V)**	I_{rms} **(A)**

Note: $\alpha = \frac{t}{T} * 180^\circ$: $\beta = 180^\circ - \alpha$

Ideal Graph:







Circuit Diagram 8.1: Single phase fully controlled bridge rectifier

Tabular Column:

Sl.No	Field voltage	V_{in} V	Firing angle	V_{OUT} V	*I amps*	*Speed rpm*

Experiment No. 8 **Date:___/___/ _____**

Speed control of DC motor using single semi converter

Aim: To conduct an experiment to control the speed of DC motor using single semi converter

Apparatus Required:

1. Speed of separately excited DC Motor speed control unit using single phase full controlled converter.
2. DC Shunt motor 0.5 H.P/180V
3. Digital Tachometer.

Procedure:

1. Make the connections are made as shown in the circuit diagram
2. Switch on the mains supply to the single semi converter kit
3. Connect the AC input to the power circuit by varying the auto transformer (say 110V) & switch ON the MCB
4. Vary the firing angle (0^0-180^0) & note down the Vout,I and speed

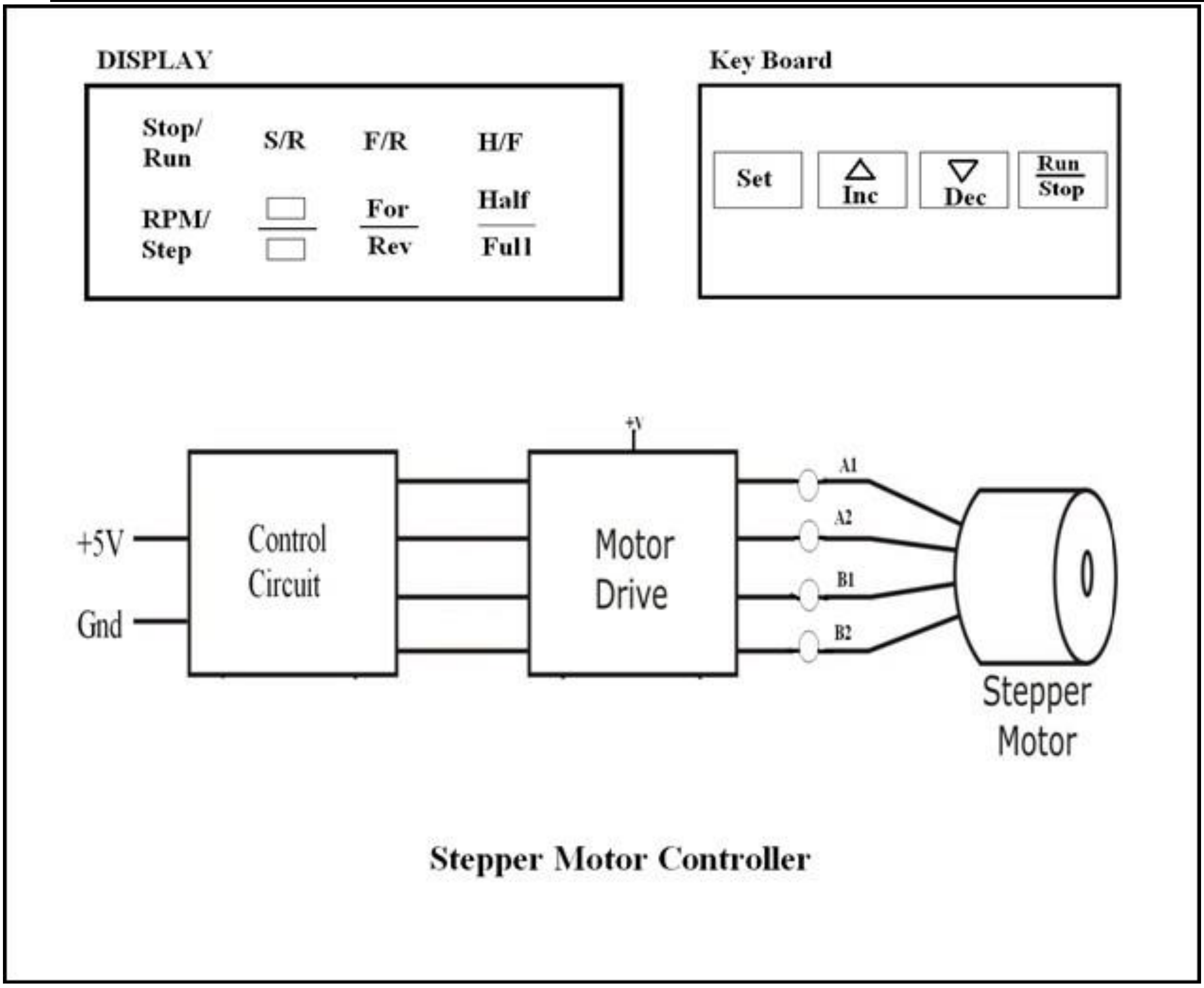

DISPLAY
Stop/ Run
S/R
F/R
H/F
RPM/ Step
For
Rev
Half
Full
Key Board
Set
Inc
Dec
Run
Stop
+V
+5V
Gnd
Control Circuit
Motor Drive
A1
A2
B1
B2
Stepper Motor
Stepper Motor Controller

Fig 11.1

Experiment No. 09 **Date:___/___/ _____**

Speed control of Stepper Motor

Aim: To study the speed control techniques of the stepper Motor.

Apparatus Required:

Sl. No.	Particulars	Quantity
1.	Stepper Motor Controller Kit	1
2.	Stepper Motor	1
3.	Connecting probes	-

Procedure:

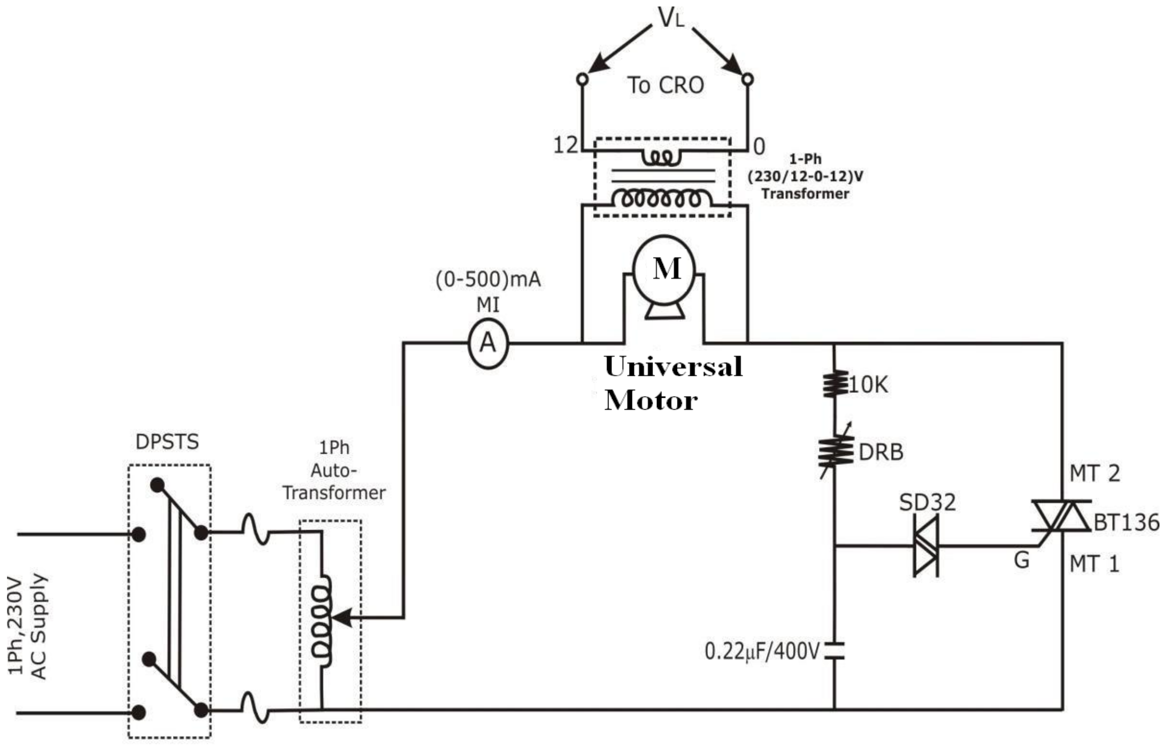
1. Connections are made as shown in Fig 11.1.
2. Plug the control unit into the power supply, The LED display shows RPM/STEP, FOR/REV and FULL/HALF.
3. Using Set, Inc, Dec, Run/Stop buttons on the keyboard select various parameters available to control the Stepper motor.
4. Now RPM/STEP will blink, select either RPM or STEP and set the respective value.
5. Select either FORWARD or REVERSE direction and select either FULL or HALF, and then press RUN button to start the rotation of Stepper Motor.
6. To stop the stepper motor, press STOP button on keyboard.
7. Repeat the 4th, 5th and 6th points for different values of RPM and STEPS.
8. Connection are made as shown in Fig 11.1.
9. Plug the control unit into the power supply.
10. Now using Set, Inc, Dec, Run/Stop buttons on the keyboard select various parameters available to control the Stepper motor.

Note:

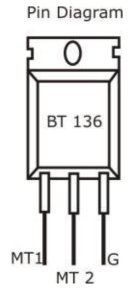
S/R: Step/RPM

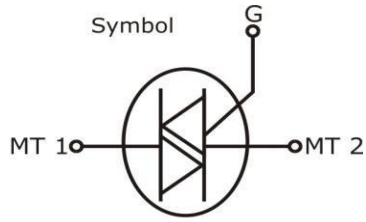
F/R: Forward(For)/Reverse(Rev)

H/F: Half/Full

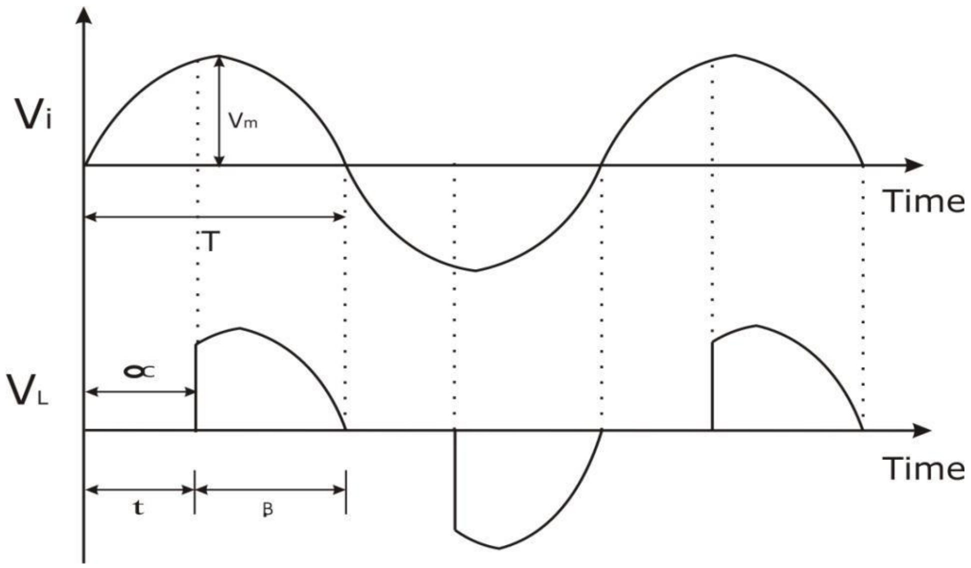


Circuit Diagram (9.1)
Speed Control of Universal motor using AC Voltage controller





Waveforms:



Experiment No. 10 **Date:___/___/ _____**

Speed Control of Universal Motor using ac voltage regulator

Aim: To conduct an experiment to control the speed of a Universal Motor using the AC Voltage controller circuit.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	TRIAC BT136	-	1
2.	DIAC SD32	-	1
3.	Resistor & Capacitor	As per design	1 each
4.	Dimmerstat (1-ph Auto-Trans.)	-	1
5.	Transformer	12 – 0 – 12	1
6.	DRB	-	1
7.	CRO with Probes	-	1
8.	Universal Motor	-	1
9.	Multimeter	-	1
10.	AC Milliammeter	(0-500)mA (MI)	1

Procedure:

1. Check the components/equipments of their correctness
2. Connection are made as shown in fig.9.1
3. Set the DRB in minimum resistance position.
4. Keep the 1-Phase Auto-transformer in zero output position and the supply switch is ON.
5. Set the Auto-transformer output voltage around 150V (use Multimeter to measure).
6. Increase the DRB value in steps and observe V_{rms} (measure across the 12-0-12 transformer primary) and speed values and tabulate it.
7. Bring back the Auto-transformer output to Zero position and the supply switch is OFF.
8. The graph between α Vs speed and β Vs speed are plotted.

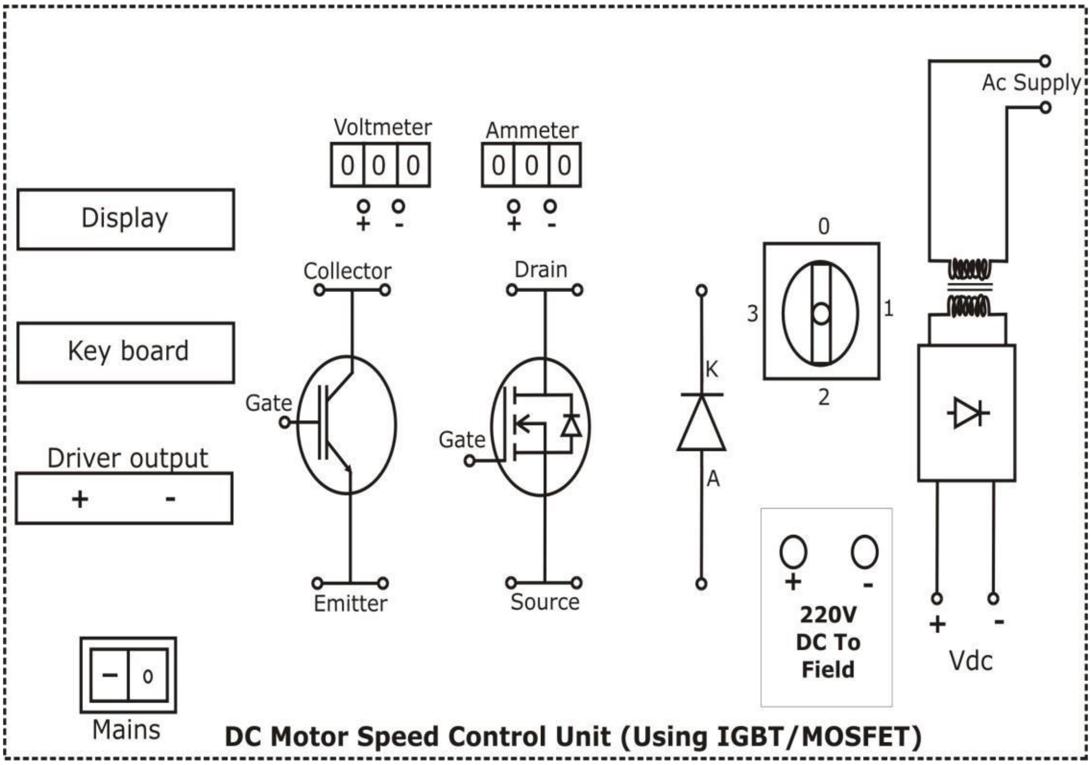
Note : Since 150 V AC input is applied do not touch any components when supply is switched on

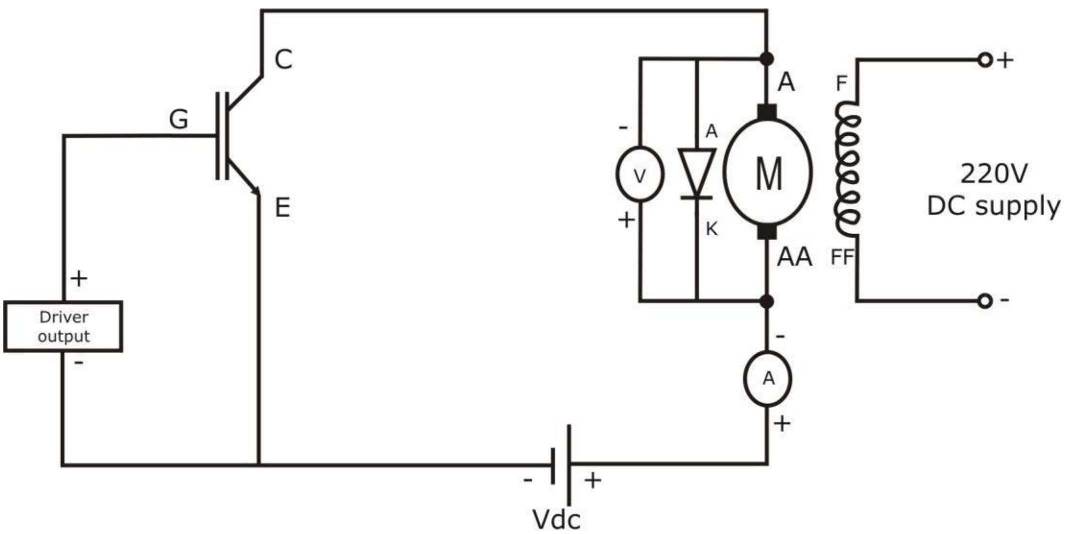
Tabular Column:

V_m =__________V T =__________ms

t (mSec)	Firing Angle (α) (deg)	Conduction Angle (β) (deg)	V_{rms} (V)	Speed (RPM)

Note: $\alpha = \frac{t}{T} * 180^\circ$: $\beta = 180^\circ - \alpha$





Circuit Diagram(8.1)
Speed control of Sep. Excited DC Motor using IGBT/MOSFET

Experiment No. 11 **Date:___/___/ _____**

Speed Control of Separately excited DC Motor Using an IGBT or MOSFET chopper

Aim: To conduct an experiment to control the speed of a separately excited DC Motor using IGBT/MOSFET Chopper.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	DC Motor speed control unit	-	1
2.	Sep. excited DC Motor		1
2.	Tachometer	Contact Type	1
3.	Connecting probes	-	-

Procedure:

1. Check the components/equipments of their correctness
2. Keep the voltage selector switch in OFF position and supply switch is ON.
3. The LCD display shows –
   POWER MOSFET/IGBT CHOPPER
   0FF DCY – 0: FRQ - 50
   Digital volt meter and ammeter shows 000
4. Measure the Field voltage using digital voltmeter. It should be 220V ± 10% approximately and the neon lamp glows.
5. Now keep the voltage select switch at position 1 and measure the voltage at VDC terminals. It should be 24 volts. The output voltage should be 48 volts when VOLT-SELECT switch at position – 2, 110 volts when the VOLT-SELECT switch at position – 3, 220 volts when the VOLT-SELECT switch position at 4 approximately.
6. Make sure that the DC supply is correct. Now observe the driver output using CRO by varying duty cycle and frequency.
7. Make sure that the driver output is proper before connecting to the gate/emitter or gate/source of IGBT or MOSFET.
8. Now all the outputs are proper. Make the connections as given in the circuit diagram 8.1.
9. Vary the duty cycle in steps and keep the frequency as constant and observe the speed of the motor and note down the values of V, I and RPM.
10. Now change the frequency in steps and keep the duty cycle as constant and tabulate the necessary values.
11. Draw the graph between duty cycle Vs speed and Frequency Vs speed.

NOTE: Connect field supply to the field terminals of the Motor before connecting to the armature supply. And the field supply should be removed only after switching OFF the armature supply.

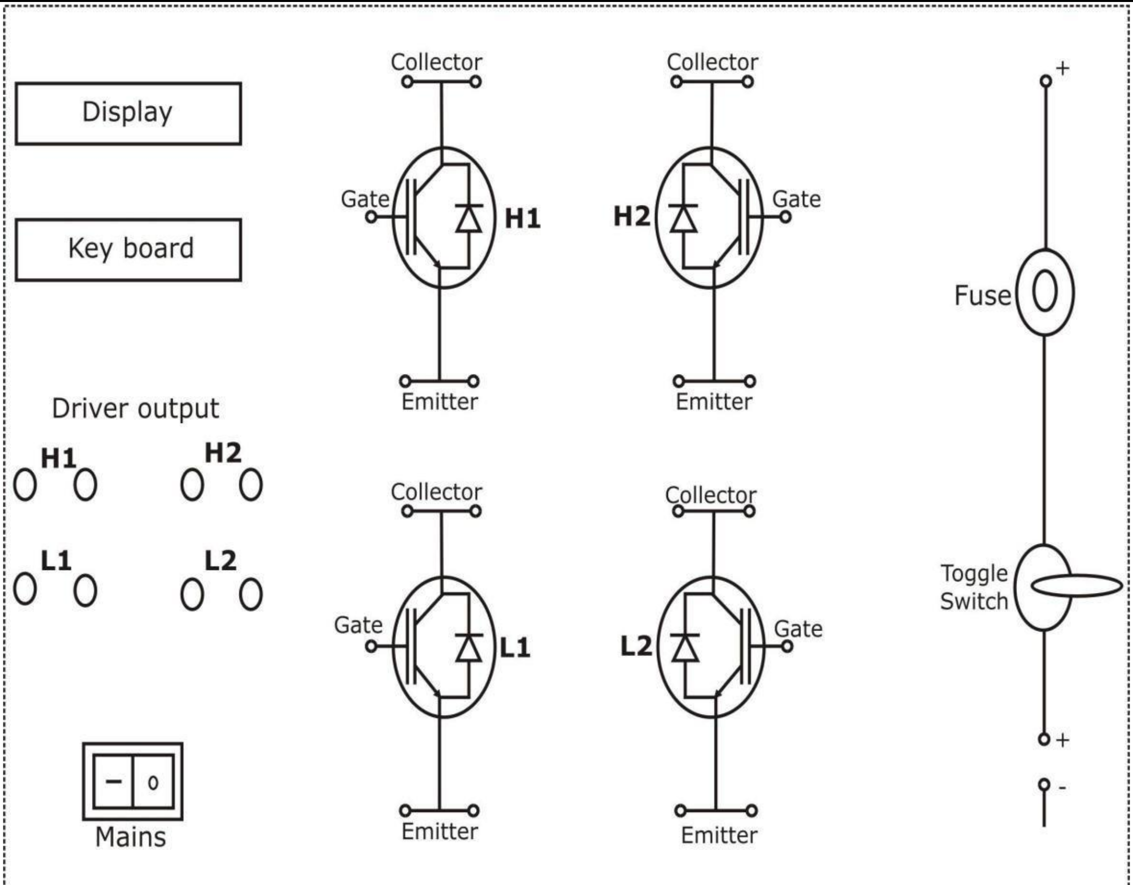
Tabular Columns:

V_{in} =__________V : Frequency =________Hz

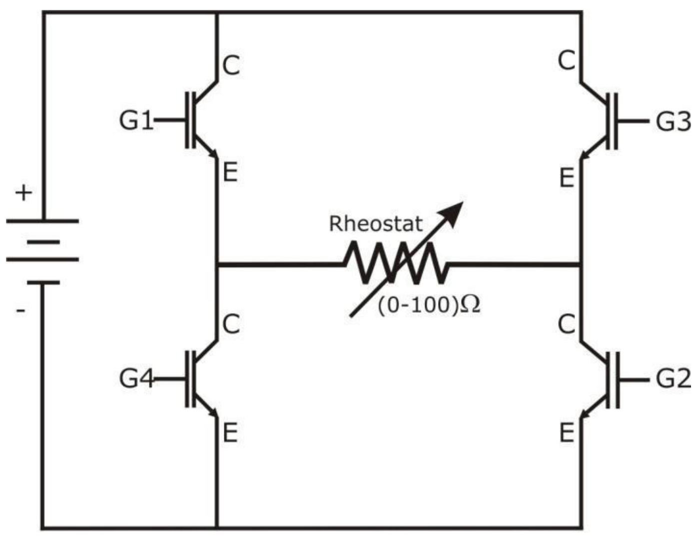
Duty cycle (%)	Vout (V)	Io (A)	Speed (rpm)

V_{in} =__________V : Duty cycle =________%

Frequency (Hz)	Vout (V)	Io (A)	Speed (rpm)



Single-phase PWM Inverter - IGBT based



Circuit diagram(10.1)
Single phase Full bridge Inverter(IGBT based)

Experiment No. 12 **Date:___/___/ _____**

Single phase full bridge Inverter using IGBT

Aim: To conduct an experiment on 1-phase full bridge PWM Inverter (IGBT based)

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	1-phase full bridge Inverter Module	-	1
2.	Rheostat	(0-100) Ω/5A	1
3.	Connecting probes	-	-

Procedure:

1. Now make the connections as given in the circuit diagram.
2. Connect DC supply from (0-30) V regulated power supply unit.
3. Connect resistive load 0–100 ohms 5 Amps Rheostat at load terminals (keep the sliding switch in middle position).
4. Connect driver output signals to the Gate and Emitter of corresponding IGBTs.
5. Switch ON the DC supply and apply 20 Volts.
6. Switch ON the mains supply. The LCD display shows 1-ph PWM inverter with modulation type and M- (modulation index) 00 and F-100 Hz and in OFF position. Now M-00 Blinks. Press INC key to set the M.I. from 00- 100%.
7. Set the Modulation Index value in steps (keep the frequency as constant) and press the Run/STOP button then measure the output voltage and tabulate it.
8. Set the frequency value in steps (keep the M.I value as constant) and press the Run/STOP button then measure the output voltage and tabulate it.

.

NOTE: The SET key works only when it is in OFF position. This is to avoid change of Modulation type when the power circuit is ON.

.

Tabular column:

Modulation Type:______________ Frequency: _____________

Modulation Index (%)	Output voltage (V)

Modulation Type:______________ Frequency: _____________

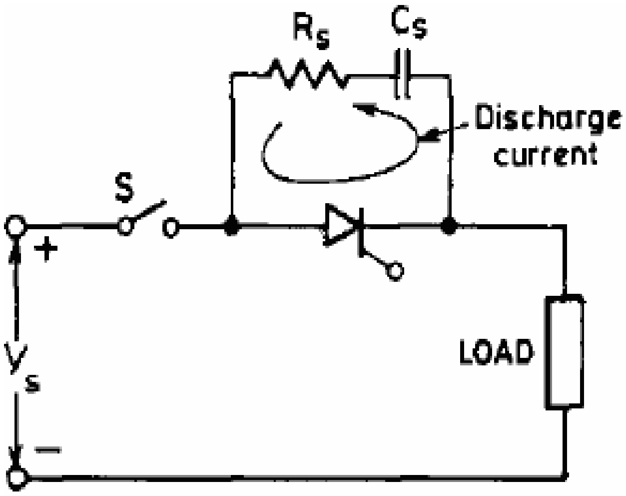
Modulation Index (%)	Output voltage (V)

Modulation Type:______________ Modulation Index: ______________

Frequency (Hz)	Output voltage (V)

Modulation Type:______________ Modulation Index: ______________

Frequency (Hz)	Output voltage (V)



Circuit Diagram(13.1)

RC Snubber circuit

Design:

$dv/dt = 0.632\ V_s / R_s C_s$

Where $R_s C_s$ is the snubber time constant.

$R_s = V_s / I_{TD}$

Where I_{TD} is the discharging current of the capacitor.

Tabular column:

For dv/dt=---------

t	VA

Experiment No. 1 **Date:___/___/ _____**

Design of snubber circuit

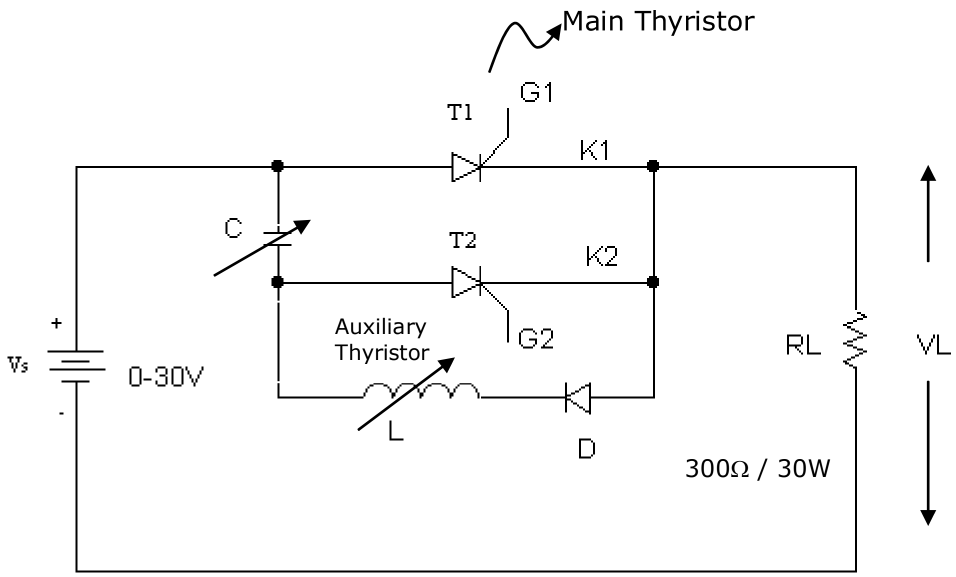
Aim: Design of snubber circuit.

Apparatus Required: Thyristor, supply, Resistance, Capacitor.

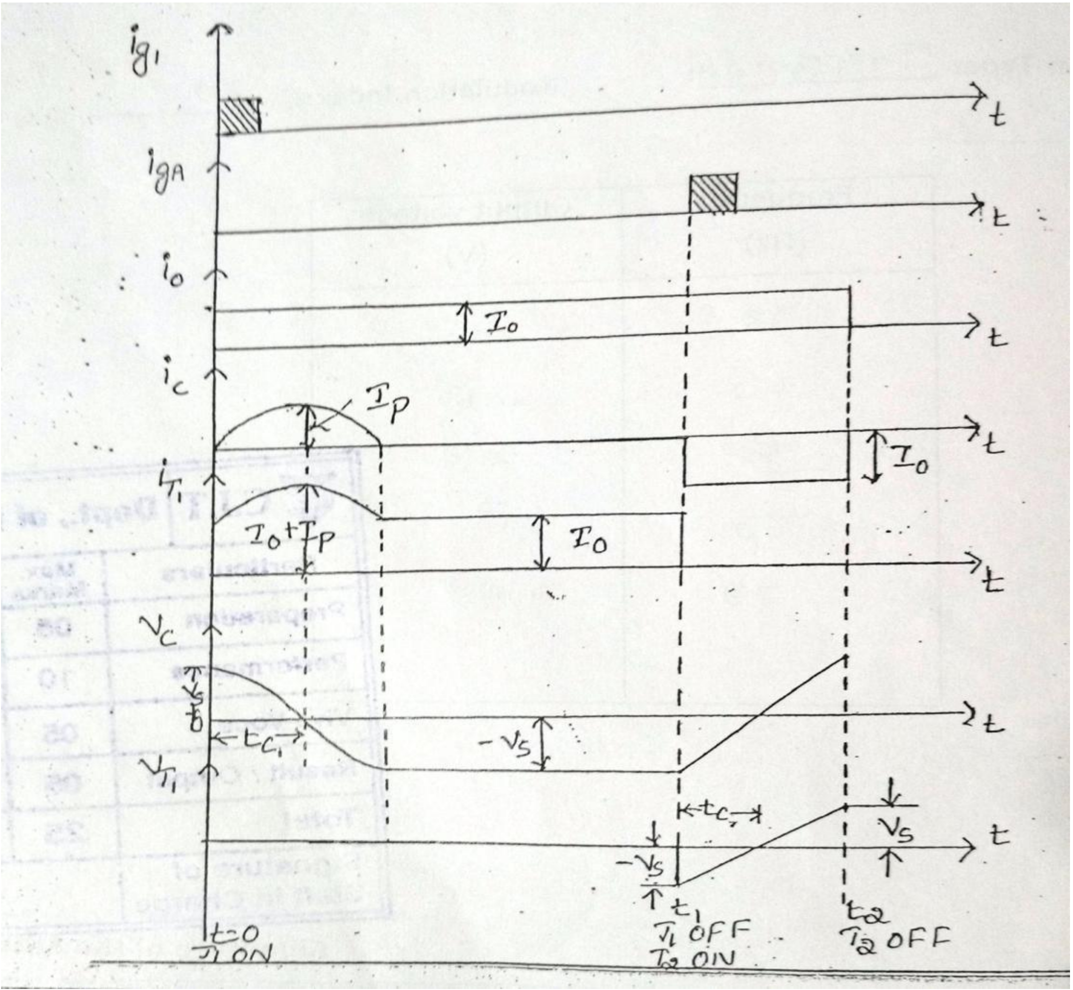
PROCEDURE:-

1. Switch s is turned on at t=0, a step voltage is applied across SCR. This voltage will have a high dv/dt. The value of snubber circuit component is calculated by using formula.
2. When SCR is in forward blocking state the capacitor will charge.
3. Therefore voltage across SCR will increase gradually. Thus the rate of change of voltage across SCR is reduced.
4. When SCR is turned on the charged capacitor will discharge through resistance R and SCR. Thus R is limit the discharge current of the capacitor and prevents damage of SCR due to over current.

Circuit Diagram:



Waveforms:



Experiment No 2 **Date:___/___/ _____**

Study of Auxiliary Commutation Circuit

Aim: To study an experiment to study the Auxiliary commutation circuit and to study the voltage commutated chopper.

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	SCR TYN 612	-	2
2.	Firing Module	-	1
3.	Diode BY127	-	1
4.	CRO Probes	-	1 set
5.	Multimeter	-	1
6.	DCB and DIB	-	1 each
7.	Resistor	30Ω / 30W 100Ω, 220Ω	1 each

Theory:

Commutation is the process of turning off a thyristor. In this auxiliary commutation circuit the main thyristor is turned off by turning on the auxiliary thyristor. Whenever we apply the triggering pulse to the main thyristor the SCR will be conducting. When we need to turn off the main thyristor the auxiliary thyristor is turned on. When the auxiliary thyristor is turned on the reverse voltage present in the capacitor is applied across the main thyristor which will turn off. Hence we call this commutation as voltage commutation. Here frequency of commutation depends on the frequency of firing signal.

Auxiliary commutation is also called as voltage commutation, Class D commutation, Parallel-capacitor commutation. For explaining class D commutation we refer to the given circuit diagram. In this circuit T1 & T2 are called main & auxiliary thyristors respectively.
Initially, main thyristor T1 and auxiliary thyristor T2 are off and capacitor is assumed charged to voltage Vs with upper plate positive. When T1 is turned on at t = 0, source voltage Vs is applied across load and load current Io begins to flow which is assumed to remain constant. With T1 on at t = 0, another oscillatory circuit consisting of C, T1, L and D is formed where the capacitor current is given by

$$i_c = V_s\sqrt{c/L}\sin(\omega_o t) = I_p \sin(\omega_0 t)$$

When $(\omega_o t) = \pi$, $i_c = 0$. Between 0<t<(π/ω_0) , $i_{T1} = I_o + I_p \sin(\omega_0 t)$. Capacitor voltage changes from + to - co-sinusoidally and the lower plate becomes positive. At $(\omega_o t) = \pi$, i_c = 0, $i_{T1} = I_o$ and $v_c = -V_s$ as shown in the waveforms.

At t_1, auxiliary thyristor T2 is turned on. Immediately after TA is on, capacitor voltage V_s applies a reverse voltage across main thyristor T1 so that V_{T1} = -V_s at t_1 and SCR T1 is turned off and $i_{T1} = 0$. The load current is now carried by C and T2. Capacitor gets charged from V_s to +V_s with constant load current I_0. The change is, therefore, linear from +V_s to -V_s as shown. Whenv_c = v_s, $i_c = 0$ at t_2, thyristor T2 is turned off. During the time T2 is on from t_1 to t_2 , V_c = V_{T1}, $i_c = I_0$. For main thyristor T1, circuit turn-off time is t_c as shown in waveforms.

With the firing of thyristor T2, a reverse voltage V_s is suddenly applied across T1; this method of commutation is therefore, also called as voltage commutation. With sudden appearance of reverse voltage across T1, its current is quenched; in fact the current momentarily reverses to recover the stored charge of T1. As an auxiliary thyristor T2 is used for turning –off the main T1, this type of commutation is also known as auxiliary commutation. When thyristor T2 is turned on, capacitor gets connected across T1 to turn it off; this type of commutation is, therefore, also called parallel-capacitor commutation.

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8. *B.K.Bose,"Energy, environment and advances in Power Electronics", IEEE Trans. On P.E. Vol 15, No.4, July 2000.*

Viva Questions-1

Static Characteristics of SCR, TRIAC

1. Explain the construction details of a thyristor.
2. What are the applications of SCR.
3. Define Latching current and Holding current.
4. Define forward break over voltage.
5. Explain the working of SCR with the help of two transistor analogy.
6. Explain different thyristor turn on methods.
7. Explain dv/dt and di/dt protection circuits of a thyristor.
8. Explain different types of thyristors.
9. Explain the importance of series and parallel operation of thyristors.
10. Define the turn off time of SCR.
11. Explain the V-I characteristics of SCR.
12. Explain the V-I characteristics of TRIAC.
13. Explain the different modes of operation of an TRIAC.
14. What are the applications of SCR.
15. What are the applications of TRIAC.
16. Explain how do we find latching current.

Static Characteristics of MOSFET, IGBT

1. Explain the constructional details of MOSFET.
2. Explain the construction details of IGBT.
3. Explain different types of MOSFETs.
4. Compare enhancement and depletion MOSFETs.
5. Define Pinch off voltage, threshold voltage of MOSFETs.
6. Explain the characteristics of MOSFET.
7. Explain the characteristics of IGBT.
8. Explain the advantages and disadvantages of MOSFET.
9. Explain the advantages and disadvantages of IGBT.
10. Explain the control characteristics of MOSFET and IGBT.
11. Compare IGBT with BJT.
12. Compare MOSFET with BJT.
13. What are the applications of MOSFET and IGBT.

Controlled HWR, FWR.

1. What is a firing circuit. Why is it needed.
2. What are the requirements of a firing circuit.
3. Explain R triggering circuit.
4. What are the advantages of pulse triggering circuits.
5. Compare R triggering and RC triggering circuits.
6. Explain the working of RC triggering circuit.
7. Explain the construction of UJT.
8. Explain the V-I characteristics of UJT.
9. Explain the working of UJT triggering circuit.
10. Explain the principle of digital firing circuits.
11. What is the roll of pulse transformer.

AC Voltage Controller using TRIAC-DIAC Combination

1. How TRIAC can be used in AC voltage controller.
2. Explain the working of the circuit given for AC voltage controller.
3. Explain the characteristics of DIAC.
4. What are the applications of AC voltage controllers.
5. What type of triggering is suitable for ac voltage controller with inductive load.

Single phase half and full controlled converter

1. What is a controlled converter?
2. What are the performance parameters of a converter?
3. Compare half controlled converter and full controlled converter.
4. What is the effect of inductive load on converters?
5. Explain the roll of free wheeling diode.
6. Explain the working of a controlled converter.
7. What is a dual converter?
8. Compare single phase and three phase converters.
9. What are the applications of controlled converters?

Speed control of Induction motor and DC motor

1. Explain the working of the circuit used for speed control of Induction motor.
2. Explain the working of the circuit used for DC motor.
3. What types of triggering pulses are used in speed control of motor circuits?

Viva Questions-2

1. What is power Electronics?
2. Mention the different methods of varying the power?
3. What are the advantages of silicon over germanium?
4. What is power device?
5. Mention the different types of power devices?
6. What is an SCR?
7. What are the features of SCR?
8. What are the applications of SCR?
9. What is a Diac?
10. What are the features of Diac?
11. What are the applications of Diac?
12. What is a Triac?
13. What are the features of Triac?
14. What are the applications of Triac?
15. What is power MOSFET?
16. What is power IGBT?
17. What are the applications of MOSFET & IGBT?
18. Compare SCR, DIAC & TRIAC?
19. Compare MOSFET, BJT & IGBT?
20. What is turn on time?
21. What is turn off time?
22. What is static Characteristics?
23. What is dynamic Characteristics?
24. What is the difference between the Static & Dynamic Characteristics?
25. Explain the Turn on Characteristics & Turn off Characteristics of SCR?
26. Explain the gate characteristics of SCR?
27. What is a current controlled device?
28. What is a Voltage controlled device?
29. Explain O/p & Transfer characteristics of MOSFET & IGBT?
30. Explain the intension of using power device in power control circuit?
31. What is a power control?
32. Why SCR is called as Unidirectional Controlled device?
33. Why Diac is called as Bidirectional controlled device?
34. Why Triac is called as Bidirectional controlled device?
35. What is rectifier?
36. What is an Inverter?
37. What is step down chopper? What is its o/p voltage equation?

38. What is step up chopper? What is its o/p voltage equation?
39. What is buck boost regulator? What is its o/p Voltage equation?
40. What is cuck regulator? What is its o/p Voltage equation?
41. Explain the working operation of single phase controlled Half wave rectifier with a) R Load (b) RL Load (c) RL load with free wheeling diode
42. What is an intention of using free wheeling across inductive load in rectifier circuit?
43. What is pulse width?
44. Why turn off time of the circuit should be greater than turn off time of the device?
45. Explain the working operation of single phase full wave controlled rectifier with a) R Load (b) RL Load (c) RL load with free wheeling diode
46. Explain the working operation of single phase half wave controlled rectifier with a) R Load (b) RL Load (c) RL load with free wheeling diode
47. Explain the working operation of single phase full controlled bridge rectifier with a) R Load (b) RL Load (c) RL load with free wheeling diode
48. Define average output voltage, RMS Voltage, peak or maximum voltage?
49. Derive an expression of average output voltage, RMS output voltage of any wave form concerned to rectifier, ac voltage controller, chopper?
50. What are cyclo converters?
51. What is cyclo inverter?
52. Why forced commutation circuit is employed in case of cyclo inverter?
53. What are the advantages of three phase circuit over single phase circuit?
54. What is firing angle or delay angle?
55. What is conduction period?
56. What is meaning of triggering?
57. What are the different types of triggering methods (can be used to trigger SCR)?
58. What are the different types of triggering methods, temperature triggering, light triggering and gate triggering?
59. Why gate triggering is preferred than other types?
60. Mention the different types of gate triggering circuit?
61. Explain the working operation of RC triggering circuit?
62. Why firing angle in case of R triggering circuit if limited to 90 degrees?
63. Explain the working operation of RC Triggering circuit?
64. Explain how firing angle will be extended to more than 90^0 by using Rc triggering Circuit?
65. What is Unijunction Transistor (UJT)?
66. Write equivalent circuit of UJT?
67. Show that V peak=Vp =nV_{BB} + V diode where n = intrinsic stand off ration, VBB= applied or base voltage?
68. Why UJT triggering circuit is superior than R & RC triggering circuit?

69. What is UJT Relaxation oscillation?
70. What is line synchronized UJT triggering circuit?
71. Explain the working operation of UJT relaxation oscillator?
72. Explain the working operation of line synchronized UJT triggering circuit with wave forms at different points?
73. Design of UJT triggering circuit?
74. When UJT will conduct?
75. How UJT exhibits negative resistance property?
76. Why SCR, DIAC, TRIAC are called negative resistance devices?
77. Derive an expression of frequency of UJT triggering pulse?
78. What is the function of pulse transformer?
79. What are the different types of voltage ratings, current ratings and power ratings? Explain each them?
80. Why do we require protection circuits for power devices?
81. What is di/dt rating? How do you protect SCR against high di/dt rating? explain
82. What is dv/dt rating? How do you protect SCR against high dv/dt rating? explain
83. What is over current? How do you protect SCR against over current? explain
84. What is over voltage? How do you protect SCR against over voltage? Explain
85. How device will be protected against heavy power dissipation?
86. Why triac has 4 modes of operations?
87. Why 1^{st}& 2^{nd} mode of operations are operating in 1^{st} Quadrant and 3^{rd} & 4^{th} mode of operations are operating 3^{rd} quadrant?
88. Why mod (1) is mot sensitive among all modes?
89. What is Commutation?
90. What is commutation circuit?
91. What is forced commutation circuit and natural commutation circuit?
92. Mention the different types of forced commutation circuits?
93. Explain the working operation of each forced commutation circuit with wave forms & derivation of designed equations (Class A, Class B, Class C, Class D, Class E and Class F commutation circuit)
94. What is latching current? What is its significance?
95. What is holding current? What is its significance?
96. What is dv/dt rating? What is its significance?
97. What is dual converter?
98. Why full wave bridge controller bridge rectifier with RL Load (not with free wheeling diode) is preferred in dual converter than half wave bridge controlled rectifier with RL load (not free wheeling diode)?
99. Why dual converter is called as four quadrant operator?
100. What is semi converter?

101. What is full converter?
102. Why gate is preferred at base of NPN transistor & not at the base of PNP transistor in SCR?
103. Derive an expression of anode current (SCR Current)?
104. Explain the working operation of SCR with two transistor analogy?
105. Explain the working operation of each practical power Electronics experiments with circuit diagram, wave forms & designed equation?
106. Why output voltage is more at lesser value of firing angle?
107. What are the differences between uncontrolled output & controlled output?
108. How do you design zener voltage regulator?
109. How do you select (design) the value of gate resistor and load resistor concerned to SCR experiments?
110. Why do you check SCR, Triac, Diac, Diode, Zener Diode, wires by using ohm meter?
111. How do you check an ammeter, voltmeter & power supply?
112. Why load resistor has higher wattage?
113. What is series Inverter? Mention the advantages, disadvantages and application of series inverter? Explain its working operation?
114. What is parallel inverter? Explain its working operation?
115. What is continuous mode & discontinuous mode of operations concerned to rectifier with a) RL Load b) RL load with free wheeling diode?
116. Input voltage = device voltage + output voltage. Prove above words?
117. What are the blocking & reverse blocking?
118. What is blocking state or region?
119. What is forward blocking and reverse blocking?
120. What is reverse recovery time?
121. What is gate pulse?
122. Why gate pulses are preferred than continuous gate voltage ?
123. S.T Turn on time =td + tr + ts
124. S.T Turn off time =trr +tgr
125. How do you design gate pulse width?
126. What is snubber circuit? How do you design snubber?
127. What is heat sink its purpose is what?
128. What is circuit breaker and fuse? Why these are used in power circuit?
129. What is ac voltage controller? Mention the different types? What are its applications?
130. Explain the working operation of a) on and off AC Voltage controller b) Unidirectional or Half wave controller C) Bidirectional or full wave AC Voltage controller with R load and RL Load with wave forms with equations?

131. Why continuous gate pulses are applied to full wave ac voltage controller with RL Load circuit?
132. Explain the working operation of static on load tap changer?
133. Why negative gate voltage should not be applied to gate of SCR?
134. Write symbols, static characteristics of all power devices concerned to syllabus?
135. Name different current controlled power devices?
136. Name different Voltage controlled power devices?
137. What is $I^2 t$ rating?

Question Bank

1. Conduct a suitable experiment obtain the V-I characteristics of the SCR and determine holding current, latching current and on state resistance.

2. Conduct a suitable experiment to determine the V-I characteristics of unidirectional four layer switch for two different gate currents. Determine breakdown voltage for two cases.

3. Conduct an experiment to obtain transfer characteristics and output characteristics of an IGBT. Determine the value of Trans-conductance and output resistance

4. Conduct an experiment to obtain transfer characteristics and drain characteristics of an MOSFET. Determine the value of Trans-conductance and drain resistance.

5. Conduct a suitable experiment using SCR in a full wave rectifier circuit to vary the 'firing angle (α)' using digital firing circuit. Plot a graph of input and output voltage with and without free-wheeling diode. a) $\alpha=60^0$ b) $\alpha=120^0$ c) $\alpha=90^0$ d) $\alpha=150^0$

6. Conduct an experiment to obtain synchronized triggering pulses using UJT to turn on SCR in a full wave rectifier with resistive load. Plot a graph of output DC voltage v/s firing angle (α).

7. Conduct a suitable experiment using SCR in a full wave rectifier circuit to vary the 'firing angle (α)' using firing module with R,R-L load. Plot a graph of input and output voltage with and without free-wheeling diode.

8. Conduct a suitable experiment to control the illumination of an incandescent lamp using TRIAC-DIAC combination. Plot a graph of V_{rms} v/s firing angle (α) and I_{rms} firing angle.

9. Conduct a suitable experiment on an inverter and plot the curve between output voltage v/s duty cycles.

10. Conduct a suitable experiment to control the speed of a single phase induction motor. Plot a graph of speed v/s firing angle (α).

11. Conduct a suitable experiment to control the speed of a DC motor. Plot a graph of speed v/s firing angle(α)

12. Conduct a suitable experiment obtain the V-I characteristics of the TRIAC.

13. Design a Snubber circuit.

Annexure

Theory of Stepper Motor:

Stepping motor is an electric motor which converts digital electric input in to a mechanical motion. Compared with other motor that can perform the same or similar functions, a control system using stepping motor has several significant advantages as follows:

1. No feed back is normally required for either position control or speed control.
2. Positional error is non-cumulative.
3. Stepping motor is compatible with modern digital equipment.

In stepping motor the stator core has 6 salient poles or teeth, while the rotor has 4 poles. Three sets of windings are arranged as shown in figure1. Each set has 2 coils connected in series. A set of winding is called a phase, consequently this machine is three phase motor. Current is supplied from a DC power source to the winding via switches 1, 2 & 3. In state (1), the winding of phase 1 is supplied with current through switch 1 or ‘phase 1 is excited’. The magnetic flux is built up at the stator poles of phase II in the manner shown in state (2) and ,a counter – clockwise torque is created owing to ‘tension’ in the inclined magnetic field lines. The rotor will then, eventually, reach state (3). Thus the rotor rotates through a fixed angle, which is termed the ‘step angle’, 15^{o} in this case, as one switching operation is carried out. If switch I is now opened to de- energize phase I, the rotor will travel another 15^{o} to reach state (4). The angular position of the rotor can thus be controlled in units of the step angle by a switching process. If the switching is carried out in sequence, the rotor will rotate with a stepped motion; the average speed can also be controlled by the switching process.

Stepping motor used for paper tape purpose is usually three or four phase motor. The tape drive system can be considered in the form of block diagram shown in fig.

The most important feature of the stepping motor is that it revolves through a fixed angle for each pulse applied to the logic sequencer. The rated value of this value of this angle (degrees) is referred to as the step angle.

Upon receiving a step command pulse, the logic sequencer determines the phase to be excited (or energized) and the phase to be de-energized and sends signals to the motor driver which is the stage which controls current supplied to the motor. The logic sequencer is usually assembled with TTL or CMOS integrated circuit chips. When potential of an output cannel from the logic sequencer is on level H (high) the power driver works to excite corresponding phase of the winding similarly if the output is at level L (low), the phase of the same number is not excited or it is turned off.

Modes of excitation:

1. Single phase excitation. 2. Two phase excitation. 3. Half-step mode excitation.

Single phase excitation**:** Table1 shows the sequences of a single phase excitation mode for 3 & 4 phase motor. The shaded parts in the table represent the excited state, & the white blanks show the phases to which current is not supplied & so are not excited. The operation by single phase excitation is also known as 1 phase on drive.

Two phase excitation*:* The operation of a motor in which 2 phases are always excited is called 2 phases on operation. The sequence for 3 & 4 phases motor are shown in table 2.

Half step mode excitation: The excitation scheme that is a combination of single phase & 2 phase excitation is so called half step operation. The excitation sequence for three phase motor is given in table 3.

Components Data Sheets:

PHILIPS INTERNATIONAL

Philips Semiconductors

Data sheet	
status	Preliminary specification
date of issue	December 1990

2N2646
Silicon unijunction transistor

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$-V_{EB2}$	emitter-base 2 voltage		–	–	30	V
I_{EM}	emitter current	peak value	–	–	2	A
P_{tot}	total power dissipation		–	–	300	mW
T_j	junction temperature		–	–	125	°C
R_{BB}	static inter-base resistance	V_{B2B1} = 3 V I_E = 0	–	7	–	kΩ
V_{EB1sat}	emitter-base 1 saturation voltage	V_{B2B1} = 10 V I_E = 50 mA	–	3.5	–	V
$I_{E(V)}$	emitter valley point current		4	6	–	mA
$I_{E(P)}$	emitter peak point current		–	1	5	μA

PINNING - TO-18

Base 2 connected to case.

PIN	DESCRIPTION
1	emitter
2	base 1
3	base 2

PIN CONFIGURATION

Fig.1 Simplified outline and symbol.

Philips Semiconductors Preliminary specification

Silicon unijunction transistor 2N2646

CHARACTERISTICS

T_{amb} = 25 °C unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
R_{BB}	static inter-base resistance	V_{B2B1} = 3 V I_E = 0	4.7	7	9.1	kΩ
TC_{RBB}	inter-base resistance temperature coefficient	V_{B2B1} = 3 V I_E = 0 T_{amb} = −55 to 125 °C	0.1	–	0.9	%/K
$-I_{EB2O}$	emitter cut-off current	$-V_{EB2}$ = 30 V I_{B1} = 0	–	–	12	V
V_{EB1sat}	emitter-base 1 saturation voltage	V_{B2B1} = 10 V I_E = 50 mA	–	3.5	–	V
I_{B2mod}	inter-base current modulation	V_{B2B1} = 10 V I_E = 50 mA	–	15	–	mA
η	input/output ratio (note 1)	V_{B2B1} = 10 V	0.56	–	0.75	
$I_{E(V)}$	emitter valley point current	V_{B2B1} = 20 V R_{B2} = 100 Ω	4	6	–	mA
$I_{E(P)}$	emitter peak point current	V_{B2B1} = 25 V	–	1	5	μA
V_{OB1M}	base 1 impulse/output voltage		3	5	–	V

Note

1. $\eta = \frac{(V_{E(P)} - V_{EB1})}{V_{B2B1}}$, when $V_{E(P)}$ = emitter peak point voltage, V_{EB1} = emitter-base 1 breakdown voltage, (approximately 0.5 V at 10 μA), and V_{B2B1} = inter-base voltage.

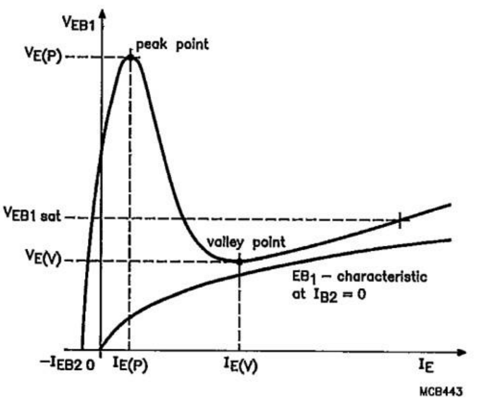


Fig.3 Impulse as a function of output voltage.

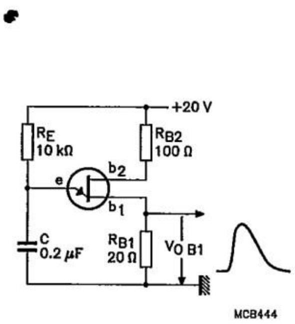


Fig.4 Impulse output circuit.

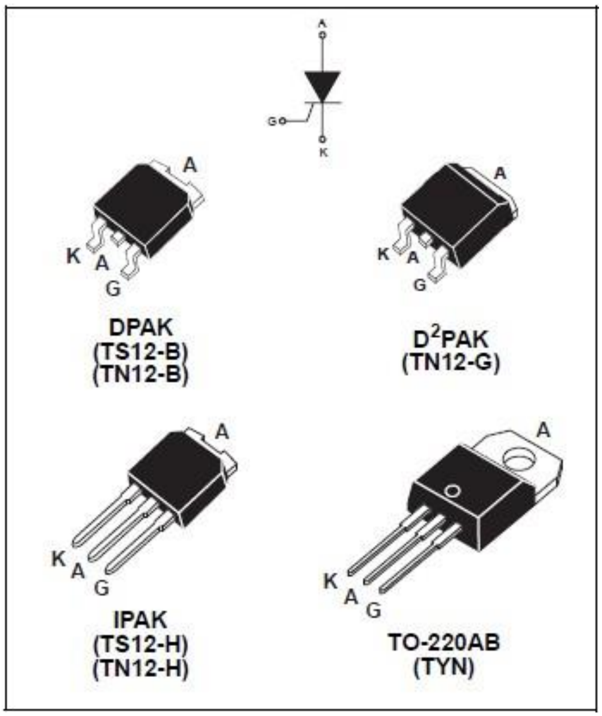
December 1990 735

TN12, TS12 and TYNx12 Series

SENSITIVE & STANDARD 12A SCRs

MAIN FEATURES:

Symbol	Value	Unit
$I_{T(RMS)}$	12	A
V_{DRM}/V_{RRM}	600 to 1000	V
I_{GT}	0.2 to 15	mA



DESCRIPTION

Available either in sensitive (TS12) or standard (TYN, TN12...) gate triggering levels, the 12A SCR series is suitable to fit all modes of control found in applications such as overvoltage crowbar protection, motor control circuits in power tools and kitchen aids, in-rush current limiting circuits, capacitive discharge ignition, voltage regulation circuits...

Available in though-hole or surface-mount packages, they provide an optimized performance in a limited space area.

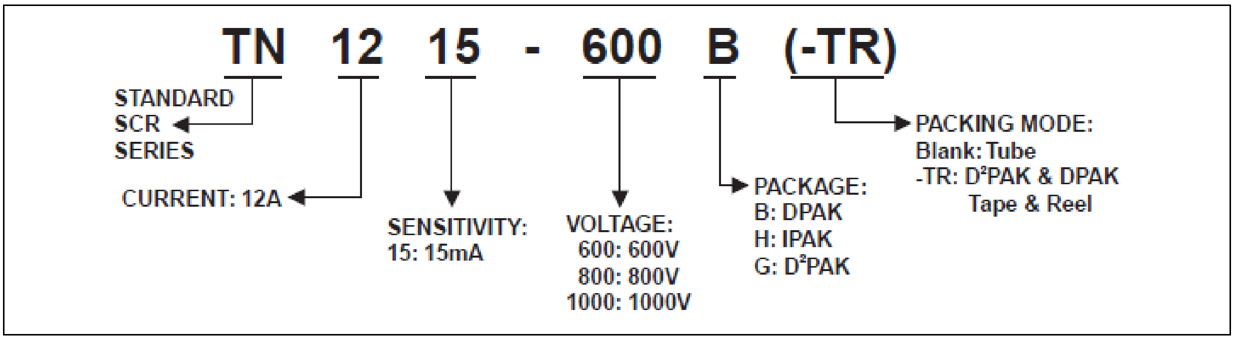
ABSOLUTE RATINGS (limiting values)

Symbol	Parameter			Value		Unit
$I_{T(RMS)}$	RMS on-state current (180° conduction angle)		Tc = 105°C	12		A
$I_{T(AV)}$	Average on-state current (180° conduction angle)		Tc = 105°C	8		A
				DPAK / IPAK	D²PAK / TO-220AB	
I_{TSM}	Non repetitive surge peak on-state current	tp = 8.3 ms	Tj = 25°C	115	146	A
		tp = 10 ms		110	140	
I^2t	I^2t Value for fusing	tp = 10 ms	Tj = 25°C	60	98	A^2s
dI/dt	Critical rate of rise of on-state current $I_G = 2 \times I_{GT}$, tr ≤ 100 ns	F = 60 Hz	Tj = 125°C	50		A/µs
I_{GM}	Peak gate current	tp = 20 µs	Tj = 125°C	4		A
$P_{G(AV)}$	Average gate power dissipation		Tj = 125°C	1		W
T_{stg} Tj	Storage junction temperature range Operating junction temperature range			- 40 to + 150 - 40 to + 125		°C
V_{RGM}	Maximum peak reverse gate voltage (for TN12 & TYN)			5		V

PRODUCT SELECTOR

Part Number	Voltage (xxx)				Sensitivity	Package
	600 V	700 V	800 V	1000 V		
TN1215-xxxB	X		X		15 mA	DPAK
TN1215-xxxG	X		X	X	15 mA	D^2PAK
TN1215-xxxH	X		X		15 mA	IPAK
TS1220-xxxB	X	X			0.2 mA	DPAK
TS1220-xxxH	X	X			0.2 mA	IPAK
TYNx12	X		X	X	30 mA	TO-220AB
TYNx12T	X		X	X	15 mA	TO-220AB

ORDERING INFORMATION



Philips Semiconductors — Product specification

Triacs sensitive gate — BT136 series E

GENERAL DESCRIPTION

Passivated, sensitive gate triacs in a plastic envelope, intended for use in general purpose bidirectional switching and phase control applications, where high sensitivity is required in all four quadrants.

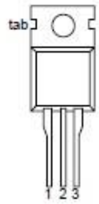
QUICK REFERENCE DATA

SYMBOL	PARAMETER	MAX.	MAX.	UNIT
	BT136-	**600E**	**800E**	
V_{DRM}	Repetitive peak off-state voltages	600	800	V
$I_{T(RMS)}$	RMS on-state current	4	4	A
I_{TSM}	Non-repetitive peak on-state current	25	25	A

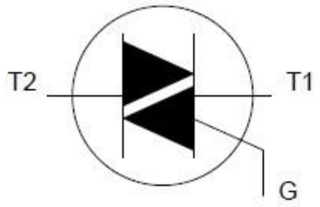
PINNING - TO220AB

PIN	DESCRIPTION
1	main terminal 1
2	main terminal 2
3	gate
tab	main terminal 2

PIN CONFIGURATION



SYMBOL



LIMITING VALUES

Limiting values in accordance with the Absolute Maximum System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.		UNIT
				-600	**-800**	
V_{DRM}	Repetitive peak off-state voltages		-	600[1]	800	V
$I_{T(RMS)}$	RMS on-state current	full sine wave; $T_{mb} \leq 107$ ˚C	-	4		A
I_{TSM}	Non-repetitive peak on-state current	full sine wave; $T_j = 25$ ˚C prior to surge				
		t = 20 ms	-	25		A
		t = 16.7 ms	-	27		A
I^2t	I^2t for fusing	t = 10 ms	-	3.1		A^2s
dI_T/dt	Repetitive rate of rise of on-state current after triggering	$I_{TM} = 6$ A; $I_G = 0.2$ A; $dI_G/dt = 0.2$ A/µs				
		T2+ G+	-	50		A/µs
		T2+ G-	-	50		A/µs
		T2- G-	-	50		A/µs
		T2- G+	-	10		A/µs
I_{GM}	Peak gate current		-	2		A
V_{GM}	Peak gate voltage		-	5		V
P_{GM}	Peak gate power		-	5		W
$P_{G(AV)}$	Average gate power	over any 20 ms period	-	0.5		W
T_{stg}	Storage temperature		-40	150		˚C
T_j	Operating junction temperature		-	125		˚C

THERMAL RESISTANCES

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$R_{th\ j-mb}$	Thermal resistance junction to mounting base	full cycle	-	-	3.0	K/W
		half cycle	-	-	3.7	K/W
$R_{th\ j-a}$	Thermal resistance junction to ambient	in free air	-	60	-	K/W

STATIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_{GT}	Gate trigger current	V_D = 12 V; I_T = 0.1 A				
		T2+ G+	-	2.5	10	mA
		T2+ G-	-	4.0	10	mA
		T2- G-	-	5.0	10	mA
		T2- G+	-	11	25	mA
I_L	Latching current	V_D = 12 V; I_{GT} = 0.1 A				
		T2+ G+	-	3.0	15	mA
		T2+ G-	-	10	20	mA
		T2- G-	-	2.5	15	mA
		T2- G+	-	4.0	20	mA
I_H	Holding current	V_D = 12 V; I_{GT} = 0.1 A	-	2.2	15	mA
V_T	On-state voltage	I_T = 5 A	-	1.4	1.70	V
V_{GT}	Gate trigger voltage	V_D = 12 V; I_T = 0.1 A	-	0.7	1.5	V
		V_D = 400 V; I_T = 0.1 A; T_j = 125 ˚C	0.25	0.4	-	V
I_D	Off-state leakage current	$V_D = V_{DRM(max)}$; T_j = 125 ˚C	-	0.1	0.5	mA

DYNAMIC CHARACTERISTICS

T_j = 25 ˚C unless otherwise stated

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
dV_D/dt	Critical rate of rise of off-state voltage	V_{DM} = 67% $V_{DRM(max)}$; T_j = 125 ˚C; exponential waveform; gate open circuit	-	50	-	V/μs
t_{gt}	Gate controlled turn-on time	I_{TM} = 6 A; $V_D = V_{DRM(max)}$; I_G = 0.1 A; dI_G/dt = 5 A/μs	-	2	-	μs

GOOD-ARK

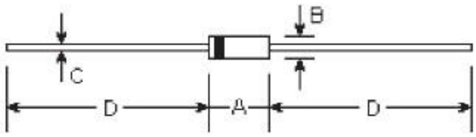
BY127, BY133, EM513, EM516

GENERAL PURPOSE PLASTIC RECTIFIER
Reverse Voltage - 1250 to 1800 Volts
Forward Current - 1.0 Ampere

Features

- The plastic package carries Underwriters Laboratory Flammability Classification 94V-0
- Construction utilizes void-free molded plastic technique
- Low reverse leakage
- Low forward voltage drop
- High current capability
- High reliability
- High surge current capability

DO-41



DIMENSIONS					
DIM	inches		mm		Note
	Min.	Max.	Min.	Max.	
A	0.165	0.205	4.2	5.2	
B	0.079	0.106	2.0	2.7	Φ
C	0.028	0.034	0.71	0.86	Φ
D	1.000	-	25.40	-	

Mechanical Data

- **Case:** Molded plastic, DO-41
- **Lead:** Axial leads, solderable per MIL-STD-202, method 208 guaranteed
- **Polarity:** Color band denotes cathode end
- **Mounting Position:** Any
- **Weight:** 0.012 ounce, 0.33 gram

Maximum Ratings and Electrical Characteristics

Ratings at 25℃ ambient temperature unless otherwise specified.
Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

	Symbols	BY127	BY133	EM513	EM516	Units
Maximum repetitive peak reverse voltage	V_{RRM}	1250	1300	1600	1800	Volts
Maximum RMS voltage	V_{RMS}	875	910	1120	1270	Volts
Maximum DC blocking voltage	V_{DC}	1250	1300	1600	1800	Volts
Maximum average forward rectified current 0.375" (9.5mm) lead length at T_A=75℃	$I_{(AV)}$	1.0				Amp
Peak forward surge current 8.3mS single half sine-wave superimposed on rated load (MIL-STD-750D 4066 method)	I_{FSM}	30.0				Amps
Maximum forward voltage at 1.0A DC and 25℃	V_F	1.1				Volts
Maximum full load reverse current at rated DC blocking voltage T_A=25℃ / T_A=100℃	I_R	5.0 200.0				μA
Typical junction capacitance (Note 1)	C_J	15.0				pF
Typical thermal resistance (Note 2)	$R_{\Theta JA}$ $R_{\Theta JL}$	50.0 25.0				℃/W
Operating and storage temperature range	T_J, T_{STG}	-55 to +150				℃

Notes:

(1) Measured at 1.0MHz and applied reverse voltage of 4.0 VDC
(2) Thermal resistance junction to ambient and from junction to lead at 0.375" (9.5mm) lead length, P.C.B. mounted

IRF540

N-CHANNEL 100V - 0.055 Ω - 22A TO-220
LOW GATE CHARGE STripFET™ II POWER MOSFET

TYPE	V_{DSS}	$R_{DS(on)}$	I_D
IRF540	100 V	<0.077 Ω	22 A

- TYPICAL $R_{DS}(on)$ = 0.055Ω
- EXCEPTIONAL dv/dt CAPABILITY
- 100% AVALANCHE TESTED
- LOW GATE CHARGE
- APPLICATION ORIENTED CHARACTERIZATION

TO-220

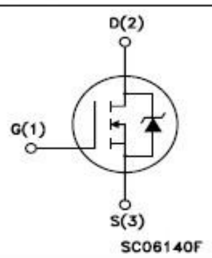
DESCRIPTION

This MOSFET series realized with STMicroelectronics unique STripFET process has specifically been designed to minimize input capacitance and gate charge. It is therefore suitable as primary switch in advanced high-efficiency, high-frequency isolated DC-DC converters for Telecom and Computer applications. It is also intended for any applications with low gate drive requirements.

APPLICATIONS

- HIGH-EFFICIENCY DC-DC CONVERTERS
- UPS AND MOTOR CONTROL

INTERNAL SCHEMATIC DIAGRAM



Ordering Information

SALES TYPE	MARKING	PACKAGE	PACKAGING
IRF540	IRF540&	TO-220	TUBE

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{DS}	Drain-source Voltage (V_{GS} = 0)	100	V
V_{DGR}	Drain-gate Voltage (R_{GS} = 20 kΩ)	100	V
V_{GS}	Gate- source Voltage	± 20	V
I_D	Drain Current (continuous) at T_C = 25°C	22	A
I_D	Drain Current (continuous) at T_C = 100°C	15	A
I_{DM}(•)	Drain Current (pulsed)	88	A
P_{tot}	Total Dissipation at T_C = 25°C	85	W
	Derating Factor	0.57	W/°C
dv/dt (1)	Peak Diode Recovery voltage slope	9	V/ns
E_{AS} (2)	Single Pulse Avalanche Energy	220	mJ
T_{stg}	Storage Temperature	-55 to 175	°C
T_j	Max. Operating Junction Temperature		

(•) Pulse width limited by safe operating area.

1) I_{SD} ≤22A, di/dt ≤300A/µs, $V_{DD} \le V_{(BR)DSS}$, $T_j \le T_{JMAX}$
(2) Starting T_j = 25 °C, I_D = 12A, V_{DD} = 30V

IRF540

THERMAL DATA

Rthj-case	Thermal Resistance Junction-case	Max	1.76	°C/W
Rthj-amb	Thermal Resistance Junction-ambient	Max	62.5	°C/W
T_l	Maximum Lead Temperature For Soldering Purpose	Typ	300	°C

ELECTRICAL CHARACTERISTICS (T_{case} = 25 °C unless otherwise specified)

OFF

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source Breakdown Voltage	I_D = 250 µA, V_{GS} = 0	100			V
I_{DSS}	Zero Gate Voltage Drain Current (V_{GS} = 0)	V_{DS} = Max Rating V_{DS} = Max Rating T_C = 125°C			1 10	µA µA
I_{GSS}	Gate-body Leakage Current (V_{DS} = 0)	V_{GS} = ± 20V			±100	nA

ON (1)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS} I_D = 250 µA	2	3	4	V
$R_{DS(on)}$	Static Drain-source On Resistance	V_{GS} = 10 V I_D = 11 A		0.055	0.077	Ω

DYNAMIC

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
g_{fs} (*)	Forward Transconductance	V_{DS} =25 V I_D = 11 A		20		S
C_{iss} C_{oss} C_{rss}	Input Capacitance Output Capacitance Reverse Transfer Capacitance	V_{DS} = 25V, f = 1 MHz, V_{GS} = 0		870 125 52		pF pF pF