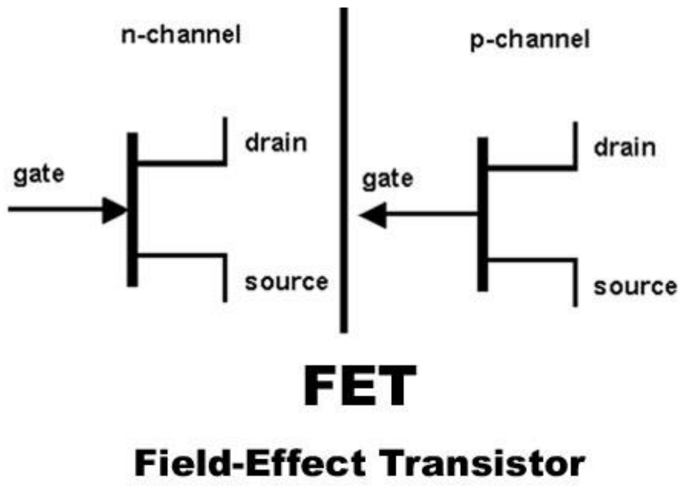
Other Electronic Devices

Contents

- Field-Effect Transistors(FETs)
  - JFETs
  - MOSFETs
- Insulate Gate Bipolar Transistors(IGBTs)
- Silicon-Controlled Rectifiers(SCRs)
- TRIACs

FETs Main Features

- “Field-effect” relates to the depletion region formed in the channel of a FET
- Voltage-controlled devices
- Voltage between Gate and Source(V_{GS}) control the current through the device



FETs Advantages

- Very high input impedance (on the order of 100 MΩ or more)
- A high degree of isolation between input and output.
- Typically produces less noise than a bipolar junction transistor (BJT), and is thus found in noise sensitive electronics such as tuners and low-noise amplifiers for VHF and satellite receivers
- Preferred device in low-voltage switching application
- Faster than BJTs
- Better thermal stability than a BJT

FETs Disadvantages

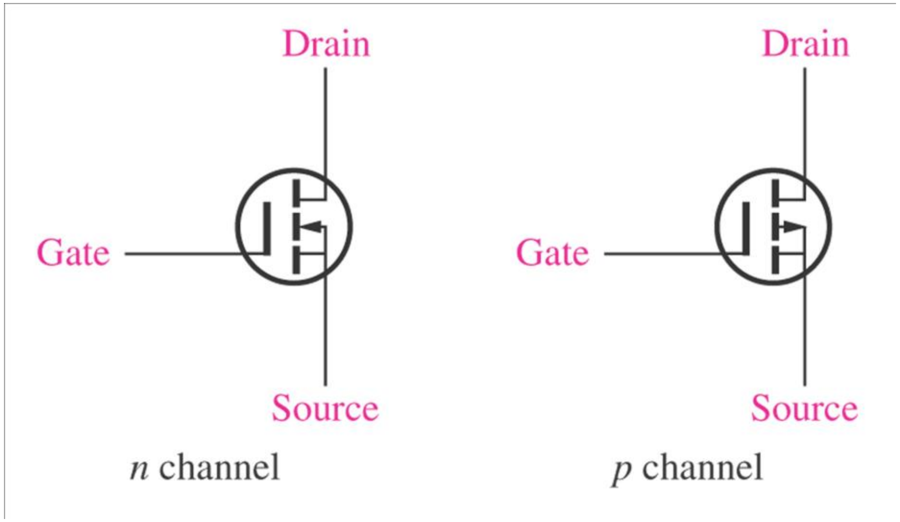
- Low gain-bandwidth product compared to a BJT
- Susceptible to overload voltages
- Vulnerable to electrostatic damage
- Low current capability

MOSFETs Features

- MOSFETs(Metal oxide semiconductor field-effect transistor)
- No pn junction structure
- Gate of MOSFET insulated from the channel by SiO_2
- 2 Types: Depletion(D) and Enhancement(E)
- Enhancement MOSFET is more widely used.

1.Depletion Type –the transistor requires the Gate-Source voltage, (V_{GS}) to switch the device “OFF”. The depletion mode MOSFET is equivalent to a “Normally Closed” switch.
2.Enhancement Type –the transistor requires a Gate-Source voltage,(V_{GS}) to switch the device “ON”. The enhancement mode MOSFET is equivalent to a “Normally Open” switch.

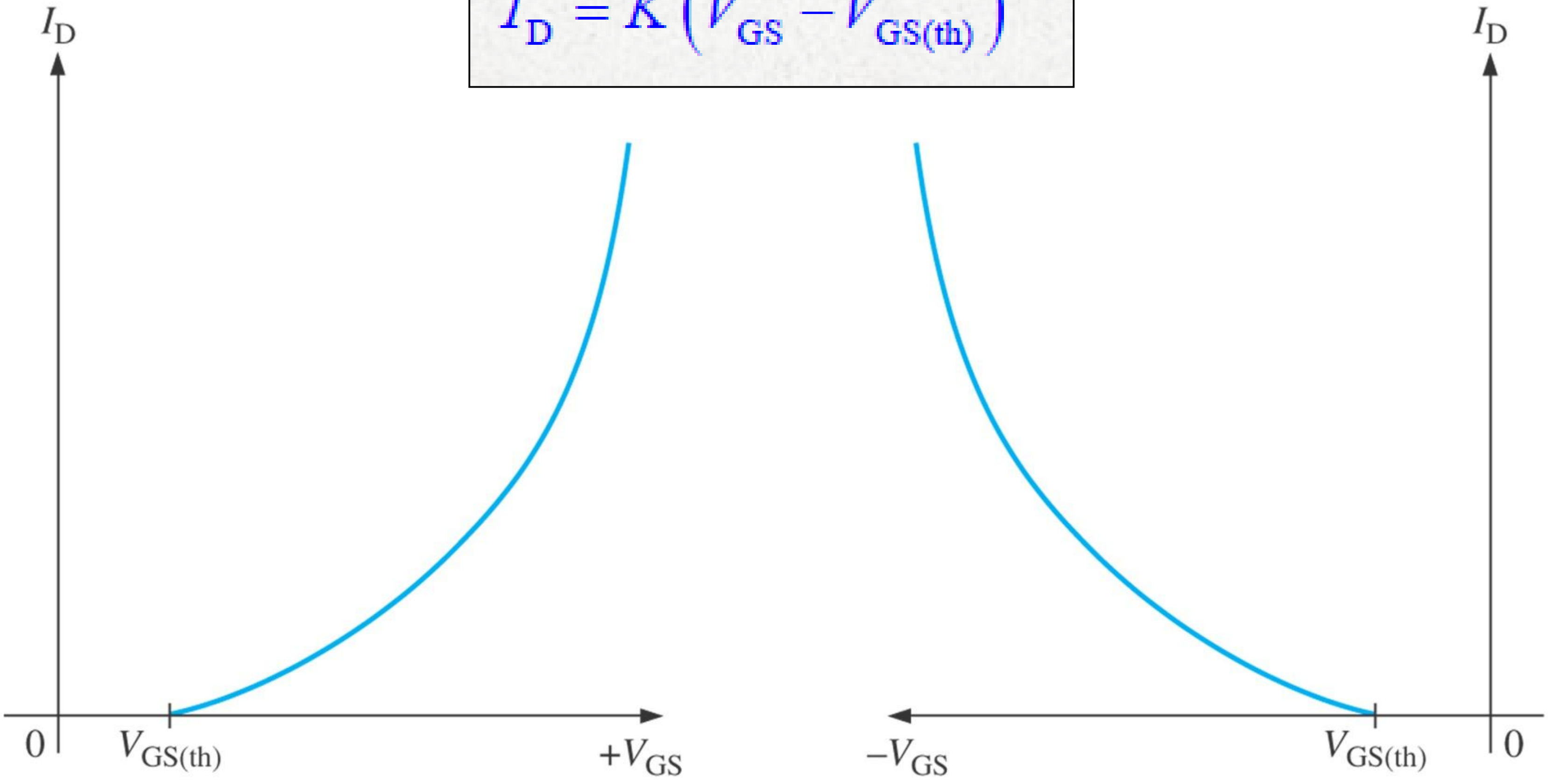
E-MOSFET Symbol



MOSFET type	V_{GS} = +ve	V_{GS} = 0	V_{GS} = -ve
N-Channel Depletion	ON	ON	OFF
N-Channel Enhancement	ON	OFF	OFF
P-Channel Depletion	OFF	ON	ON
P-Channel Enhancement	OFF	OFF	ON

E-MOSFET general transfer characteristic curves

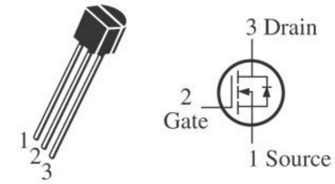
$$I_D = K\left(V_{GS} - V_{GS(th)}\right)^2$$



(a) *n* channel (b) *p* channel

2N7008

Case 29-04, Style 22
TO-92 (TO-226AA)



TMOS FET
Transistor

***N* channel — Enhancement**

Maximum Ratings

Rating	Symbol	Value	Unit
Drain-Source voltage	V_{DSS}	60	V dc
Drain-Gate voltage (R_{GS} = 1 MΩ)	V_{DGR}	60	V dc
Gate-Source voltage	V_{GS}	±40	V dc
Drain current Continuous Pulsed	 I_D I_{DM}	 150 1000	mA dc
Total power dissipation @ T_A = 25°C Derate above 25°C	P_D	400 3.2	mW mW/°C
Operating and storage temperature range	T_J, T_{stg}	–55 to +150	°C

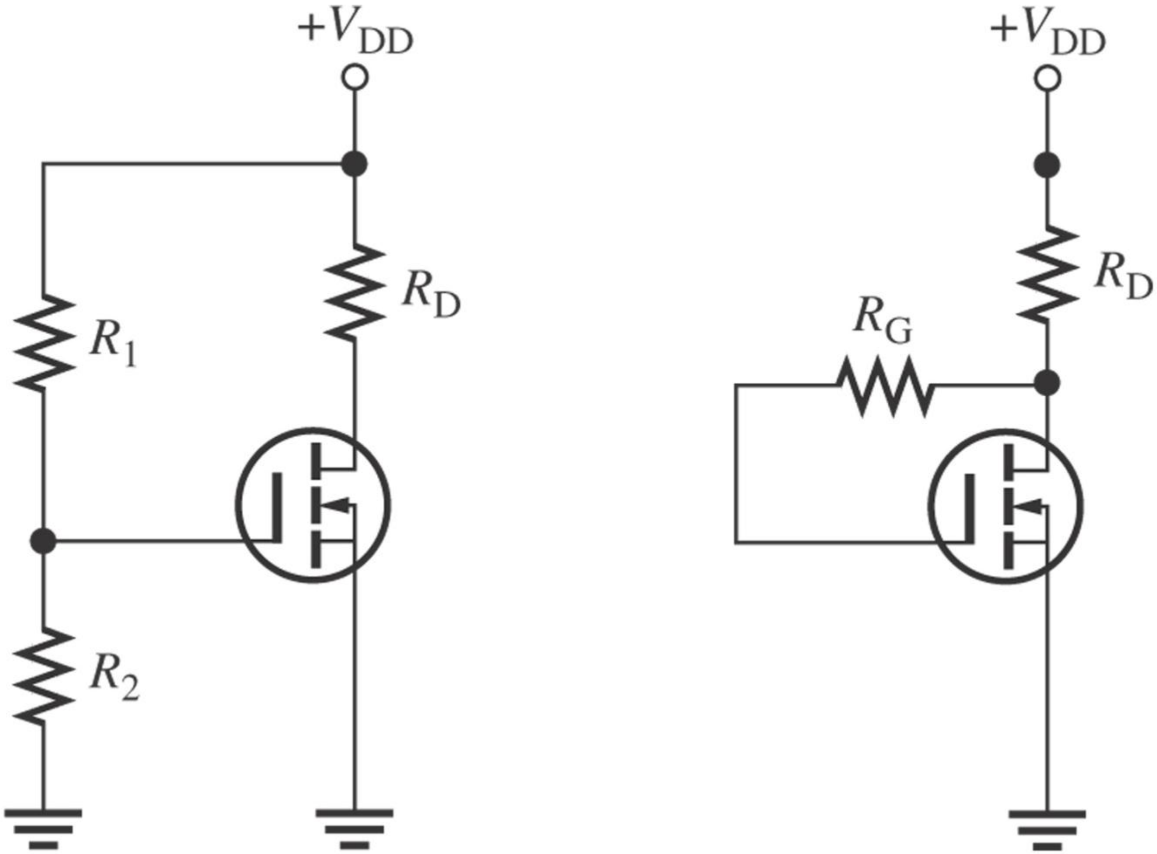
Thermal Characteristics

Thermal resistance junction to ambient	$R_{\theta JA}$	312.5	°C/W
Maximum lead temperature for soldering purposes, 1/16" from case for 10 seconds	T_L	300	°C

Electrical Characteristics (T_C = 25°C unless otherwise noted.)

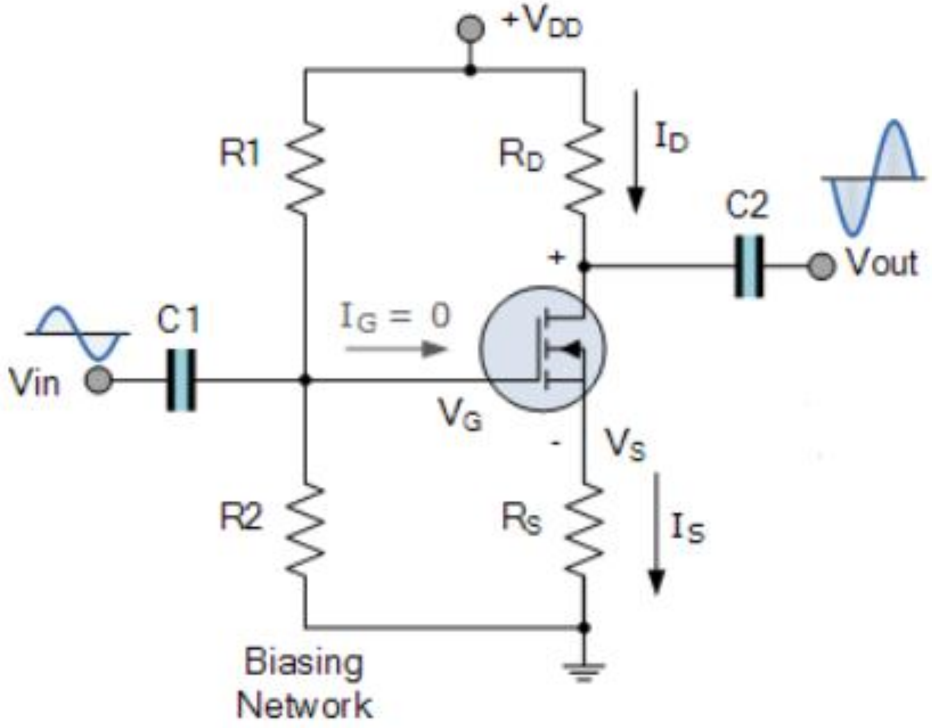
Characteristic		Symbol	Min	Max	Unit
OFF Characteristics					
Drain-Source breakdown voltage (V_{GS} = 0, I_D = 100 μA)		$V_{(BR)DSS}$	60	–	V dc
Zero gate voltage drain current (V_{DS} = 50 V, V_{GS} = 0) (V_{DS} = 50 V, V_{GS} = 0, T_J = 125°C)		I_{DSS}	 – –	 1.0 500	μA dc
Gate-Body leakage current, forward (V_{GSF} = 30 V dc, V_{DS} = 0)		I_{GSSF}	–	–100	nA dc
ON Characteristics					
Gate threshold voltage ($V_{DS} = V_{GS}$, I_D = 250 μA)		$V_{GS(th)}$	1.0	2.5	V dc
Static drain-source on-resistance (V_{GS} = 5.0 V dc, I_D = 50 A dc) (V_{GS} = 10 V dc, I_D = 500 mA dc, T_C = 125°C)		$r_{DS(on)}$	 – –	 7.5 13.5	Ohm
Drain-Source on-voltage (V_{GS} = 5.0 V, I_D = 50 mA) (V_{GS} = 10 V, I_D = 500 mA)		$V_{DS(on)}$	 – –	 1.5 3.75	V dc
On-state drain current (V_{GS} = 10 V, $V_{DS} \geq 2.0V_{D(on)}$)		$I_{D(on)}$	500	–	mA
Forward transconductance ($V_{DS} \geq 2.0V_{DS(on)}$, I_D = 200 mA)		g_{fs}	80	–	μmhos or μS
Dynamic Characteristics					
Input capacitance	(V_{DS} = 25 V, V_{GS} = 0 f = 1.0 MHz)	C_{iss}	–	50	pF
Output capacitance		C_{oss}	–	25	
Reverse transfer capacitance		C_{rss}	–	5.0	
Switching Characteristics					
Turn-On delay time	(V_{DD} = 30 V, I_D = 200 mA R_{gen} = 25 ohms, R_L = 150 ohms)	t_{on}	–	20	ns
Turn-Off delay time		t_{off}	–	20	

MOSFETs Bias



(a) Voltage-divider bias (b) Drain-feedback bias

Enhancement-mode N-Channel MOSFET Amplifier



MOSFETs Summary

The Metal Oxide Semiconductor Field Effect Transistor, or **MOSFET** for short, has an extremely high input gate resistance with the current flowing through the channel between the source and drain being controlled by the gate voltage. Because of this high input impedance and gain, MOSFETs can be easily damaged by static electricity if not carefully protected or handled.

MOSFET's are ideal for use as electronic switches or as common-source amplifiers as their power consumption is very small. Typical applications for metal oxide semiconductor field effect transistors are in Microprocessors, Memories, Calculators and Logic CMOS Gates etc.

Key Terms

MOSFET	Metal oxide semiconductor field effect transistor; one of two major types of FETs; sometimes called IGFET.
Depeletion	In a MOSFET, the process of removing or depleting the channel of charge carriers and thus decreasing the channel conductivity.
Enhancement	In a MOSFET, the process of creating a channel or increasing the conductivity of the channel by the addition of charge carriers.

Power MOSFETs

-Operating as similar as tradition MOSFET but with higher power rating.

-High operating frequency i.e. normally >20kHz

-Switching ON/OFF by voltage signal; i.e. ±15-20V

Power MOSFET
12 Amps, 60 Volts
N–Channel TO–220

This Power MOSFET is designed to withstand high energy in the avalanche and commutation modes. Designed for low voltage, high speed switching applications in power supplies, converters and power motor controls, these devices are particularly well suited for bridge circuits where diode speed and commutating safe operating areas are critical and offer additional safety margin against unexpected voltage transients.

- On–resistance Area Product about One–half that of Standard MOSFETs with New Low Voltage, Low $R_{DS(on)}$ Technology
- Faster Switching than E–FET Predecessors
- Avalanche Energy Specified
- I_{DSS} and $V_{DS(on)}$ Specified at Elevated Temperature
- Static Parameters are the Same for both TMOS V and TMOS E–FET

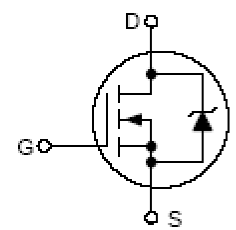
MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain–Source Voltage	V_{DSS}	60	Vdc
Drain–Gate Voltage (R_{GS} = 1.0 MΩ)	V_{DGR}	60	Vdc
Gate–Source Voltage – Continuous – Non–Repetitive ($t_p \le$ 10 ms)	 V_{GS} V_{GSM}	 ± 20 ± 25	 Vdc Vpk
Drain Current – Continuous @ 25°C – Continuous @ 100°C – Single Pulse ($t_p \le$ 10 µs)	I_D I_D I_{DM}	12 7.3 37	Adc Apk
Total Power Dissipation @ 25°C Derate above 25°C	P_D	48 0.32	Watts W/°C
Operating and Storage Temperature Range	T_J, T_{stg}	–55 to 175	°C
Single Pulse Drain–to–Source Avalanche Energy – Starting T_J = 25°C	E_{AS}	72	mJ

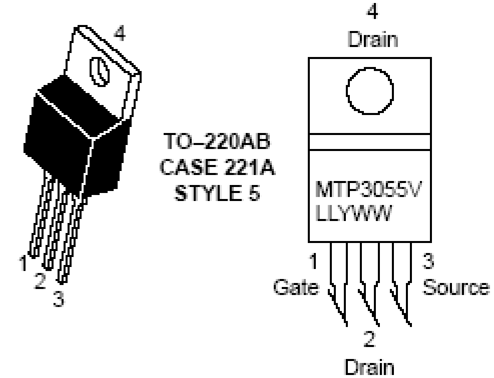
ON Semiconductor™

http://onsemi.com

12 AMPERES
50 VOLTS
$R_{DS(on)}$ = 150 mΩ

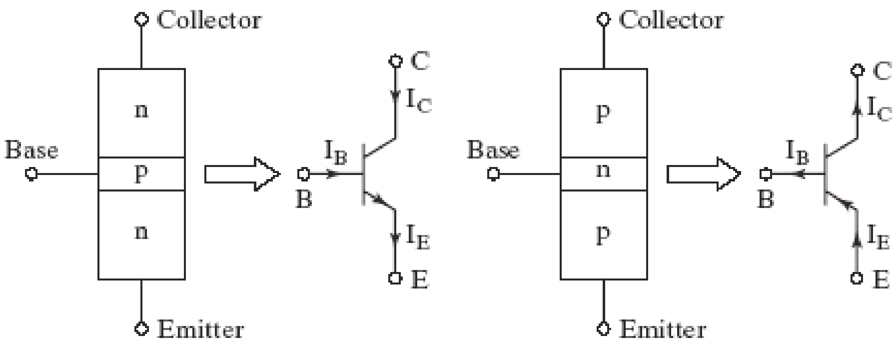


MARKING DIAGRAM & PIN ASSIGNMENT

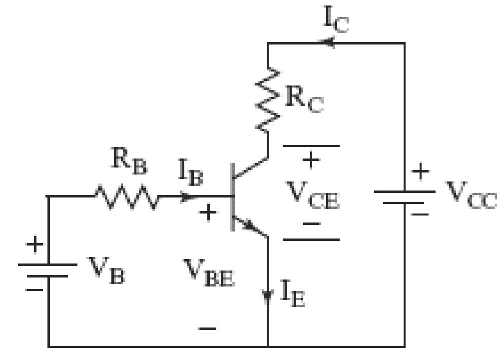


Power Transistor

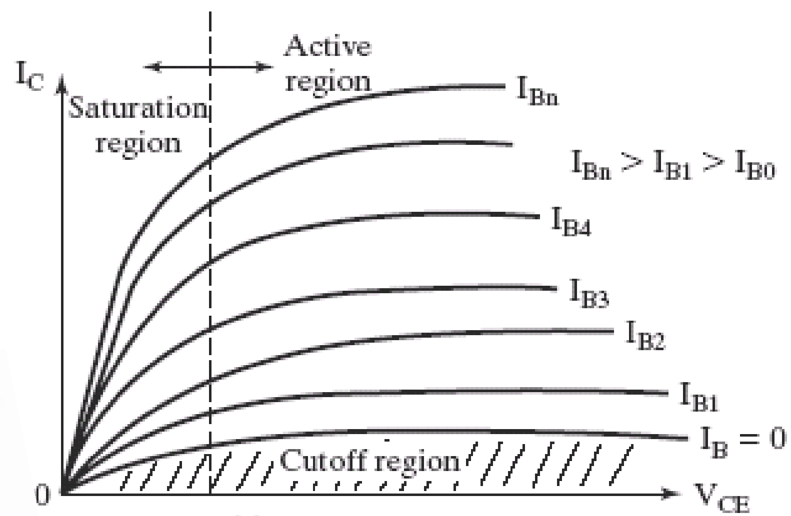
- Its characteristic is as normal BJT but with higher power rating.
- It is a current controlled switching devices.
- V_{CE} (on-state) is varied depending on current and voltage rating



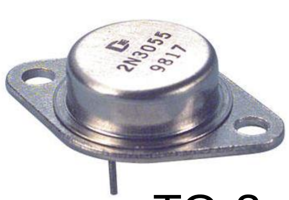
(a) NPN and PNP



(b) Switching circuit



(c) Characteristic



TO-3

TO-220

TO-92

IGBTs(Insulated Gate Bipolar Transistor)

- Its operation is similar to BJT but unlike BJT, *IGBT requires voltage signal for switching.* It can be considered as an advantage combination between BJT and MOSFET.
- High current capability
- Medium operating frequency i.e. normally 5-20 kHz

DYNEX SEMICONDUCTOR

GP200MHS12

Half Bridge IGBT Module

Replaces GP200MHB12S January 1999 version, DS4339-5.5 — DS5296-1.5 November 2000

FEATURES

- Non Punch Through Silicon
- Isolated Copper Baseplate
- Low Inductance Internal Construction

KEY PARAMETERS

V_{CES}		1200V
$V_{CE(sat)}$	(typ)	2.7V
I_C	(max)	200A
$I_{C(PK)}$	(max)	400A

APPLICATIONS

- High Power Inverters
- Motor Controllers
- Induction Heating
- Resonant Converters

The Powerline range of high power modules includes half bridge and single switch configurations covering voltages from 600V to 3300V and currents up to 4800A.

The GP200MHS12 is a half bridge 1200V, n channel enhancement mode, insulated gate bipolar transistor (IGBT) module. The IGBT has a wide reverse bias safe operating area (RBSOA) ensuring reliability in demanding applications.

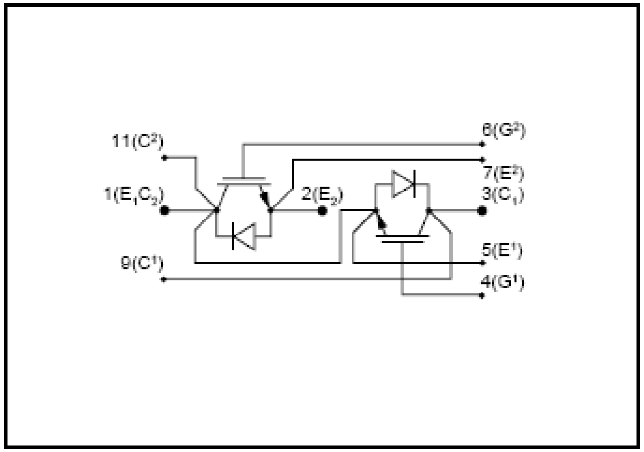


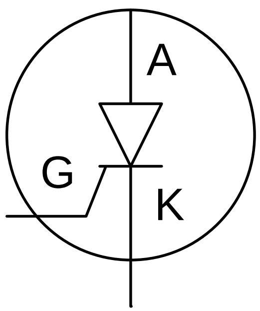
Fig. 1 Half bridge circuit diagram

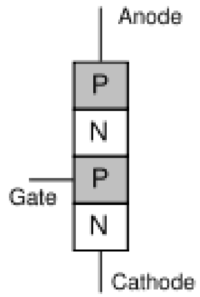
Symbol	Parameter	Test Conditions	Max.	Units
V_{CES}	Collector-emitter voltage	V_{GE} = 0V	1200	V
V_{GES}	Gate-emitter voltage	-	±20	V
I_C	Collector current	DC, T_{case} = 72°C	200	A
$I_{C(PK)}$	Peak collector current	1ms, T_{case} = 72°C	400	A
P_{max}	Max. transistor power dissipation	T_{case} = 25°C, T_j = 150°C	1490	W
V_{isol}	Isolation voltage	Commoned terminals to base plate. AC RMS, 1 min, 50Hz	2500	V

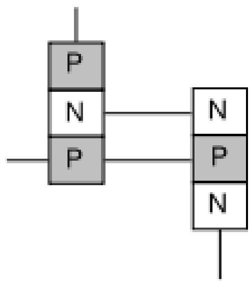
Power MOSFETs vs IGBTs

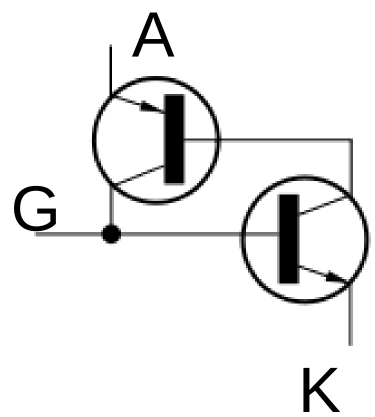
- Power MOSFETs: *Higher switching frequency* but low current
- IGBT:Not too high switching frequency but *higher current capability*
- On-stage voltage(i.e. conduction or forward) of IGBT is lower.

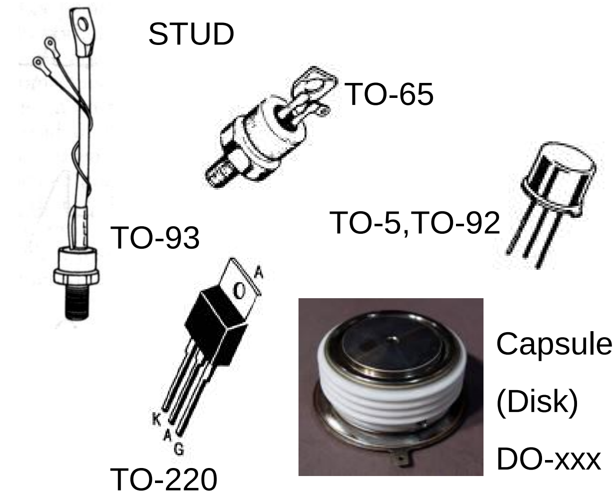
SCRs(Silicon-Controlled Rectifiers)







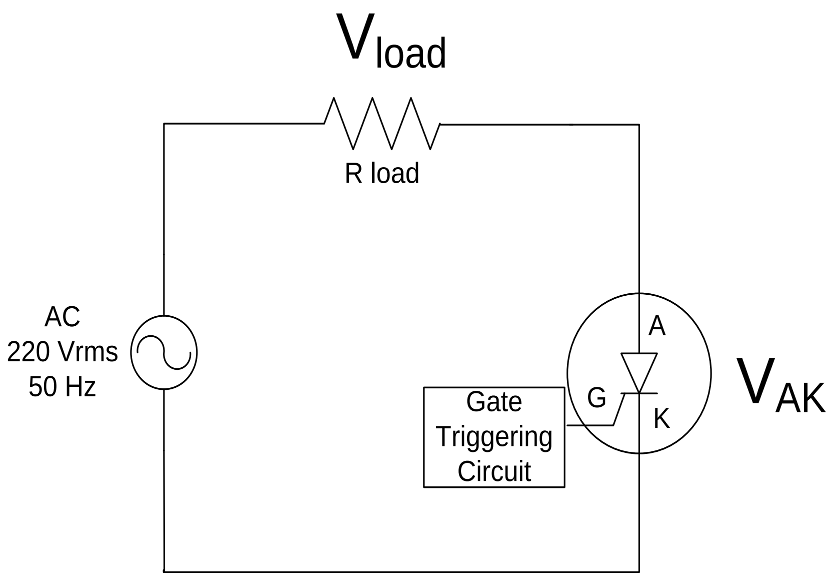


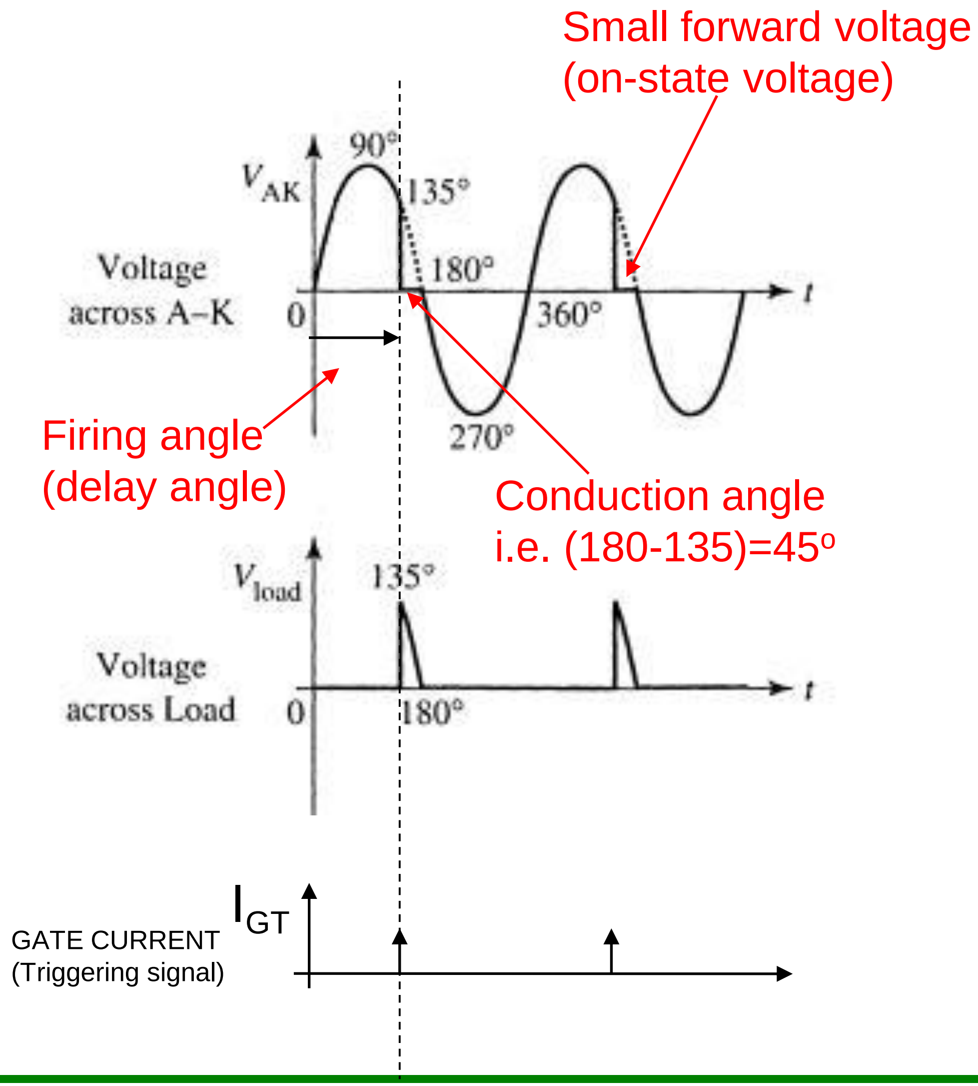


- A silicon-controlled rectifier (or semiconductor-controlled rectifier) is a 4-layer solid state device that controls current flow.
- SCRs are used in power switching converter, phase control, dimmer, chopper, battery chargers, and inverter circuits.

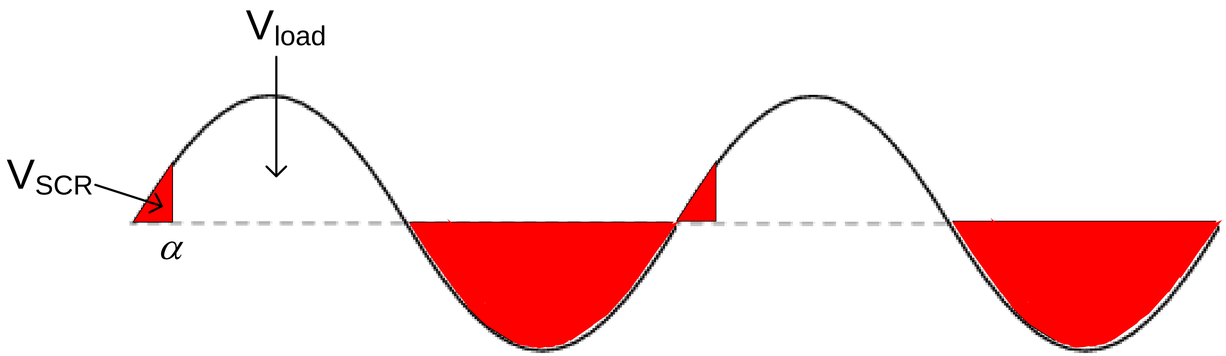
<u>Complementary latch:</u> when SCRs stay on, stay on all by itself and when it stays off, it stays off by itself.
Note. It's called a complementary latch since it's usually made from a pair of transistors that are said to compliment one another.

SCR waveform





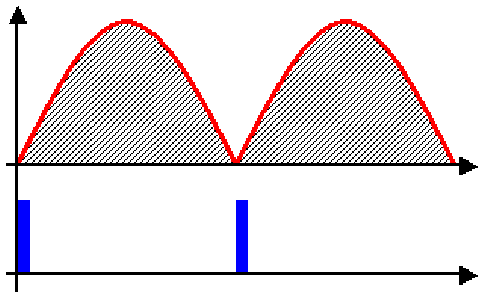
Output Voltage



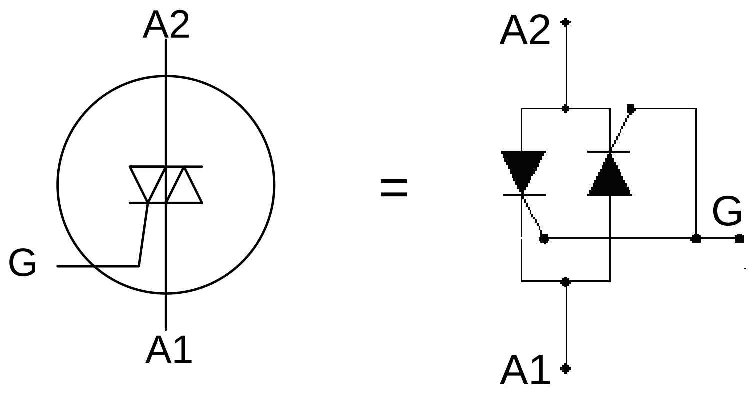
Output voltage can be calculated by integrating the output equation(average area in one period)

$$V_{load} = \frac{1}{2\pi}\int_{\alpha}^{\pi}\sqrt{2}\,V_{RMS}\sin(\omega t)\,d(\omega t)$$

$$= \frac{\sqrt{2}\,V_{RMS}}{2\pi}(1+\cos\alpha)$$

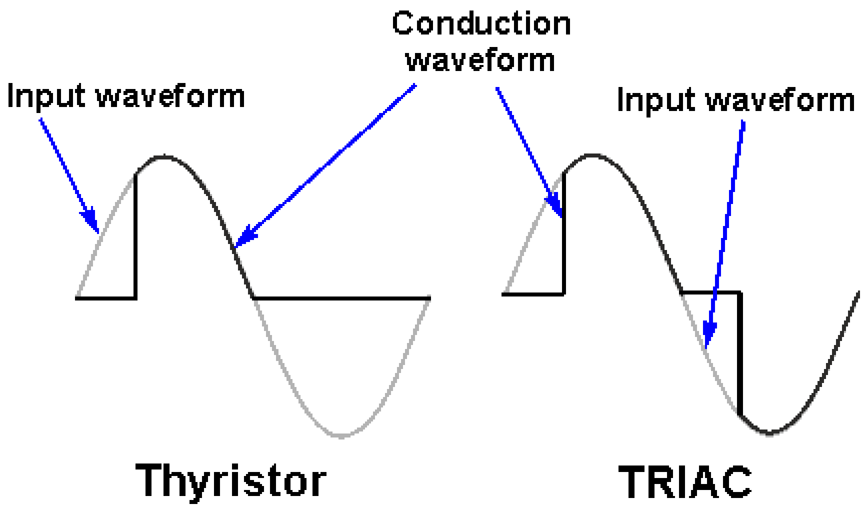


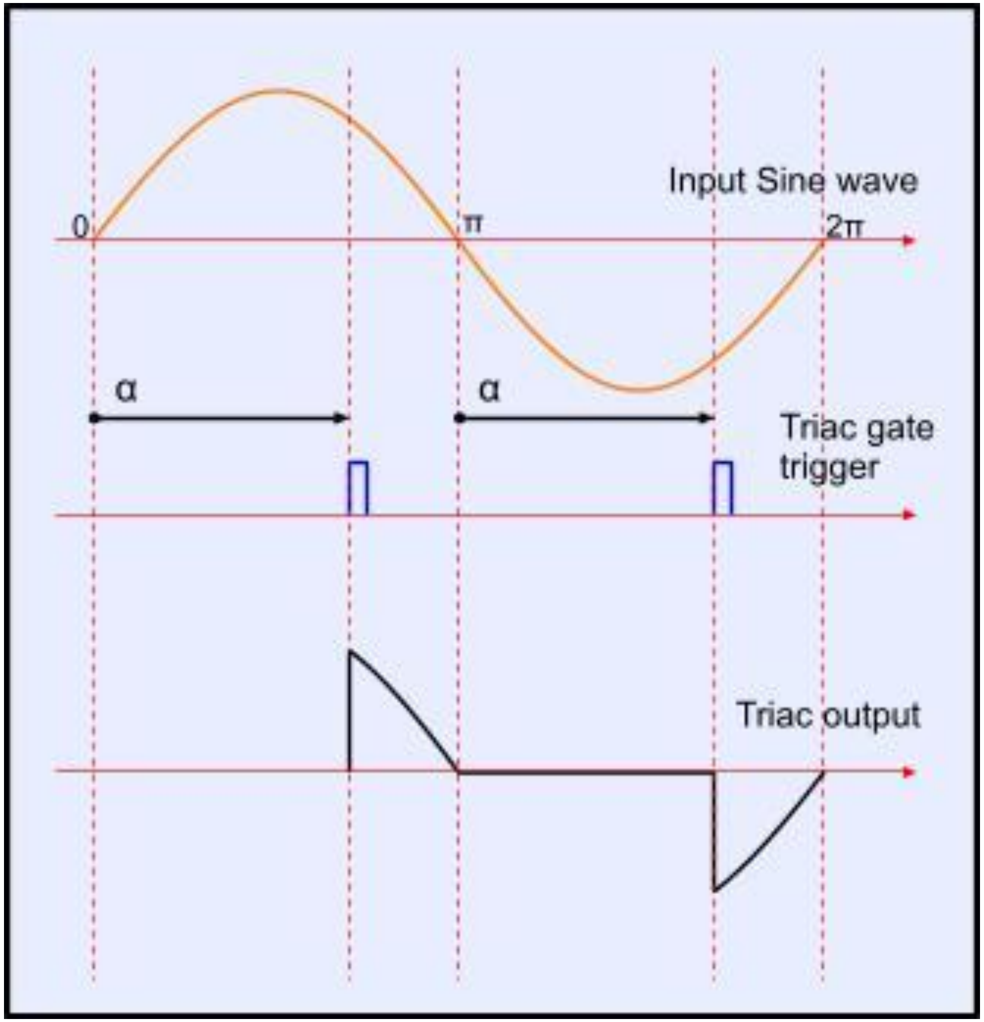
TRIACs



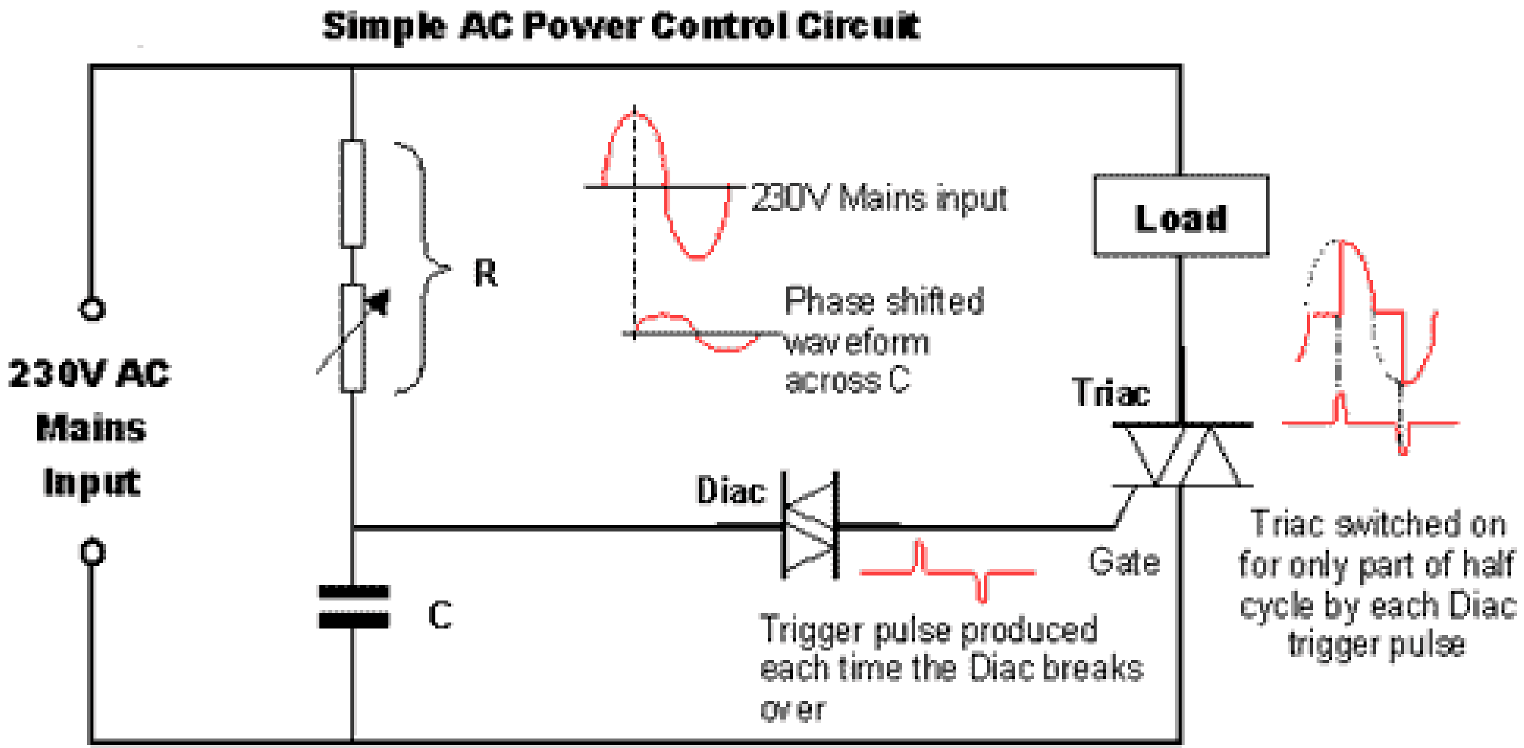
- A TRIAC, or TRIode for Alternating Current is an electronic component approximately equivalent to two silicon-controlled rectifiers (SCRs) joined in inverse parallel.
- Bidirectional switch can conduct current in either direction when it is triggered. It can be triggered by either a positive or a negative voltage being applied to its gate.(very suitable to switch ac circuit).Once triggered, it continues to conduct until the current through it drops below holding current, naturally at the end of a half-cycle of the main supply.
- TRIACs are used in **ac system** applications such as *light dimmers, speed controls of electric fans and electric motors.*

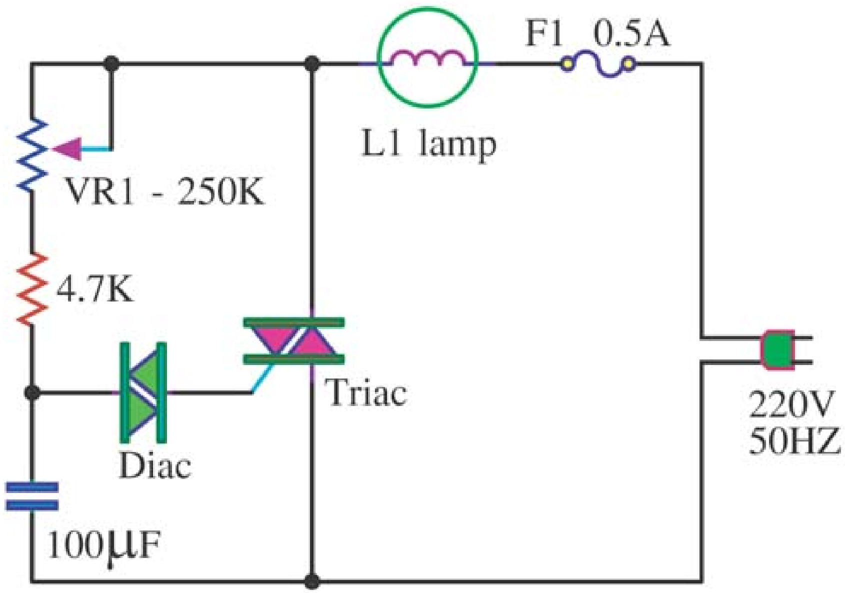
TRIAC Waveforms





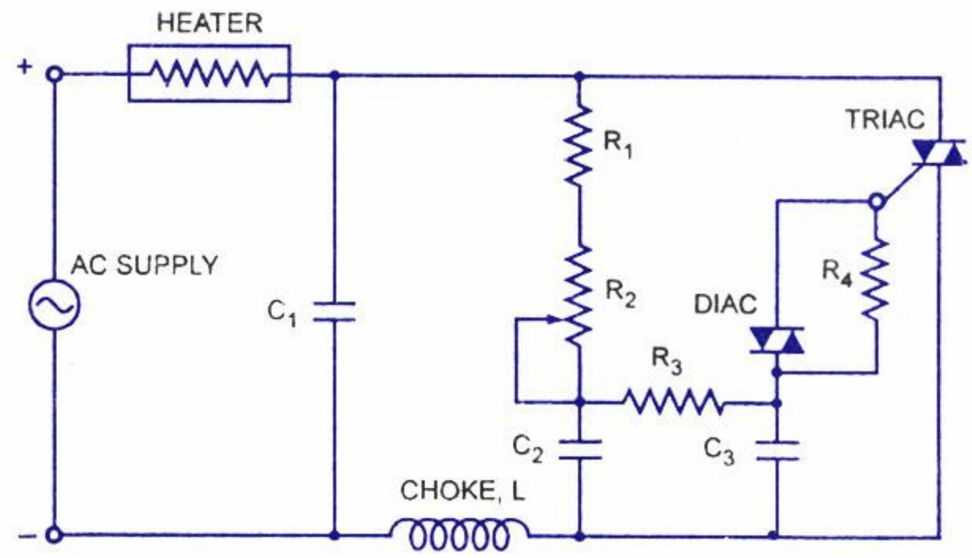
TRIAC Applications



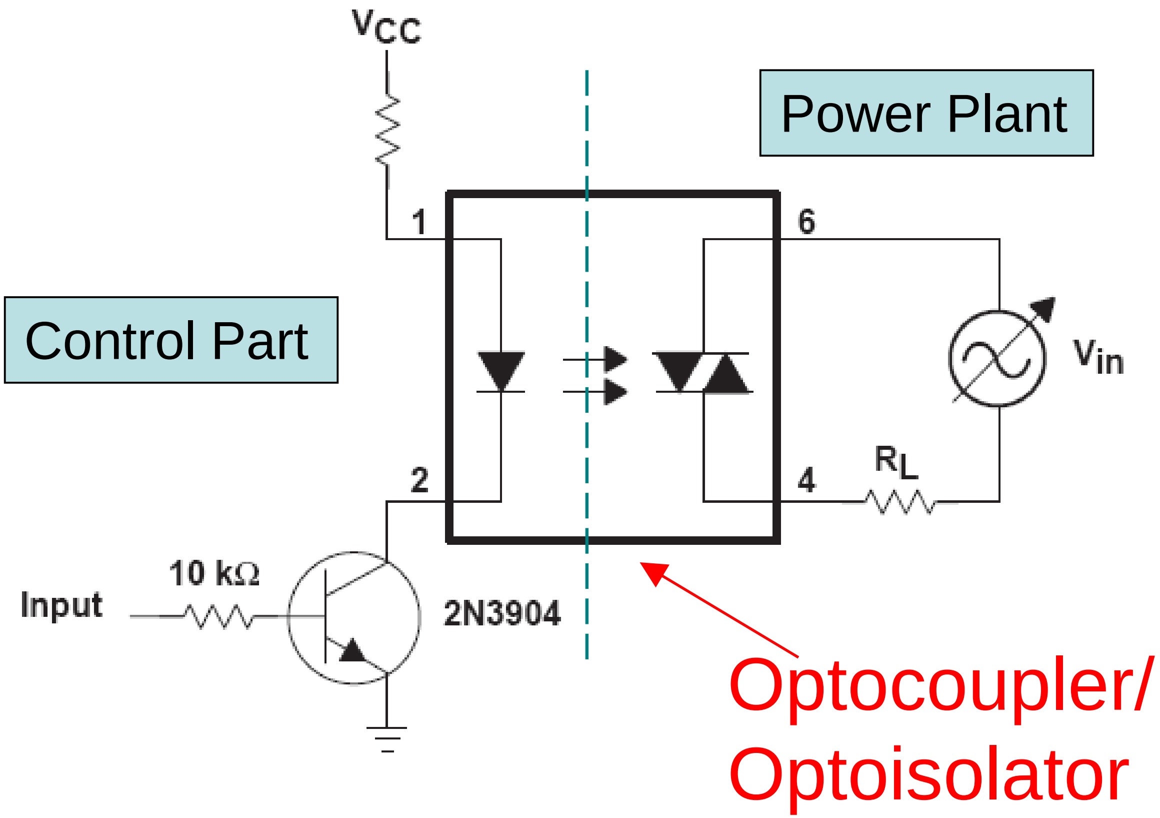


Dimmer Circuit

Heater Control Circuit



Optoisolated Triggering Circuit



Optocoupler

MOC3020 THRU MOC3023
OPTOCOUPLERS/OPTOISOLATORS

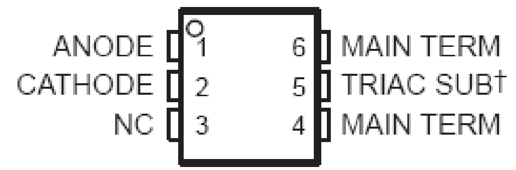
SOES025A – OCTOBER 1986 – REVISED APRIL 1998

- 400 V Phototriac Driver Output
- Gallium-Arsenide-Diode Infrared Source and Optically-Coupled Silicon Traic Driver (Bilateral Switch)
- UL Recognized . . . File Number E65085
- High Isolation . . . 7500 V Peak
- Output Driver Designed for 220 Vac
- Standard 6-Terminal Plastic DIP
- Directly Interchangeable with Motorola MOC3020, MOC3021, MOC3022, and MOC3023

typical 115/240 Vac(rms) applications

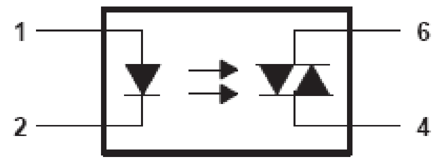
- Solenoid/Valve Controls
- Lamp Ballasts
- Interfacing Microprocessors to 115/240 Vac Peripherals
- Motor Controls
- Incandescent Lamp Dimmers

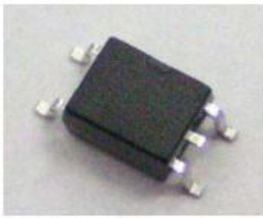
MOC3020 – MOC3023 . . . PACKAGE
(TOP VIEW)



† Do not connect this terminal
NC – No internal connection

logic diagram





MOC3031M, MOC3032M, MOC3033M, MOC3041M, MOC3042M, MOC3043M
6-Pin DIP Zero-Cross Optoisolators Triac Driver Output (250/400 Volt Peak)

Features

- Simplifies logic control of 115 VAC power
- Zero voltage crossing
- dv/dt of 2000 V/µs typical, 1000 V/µs guaranteed
- VDE recognized (File # 94766), ordering option V (e.g., MOC3043VM)

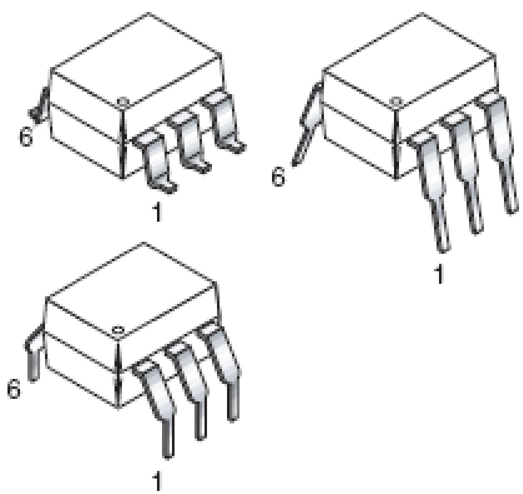
Applications

- Solenoid/valve controls
- Static power switches
- Temperature controls
- AC motor starters
- Lighting controls
- AC motor drives
- E.M. contactors
- Solid state relays

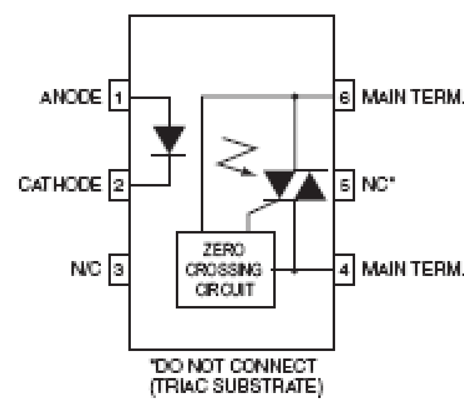
Description

The MOC303XM and MOC304XM devices consist of a AlGaAs infrared emitting diode optically coupled to a monolithic silicon detector performing the function of a zero voltage crossing bilateral triac driver.

They are designed for use with a triac in the interface of logic systems to equipment powered from 115 VAC lines, such as teletypewriters, CRTs, solid-state relays, industrial controls, printers, motors, solenoids and consumer appliances, etc.

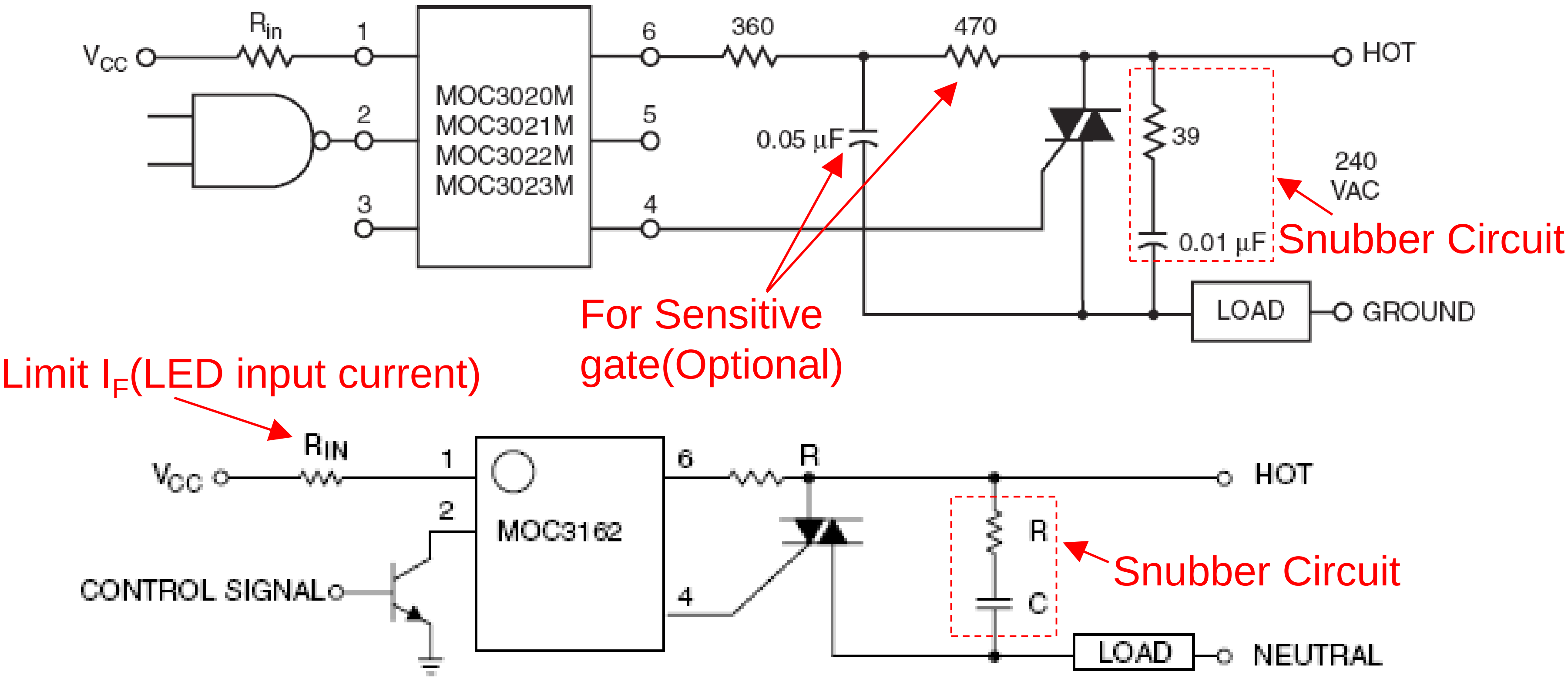


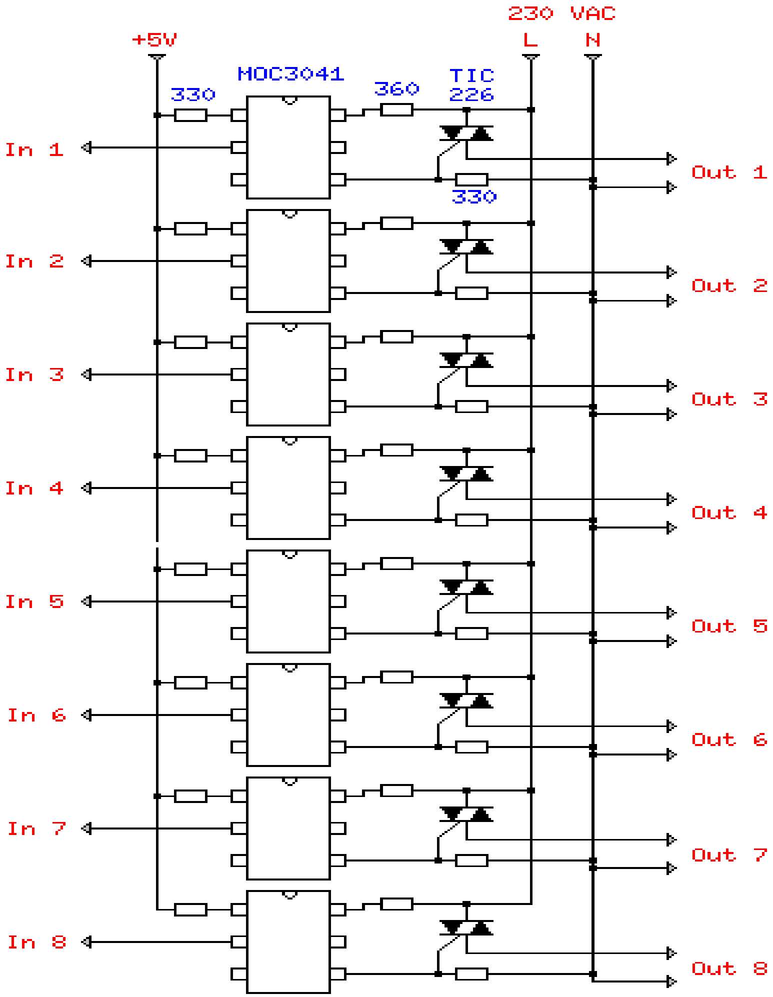
Schematic



Example

Note: This opto-isolator/driver *should not* be used to drive a load directly. It is intended to be a trigger for power device.





Each output consists of a MOC3041 Optoisolator Triac Driver followed by a TIC226 TRIAC.

This circuit receives separated 8 inputs and switches the lights off/on when it receives one. The light will on when In 1-8 is Low/High ??

Device Selection

- Following are common consideration when selecting devices.

- Power Rating i.e. maximum current and voltage
- Switching Frequency(How fast the circuit requires→ determine control dynamic and switching loss)
- Gate Drive Requirement i.e. simple or bipolar
- Breakdown Voltage (circuit connection)
- Power Loss(when efficiency is critical) i.e. on-stage voltage or resistance