PROJECT

Diode Data

The characteristics, codes, data, encapsulations and various formulas relating to diodes, thyristors, triacs and LEDs.

Mike Tooley

Semiconductor diodes are generally a single p-n junction of either silicon (Si) or germanium (Ge) material. In order to obtain conduction, the p-type material (the p-type connection constitutes the anode while the n-type connection constitutes the cathode). The direction of current flow is from anode to cathode when the diode is conducting, as shown in Fig.1. Very little current (negligible in the case of the most silicon devices) flows in the reverse direction (Fig.2).

Diodes exhibit a low resistance to current flow in one direction and a high resistance to current flow in the other. The

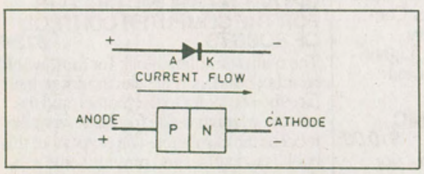


Fig. 1. Forward biased (conducting) diode.

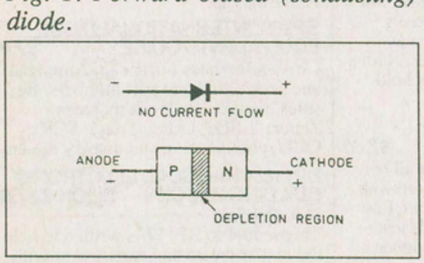


Fig. 2. Reverse biased (non-conducting) diode.

direction in which the current flows is referred to as the forward direction while that in which negligible current flows is known as the reverse direction. When a diode is conducting, a diode is said to be forward biased and a small voltage (ideally zero) is dropped across it. This voltage is known as the forward voltage drop. The maximum reverse voltage (Vrrm) or peak inverse voltage (PIV).

Typical values of forward current and forward voltage for commonly available silicon and germanium diodes are given below:

insert "forward current" table

Germanium diodes conduct at lower forward voltages than their silicon counterparts, but they tend to exhibit considerably more reverse leakage current. Furthermore, the forward resistance of a conducting silicon diode is much lower than that of a comparable germanium type. Hence germanium diodes are used primarily for signal detection purposes whereas silicon devices are used for rectification and for general purpose applications. Typical forward and reverse characteristics for comparable germanium and silicon diodes are shown in Fig.3. Diodes are often divided into signal and rectifier types, according to their principal field of application. Signal diodes require consis-

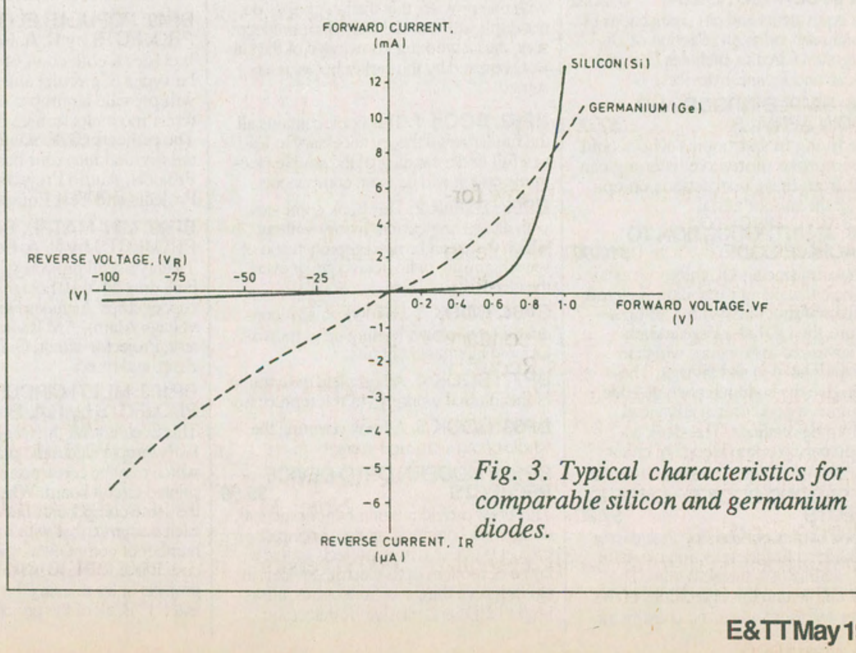


Fig. 3. Typical characteristics for comparable silicon and germanium diodes.

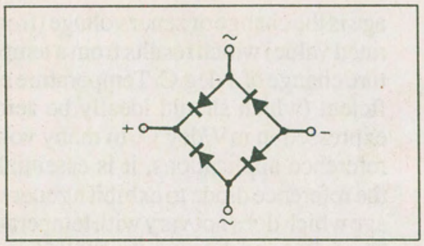


Fig. 4. Bridge rectifier arrangement.

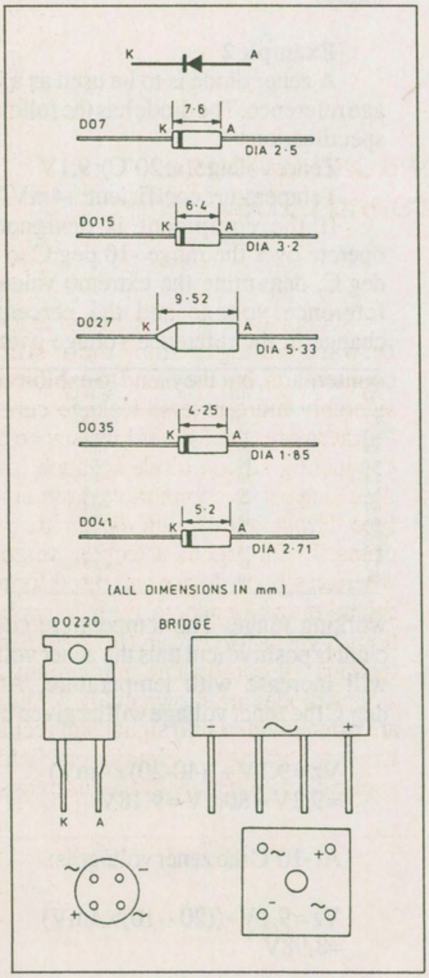


Fig. 5. Diode encapsulations.

tent forward characteristics with low forward voltage drop.

Rectifier diodes need to be able to cope with high values of reverse voltage and large values of forward current, consistency of characteristics is of secondary importance in such applications. Rectifier diodes are often available in the form of a bridge (see Fig.4) which provides fullwave rectification. Various diode encapsulations are illustrated in Fig.5.

Diode Coding

The European system for classifying semiconductor diodes involves an alphanumeric code which employs either two letters and three figures (general purpose diodes) or three letters and two figures (special purpose diodes). The first two letters have the following significance:

First letter - semiconductor material:
A germanium
B silicon
C gallium arsenide etc
D photodiodes etc
Second letter - application:
A general purpose
B tuning (varicap) diode
E tunnel diode
P photovoltaic diode
Q light emitting diode
T controlled rectifier
X varactor diode
Y power rectifier
Z zener diode

In the case of diodes for specialized applications, the third letter does not generally have any particular significance. Zener diodes have an additional letter (which appears after the numbers) which denotes the tolerance of the zener voltage. The following letters are used:

A 1%
B 2%
C 5%
D 10%

Zener diodes also have additional characters which indicate the zener voltage (e.g., 9V1 denotes 9.1V).

Example 1
Identify each of the following diodes:
(i) AA113
(ii) BB105
(iii) BZY88C4V7

Diode (i) is a general purpose germanium diode.

Diode (ii) is a silicon diode for tuning applications (sometimes referred to as varicap).

Diode (iii) is a silicon zener diode having 5% tolerance and 4.7V zener voltage.

Diode data

The following tables summarize the characteristics of a variety of popular semiconductor diodes:

Note: Most of the bridge rectifiers listed are available in 200V, 400V and 600V versions. It is important to ensure that manufacturers' voltage ratings are not exceeded.

Hints and tips

* When designing power supply circuits (in which appreciable currents are present) it is important to allow for the forward voltage drop associated with each rectifier diode. In a bridge rectifier, for example, two diodes will be conducting any one time. The total forward voltage drop associated with these diodes can approach 2V and this should be allowed for when

Devices, applications, equivalents and case styles

Device	*Material*	*Application*	*Near equiv.*	*Case style*
1N4001	silicon	rectifier		DO41
1N4002	silicon	rectifier		DO41
1N4003	silicon	rectifier		DO41
1N4004	silicon	rectifier		DO41
1N4005	silicon	rectifier		DO41
1N4006	silicon	rectifier		DO41
1N4007	silicon	rectifier	BY127	DO41
1N4148	silicon	general purpose	1N914, 1N916	DO35
1N5400	silicon	rectifier		DO27
1N5401	silicon	rectifier		DO27
1N5402	silicon	rectifier		DO27
1N5404	silicon	rectifier		DO27
1N5406	silicon	rectifier		DO27
1N5407	silicon	rectifier		DO27
1N5408	silicon	rectifier		DO27
1N914	silicon	general purpose	1N916, 1N4148	DO35
1N916	silicon	general purpose	1N914, 1N4148	DO35
AA113	germanium	general purpose		DO7
AA119	germanium	RF detector		DO7
BAR28	Schottky	RF detector		DO35
BAX13	silicon	general purpose		DO35
BAX16	silicon	general purpose		DO35
BY126	silicon	rectifier	1N4005	DO15
BY127	silicon	rectifier	1N4007	DO15
HSCH1001	Schottky	RF detector		DO35
OA200	silicon	general purpose		DO7
OA202	silicon	general purpose		DO7
OA47	germanium	general purpose		DO7
OA90	germanium	RF detector		DO7
OA91	germanium	general purpose	OA95	DO7
OA95	germanium	general purpose	OA91	DO7

General purpose, signal and RF diodes

Device	*Material*	*PIV*	I_f	I_r *max*
1N4148	silicon	100V	75mA	25nA
1N914	silicon	100V	75mA	25nA
1N916	silicon	100V	75mA	25nA
AA113	germanium	60V	10mA	200μA
AA119	germanium	45V	35mA	350μA
BAR28	Schottky	70V		200nA
BAX13	silicon	50V	75mA	200nA
Bax16	silicon	150V	200mA	100nA
HSCH1001	Schottky	60V	15mA	200nA
OA200	silicon	50V	80mA	100nA
OA202	silicon	150V	40mA	100nA
OA47	germanium	25V	110mA	100μA
OA90	germanium	30V	10mA	1.1mA
OA91	germanium	115V	50mA	275μA
OA95	germanium	115V	50mA	250μA

Silicon rectifier and power diodes

Device	*PIV*	I_{fav}	V_f	I_r *max*
1N4001	50V	1A	1.1V	10μA
1N4002	100V	1A	1.1V	10μA
1N4003	200V	1A	1.1V	10μA
1N4004	400V	1A	1.1V	10μA
1N4005	600V	1A	1.1V	10μA
1N4006	800V	1A	1.1V	10μA
1N4007	1000V	1A	1.1V	10μA
1N5400	50V	3A	1.1V	10μA
1N5401	100V	3A	1.1V	10μA
1N5402	200V	3A	1.1V	10μA
1N5404	400V	3A	1.1V	10μA
1N5406	600V	3A	1.1V	10μA
1N5407	800V	3A	1.1V	10μA
1N5408	1000V	3A	1.1V	10μA
BY126	650V	1A	1.1V	10μA
BY127	1250V	1A	1.1V	10μA
BY397	200V	2A	1.1V	10μA
BY399	800V	2A	1.1V	10μA

Bridge rectifiers

Type/series	*Encapsulation*	*Mounting surface*	*Max. forward current (A)*
Vm	4-pin d.i.l.	PCB	0.9
DB	4-pin d.i.l.	PCB	1
WO	cylindrical	PCB	1
SKB2	in-line	PCB	1.6
BR8	in-line	PCB	2
BR3	square	PCB	3
KBPC	square	PCB	2 to 6
BR6	square	PCB	6
BR15	epoxy-potted	heatsink	15
SKB25	epoxy-potted	heatsink	6 to 35

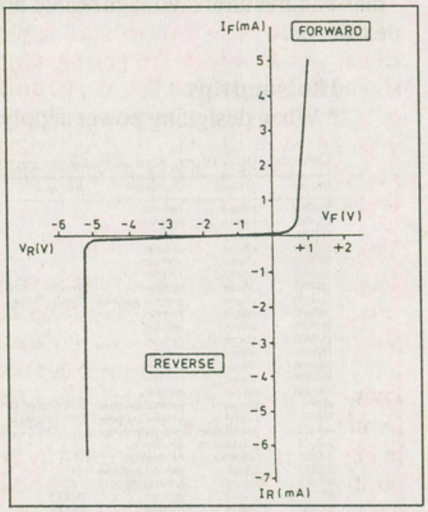


Fig. 6. Typical zener diode characteristics.

determining the AC input voltage to the rectifier.

* The reverse leakage current of a diode increases markedly as the junction temperature increases. This results in a reduction in overall efficiency (ratio of forward current to reverse current) at high temperatures.

* Operating a diode at, or beyond, the stated limits for Vrrm or PIV will result in a high risk of breakdown. Since rectifier failure can have disastrous consequences, it is always advisable to operate diodes well within the stated limits (to ensure safety, a 100% margin should be allowed).

* Schottky diodes exhibit a forward voltage drop which is approximately half that of conventional silicon diodes coupled with very fast reverse recovery. Schottky diodes are thus preferred in switching applications (e.g., switched mode power supplies) where very low forward voltage drop and fast switching is a prime consideration.

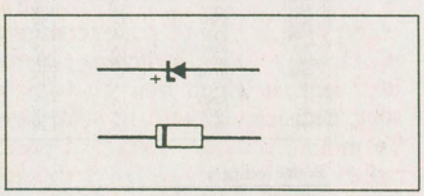


Fig. 7. Zener diode encapsulation.

Zener diodes

Zener diodes are silicon diodes which are specially designed to exhibit consistent reverse breakdown characteristics. Zener diodes are available in various families (according to their general characteristics, encapsulation and power ratings) with reverse breakdown (zener) voltages in the E12 and E24 series (ranging form 2.4V to 91V). A typical characteristic for a 5.1V zener diode is shown in Fig.6.

The following series of zener diodes are commonly available:

BZX88 series:

Miniature glass encapsulated diodes rated at 500mW (at 25 deg.C). Zener voltages range from 2.7V to 15V (voltages are quoted for 5mA reverse current at 25 deg.C).

BZX55 series:

Low-power diodes rated at 500mW and offering zener voltages in the range 2.4V to 91V.

BZX61 series:

Encapsulated alloy junction rated at 1.3W (25 deg. C ambient).

Zener voltages range from 7,5V to 72V.

BZX85 series:

Medium-power glass-encapsulated diodes rated at 1.3W and offering

zener voltages in the range 5.1V to 62V.

BZY93 series:

High power diodes in stud mounting encapsulation. Rated at 200W for ambient temperatures up to 75 deg.C. Zener voltages range from 9.1V to 75V.

BZY97 series:

Medium power wire-ended diodes rated at 1.5W and offering zener voltages in the range 9.1V to 37V.

1N5333 series:

Plastic encapsulated diodes rated at 5W. Zener voltages range from 3.3V to 24V.

Zener diodes are generally plastic or glass encapsulated in the same manner as conventional silicon diodes. As with conventional silicon diodes, the cathode connection is marked with a stripe (see Fig.7).

The slope resistance of a zener diode is the rate of change of reverse voltage (zener voltage) with diode current. Slope resistance is measured in the breakdown region and expressed in ohms. An ideal zener diode would have zero slope resistance (i.e. the diode would conduct perfectly at its rated zener voltage). In practice, values of 200 or less can be achieved. The temperature coefficient of zener voltage is the change of zener voltage (from its rated value) which results from a temperature change of 1 deg.C. Temperature coefficient (which should ideally be zero) is expressed in mV/deg.C. In many voltage reference applications, it is essential for the reference diode to exhibit a zener voltage which does not vary with temperature. The following data (for the BZX55 series) is typical of most low- power zener diodes:

Example 2

A zener diode is to be used as a voltage reference. The diode has the following specifications:

Zener voltage (at 20°C): 9.1V

Temperature coefficient: +4mV/°C

If the equipment is designed to operate over the range -10 deg.C to +40 deg.C, determine the extreme values of reference voltage and the percentage change in the reference voltage over the working range. The temperature coefficient is positive and thus the zener voltage will increase with temperature. At 40 deg.C the zener voltage will be given by:

Zener voltage (V)	*Slope resistance (Ω)*	*Temperature coefficient (mV/°C)*
2.7	100	−3.5
3.3	95	−3.5
3.9	90	−3.5
4.7	80	−3.5
5.1	60	−2.7
5.6	40	−2.0
6.2	10	+0.4
6.8	12	+1.2
7.5	14	+2.5
8.2	16	+3.2
9.1	18	+3.8
10	20	+4.5

$$V_z = 9.1V + ((40-20) \times 4mV)$$
$$= 9.1V + 80mV = 9.18V$$

At -10°C the zener voltage is:

$$V_z = 9.1V - ((20 - -10) \times 4mV)$$
$$= 8.98V$$

Hints and tips:

* Zener diodes may be connected in series to obtain higher voltages. As an example, a 15.9V reference can be produced by connecting a 6.8V zener diode in series with a 9.1V zener diode.

* Care must be taken to ensure that zener diodes operate within their rated power dissipation.

* Zener diodes generally perform best when rated at voltages of between 5V and 6V. Hence, in order to obtain optimum performance (in terms of both slope resistance and temperature coefficient) reference voltage sources based upon zener diodes should utilise components which have zener voltages of between

5.1V and 6.2V where necessary, external circuitry can be used to provide voltage amplification.

* Zener diodes can generate a significant amount of noise and, in applications which involve significant voltage gain (e.g.the stabilization of an amplifier bias supply) it is essential to provide adequate decoupling. A parallel connected capacitor of between 1uF and 100uF will provide effective in most applications.

Thyristors

Thyristors (or silicon controlled rectifiers) are three-terminal devices which can be used for switching and ACpower control. Thyristors can switch very rapidly from a nonconducting to a conducting state. In the off state, the thyristor exhibits negligible leakage current while, in the on state the device exhibits very low resistance. This results in very little power loss within the thyristor even when appreciable power levels are being controlled. Once switched into the conducting state, the thyristor will remain conducting (i.e., it is latched in the on state) until the forward current is removed from the device. n DC applications this necessitates the interruption (or disconnection) of the supply before the device can be reset into its nonconducting state. Where the device is used with an alternating supply, the device will automatically become reset whenever the main supply reverses. The device can them be triggered on the next half-cycle having correct polarity otpermit conduction. Like their conventional silicon diode counterparts, thyristors have anode and cathode connections; control is applied by means of gate terminal (see Fig.8). The device is triggered into the conducting (on state) by means of the application of a current pulse to this material.

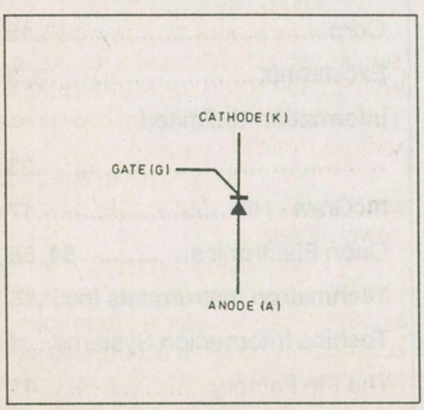


Fig. 8. Thyristor connections.

Thyristor data

The table summarizes the characteristics of a variety of popular thyristors:

Hints and tips:

* Wherever possible, thyristor trigger pulses should have the fastest possible rise times. Signals with slow rise times or poorly defined edges are generally unsatisfactory for triggering purposes.

* Sufficient gate current must be made available in order to ensure effective triggering.

* Thyristors will turn on faster (and power dissipation within the device will be minimized) as gate current is increased. Care should, however, be taken to ensure that the peak value of gate does not exceed the rated value for the device.

Type	$I_{F(AV)}$	V_{RRM}	V_{GT}	I_{GT}	*Case style*
2N4443	5.1A	400V	1.5V	30mA	TO220
2N4444	5.1A	600V	1.5V	30mA	TO220
BT106	1A	700V	3.5V	50mA	Stud
BT152	13A	600V	1V	32mA	TO220
BTX18-400	1A	500V	2V	5mA	TO5
BTY79-400R	6.4A	400V	3V	30mA	Stud
BTY79-600R	6.4A	600V	3V	30mA	Stud
BTY79-800R	6.4A	800V	3V	30mA	Stud
TIC106A	3.2A	100V	1.2V	200μA	TO220
TIC106B	3.2A	200V	1.2V	200μA	TO220
TIC106C	3.2A	300V	1.2V	200μA	TO220
TIC106D	3.2A	400V	1.2V	200μA	TO220
TIC106E	3.2A	500V	1.2V	200μA	TO220
TIC106M	3.2A	600V	1.2V	200μA	TO220
TIC106S	3.2A	700V	1.2V	200μA	TO220
TIC106N	3.2A	800V	1.2V	200μA	TO220
TIC116A	5A	100V	2.5V	20mA	TO220
TIC116B	5A	200V	2.5V	20mA	TO220
TIC116C	5A	300V	2.5V	20mA	TO220
TIC116D	5A	400V	2.5V	20mA	TO220
TIC116E	5A	500V	2.5V	20mA	TO220
TIC116M	5A	600V	2.5V	20mA	TO220
TIC116S	5A	700V	2.5V	20mA	TO220
TIC116N	5A	800V	2.5V	20mA	TO220
TIC126A	7.5A	100V	2.5V	20mA	TO220
TIC126B	7.5A	200V	2.5V	20mA	TO220
TIC126C	7.5A	300V	2.5V	20mA	TO220
TIC126D	7.5A	400V	2.5V	20mA	TO220
TIC126E	7.5A	500V	2.5V	20mA	TO220
TIC126M	7.5A	600V	2.5V	20mA	TO220
TIC126S	7.5A	700V	2.5V	20mA	TO220
TIC126N	7.5A	800V	2.5V	20mA	TO220
TICP106D	2A	400V	1V	200μA	TO92
TICP106M	2A	600V	1V	200μA	TO92

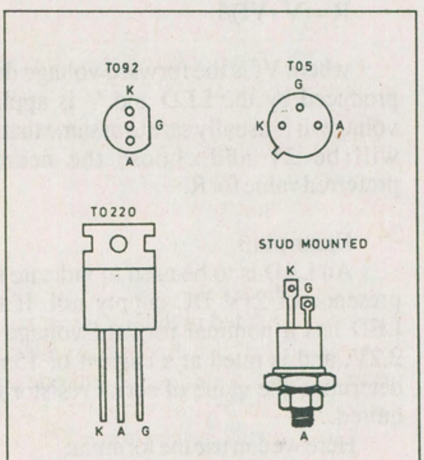


Fig. 9. Thyristor encapsulations and pin connections.

* The pulse width of the trigger pulse applied to the gate of a thyristor must be kept short in order to minimize gate power dissipation.

* In order to obtain an adequate range of control in AC power control applications, the thyristor triggering circuit should be designed so that it will proved effective triggering over a sufficiently wide angle of the *applied AC voltage. Failure to observe this rule will result in a limited range of control.

Triacs

Triacs are a refinement of the thyristor which, when triggered, conduct on both positive and negative half-cycles of the applied voltage. Triacs have three terminals known as main terminal one (MT1), main terminal two (MT2) and gate (G), as shown in Fig.10. Triacs can be triggered by both positive and negative voltages present at the gate. Triacs thus provide full- wave control and offer superior performance in AC power control applications when compared with thyristors which only provide half-wave control. In order to simplify the design of triggering circuits, triacs are often used in conjunction with diacs (equivalent to a bi- directional zener diode). A typical diac conducts heavily when the applied voltage exceeds approximately +/- 32V. Once in the conducting state, the resistance of the diac falls to a very low value and thus a large value of current will flow. The characteristic of a typical diac is shown in Fig.11.

Triac data

The following table summarizes the characteristics of a variety of popular triacs:

Hints and tips

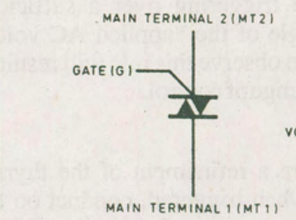
* Thyristors and triacs switch on and off very rapidly. In AC power control applications, this rapid switching can result in transients which may be conveyed some distance via the AC mains wiring. To minimize such effects and prevent radiation of noise, an L-C filter should be fitted in close proximity to the power control device, as shown in Fig.13.

LEDs

Light emitting diodes (LEDs) can be used as general purpose indicators and, compared with conventional filament lamps, operate from significantly smaller vol-

Type	$I_{T(RMS)}$	V_{RRM}	V_{GT}	$I_{GT(TYP)}$	*Case style*
BT139	15A	600V	1.5V	5mA	TO220
TIC206M	4A	600V	2V	5mA	TO220
TIC216M	6A	600V	3V	5mA	TO220
TIC225M	8A	600V	2V	20mA	TO220
TIC226M	8A	600V	2V	50mA	TO220
TIC236M	12A	600V	2V	50mA	TO220
TIC246M	16A	600V	2V	50mA	TO220
TICP206D	1.5A	400V	2.5V	2.5mA	TO92
TICP206M	1.5A	600V	2.5V	2.5mA	TO92

Fig. 10. Triac connections.



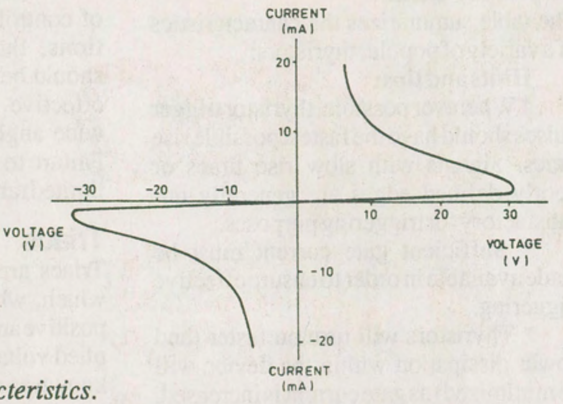


Fig. 11. Typical diac characteristics.

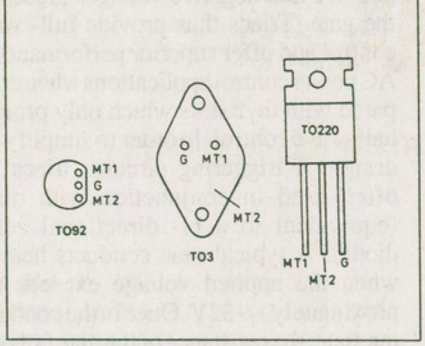


Fig. 12. Triac encapsulations.

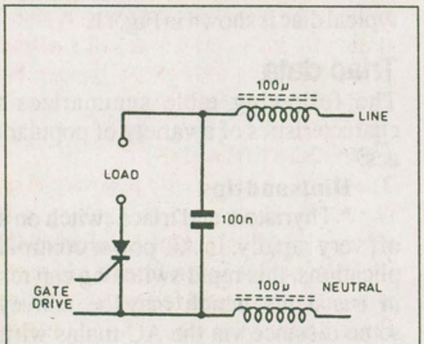


Fig. 13. Simple power line filter.

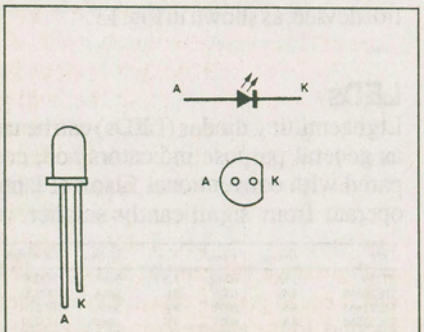


Fig. 14. Round LED encapsulation..

tages and currents. LEDs are also very much more reliable than filament lamps. Most LEDs will provide a reasonable level of light output when a forward current of between 5mA and 20mA is applied.

Light emitting diodes are variable in various formats with the round types being most popular. Round LEDs are commonly available in the 3mm and 5mm (0.2 inch) diameter plastic packages (see Fig.14) and also in 5mm x 2mm rectangular format. The viewing angle for round LEDs tends to be in the region of 20° to 40°, whereas for rectangular types this is increased to around 100°.

In order to limit the forward current to an appropriate value, it is usually necessary to include a fixed resistor in series with a LED indicator. The value of the resistor may be calculated from:

$$R = (V - Vf)/I$$

where Vf is the forward voltage drop produced by the LED and V is applied voltage. It is usually safe to assume that Vf will be 2V and choose the nearest preferred value for R.

Example 3

An LED is to be used to indicate the presence of 21V DC supply rail. If the LED has a nominal forward voltage of 2.2V, and is rated at a current of 15mA determine the value of series resistor required.

Here we can use the formula:

$$R = (V - Vf)/I$$

$$= (21 - 2.2V)/.015 = 1.25k$$

The nearest standard value is 1k2. The power dissipated in the resistor will be .015 times 18.8V, or 280mW.

Hints and tips:

* Avoid inadvertent reverse LED connection. Reverse voltages in excess of about 5V will cause permanent damage.

* For battery powered equipment (particularly where a number of LED indicators are used) minimal values of forward current should be employed in order to ensure long battery life. A forward current of 5mA (per LED) will be perfectly adequate in many applications.

* Where several LEDs are to be used together, they should be connected in series (and not in parallel) in order to ensure equal levels of light output.

* Yellow and green LED generally give less output (for a given forward current) than their standard red counterparts. To maintain an equal light output when several LEDs of different colours are used together, different values of series resistor may be employed. As a rule of thumb, series resistors for yellow and green LEDs should be chosen so that they are 10% to 15% lower in value than those used with red diodes (care should, however, be taken to ensure that operating currents are still within the manufacturer's specified upper limit).

* In applications involving low AC voltages, a conventional low-current silicon diode (e.g. 1N4148) can be wired in parallel with a LED to provide a simple AC indicator.

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