MOTOROLA Semiconductors
BOX 20912 • PHOENIX, ARIZONA 85036

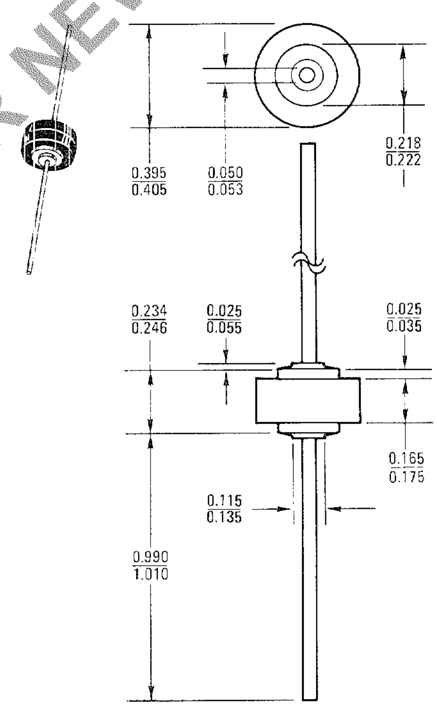
# MR820 MR821 MR822 MR824 MR826

## Designers Data Sheet

### SUBMINIATURE SIZE, AXIAL LEAD MOUNTED FAST RECOVERY POWER RECTIFIERS

. . . designed for special applications such as dc power supplies, inverters, converters, ultrasonic systems, choppers, low RF interference and free wheeling diodes. A complete line of fast recovery rectifiers having typical recovery time of 100 nanoseconds providing high efficiency at frequencies to 250 kHz.

**FAST RECOVERY POWER RECTIFIERS**
**50-600 VOLTS**
**5.0 AMPERES**
DS 6073




CASE 194

### Designer's Data for "Worst Case" Conditions

The Designers▲ Data sheets permit the design of most circuits entirely from the information presented. Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

MAXIMUM RATINGS

| Rating | Symbol | MR820 | MR821 | MR822 | MR824 | MR826 | Unit |
|---|---|---|---|---|---|---|---|
| Peak Repetitive Reverse Voltage<br>Working Peak Reverse Voltage<br>DC Blocking Voltage | $V_{RRM}$<br>$V_{RWM}$<br>$V_R$ | 50 | 100 | 200 | 400 | 600 | Volts |
| Non-Repetitive Peak Reverse Voltage | $V_{RSM}$ | 75 | 150 | 250 | 450 | 650 | Volts |
| RMS Reverse Voltage | $V_{R(RMS)}$ | 35 | 70 | 140 | 280 | 420 | Volts |
| Average Rectified Forward Current (Single phase, resistive load, $T_A = 55^oC$) (1) | $I_O$ | ← 5.0 → | | | | | Amp |
| Non-Repetitive Peak Surge Current (Surge applied at rated load conditions) | $I_{FSM}$ | ← 300 → | | | | | Amp |
| Operating and Storage Junction Temperature Range (2) | $T_J, T_{stg}$ | ← -65 to +175 → | | | | | $^oC$ |

THERMAL CHARACTERISTICS

| Characteristic | Symbol | Max | Unit |
|---|---|---|---|
| Thermal Resistance, Junction to Ambient (Recommended Printed Circuit Board Mounting, See Note 6, Page 8) | $R_{\theta JA}$ | 25 | $^oC/W$ |

ELECTRICAL CHARACTERISTICS

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Instantaneous Forward Voltage ($I_F$ = 15.7 Amp, $T_J = 150^oC$) | $v_F$ | – | 0.75 | 1.05 | Volts |
| Forward Voltage ($I_F$ = 5.0 Amp, $T_J = 25^oC$) | $V_F$ | – | 0.9 | 1.0 | Volts |
| Maximum Reverse Current, (rated dc voltage) $T_J = 25^oC$ | $I_R$ | – | 5.0 | 25 | µA |
| $T_J = 100^oC$ MR820 | | – | – | 0.5 | mA |
| MR821 | | – | 0.25 | 0.5 | |
| MR822 | | – | – | 0.6 | |
| MR824 | | – | – | 0.8 | |
| MR826 | | – | 0.4 | 1.0 | |

REVERSE RECOVERY CHARACTERISTICS

| Characteristic | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Reverse Recovery Time | $t_{rr}$ | | | | ns |
| ($I_F$ = 1.0 Amp to $V_R$ = 30 Vdc, Figure 25) | | – | 100 | 200 | |
| ($I_{FM}$ = 15 Amp, di/dt = 25 A/µs, Figure 26) | | – | 150 | 300 | |
| Reverse Recovery Current ($I_F$ = 1.0 Amp to $V_R$ = 30 Vdc, Figure 25) | $I_{RM(REC)}$ | – | – | 2.0 | Amp |

(1) Must be derated for reverse power dissipation. See Note 3
(2) Derate as shown in Figure 1.
▲Trademark of Motorola Inc.

### MECHANICAL CHARACTERISTICS

CASE: Void Free, Transfer Molded
FINISH: External Surfaces are Corrosion Resistant
POLARITY: Indicated by Diode Symbol
WEIGHT: 2.5 Grams (Approximately)
MAXIMUM LEAD TEMPERATURE FOR SOLDERING PURPOSES: 350°C, 3/8" from case for 10 s at 5.0 lb. tension.

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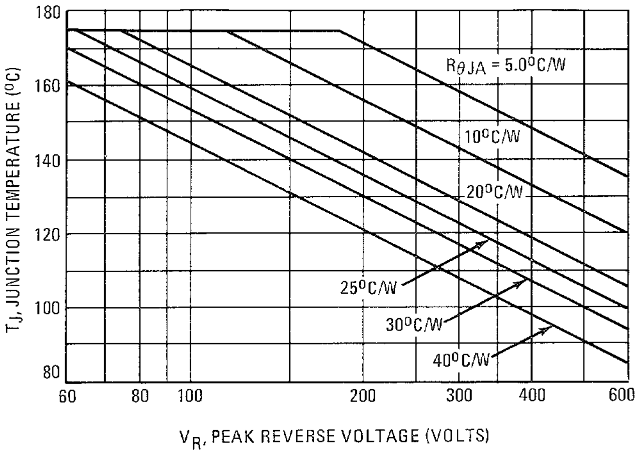
## MAXIMUM CURRENT AND TEMPERATURE RATINGS

FIGURE 1 — MAXIMUM ALLOWABLE JUNCTION TEMPERATURE




**NOTE 1**

**MAXIMUM JUNCTION TEMPERATURE DERATING**

When operating this rectifier at junction temperatures over approximately 85°C, reverse power dissipation and the possibility of thermal runaway must be considered. The data of Figure 1 is based upon worst case reverse power and should be used to derate $T_{J(max)}$ from its maximum value of 175°C. See Note 3 for additional information on derating for reverse power dissipation.

When current ratings are computed from $T_{J(max)}$ and reverse power dissipation is also included, ratings vary with reverse voltage as shown on Figures 2 thru 5.

## RESISTIVE LOAD RATINGS

**PRINTED CIRCUIT BOARD MOUNTING — SEE NOTE 6, PAGE 8**

FIGURE 2 — SINE WAVE INPUT

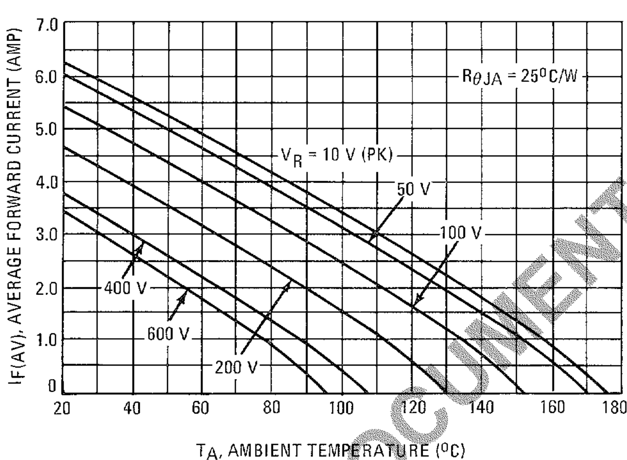



FIGURE 3 — SQUARE WAVE INPUT

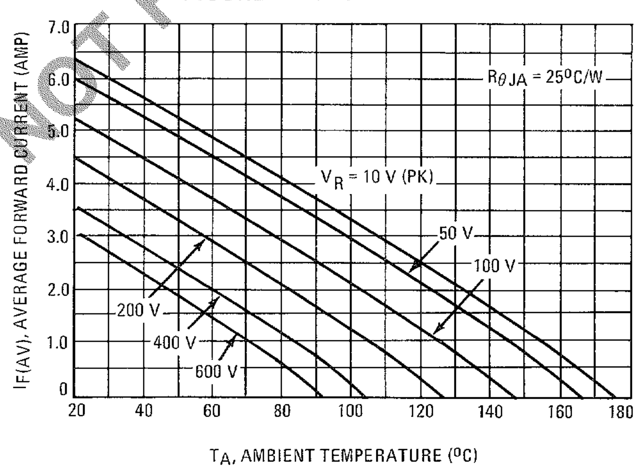



FIGURE 4 — SINE WAVE INPUT

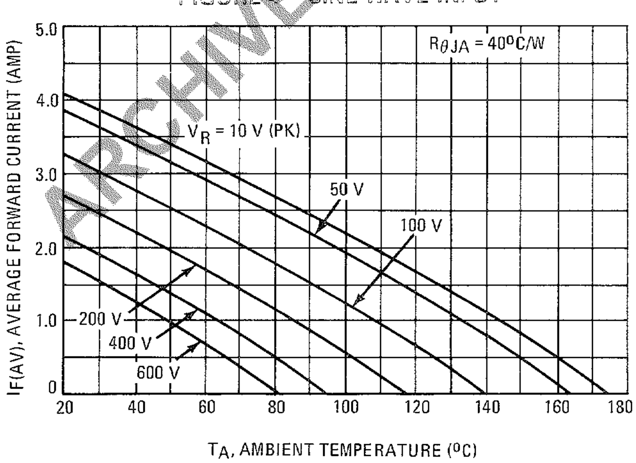
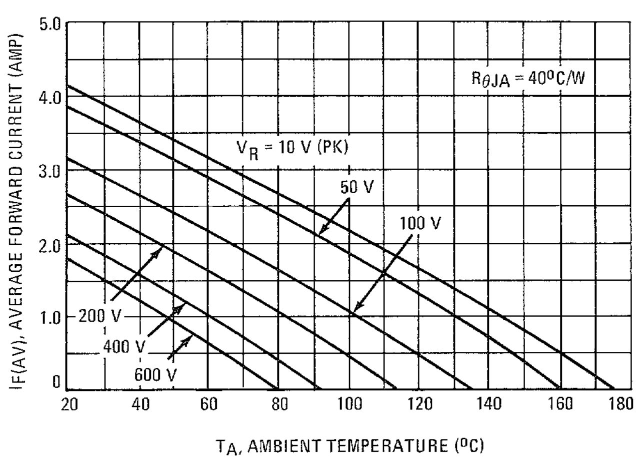



FIGURE 5 — SQUARE WAVE INPUT

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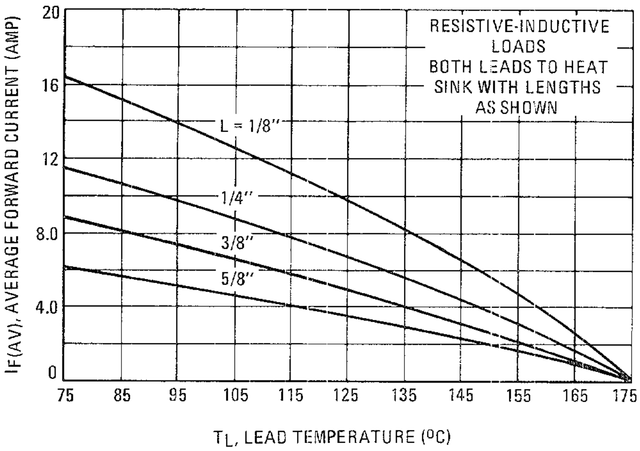
## MAXIMUM CURRENT RATINGS

**NOTE 2**

Current derating data is based upon the thermal response data of Figure 29 and the forward power dissipation data of Figures 19 and 20. Since reverse power dissipation is not considered in Figures 6 thru 11, additional derating for reverse voltage and for junction to ambient thermal resistance must be applied. See Note 3.

### SINE WAVE INPUT

FIGURE 6 — EFFECT OF LEAD LENGTHS, RESISTIVE LOAD




### SQUARE WAVE INPUT

FIGURE 7 — EFFECT OF LEAD LENGTHS, RESISTIVE LOAD

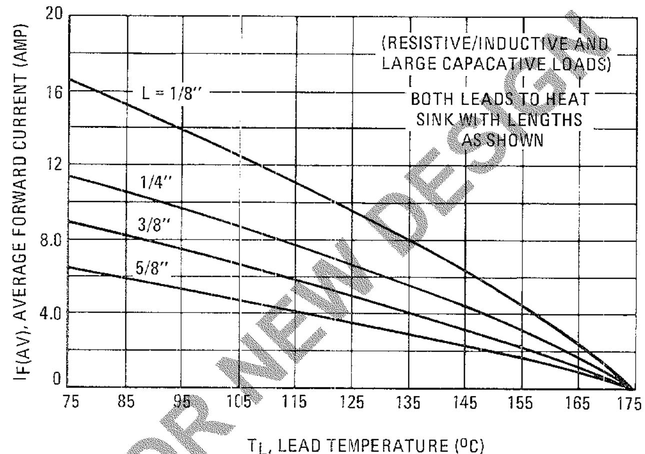



FIGURE 8 — 1/8″ LEAD LENGTH, VARIOUS LOADS

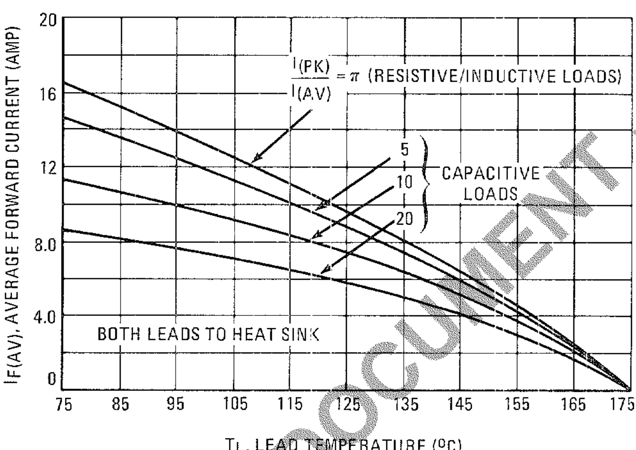



FIGURE 9 — 1/8″ LEAD LENGTH, VARIOUS LOADS

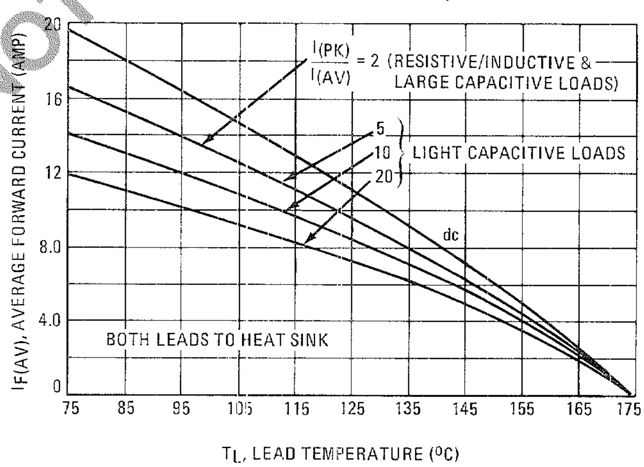



FIGURE 10 — PRINTED CIRCUIT BOARD MOUNTING, VARIOUS LOADS

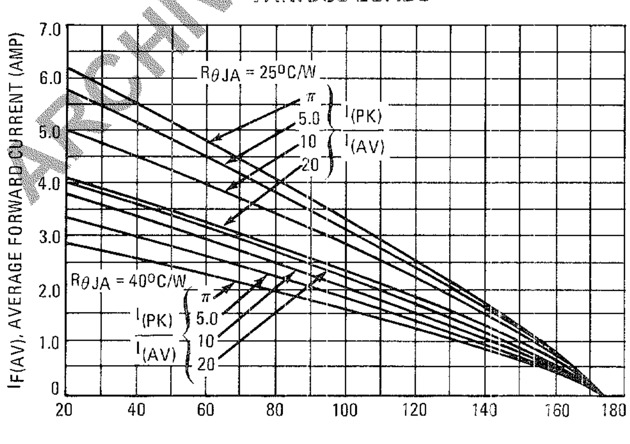
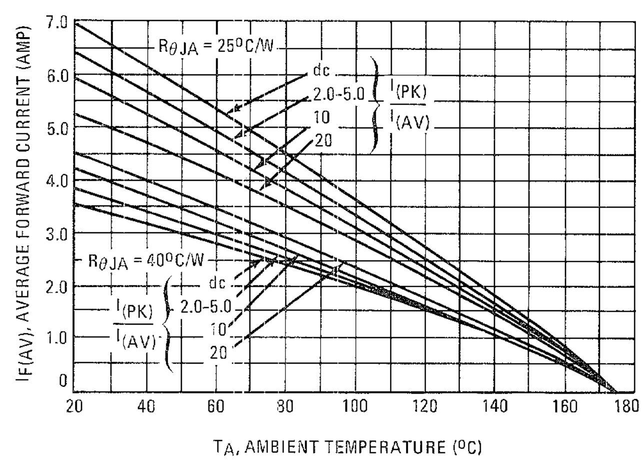



FIGURE 11 — PRINTED CIRCUIT BOARD MOUNTING, VARIOUS LOADS

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## REVERSE POWER DISSIPATION AND CURRENT

### NOTE 3
### DERATING FOR REVERSE POWER DISSIPATION

In this rectifier, power loss due to reverse current is generally not negligible. For reliable circuit design, the maximum junction temperature must be limited to either 175°C or the temperature which results in thermal runaway. Proper derating may be accomplished by use of equation 1 or equation 2.

Equation 1 $T_A = T_1 - (175 - T_{J(max)}) - P_R R_{\theta JA}$

Where: $T_1$ = Maximum Allowable Ambient Temperature neglecting reverse power dissipation (from Figures 10 or 11)

$T_{J(max)}$ = Maximum Allowable Junction Temperature to prevent thermal runaway or 175°C, which ever is lower. (See Figure 1).

$P_R$ = Reverse Power Dissipation (From Figure 12 or 13, adjusted for $T_{J(max)}$ as shown below)

$R_{\theta JA}$ = Thermal Resistance, Junction to Ambient.

When thermal resistance, junction to ambient, is over 20°C/W, the effect of thermal response is negligible. Satisfactory derating may be found by using:

Equation 2 $T_A = T_{J(max)} - (P_R + P_F) R_{\theta JA}$

$P_F$ = Forward Power Dissipation (See Figures 19 & 20)

Other terms defined above.

The reverse power given on Figures 12 and 13 is calculated for $T_J$ = 150°C. When $T_J$ is lower, $P_R$ will decrease; its value can be found by multiplying $P_R$ by the normalized reverse current from Figure 14 at the temperature of interest.

The reverse power data is calculated for half wave rectification circuits. For full wave rectification using either a bridge or a center-tapped transformer, the data for resistive loads is equivalent when $V_P$ is the line to line voltage across the rectifiers. For capacitive loads, it is recommended that the dc case on Figure 13 be used, regardless of input waveform, for bridge circuits. For capacitively loaded full wave center-tapped circuits, the 20:1 data of Figure 12 should be used for sine wave inputs and the capacitive load data of Figure 13 should be used for square wave inputs regardless of $I_{(pk)}/I_{(av)}$. For these two cases, $V_P$ is the voltage across one leg of the transformer.

EXAMPLE:

Find Maximum Ambient Temperature for $I_{AV}$ = 2 A, Capacitive Load of $I_{PK}/I_{AV}$ = 20, Input Voltage = 120 V (rms) Sine Wave, $R_{\theta JA}$ = 25°C/W, Half Wave Circuit.

Solution 1:

Step 1: Find $V_P$; $V_P = \sqrt{2}\, V_{in}$ = 169 V, $V_{R(pk)}$ = 338 V
Step 2: Find $T_{J(max)}$ from Figure 1. Read $T_{J(max)}$ = 119°C.
Step 3: Find $P_{R(max)}$ from Figure 12. Read $P_R$ = 770 mW @ 140°C
Step 4: Find $I_R$ normalized from Figure 14. Read $I_{R(norm)}$ = 0.4
Step 5: Correct $P_R$ to $T_{J(max)}$. $P_R = I_{R(norm)} \times P_R$ (Figure 12) $P_R$ = 0.4 x 770 = 310 mW.
Step 6: Find $P_F$ from Figure 19. Read $P_F$ = 2.4 W.
Step 7: Compute $T_A$ from $T_A = T_{J(max)} - (P_R + P_F) R_{\theta JA}$
$T_A$ = 119 - (0.31 + 2.4) (25)
$T_A$ = 51°C

Solution 2:

Steps 1 thru 5 are as above.
Step 6: Find $T_A = T_1$ from Figure 10. Read $T_A$ = 115°C.
Step 7: Compute $T_A$ from $T_A = T_1 - (175 - (T_{J(max)}) - P_R R_{\theta JA}$
$T_A$ = 115 - (175 - 119) - (0.31) (25)
$T_A$ = 51°C

At times, a discrepancy between methods will occur because thermal response is factored into Solution 2.

FIGURE 12 — SINE WAVE INPUT DISSIPATION

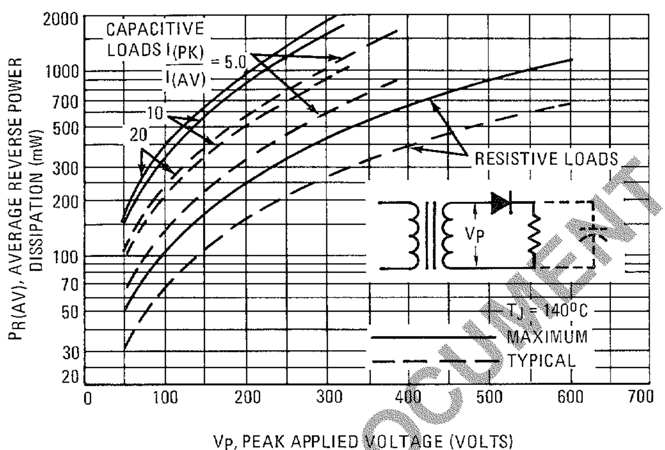



FIGURE 13 — SQUARE WAVE INPUT DISSIPATION

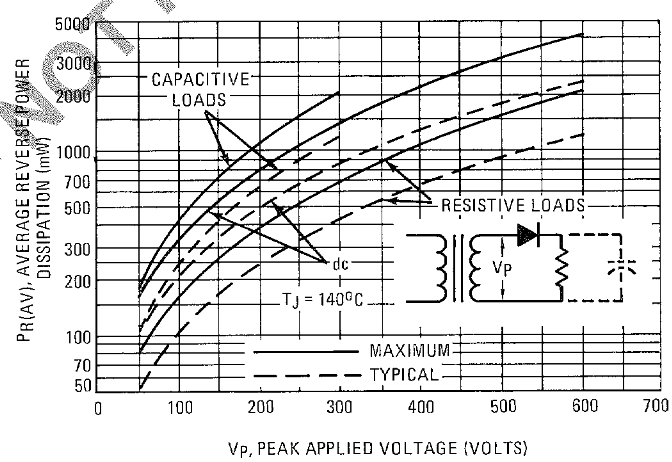



FIGURE 14 — NORMALIZED REVERSE CURRENT

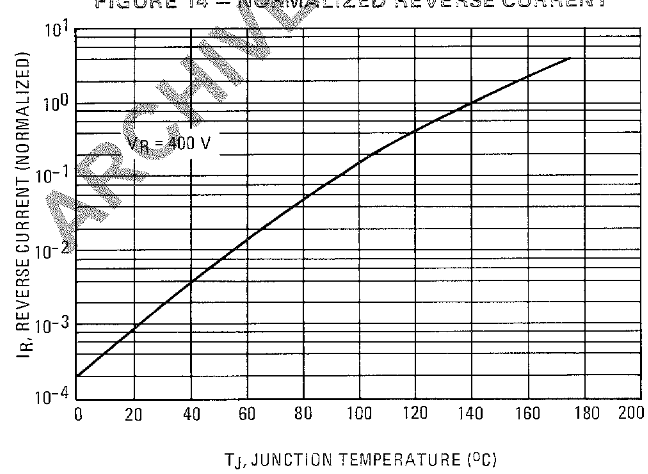
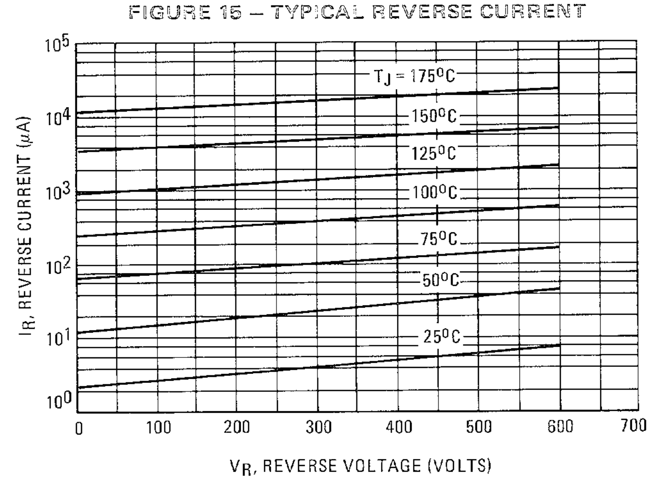



FIGURE 15 — TYPICAL REVERSE CURRENT

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## STATIC CHARACTERISTICS

FIGURE 16 — FORWARD VOLTAGE

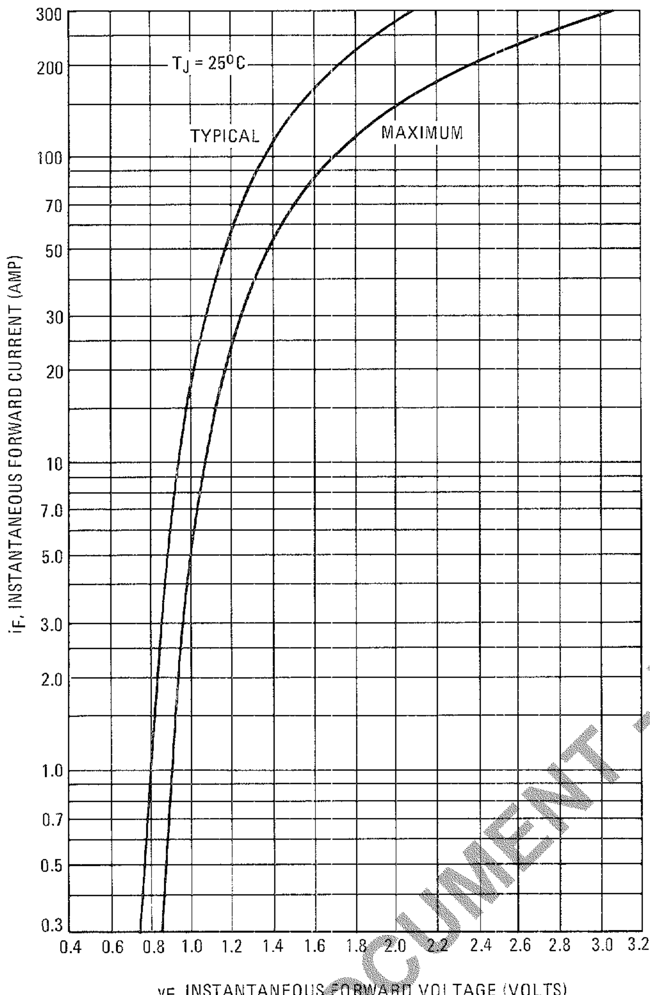



FIGURE 17 — MAXIMUM SURGE CAPABILITY

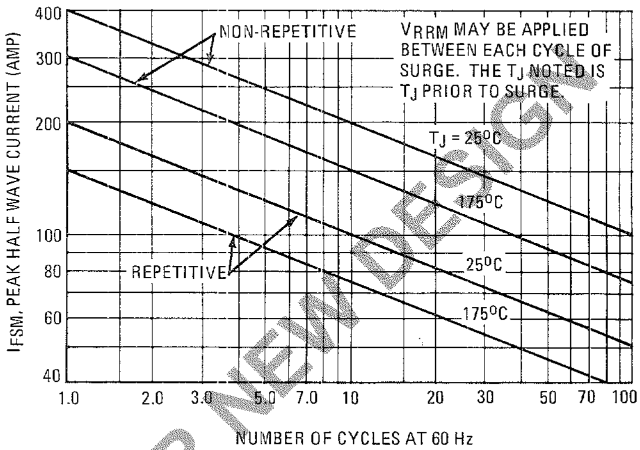
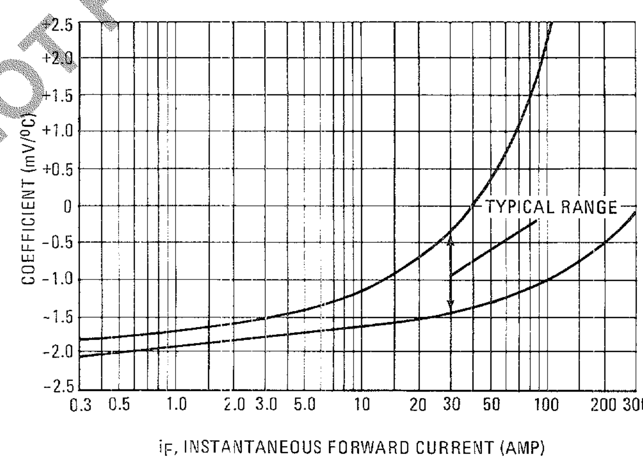



FIGURE 18 — FORWARD VOLTAGE TEMPERATURE COEFFICIENT




## MAXIMUM FORWARD POWER DISSIPATION

FIGURE 19 — SINE WAVE INPUT

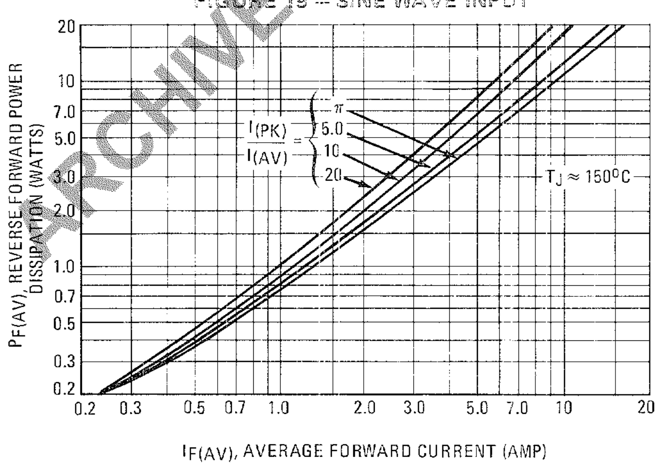
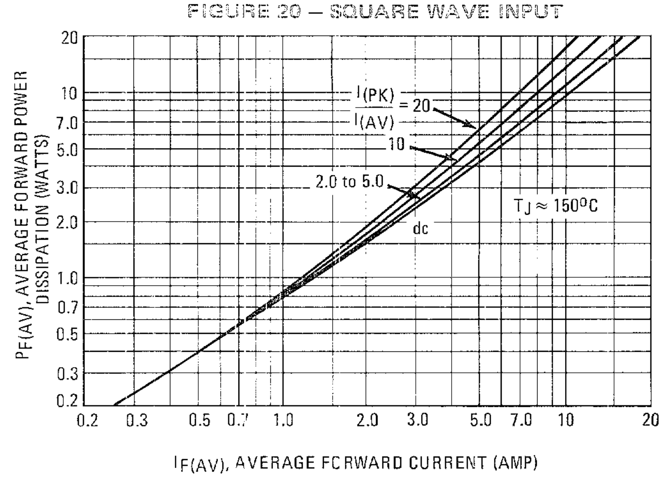



FIGURE 20 — SQUARE WAVE INPUT

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## TYPICAL RECOVERED STORED CHARGE DATA

**(See Note 4)**

FIGURE 21 — $T_J = 25^{\circ}C$

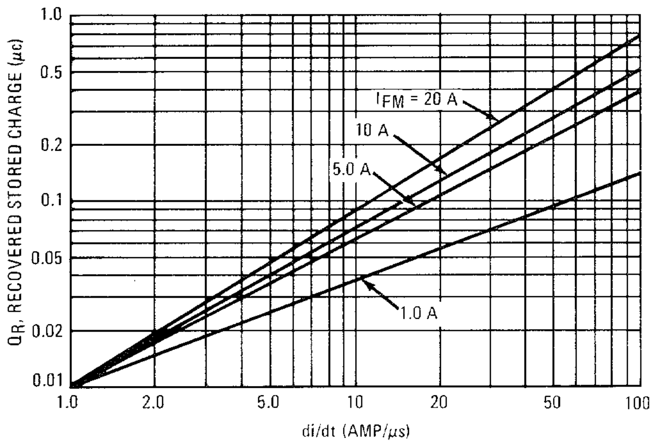



FIGURE 22 — $T_J = 75^{\circ}C$

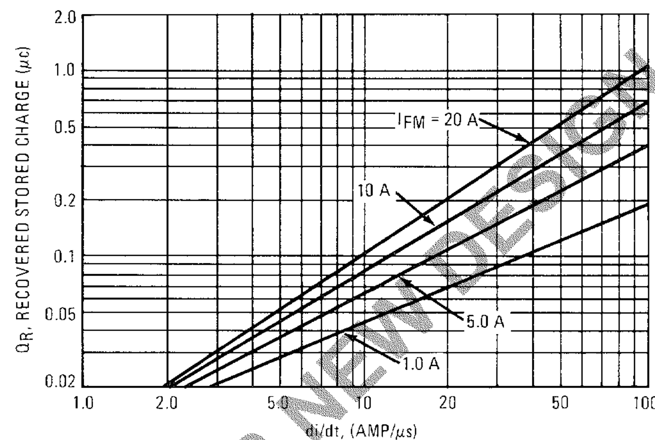



FIGURE 23 — $T_J = 100^{\circ}C$

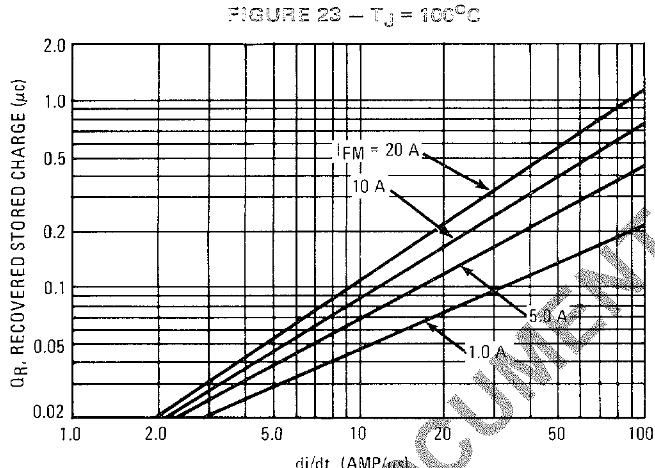
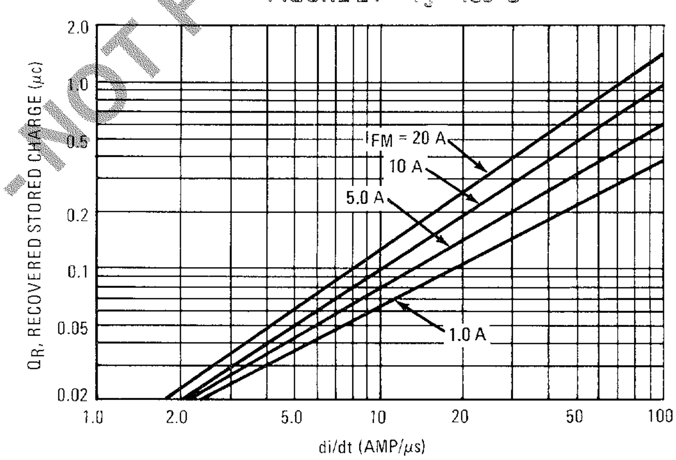



FIGURE 24 — $T_J = 150^{\circ}C$



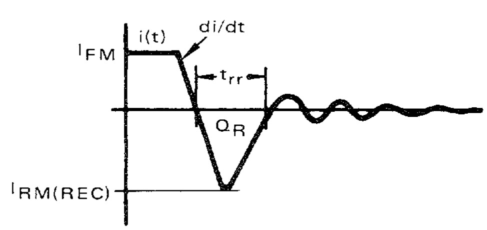

### NOTE 4

Reverse recovery time is the period which elapses from the time that the current, thru a previously forward biased rectifier diode, passes thru zero going negatively until the reverse current recovers to a point which is less than 10% peak reverse current.

Reverse recovery time is a direct function of the forward current prior to the application of reverse voltage.

For any given rectifier, recovery time is very circuit dependent. Typical and maximum recovery time of all Motorola fast recovery power rectifiers are rated under a fixed set of conditions using $I_F = 1.0$ A, $V_R = 30$ V. In order to cover all circuit conditions, curves are given for typical recovered stored charge versus commutation di/dt for various levels of forward current and for junction temperatures of 25°C, 75°C, 100°C, and 150°C.

To use these curves, it is necessary to know the forward current level just before commutation, the circuit commutation di/dt, and the operating junction temperature. The reverse recovery test current waveform for all Motorola fast recovery rectifiers is shown.




From stored charge curves versus di/dt, recovery time ($t_{rr}$) and peak reverse recovery current ($I_{RM(REC)}$) can be closely approximated using the following formulas:

$$t_{rr} = 1.41 \times \left[\frac{Q_R}{di/dt}\right]^{1/2}$$

$$I_{RM(REC)} = 1.41 \times \left[Q_R \times di/dt\right]^{1/2}$$

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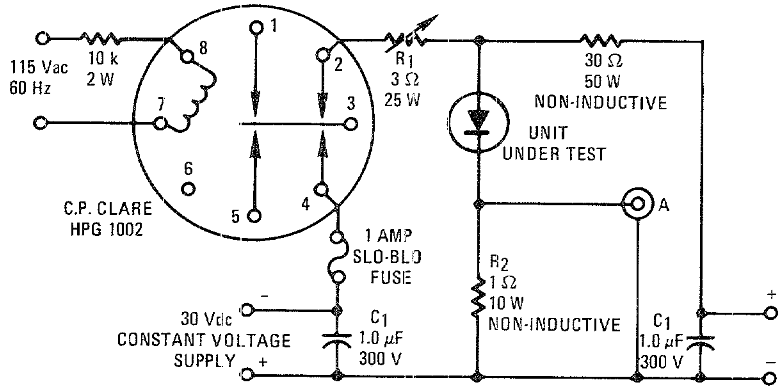
## DYNAMIC CHARACTERISTICS

FIGURE 25 — REVERSE RECOVERY CIRCUIT




A -- TEKTRONIX 545A, K PLUG IN PRE-AMP, P6000 PROBE OR EQUIVALENT

$R_1$ -- ADJUSTED FOR 1.4 Ω BETWEEN POINT 2 OF RELAY AND RECTIFIER INDUCTANCE ≈ 38 µH

$R_2$ -- TEN-1 W, 10 Ω, 1% CARBON CORE IN PARALLEL

$T_A = 25\ ^{+10}_{-0}\ ^\circ C$ FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

1.0 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3 mVrms MAX
$Z_{out}$ = 1½ Ω MAX, DC to 2 kHz

FIGURE 26 — JEDEC REVERSE RECOVERY CIRCUIT

R1 = 50 Ohms
R2 = 250 Ohms
D1 = 1N4723
D2 = 1N4001
D3 = 1N4933
SCR1 = MCR729-10
C1 = 0.5 to 50 µF
C2 ≈ 4000 µF
L1 = 1.0 - 27 µH
T1 = Variac Adjusts $I_{(PK)}$ and di/dt
T2 = 1:1
T3 = 1:1 (to trigger circuit)

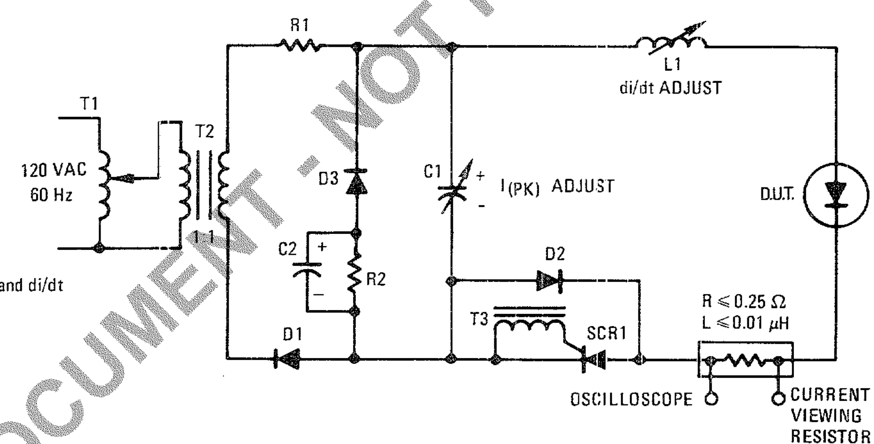



FIGURE 27 — FORWARD RECOVERY TIME

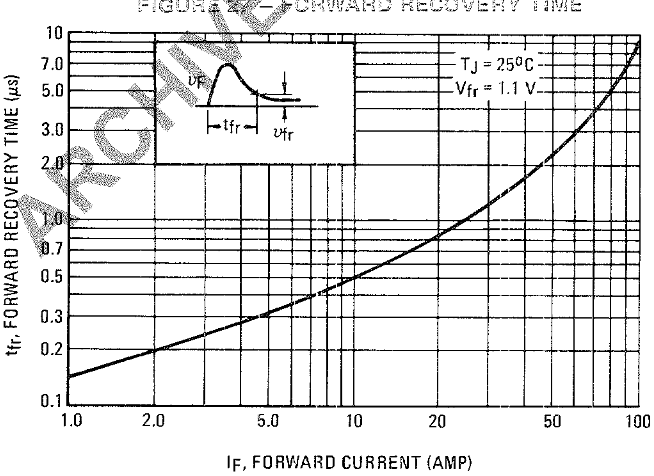
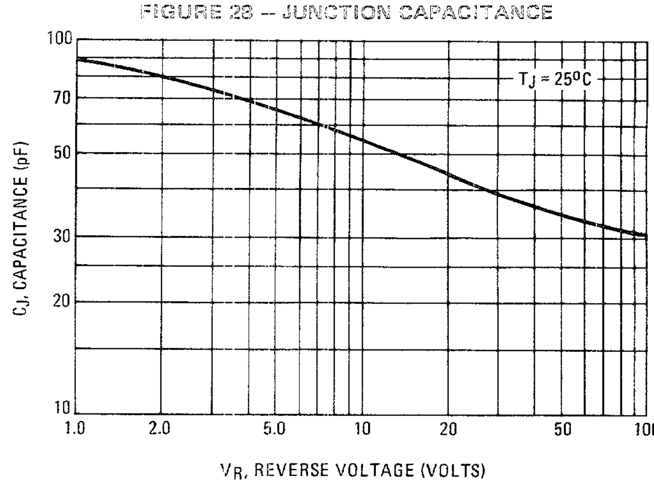



FIGURE 28 — JUNCTION CAPACITANCE

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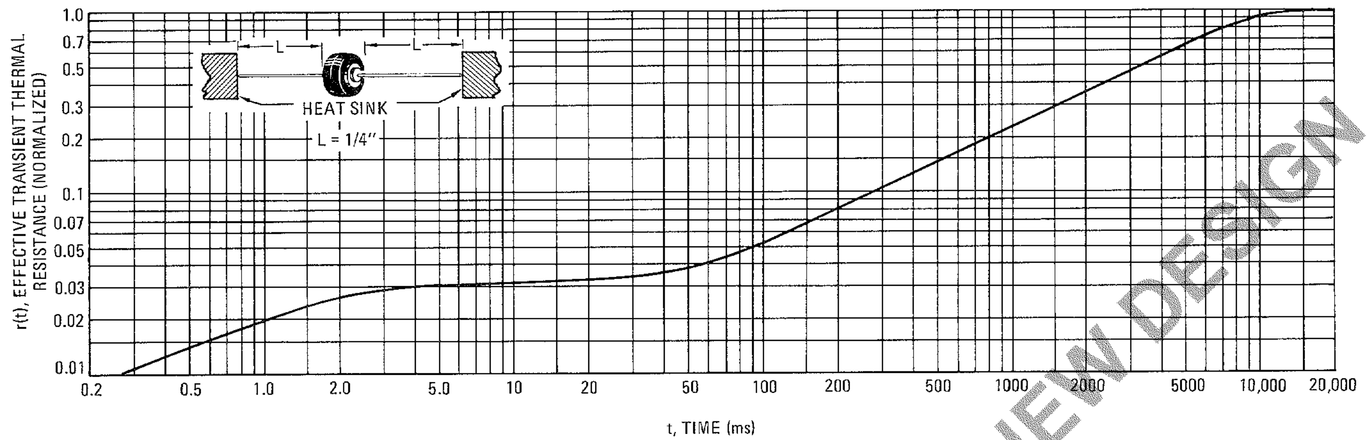
## THERMAL CHARACTERISTICS

FIGURE 29 – THERMAL RESPONSE




### NOTE 5

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended:

The temperature of the lead should be measured using a thermocouple placed on the lead as close as possible to the tie point. The thermal mass connected to the tie point is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of $T_L$, the junction temperature may be determined by:

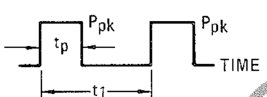
$$T_J = T_L + \Delta T_{JL}$$

where $\Delta T_{JL}$ is the increase in junction temperature above the lead temperature. It may be determined by:

$$\Delta T_{JL} = P_{pk} \cdot R_{\theta JL} \left[D + (1 - D) \cdot r(t_1 + t_p) + r(t_p) - r(t_1)\right]$$

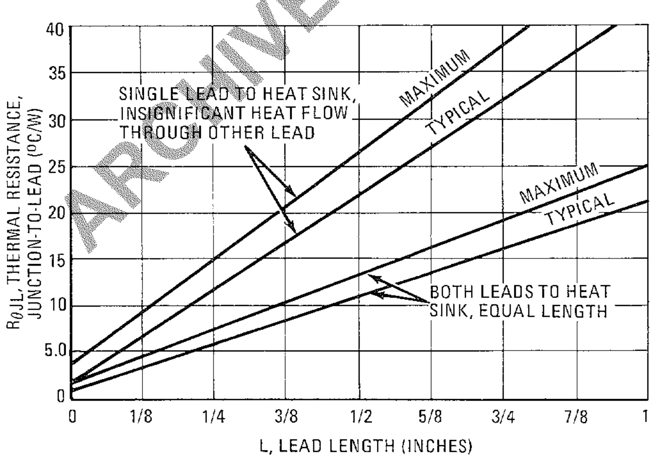
where $r(t)$ = normalized value of transient thermal resistance at time t from Figure 29, i.e.:

$r(t_1 + t_p)$ = normalized value of transient thermal resistance at time $t_1 + t_p$.

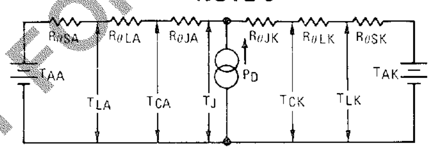



DUTY CYCLE = $t_p/t_1$
PEAK POWER, $P_{pk}$, is peak of an equivalent square power pulse.

FIGURE 30 – STEADY-STATE THERMAL RESISTANCE




### NOTE 6




Use of the above model permits junction to lead thermal resistance for any mounting configuration to be found. Lowest values occur when one side of the rectifier is brought as close as possible to the heat sink as shown below. Terms in the model signify:

| | |
|---|---|
| $T_A$ = Ambient Temperature | $R_{\theta S}$ = Thermal Resistance, Heat sink to Ambient |
| $T_L$ = Lead Temperature | $R_{\theta L}$ = Thermal Resistance, Lead to Heat Sink |
| $T_C$ = Case Temperature | $R_{\theta J}$ = Thermal Resistance, Junction to Case |
| $T_J$ = Junction Temperature | $P_D$ = Power Dissipation = $P_F + P_R$ |
| | $P_F$ = Forward Power Dissipation |
| | $P_R$ = Reverse Power Dissipation |

(Subscripts A and K refer to anode and cathode sides respectively). Values for thermal resistance components are:

$R_{\theta L}$ = 40°C/W/IN. Typically and 44°C/W/IN Maximum.
$R_{\theta J}$ = 2°C/W Typically and 4°C/W Maximum.

Since $R_{\theta J}$ is so low, measurements of the case temperature, $T_C$, will be approximately equal to junction temperature in practical lead mounted applications. When used as a 60 Hz rectifier, the slow thermal response holds $T_{J(PK)}$ close to $T_{J(AV)}$. Therefore maximum lead temperature may be found as follows:

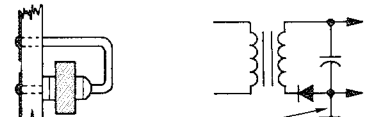
$$T_L = T_{J(max)} - \Delta T_{JL}$$

where

$\Delta T_{JL}$ can be approximated as follows:

$\Delta T_{JL} \approx R_{\theta JL} \cdot P_D$; $P_D$ is the sum of forward and reverse power dissipation shown in Figures 12 & 19 for sine wave operation and Figures 13 & 20 for square wave operation.

The recommended method of mounting to a P.C. board is shown on the sketch, where $R_{\theta JA}$ is approximately 25°C/W for a 1-1/2″ x 1-1/2″ copper surface area. Values of 40°C/W are typical for mounting to terminal strips or P.C. boards where available surface area is small.




Recommended mounting for half wave circuit

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