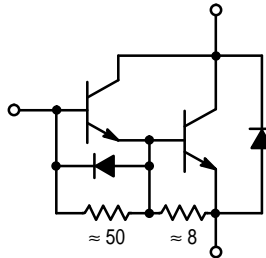


# SWITCHMODE Series

## NPN Silicon Power Darlington Transistors with Base-Emitter Speedup Diode

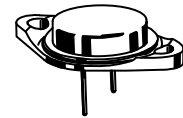
The MJ10015 and MJ10016 Darlington transistors are designed for high-voltage, high-speed, power switching in inductive circuits where fall time is critical. They are particularly suited for line-operated switchmode applications such as:

- Switching Regulators
- Motor Controls
- Inverters
- Solenoid and Relay Drivers
- Fast Turn-Off Times
  - 1.0  $\mu$ s (max) Inductive Crossover Time — 20 Amps
  - 2.5  $\mu$ s (max) inductive Storage Time — 20 Amps
- Operating Temperature Range  $-65$  to  $+200^{\circ}\text{C}$
- Performance Specified for
  - Reversed Biased SOA with Inductive Load
  - Switching Times with Inductive Loads
  - Saturation Voltages
  - Leakage Currents



**MJ10015**  
**MJ10016**

**50 AMPERE**  
**NPN SILICON**  
**POWER DARLINGTON**  
**TRANSISTORS**  
**400 AND 500 VOLTS**  
**250 WATTS**



**CASE 197-05**  
**TO-204AE TYPE**  
**(TO-3 TYPE)**

### MAXIMUM RATINGS

Rating	Symbol	MJ10015	MJ10016	Unit
Collector-Emitter Voltage	$V_{CEO}$	400	500	Vdc
Collector-Emitter Voltage	$V_{CEV}$	600	700	Vdc
Emitter Base Voltage	$V_{EB}$	8.0		Vdc
Collector Current — Continuous	$I_C$	50		Adc
— Peak (1)	$I_{CM}$	75		
Base Current — Continuous	$I_B$	10		Adc
— Peak (1)	$I_{BM}$	15		
Total Power Dissipation @ $T_C = 25^{\circ}\text{C}$	$P_D$	250		Watts
@ $T_C = 100^{\circ}\text{C}$		143		
Derate above $25^{\circ}\text{C}$		1.43		W/ $^{\circ}\text{C}$
Operating and Storage Junction Temperature Range	$T_J, T_{stg}$	$-65$ to $+200$		$^{\circ}\text{C}$

### THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	0.7	$^{\circ}\text{C/W}$
Maximum Lead Temperature for Soldering Purposes: 1/8" from Case for 5 Seconds	$T_L$	275	$^{\circ}\text{C}$

(1) Pulse Test: Pulse Width = 5 ms, Duty Cycle  $\leq 10\%$ .

SWITCHMODE is a trademark of Motorola, Inc.

REV 1

**ELECTRICAL CHARACTERISTICS** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
<b>OFF CHARACTERISTICS (1)</b>					
Collector–Emitter Sustaining Voltage (Table 1) ( $I_C = 100\text{ mA}$ , $I_B = 0$ , $V_{\text{clamp}} = \text{Rated } V_{\text{CEO}}$ )	$V_{\text{CEO(sus)}}$	400 500	— —	— —	Vdc
Collector Cutoff Current ( $V_{\text{CEV}} = \text{Rated Value}$ , $V_{\text{BE(off)}} = 1.5\text{ Vdc}$ )	$I_{\text{CEV}}$	—	—	0.25	mAdc
Emitter Cutoff Current ( $V_{\text{EB}} = 2.0\text{ Vdc}$ , $I_C = 0$ )	$I_{\text{EBO}}$	—	—	350	mAdc

**SECOND BREAKDOWN**

Second Breakdown Collector Current with Base Forward Biased	$I_{\text{S/b}}$	See Figure 7			
Clamped Inductive SOA with Base Reverse Biased	RBSOA	See Figure 8			

**ON CHARACTERISTICS (1)**

DC Current Gain ( $I_C = 20\text{ Adc}$ , $V_{\text{CE}} = 5.0\text{ Vdc}$ ) ( $I_C = 40\text{ Adc}$ , $V_{\text{CE}} = 5.0\text{ Vdc}$ )	$h_{\text{FE}}$	25 10	— —	— —	—
Collector–Emitter Saturation Voltage ( $I_C = 20\text{ Adc}$ , $I_B = 1.0\text{ Adc}$ ) ( $I_C = 50\text{ Adc}$ , $I_B = 10\text{ Adc}$ )	$V_{\text{CE(sat)}}$	— —	— —	2.2 5.0	Vdc
Base–Emitter Saturation Voltage ( $I_C = 20\text{ Adc}$ , $I_B = 1.0\text{ Adc}$ )	$V_{\text{BE(sat)}}$	—	—	2.75	Vdc
Diode Forward Voltage (2) ( $I_F = 20\text{ Adc}$ )	$V_f$	—	2.5	5.0	Vdc

**DYNAMIC CHARACTERISTIC**

Output Capacitance ( $V_{\text{CB}} = 10\text{ Vdc}$ , $I_E = 0$ , $f_{\text{test}} = 100\text{ kHz}$ )	$C_{\text{ob}}$	—	—	750	pF
--	-----------------	---	---	-----	----

**SWITCHING CHARACTERISTICS**

Resistive Load (Table 1)						
Delay Time	$(V_{CC} = 250\text{ Vdc}, I_C = 20\text{ A},$ $I_{B1} = 1.0\text{ Adc}, V_{BE(off)} = 5\text{ Vdc}, t_p = 25\text{ }\mu\text{s}$ Duty Cycle $\leq 2\%$ ).	$t_d$	—	0.14	0.3	$\mu\text{s}$
Rise Time		$t_r$	—	0.3	1.0	$\mu\text{s}$
Storage Time		$t_s$	—	0.8	2.5	$\mu\text{s}$
Fall Time		$t_f$	—	0.3	1.0	$\mu\text{s}$
Inductive Load, Clamped (Table 1)						
Storage Time	$(I_C = 20\text{ A(pk)}, V_{\text{clamp}} = 250\text{ V}, I_{B1} = 1.0\text{ A},$ $V_{BE(off)} = 5.0\text{ Vdc})$	$t_{sv}$	—	1.0	2.5	$\mu\text{s}$
Crossover Time		$t_c$	—	0.36	1.0	$\mu\text{s}$

(1) Pulse Test: Pulse Width =  $300\text{ }\mu\text{s}$ , Duty Cycle  $\leq 2\%$ .

(2) The internal Collector–to–Emitter diode can eliminate the need for an external diode to clamp inductive loads.

Tests have shown that the Forward Recovery Voltage ( $V_f$ ) of this diode is comparable to that of typical fast recovery rectifiers.

## TYPICAL CHARACTERISTICS

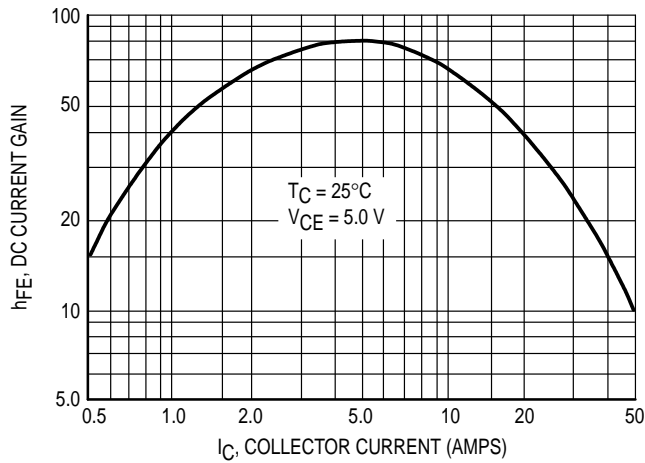


Figure 1. DC Current Gain

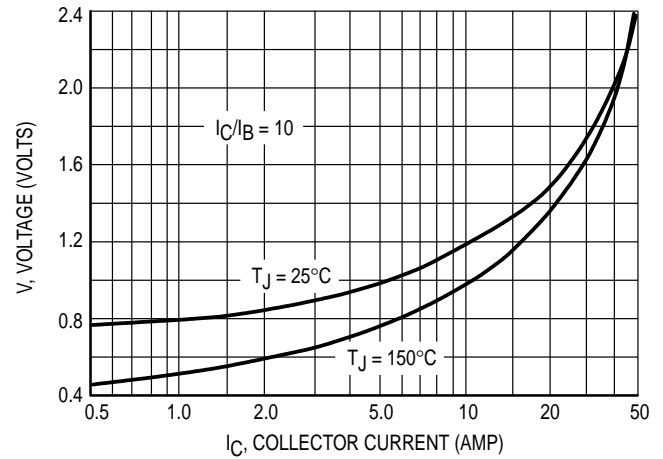


Figure 2. Collector-Emitter Saturation Voltage

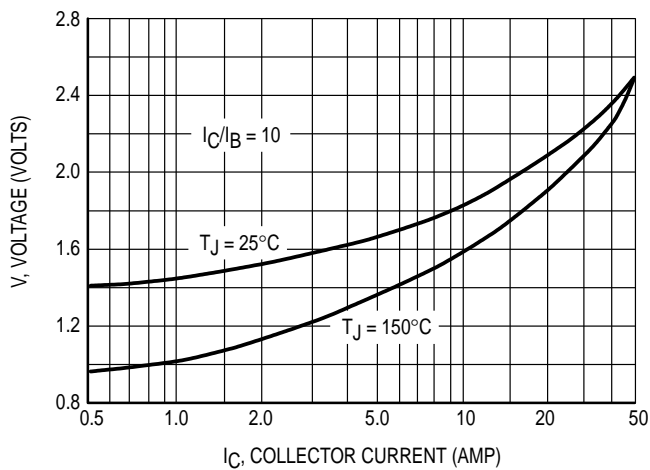


Figure 3. Base-Emitter Saturation Voltage

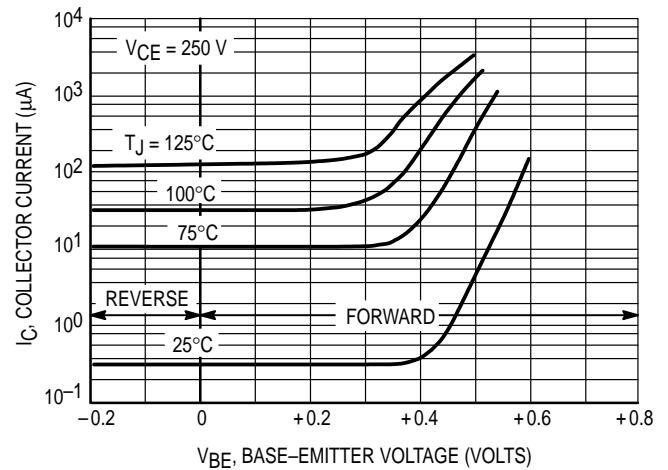


Figure 4. Collector Cutoff Region

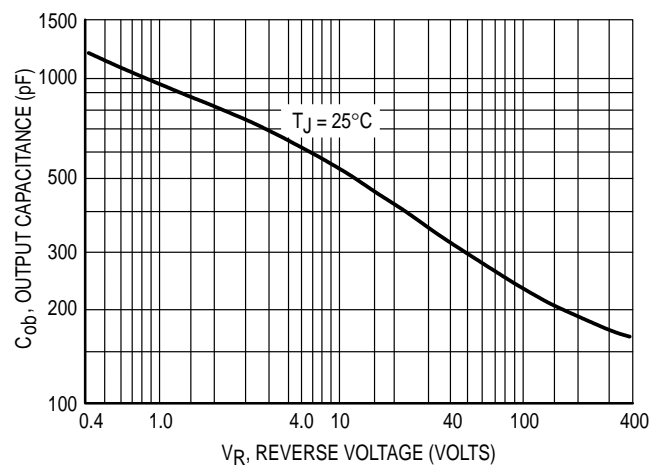
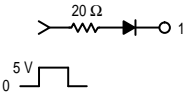
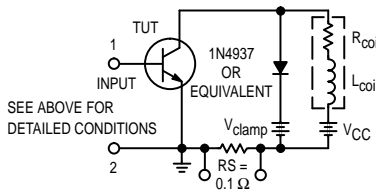
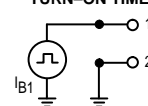
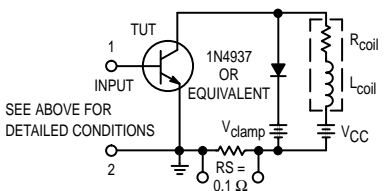
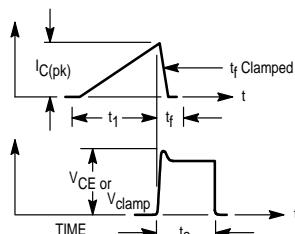
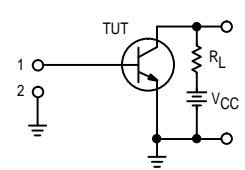


Figure 5. Output Capacitance

Table 1. Test Conditions for Dynamic Performance

	$V_{CEO(sus)}$	$V_{CEX}$ AND INDUCTIVE SWITCHING	RESISTIVE SWITCHING
INPUT CONDITIONS	 <p>PW Varied to Attain <math>I_C = 100 \text{ mA}</math></p>	<p>INDUCTIVE TEST CIRCUIT</p>  <p>SEE ABOVE FOR DETAILED CONDITIONS</p>	<p>TURN-ON TIME</p>  <p><math>I_{B1}</math> adjusted to obtain the forced <math>h_{FE}</math> desired</p> <p>TURN-OFF TIME</p> <p>Use inductive switching driver as the input to the resistive test circuit.</p>
CIRCUIT VALUES	$L_{coil} = 10 \text{ mH}$ , $V_{CC} = 10 \text{ V}$ $R_{coil} = 0.7 \Omega$ $V_{clamp} = V_{CEO(sus)}$	$L_{coil} = 180 \mu\text{H}$ $R_{coil} = 0.05 \Omega$ $V_{CC} = 20 \text{ V}$	$V_{CC} = 250 \text{ V}$ $R_L = 12.5 \Omega$ Pulse Width = $25 \mu\text{s}$
TEST CIRCUITS	<p>INDUCTIVE TEST CIRCUIT</p>  <p>SEE ABOVE FOR DETAILED CONDITIONS</p>	<p>OUTPUT WAVEFORMS</p>  <p><math>t_1</math> Adjusted to Obtain <math>I_C</math></p> $t_1 = \frac{L_{coil} (I_{Cpk})}{V_{CC}}$ $t_2 = \frac{L_{coil} (I_{Cpk})}{V_{Clamp}}$ <p>Test Equipment Scope — Tektronix 475 or Equivalent</p>	<p>RESISTIVE TEST CIRCUIT</p> 

\* Adjust  $-V$  such that  $V_{BE(off)} = 5 \text{ V}$  except as required for RBSOA (Figure 8).

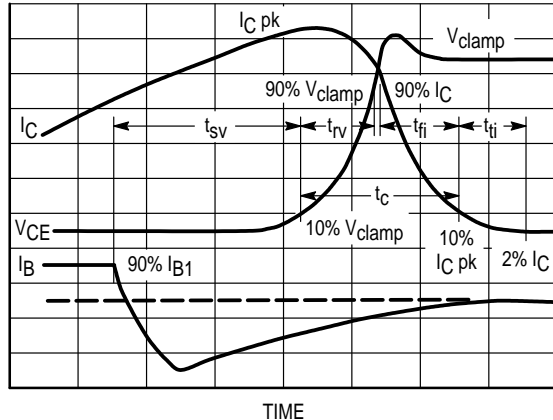


Figure 6. Inductive Switching Measurements

### SWITCHING TIMES NOTE

In resistive switching circuits, rise, fall, and storage times have been defined and apply to both current and voltage waveforms since they are in phase. However, for inductive loads which are common to SWITCHMODE power supplies

and hammer drivers, current and voltage waveforms are not in phase. Therefore, separate measurements must be made on each waveform to determine the total switching time. For this reason, the following new terms have been defined.

$t_{SV}$  = Voltage Storage Time, 90%  $I_{B1}$  to 10%  $V_{clamp}$

$t_{RV}$  = Voltage Rise Time, 10–90%  $V_{clamp}$

$t_{fj}$  = Current Fall Time, 90–10%  $I_C$

$t_{ti}$  = Current Tail, 10–2%  $I_C$

$t_c$  = Crossover Time, 10%  $V_{clamp}$  to 10%  $I_C$

For the designer, there is minimal switching loss during storage time and the predominant switching power losses occur during the crossover interval and can be obtained using the standard equation from AN-222:

$$P_{SWT} = 1/2 V_{CC} I_C (t_c) f$$

In general,  $t_{RV} + t_{fj} \approx t_c$ . However, at lower test currents this relationship may not be valid.

As is common with most switching transistors, resistive switching is specified and has become a benchmark for designers. However, for designers of high frequency converter circuits, the user oriented specifications which make this a "SWITCHMODE" transistor are the inductive switching speeds ( $t_c$  and  $t_{SV}$ ) which are guaranteed.

The Safe Operating Area figures shown in Figures 7 and 8 are specified ratings for these devices under the test conditions shown.

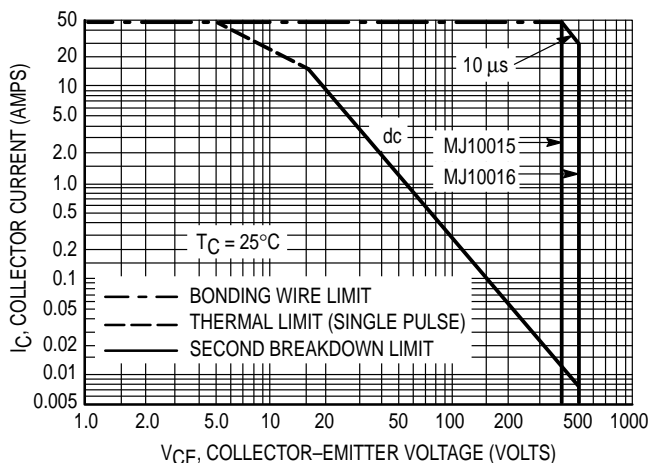


Figure 7. Forward Bias Safe Operating Area

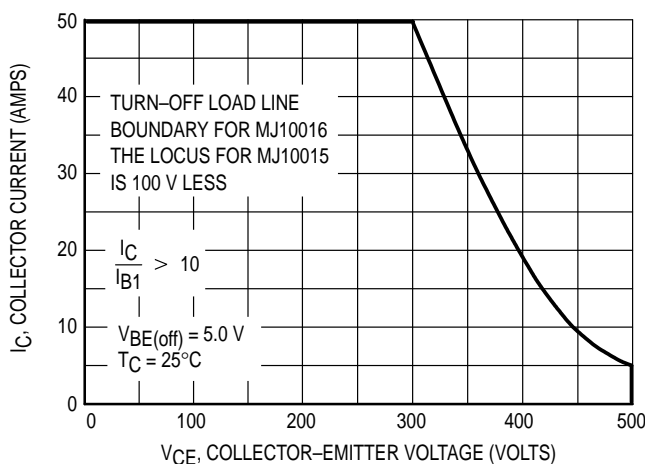


Figure 8. Reverse Bias Switching Safe Operating Area

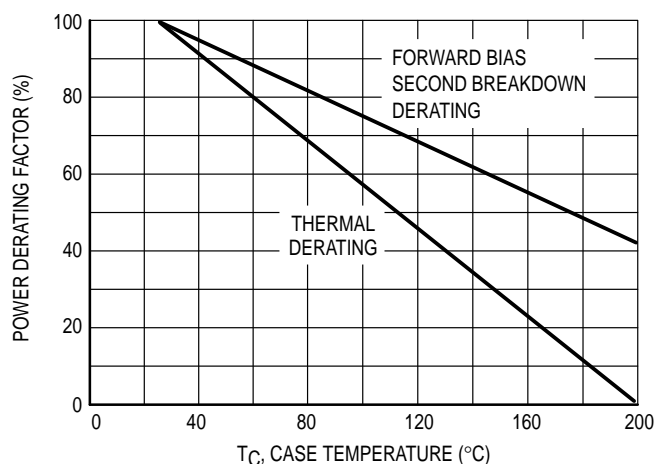


Figure 9. Power Derating

## SAFE OPERATING AREA INFORMATION

### FORWARD BIAS

There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate  $I_C - V_{CE}$  limits of the transistor that must be observed for reliable operation, i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 7 is based on  $T_C = 25^\circ\text{C}$ ;  $T_{J(pk)}$  is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when  $T_C \geq 25^\circ\text{C}$ . Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Figure 7 may be found at any case temperature by using the appropriate curve on Figure 9.

### REVERSE BIAS

For inductive loads, high voltage and high current must be sustained simultaneously during turn-off, in most cases, with the base to emitter junction reverse biased. Under these conditions the collector voltage must be held to a safe level at or below a specific value of collector current. This can be accomplished by several means such as active clamping, RC snubbing, load line shaping, etc. The safe level for these devices is specified as Reverse Bias Safe Operating Area and represents the voltage-current condition allowable during reverse biased turn-off. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 8 gives the complete RBSOA characteristics.

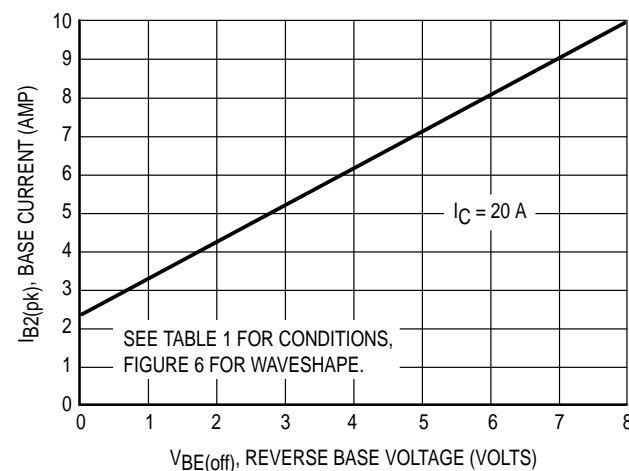
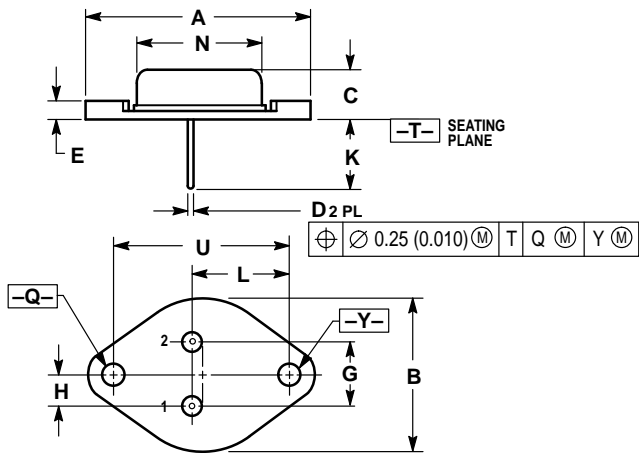


Figure 10. Typical Reverse Base Current versus  $V_{BE(off)}$  With No External Base Resistance

PACKAGE DIMENSIONS




NOTES:  
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.  
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	1.510	1.550	38.35	39.37
B	0.980	1.050	24.89	26.67
C	0.250	0.335	6.35	8.51
D	0.057	0.063	1.45	1.60
E	0.060	0.135	1.52	3.43
G	0.420	0.440	10.67	11.18
H	0.205	0.225	5.21	5.72
K	0.440	0.480	11.18	12.19
L	0.655	0.675	16.64	17.15
N	0.760	0.830	19.30	21.08
Q	0.151	0.175	3.84	4.19
U	1.177	1.197	29.90	30.40

STYLE 1:  
PIN 1. BASE  
2. EMITTER  
CASE: COLLECTOR

CASE 197-05  
TO-204AE TYPE  
(TO-3 TYPE)  
ISSUE J

Motorola reserves the right to make changes without further notice to any products herein. Motorola makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Motorola assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters can and do vary in different applications. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. Motorola does not convey any license under its patent rights nor the rights of others. Motorola products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Motorola product could create a situation where personal injury or death may occur. Should Buyer purchase or use Motorola products for any such unintended or unauthorized application, Buyer shall indemnify and hold Motorola and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Motorola was negligent regarding the design or manufacture of the part. Motorola and  are registered trademarks of Motorola, Inc. Motorola, Inc. is an Equal Opportunity/Affirmative Action Employer.

How to reach us:  
USA/EUROPE: Motorola Literature Distribution;  
P.O. Box 20912; Phoenix, Arizona 85036. 1-800-441-2447

MFAX: RMFAX0@email.sps.mot.com - TOUCHTONE (602) 244-6609  
INTERNET: <http://Design-NET.com>

JAPAN: Nippon Motorola Ltd.; Tatsumi-SPD-JLDC, Toshikatsu Otsuki,  
6F Seibu-Butsuryu-Center, 3-14-2 Tatsumi Koto-Ku, Tokyo 135, Japan. 03-3521-8315

HONG KONG: Motorola Semiconductors H.K. Ltd.; 8B Tai Ping Industrial Park,  
51 Ting Kok Road, Tai Po, N.T., Hong Kong. 852-26629298

