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 μs (max) Inductive Crossover Time 20 Amps
 - $2.5 \,\mu\text{s}$ (max) inductive Storage Time 20 Amps
- Operating Temperature Range –65 to +200°C
- Performance Specified for
- Reversed Biased SOA with Inductive Load Switching Times with Inductive Loads Saturation Voltages Leakage Currents





250 WATTS

MJ10015 MJ10016

CASE 197–05 TO–204AE TYPE (TO–3 TYPE)

MAXIMUM RATINGS

Rating	Symbol	MJ10015	MJ10016	Unit
Collector-Emitter Voltage	VCEO	400 500		Vdc
Collector-Emitter Voltage	VCEV	600	700	Vdc
Emitter Base Voltage	VEB	8	Vdc	
Collector Current — Continuous — Peak (1)	I _С IСМ	5 7	Adc	
Base Current — Continous — Peak (1)	I _B I _{BM}	10 15		Adc
Total Power Dissipation @ $T_C = 25^{\circ}C$ @ $T_C = 100^{\circ}C$ Derate above 25°C	PD	250 143 1.43		Watts W/°C
Operating and Storage Junction Temperature Range	TJ, T _{stg}	-65 to	°C	

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	R _{θJC}	0.7	°C/W
Maximum Lead Temperature for Soldering Purposes: 1/8" from Case for 5 Seconds	ΤL	275	°C

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

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REV 1



MJ10015 MJ10016

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Тур	Мах	Unit
DFF CHARACTERISTICS (1)					
Collector-Emitter Sustaining Voltage (Table 1)MJ10015(IC = 100 mA, IB = 0, V _{Clamp} = Rated V _{CEO})MJ10015MJ10016MJ10016	VCEO(sus)	400 500			Vdc
Collector Cutoff Current (V _{CEV} = Rated Value, V _{BE(off)} = 1.5 Vdc)	ICEV	_	-	0.25	mAdc
Emitter Cutoff Current ($V_{EB} = 2.0 \text{ Vdc}, I_{C} = 0$)	IEBO	_	-	350	mAdc
SECOND BREAKDOWN					•
Second Breakdown Collector Current with Base Forward Biased	I _{S/b}	See Figure 7		7	
Clamped Inductive SOA with Base Reverse Biased	RBSOA	See Figure 8			
ON CHARACTERISTICS (1)					
DC Current Gain ($I_C = 20$ Adc, $V_{CE} = 5.0$ Vdc) ($I_C = 40$ Adc, $V_{CE} = 5.0$ Vdc)	hFE	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 _{CE(sat)}			2.2 5.0	Vdc
Base–Emitter Saturation Voltage $(I_C = 20 \text{ Adc}, I_B = 1.0 \text{ Adc})$	V _{BE(sat)}	—	—	2.75	Vdc
Diode Forward Voltage (2) (I _F = 20 Adc)	V _f	_	2.5	5.0	Vdc
DYNAMIC CHARACTERISTIC					
Output Capacitance ($V_{CB} = 10 \text{ Vdc}, I_E = 0, f_{test} = 100 \text{ kHz}$)	C _{ob}	—	_	750	pF
SWITCHING CHARACTERISTICS					
Resistive Load (Table 1)					
Delay Time	td	—	0.14	0.3	μs
Rise Time $(V_{CC} = 250 \text{ Vdc}, I_C = 20 \text{ A}, I_C = 20 \text{ A})$	tr	_	0.3	1.0	μs
Storage Time $I_{B1} = 1.0 \text{ Adc}, V_{BE(off)} = 5 \text{ Vdc}, t_p = 25 \mu\text{s}$ Duty Cycle $\leq 2\%$).	t _S	_	0.8	2.5	μs
Fall Time	t _f	_	0.3	1.0	μs
Inductive Load, Clamped (Table 1)					•
Storage Time (I _C = 20 A(pk), V _{clamp} = 250 V, I _{B1} = 1.0 A,	t _{sv}		1.0	2.5	μs
Crossover Time VBE(off) = 5.0 Vdc)	t _c	_	0.36	1.0	μs

(1) Pulse Test: Pulse Width = $300 \,\mu$ 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 (Vf) of this diode is comparable to that of typical fast recovery rectifiers.

TYPICAL CHARACTERISTICS







Figure 2. Collector–Emitter Saturation Voltage



Figure 3. Base–Emitter Saturation Voltage

Figure 4. Collector Cutoff Region



Motorola Bipolar Power Transistor Device Data

MJ10015 MJ10016





* Adjust – V such that $V_{BE(off)}$ = 5 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% IB1 to 10% V_{clamp}
- t_{rv} = Voltage Rise Time, 10–90% V_{clamp}
- t_{fi} = Current Fall Time, 90–10% IC
- tti = Current Tail, 10-2% IC

 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_{IV} + t_{fi} \cong $t_{\text{C}}.$ 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 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 $T_C = 25^{\circ}C$; $T_{J(pk)}$ is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when $T_C \ge 25^{\circ}C$. 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



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