MJE13009-K

NPN SILICON TRANSISTOR

SWITCHMODE SERIES NPN SILICON POWER **TRANSISTORS**

DESCRIPTION

The MJE13009-K is designed for high-voltage, high-speed power switching inductive circuits where fall time is critical. They are particularly suited for 115 and 220V switch mode applications such as Switching Regulators, Inverters, Motor Controls, Solenoid/Relay drivers and Deflection circuits.

TO-3P TO-220

FEATURES

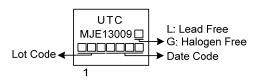
- * V_{CEO} 400V and 300 V
- * Reverse Bias SOA with Inductive Loads @ T_C = 100°C
- * Inductive Switching Matrix 3 ~ 12 Amp, 25 and 100°C t_{C} @ 8 A, 100°C is 120 ns (Typ.)
- * 700 V Blocking Capability
- * SOA and Switching Applications Information

ORDERING INFORMATION

Ordering Number		Dookogo	Pin Assignment			Doolsing	
Lead Free	Halogen Free Package		1	2	3	Packing	
MJE13009L-K-TA3-T	MJE13009G-K-TA3-T	TO-220	В	С	Е	Tube	
MJE13009L-K-T3P-T	MJE13009G-K-T3P-T	TO-3P	В	С	Ē	Tube	

Note: Pin Assignment: E: Emitter C: Collector B: Base MJE13009G-K-TA3-T (1) T: Tube (1)Packing Type (2) T3P: TO-3P, TA3: TO-220 (2)Package Type (3) G: Halogen Free and Lead Free, L: Lead Free (3)Green Package

MARKING



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■ ABSOLUTE MAXIMUM RATINGS (T_A = 25°C)

PARAMETER		SYMBOL	RATINGS	UNIT	
Collector-Emitter Voltage		V_{CEO}	400	V	
Collector-Emitter Voltage (V _{BE} =-1.5V)		V_{CEV}	700	V	
Emitter Base Voltage	_	V_{EBO}	9	V	
Callantar Commant	Continuous	Ic	12	۸	
Collector Current	Peak (Note 3)	I _{CM}	24	A	
Dana Cumant	Continuous	I _B	6	۸	
Base Current	Peak (Note 3)	I _{BM}	12	A	
Emitter Current	Continuous	lΕ	18	^	
Emitter Current	Peak (Note 3)	I _{EM}	36	A	
Dawer Dissipation	TO-220		2	w	
Power Dissipation	TO-3P	Б	80	VV	
Devete chave 25°C	TO-220	P_D	16	77. A.V.O.	
Derate above 25°C	TO-3P		640	mW/°C	
Junction Temperature		TJ	+150	°C	
Storage Temperature		T _{STG}	-40 ~ +150	°C	

Note: 1. Pulse Test: Pulse Width = 5ms, Duty Cycle ≤ 10%

- 2. Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.
- 3. Pulse Test: Pulse Width = 300µs, Duty Cycle = 2%

■ THERMAL DATA

PARAMETER		SYMBOL	RATINGS	UNIT
Lunction to Ambient	TO-220	0	54	°C // //
Junction to Ambient	TO-3P	θ_{JA}	21	°C/W
lunation to Coop	TO-220	0	4	°C/M
Junction to Case	TO-3P	θ _{JC}	1.55	°C/W



■ ELECTRICAL CHARACTERISTICS (T_C= 25°C, unless otherwise specified.)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
OFF CHARACTERISTICS (Note)							
Collector- Emitter Sustaining Voltage	V_{CEO}	$I_{C} = 10 \text{mA}, I_{B} = 0$	400			V	
Collector Cutoff Current		$V_{BE(OFF)} = 1.5V_{DC}$			1	m ^	
V _{CBO} =Rated Value	I _{CEV}	$V_{BE(OFF)} = 1.5V_{DC}, T_{C} = 100^{\circ}C$			5	mA	
Emitter Cutoff Current	I _{EBO}	$V_{EB} = 9V_{DC}, I_C = 0$			1	mA	
ON CHARACTERISTICS (Note)							
DC Current Gain	h _{FE1}	$I_{C} = 5A, V_{CE} = 5V$			40		
DC Current Gain	h _{FE 2}	$I_{C} = 8A, V_{CE} = 5V$			30		
		$I_C = 5A, I_B = 1A$			1	V	
Current Emitter Seturation Voltage	\/	$I_C = 8A, I_B = 1.6A$			1.5	V	
Current-Emitter Saturation Voltage	$V_{CE(SAT)}$	$I_{C} = 12A, I_{B} = 3A$			3	V	
		$I_C = 8A$, $I_B = 1.6A$, $T_C = 100$ °C			2	V	
	V _{BE(SAT)}	$I_C = 5A, I_B = 1A$			1.2	V	
Base-Emitter Saturation Voltage		$I_C = 8A, I_B = 1.6A$			1.6	V	
		$I_C = 8A$, $I_B = 1.6A$, $T_C = 100$ °C			1.5	V	
DYNAMIC CHARACTERISTICS							
Transition frequency	f_T	$I_C = 500 \text{mA}, V_{CE} = 10 \text{V}, f = 1 \text{MHz}$	4			MHz	
Output Capacitance	C _{OB}	$V_{CB} = 10V, I_{E} = 0, f = 0.1MHz$		180		pF	
SWITCHING CHARACTERISTICS (Re	esistive Load	, Table 1)					
Delay Time	t _{DLY}	\/ - 405\/da - 0A		0.06	0.1	μs	
Rise Time	t _R	$V_{CC} = 125 V dc, I_C = 8A$		0.45	1	μs	
Storage Time	t _S	$I_{B1} = I_{B2} = 1.6A$, $t_P = 25\mu s$		1.3	4	μs	
all Time t _F		-Duty Cycle ≤1%		0.2	0.7	μs	
Inductive Load, Clamped (Table 1, Fig. 13)							
Voltage Storage Time	ts	I _C =8A, V _{CLAMP} =300V, I _{B1} =1.6A		0.92	2.3	μs	
Crossover Time	t _C	$V_{BE(OFF)} = 5V, T_C = 100^{\circ}C$		0.12	0.7	μs	

Note: Pulse Test: Pulse Wieth = 300µs, Duty Cycle = 2%



■ TABLE 1. TEST CONDITIONS FOR DYNAMIC PERFORMANCE

	REVERSE BIAS SAFE OPERATING AREA AND INDUCTIVE SWITCHING	RESISTIVE SWITCHING
TEST CIRCUITS	$\begin{array}{c} +5V \\ \\ \hline \\ DUTY CYCLE \leq 10\% \\ t_R, t_F \leq 10 \text{ ns} \end{array} \begin{array}{c} +5V \\ \\ \hline \\ 0.001 \mu F \\ \\ \hline \\ 1N4933 \\ \hline \\ 1k \\ \\ \hline \\ 1N4933 \\ \hline \\ 1k \\ \\ \hline \\ 2N2222 \\ \\ \hline \\ 1N4933 \\ \hline \\ 1k \\ \\ \hline \\ 100 \\ \hline \\ 100 \\ \hline \\ 2770 \\ \hline \\ 100 \\ \hline \\ 10$	+125V R _B TUT SCOPE -4.0V
CIRCUIT VALUES	Coil Data: Ferroxcube Core #6656 GAP for $200\mu H/20A$ V_{CC} = $20V$ Full Bobbin (~16 Turns) #16 L_{COIL} = $200\mu H$ V_{CLAMP} = $300V_{DC}$	V_{CC} = 125 V R_{C} = 15 Ω D1 = 1N5820 or Equiv. R_{B} = Ω
TEST WAVEFORMS	OUTPUT WAVEFORMS $t_{\text{F}} \text{ CLAMPED}$ $t_{\text{E}} \text{ UNCLAMPED 9 } t_{2} \text{ t1 ADJUSTED TO OBTAIN IC}$ $t_{\text{T}} \approx \frac{L_{\text{COIL}}(I_{\text{CM}})}{V_{\text{CC}}}$ $t_{\text{T}} \approx \frac{L_{\text{COIL}}(I_{\text{CM}})}{V_{\text{CLAMP}}}$ $t_{\text{COIM}} = \frac{L_{\text{COIL}}(I_{\text{CM}})}{V_{\text{CLAMP}}}$ $t_{\text{COIM}} = \frac{L_{\text{COIL}}(I_{\text{CM}})}{V_{\text{CLAMP}}}$	$+10V$ $25\mu s$ $t_R, t_F < 10 \text{ ns}$ Duty Cycle = 1.0% $R_B \text{ and } R_C \text{ adjusted}$ for desired $I_B \text{ and } I_C$

■ TABLE 2. APPLICATIONS EXAMPLES OF SWITCHING CIRCUITS

CIRCUIT	LOAD LINE DIAGRAMS	TIME DIAGRAMS
SERIES SWITCHING REGULATOR Vcc Vout	TURN-ON (FORWARD BIAS) SOA $t_{ON} \le 10 \text{ ms}$ DUTY CYCLE $\le 10\%$ $P_D = 4000 \text{ W}$ (2) TURN-OFF (REVERSE BIAS) SOA $1.5 \text{ V} \le V_{\text{BE}(OFF)} \le 9.0 \text{ V}$ DUTY CYCLE $\le 10\%$ TURN-OFF $V_{\text{CC}} = 100\%$ COLLECTOR VOLTAGE	V _{CE} V _{CC} t
RINGING CHOKE INVERTER Vcc Vout	TURN-ON (FORWARD BIAS) SOA $t_{ON} \leqslant 10 \text{ ms} $ $DUTY \text{ CYCLE} \leqslant 10\%$ $T_C = 100^{\circ}\text{C} \qquad P_D = 4000 \text{ W (2)}$ $350V$ $12A \qquad TURN-OFF \text{ (REVERSE BIAS) SOA}$ $1.5 \text{ V} \leqslant \text{V}_{BE(off)} \leqslant 9.0 \text{ V}$ $DUTY \text{ CYCLE} \leqslant 10\%$ $TURN-ON \qquad 1.5 \text{ V} \leqslant \text{V}_{BE(off)} \leqslant 9.0 \text{ V}$ $DUTY \text{ CYCLE} \leqslant 10\%$ $COLLECTOR \text{ VOLTAGE}$	V _{CE} LEAKAGE SPIKE V _{CC} V _{CC} toff toff toff toff t t t t t t t t t t t t
PUSH-PULL INVERTER/CONVERTER Vout	TURN-ON (FORWARD BIAS) SOA $t_{ON} \leq 10 \text{ ms}$ DUTY CYCLE $\leq 10\%$ $T_{C} = 100^{\circ}\text{C}$ $P_{D} = 4000 \text{ W } \text{(2)}$ $350V$ $12A$ $TURN-ON$ $1.5 \text{ V} \leq V_{BE(off)} \leq 9.0 \text{ V}$ DUTY CYCLE $\leq 10\%$ V_{CC} $400V \text{ (1)}$ $700V \text{ (1)}$ $COLLECTOR \text{ VOLTAGE}$	V _{CE} V _{CC} V _{CC} V _{CC} t t
SOLENOID DRIVER Vcc SOLENOID	TURN-ON (FORWARD BIAS) SOA $t_{ON} \leq 10 ms$ DUTY CYCLE $\leq 10\%$ $T_{C} = 100^{\circ}C$ $P_{D} = 4000 \text{ W } \textcircled{2}$ $12A$ $TURN-OFF \text{ (REVERSE BIAS) SOA} \\ 1.5 \text{ V } \leq \text{V}_{BE(OFF)} \leq 9.0 \text{ V} \\ DUTY \text{ CYCLE } \leq 10\%$ $TURN-OFF$ $TURN-ON$ 2 V_{CC} $400 \text{ V } \textcircled{1}$ $700 \text{ V } \textcircled{1}$ $COLLECTOR \text{ VOLTAGE}$	Ic ton toff t

■ TABLE 3. TYPICAL INDUCTIVE SWITCHING PERFORMANCE

I _C (A)	T _C (°C)	t _{SV} (ns)	t _{RV} (ns)	t _{FI} (ns)	t _{⊺l} (ns)	t _C (ns)
2	25	770	100	150	200	240
3	100	1000	230	160	200	320
_	25	630	72	26	10	100
5	100	820	100	55	30	180
0	25	720	55	27	2	77
8	100	920	70	50	8	120
10	25	640	20	17	2	41
12	100	800	32	24	4	54

■ SWITCHING TIME NOTES

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_{CEM}

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

t_{FI} = Current Fall Time, 90–10% I_{CM}

 t_{TI} = Current Tail, 10–2% I_{CM}

 t_C = Crossover Time, 10% V_{CEM} to 10% I_{CM}

An enlarged portion of the turn-off waveforms is shown in Fig. 13 to aid in the visual identity of these terms.

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:

 $P_{SWT} = 1/2 V_{CC}I_{C}(t_{C}) f$

Typical inductive switching waveforms are shown in Fig. 14. In general, t_{RV} + $t_{FI} \approx t_{C}$. However, at lower test currents this relationship may not be valid.

As is common with most switching transistors, resistive switching is specified at 25° C 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 at 100° C.



■ TYPICAL CHARATERISTICS

Fig. 1 Forward Bias Safe Operating Area

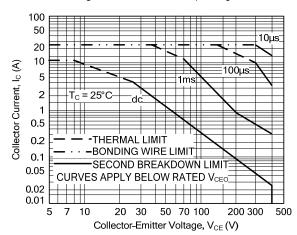


Fig. 2 Reverse Bias Switching Safe Operating Area

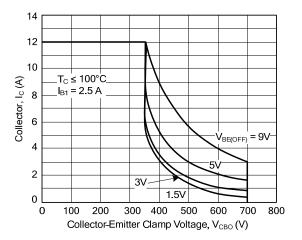
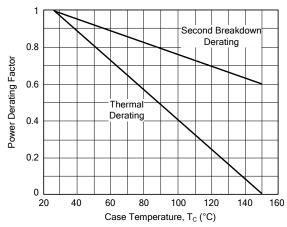


Fig. 3 Forward Bias Power Derating

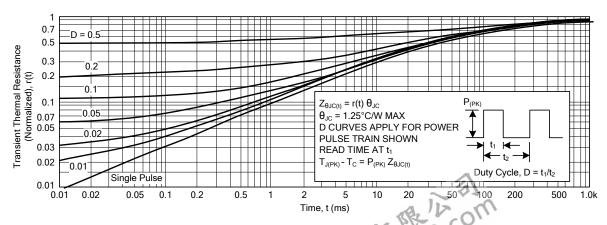


There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation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

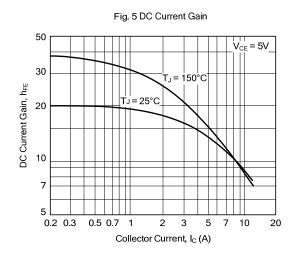
The data of Fig. 1 is based on $T_{\text{C}}{=}25^{\circ}\text{C};~T_{\text{J(PK)}}$ is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when $T_{\text{C}} \geq 25^{\circ}\text{C}.$ Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Fig. 1 may be found at any case temperature by using the appropriate curve on Fig. 3.

 $T_{\text{J(PK)}}$ may be calculated from the data in Fig. 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown. Use of reverse biased safe operating area data (Fig. 2) is discussed in the applications information section.

Fig. 4 Typical Thermal Response [Z_{0,JC}(t)]



■ TYPICAL CHARACTERISTICS (Cont.)



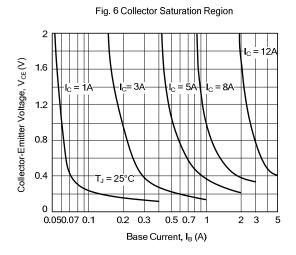
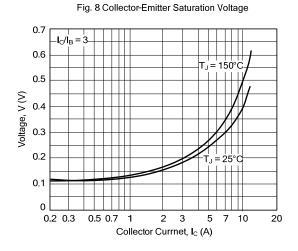
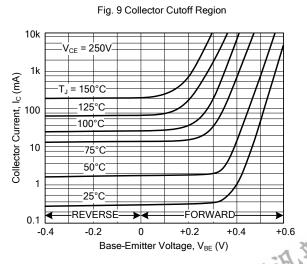
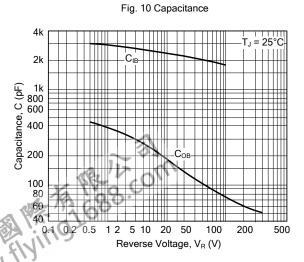


Fig. 7 Base-Emitter Saturation Voltage

1.4
1.2
1.2
1.2
1.3
0.6
0.4
0.2 0.3 0.5 0.7 1 2 3 5 7 10 20
Collector Current, I_C (A)

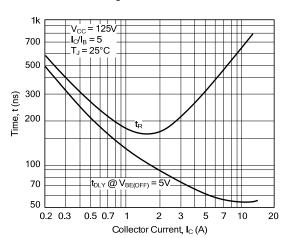






■ RESISTIVE SWITCHING PERFORMANCE

Fig. 11. Turn-On Time



2k
1k
700

y_{CC} = 125V

l_C/l_B = 5
T_J = 25°C

100

100

Collector Crrent, Ic (A)

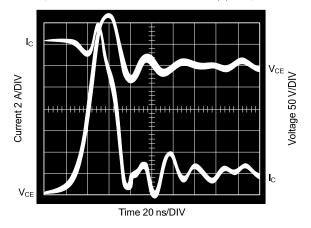
7

0.2 0.3

0.5 0.7

Fig. 12 Turn-Off Time

Fig. 13 Typical Inductive Switching Waveforms (at 300V and 12A with I_{B1} = 2.4A and $V_{BE(off)}$ = 5V)



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