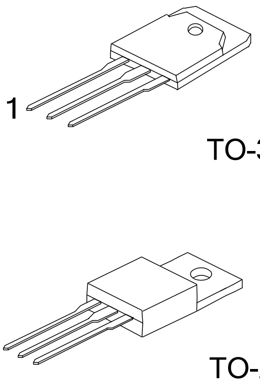
# UTC UNISONIC TECHNOLOGIES CO., LTD

## 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.

## ■ 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 | | Package | Pin Assignment | | | Packing |
|---|---|---|---|---|---|---|
| Lead Free | Halogen Free | | 1 | 2 | 3 | |
| MJE13009L-K-TA3-T | MJE13009G-K-TA3-T | TO-220 | B | C | E | Tube |
| MJE13009L-K-T3P-T | MJE13009G-K-T3P-T | TO-3P | B | C | E | Tube |

| MJE13009L-K-TA3-T | |
|---|---|
| (1)Packing Type | (1) T: Tube |
| (2)Package Type | (2) TA3: TO-220, T3P: TO-3P |
| (3)Lead Free | (3) L: Lead Free, G: Halogen Free |

## ■ 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 |
| Collector Current | Continuous | $I_C$ | 12 | A |
| | Peak (Note 3) | $I_{CM}$ | 24 | |
| Base Current | Continuous | $I_B$ | 6 | A |
| | Peak (Note 3) | $I_{BM}$ | 12 | |
| Emitter Current | Continuous | $I_E$ | 18 | A |
| | Peak (Note 3) | $I_{EM}$ | 36 | |
| Power Dissipation | TO-220 | $P_D$ | 2 | W |
| | TO-3P | | 80 | |
| Derate above 25°C | TO-220 | | 16 | mW/°C |
| | TO-3P | | 640 | |
| Junction Temperature | | $T_J$ | +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 |
|---|---|---|---|---|
| Junction to Ambient | TO-220 | $\theta_{JA}$ | 54 | °C/W |
| | TO-3P | | 21 | |
| Junction to Case | TO-220 | $\theta_{JC}$ | 4 | °C/W |
| | TO-3P | | 1.55 | |

## ■ ELECTRICAL CHARACTERISTICS ($T_C$= 25℃, unless otherwise specified.)

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** (Note) | | | | | | |
| Collector- Emitter Sustaining Voltage | $V_{CEO}$ | $I_C$ = 10mA, $I_B$ = 0 | 400 | | | V |
| Collector Cutoff Current $V_{CBO}$=Rated Value | $I_{CEV}$ | $V_{BE(OFF)}$ = 1.5$V_{DC}$ | | | 1 | mA |
| | | $V_{BE(OFF)}$ = 1.5$V_{DC}$, $T_C$ = 100°C | | | 5 | |
| Emitter Cutoff Current | $I_{EBO}$ | $V_{EB}$ = 9$V_{DC}$, $I_C$ = 0 | | | 1 | mA |
| **ON CHARACTERISTICS** (Note) | | | | | | |
| DC Current Gain | $h_{FE1}$ | $I_C$ = 5A, $V_{CE}$ = 5V | | | 40 | |
| | $h_{FE2}$ | $I_C$ = 8A, $V_{CE}$ = 5V | | | 30 | |
| Current-Emitter Saturation Voltage | $V_{CE(SAT)}$ | $I_C$ = 5A, $I_B$ = 1A | | | 1 | V |
| | | $I_C$ = 8A, $I_B$ = 1.6A | | | 1.5 | V |
| | | $I_C$ = 12A, $I_B$ = 3A | | | 3 | V |
| | | $I_C$ = 8A, $I_B$ = 1.6A, $T_C$ = 100°C | | | 2 | V |
| Base-Emitter Saturation Voltage | $V_{BE(SAT)}$ | $I_C$ = 5A, $I_B$ = 1A | | | 1.2 | V |
| | | $I_C$ = 8A, $I_B$ = 1.6A | | | 1.6 | V |
| | | $I_C$ = 8A, $I_B$ = 1.6A, $T_C$ = 100°C | | | 1.5 | V |

■ ELECTRICAL CHARACTERISTICS(Cont.)

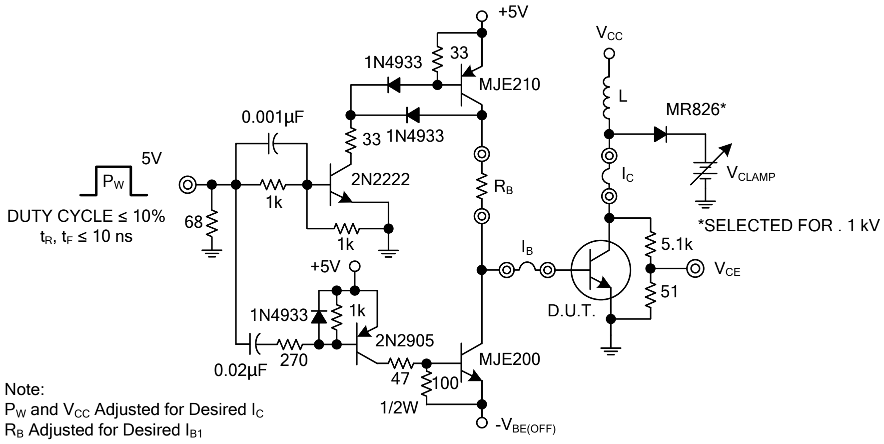
| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **DYNAMIC CHARACTERISTICS** | | | | | | |
| Transition frequency | $f_T$ | $I_C$ = 500mA, $V_{CE}$ = 10V, f = 1MHz | 4 | | | MHz |
| Output Capacitance | $C_{OB}$ | $V_{CB}$ = 10V, $I_E$ = 0, f = 0.1MHz | | 180 | | pF |
| **SWITCHING CHARACTERISTICS** (Resistive Load, Table 1) | | | | | | |
| Delay Time | $t_{DLY}$ | $V_{CC}$ = 125Vdc, $I_C$ = 8A<br>$I_{B1}$ = $I_{B2}$ = 1.6A, $t_P$ = 25μs<br>Duty Cycle ≤1% | | 0.06 | 0.1 | μs |
| Rise Time | $t_R$ | | | 0.45 | 1 | μs |
| Storage Time | $t_S$ | | | 1.3 | 4 | μs |
| Fall Time | $t_F$ | | | 0.2 | 0.7 | μs |
| **Inductive Load, Clamped** (Table 1, Fig. 13) | | | | | | |
| Voltage Storage Time | $t_S$ | $I_C$=8A, $V_{CLAMP}$=300V, $I_{B1}$=1.6A<br>$V_{BE(OFF)}$ = 5V, $T_C$ = 100°C | | 0.92 | 2.3 | μs |
| Crossover Time | $t_C$ | | | 0.12 | 0.7 | μs |

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

## ■ TABLE 1. TEST CONDITIONS FOR DYNAMIC PERFORMANCE

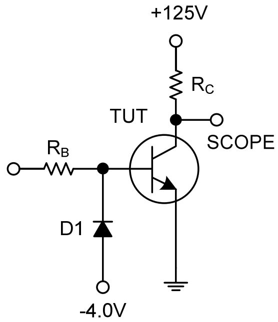
### TEST CIRCUITS

**REVERSE BIAS SAFE OPERATING AREA AND INDUCTIVE SWITCHING**




Note:
$P_W$ and $V_{CC}$ Adjusted for Desired $I_C$
$R_B$ Adjusted for Desired $I_{B1}$

**RESISTIVE SWITCHING**




### CIRCUIT VALUES

**Reverse bias safe operating area and inductive switching:**

Coil Data:
Ferroxcube Core #6656
Full Bobbin (~16 Turns) #16

GAP for 200μH/20A
$L_{COIL}$ = 200μH

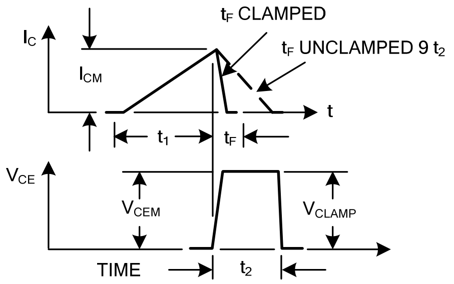
$V_{CC}$ = 20V
$V_{CLAMP}$ = 300$V_{DC}$

**Resistive switching:**

$V_{CC}$ = 125V
$R_C$ = 15Ω
D1 = 1N5820 or Equiv.
$R_B$ = Ω

### TEST WAVEFORMS

OUTPUT WAVEFORMS

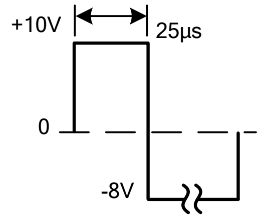



t1 ADJUSTED TO OBTAIN IC

$$t_1 \approx \frac{L_{COIL}\ (I_{CM})}{V_{CC}}$$

$$t_2 \approx \frac{L_{COIL}\ (I_{CM})}{V_{CLAMP}}$$

Test Equipment
Scope-Tektronics
475 or Equivalent

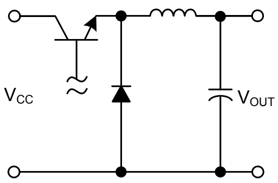


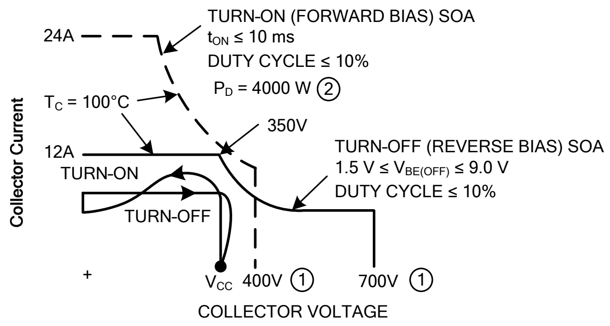

$t_R$, $t_F$ < 10 ns
Duty Cycle = 1.0%
$R_B$ and $R_C$ adjusted for desired $I_B$ and $I_C$

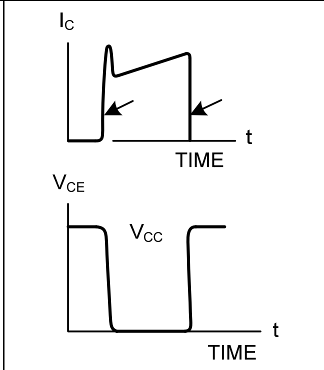
## ■ TABLE 2. APPLICATIONS EXAMPLES OF SWITCHING CIRCUITS

| CIRCUIT | LOAD LINE DIAGRAMS | TIME DIAGRAMS |
|---|---|---|

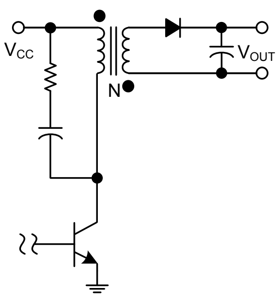
SERIES SWITCHING REGULATOR

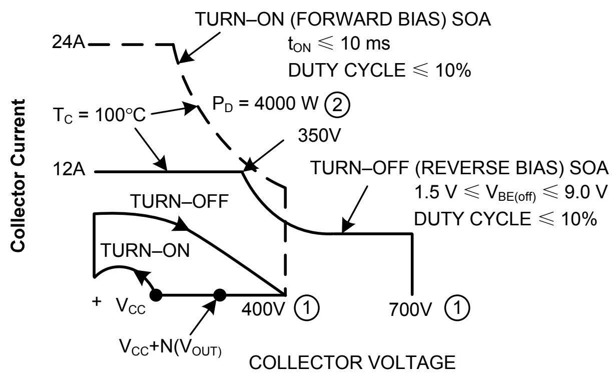


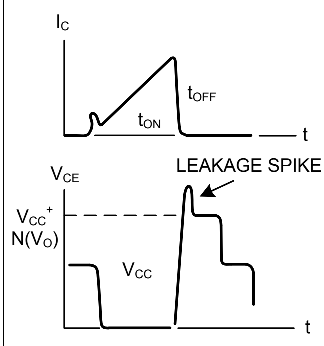



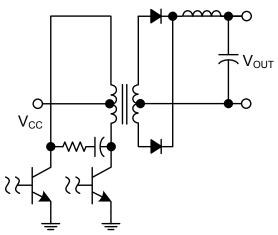

RINGING CHOKE INVERTER

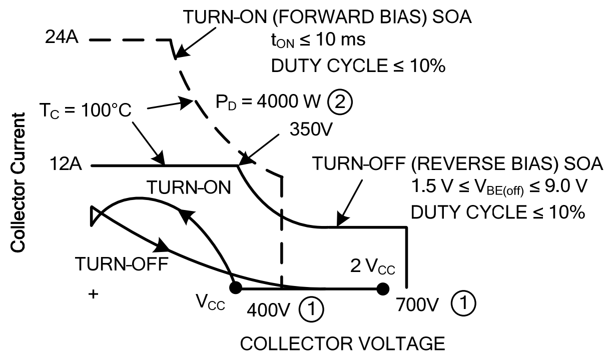


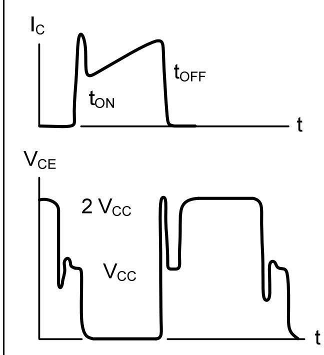



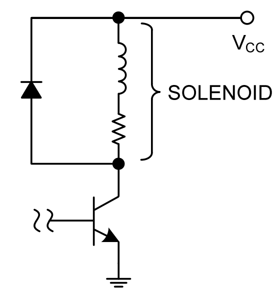

PUSH–PULL INVERTER/CONVERTER

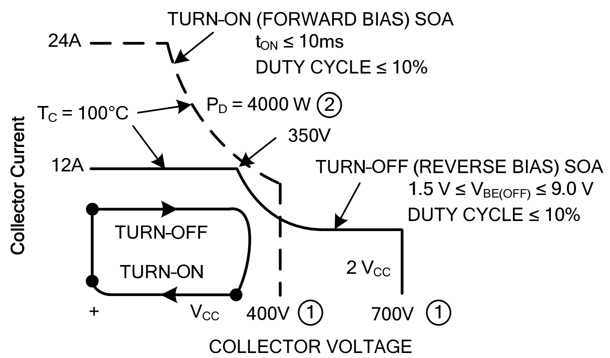


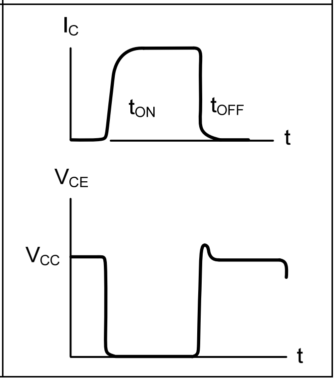




SOLENOID DRIVER



## ■ TABLE 3. TYPICAL INDUCTIVE SWITCHING PERFORMANCE

| $I_C$(A) | $T_C$(°C) | $t_{SV}$(ns) | $t_{RV}$(ns) | $t_{FI}$(ns) | $t_{TI}$(ns) | $t_C$(ns) |
|---|---|---|---|---|---|---|
| 3 | 25 | 770 | 100 | 150 | 200 | 240 |
| | 100 | 1000 | 230 | 160 | 200 | 320 |
| 5 | 25 | 630 | 72 | 26 | 10 | 100 |
| | 100 | 820 | 100 | 55 | 30 | 180 |
| 8 | 25 | 720 | 55 | 27 | 2 | 77 |
| | 100 | 920 | 70 | 50 | 8 | 120 |
| 12 | 25 | 640 | 20 | 17 | 2 | 41 |
| | 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℃ 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℃.

## ■ TYPICAL CHARATERISTICS

Fig. 1 Forward Bias Safe Operating Area

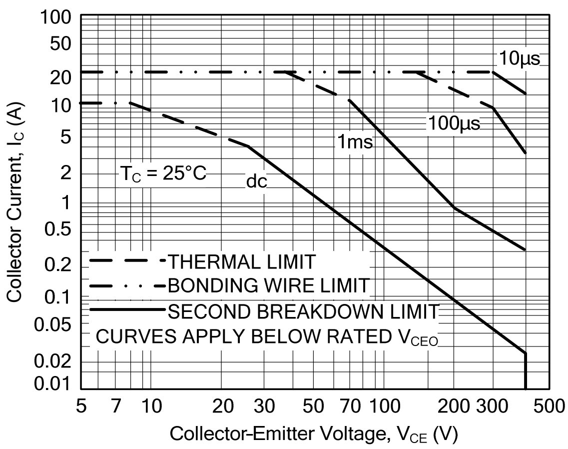



Fig. 2 Reverse Bias Switching Safe Operating Area

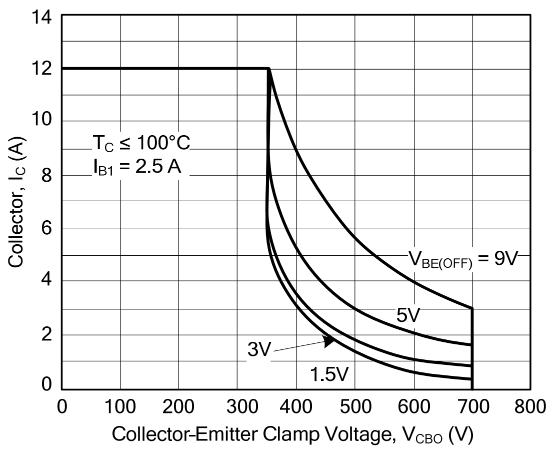
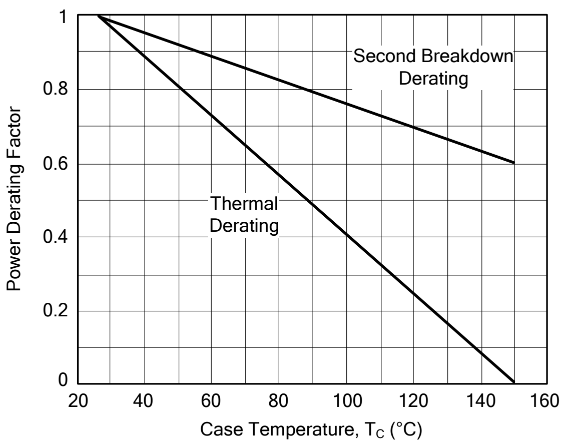



Fig. 3 Forward Bias Power Derating

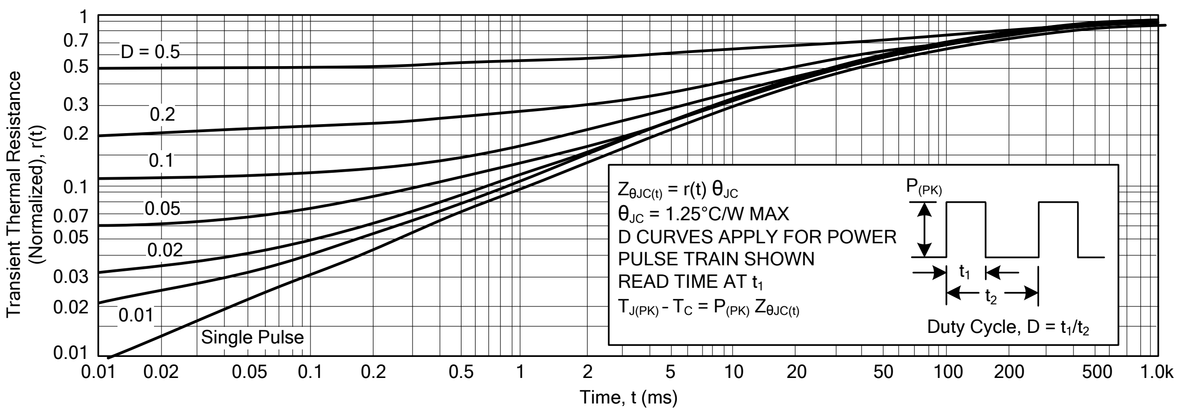



There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate $I_C$ - $V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater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

The data of Fig. 1 is based on $T_C$=25°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°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.

$T_{J(PK)}$ 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 [$Z_{\theta JC}(t)$]



■ TYPICAL CHARACTERISTICS (Cont.)

Fig. 5 DC Current Gain

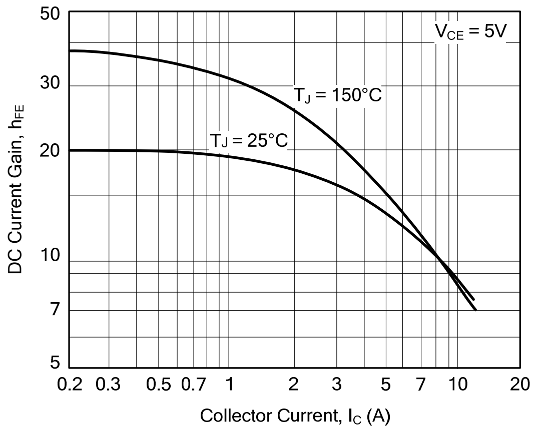



Fig. 6 Collector Saturation Region

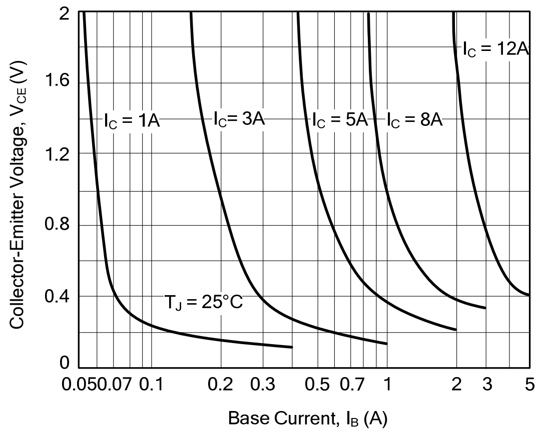



Fig. 7 Base-Emitter Saturation Voltage

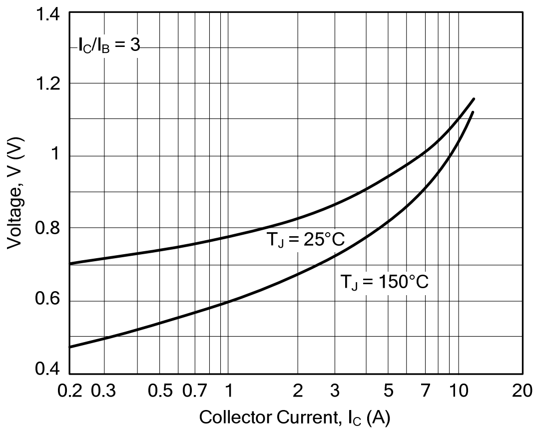



Fig. 8 Collector-Emitter Saturation Voltage

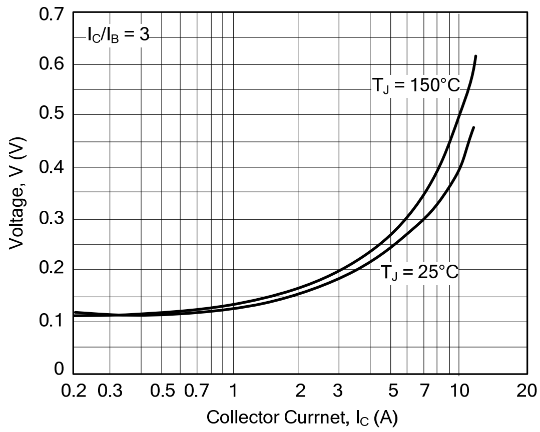



Fig. 9 Collector Cutoff Region

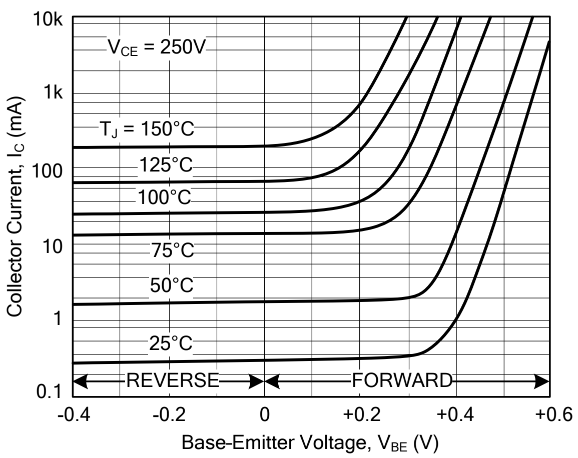
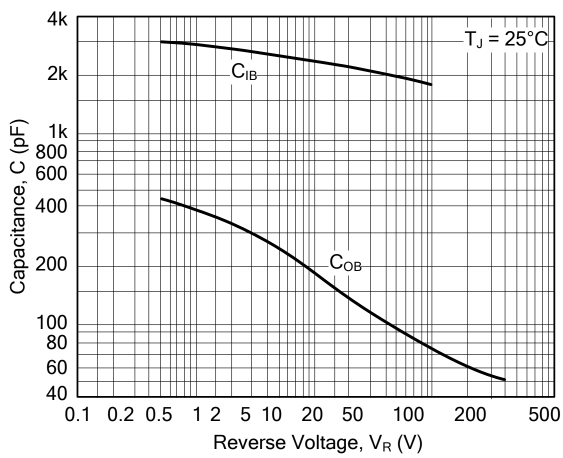



Fig. 10 Capacitance



■ RESISTIVE SWITCHING PERFORMANCE

Fig. 11. Turn-On Time

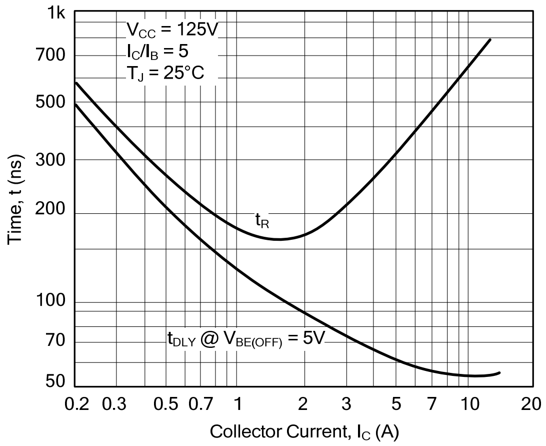



Fig. 12 Turn-Off Time

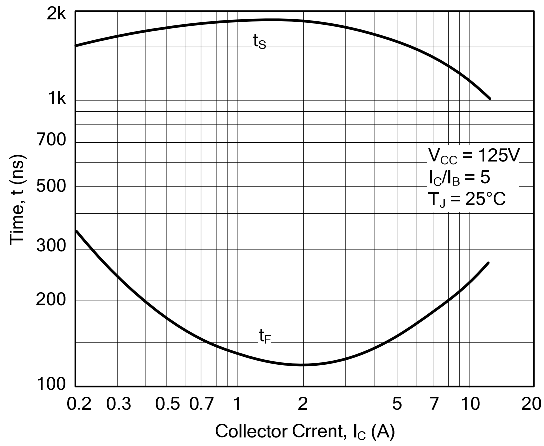



Fig. 13 Typical Inductive Switching Waveforms
(at 300V and 12A with $I_{B1}$ = 2.4A and $V_{BE(off)}$ = 5V)