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January 2016

# FJP2160D

## ESBC™ Rated NPN Silicon Transistor

### Applications

- High Voltage and High Speed Power Switch Application
- Emitter-Switched Bipolar/MOSFET Cascode Application (ESBC™)
- Smart Meter, Smart Breakers, HV Industrial Power Supplies
- Motor Driver and Ignition Driver

### ESBC Features (FDC655 MOSFET)

$V_{CS(ON)}$	$I_C$	Equiv $R_{CS(ON)}$
0.131 V	0.5 A	0.261 $\Omega^{(1)}$

- Low Equivalent On Resistance
- Very Fast Switch: 150 KHz
- Squared RBSOA: Up to 1600 V
- Avalanche Rated
- Low Driving Capacitance, no Miller Capacitance (Typ. 12 pF Capacitance at 200 V)
- Low Switching Losses
- Reliable HV switch: No False Triggering due to High dv/dt Transients.

### Description

The FJP2160D is a low-cost, high performance power switch designed to provide the best performance when used in an ESBC™ configuration in applications such as: power supplies, motor drivers, Smart Grid, or ignition switches. The power switch is designed to operate up to 1600 volts and up to 3 amps while providing exceptionally low on-resistance and very low switching losses.

The ESBC™ switch is designed to be easy to drive using off-the-shelf power supply controllers or drivers. The ESBC™ MOSFET is a low-voltage, low-cost, surface mount device that combines low-input capacitance and fast switching. The ESBC™ configuration further minimizes the required driving power because it does not have Miller capacitance.

The FJP2160D provides exceptional reliability and a large operating range due to its square reverse-bias-safe-operating-area (RBSOA) and rugged design. The device is avalanche rated and has no parasitic transistors so is not prone to static dv/dt failures.

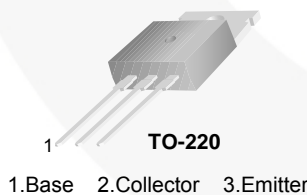


Figure 1. Pin Configuration

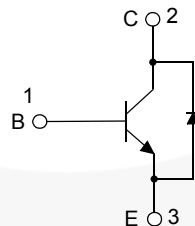


Figure 2. Internal Schematic Diagram

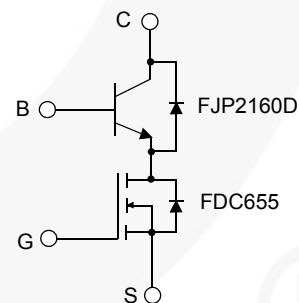


Figure 3. ESBC Configuration<sup>(2)</sup>

### Ordering Information

Part Number	Marking	Package	Packing Method
FJP2160DTU	J2160D	TO-220 3L	Tube

#### Notes:

1. Figure of Merit.
2. Other Fairchild MOSFETs can be used in this ESBC application.

## Absolute Maximum Ratings<sup>(3)</sup>

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.

Symbol	Parameter	Value	Unit
$V_{CBO}$	Collector-Base Voltage	1600	V
$V_{CEO}$	Collector-Emitter Voltage	800	V
$V_{EBO}$	Emitter-Base Voltage	12	V
$I_C$	Collector Current	2	A
$I_{CP}$	Collector Current (Pulse)	3	A
$I_B$	Base Current	1	A
$I_{BP}$	Base Current (Pulse)	2	A
$P_D$	Power Dissipation ( $T_C = 25^\circ\text{C}$ )	100	W
$T_J$	Operating and Junction Temperature Range	- 55 to +125	$^\circ\text{C}$
$T_{STG}$	Storage Temperature Range	- 65 to +150	$^\circ\text{C}$
EAS	Avalanche Energy ( $T_J = 25^\circ\text{C}$ , 8 mH)	3.5	mJ

### Note:

3. Pulse test: pulse width = 20  $\mu\text{s}$ , duty cycle  $\leq 10\%$

## Thermal Characteristics

Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.

Symbol	Parameter	Max.	Unit
$R_{\theta jc}$	Thermal Resistance, Junction-to-Case	1.25	$^\circ\text{C/W}$
$R_{\theta ja}$	Thermal Resistance, Junction-to-Ambient	80	$^\circ\text{C/W}$

## Electrical Characteristics

Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$BV_{CBO}$	Collector-Base Breakdown Voltage	$I_C = 0.5\text{ mA}, I_E = 0$	1600	1689		V
$BV_{CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 5\text{ mA}, I_B = 0$	800	870		V
$BV_{EBO}$	Emitter-Base Breakdown Voltage	$I_E = 0.5\text{ mA}, I_C = 0$	12.0	14.8		V
$I_{CES}$	Collector Cut-Off Current	$V_{CE} = 1600\text{ V}, V_{BE} = 0$		0.01	100	$\mu\text{A}$
$I_{CEO}$	Collector Cut-Off Current	$V_{CE} = 800\text{ V}, I_B = 0$		0.01	100	$\mu\text{A}$
$I_{EBO}$	Emitter Cut-Off Current	$V_{EB} = 12\text{ V}, I_C = 0$		0.05	500	$\mu\text{A}$
$h_{FE}$	DC Current Gain	$V_{CE} = 3\text{ V}, I_C = 0.4\text{ A}$	20	29	35	
		$V_{CE} = 10\text{ V}, I_C = 5\text{ mA}$	20	43		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 0.25\text{ A}, I_B = 0.05\text{ A}$		0.16	0.45	V
		$I_C = 0.5\text{ A}, I_B = 0.167\text{ A}$		0.12	0.35	
		$I_C = 1\text{ A}, I_B = 0.33\text{ A}$		0.25	0.75	
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C = 500\text{ mA}, I_B = 50\text{ mA}$		0.74	1.20	V
		$I_C = 2\text{ A}, I_B = 0.4\text{ A}$		0.85	1.20	
$C_{ib}$	Input Capacitance	$V_{EB} = 10\text{ V}, I_C = 0, f = 1\text{ MHz}$		745	1000	pF
$C_{ob}$	Output Capacitance	$V_{CB} = 200\text{ V}, I_E = 0, f = 1\text{ MHz}$		15		pF
$f_T$	Current Gain Bandwidth Product	$I_C = 0.1\text{ A}, V_{CE} = 10\text{ V}$		5		MHz
$V_F$	Diode Forward Voltage	$I_F = 0.4\text{ A}$		0.76	1.20	V
		$I_F = 1\text{ A}$		0.83	1.50	

## ESBC Configured Electrical Characteristics<sup>(4)</sup>

Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$f_T$	Current Gain Bandwidth Product	$I_C = 0.1\text{ A}, V_{CE} = 10\text{ V}$		25		MHz
$t_{f_i}$	Inductive Current Fall Time	$V_{GS} = 10\text{ V}, R_G = 47\ \Omega,$ $V_{Clamp} = 500\text{ V},$ $t_p = 3.1\ \mu\text{s}, I_C = 0.3\text{ A},$ $I_B = 0.03\text{ A}, L_C = 1\text{ mH},$ $SRF = 480\text{ kHz}$		137		ns
$t_s$	Inductive Storage Time			350		ns
$V_{t_f}$	Inductive Voltage Fall Time			120		ns
$V_{t_r}$	Inductive Voltage Rise Time			100		ns
$t_c$	Inductive Crossover Time			137		ns
$t_{f_i}$	Inductive Current Fall Time		$V_{GS} = 10\text{ V}, R_G = 47\ \Omega,$ $V_{Clamp} = 500\text{ V},$ $t_p = 10\ \mu\text{s}, I_C = 1\text{ A},$ $I_B = 0.2\text{ A}, L_C = 1\text{ mH},$ $SRF = 480\text{ kHz}$		35	
$t_s$	Inductive Storage Time			980		ns
$V_{t_f}$	Inductive Voltage Fall Time			30		ns
$V_{t_r}$	Inductive Voltage Rise Time			195		ns
$t_c$	Inductive Crossover Time			210		ns
$V_{CSW}$	Maximum Collector Source Voltage at Turn-off without Snubber	$h_{FE} = 5, I_C = 2\text{ A}$		1600		
$I_{GS(OS)}$	Gate-Source Leakage Current	$V_{GS} = \pm 20\text{ V}$		1.0		nA
$V_{CS(ON)}$	Collector-Source On Voltage	$V_{GS} = 10\text{ V}, I_C = 2\text{ A}, I_B = 0.67\text{ A},$ $h_{FE} = 3$		2.210		V
		$V_{GS} = 10\text{ V}, I_C = 1\text{ A}, I_B = 0.33\text{ A},$ $h_{FE} = 3$		0.321		
		$V_{GS} = 10\text{ V}, I_C = 0.5\text{ A}, I_B = 0.17\text{ A},$ $h_{FE} = 3$		0.131		
		$V_{GS} = 10\text{ V}, I_C = 0.3\text{ A}, I_B = 0.06\text{ A},$ $h_{FE} = 5$		0.166		
$V_{GS(th)}$	Gate Threshold Voltage	$V_{BS} = V_{GS}, I_B = 250\ \mu\text{A}$		1.9		V
$C_{iss}$	Input Capacitance ( $V_{GS} = V_{CB} = 0$ )	$V_{CS} = 25\text{ V}, f = 1\text{ MHz}$		470		pF
$Q_{GS(tot)}$	Gate-Source Charge $V_{CB} = 0$	$V_{GS} = 10\text{ V}, I_C = 8\text{ A}, V_{CS} = 25\text{ V}$		9		nC
$r_{DS(ON)}$	Static Drain-Source On Resistance	$V_{GS} = 10\text{ V}, I_D = 6.3\text{ A}$		21		m $\Omega$
		$V_{GS} = 4.5\text{ V}, I_D = 5.5\text{ A}$		26		
		$V_{GS} = 10\text{ V}, I_D = 6.3\text{ A}, T_J = 125^\circ\text{C}$		30		

### Note:

4. Used typical FDC655 MOSFET values in table. Values can vary if other Fairchild MOSFETs are used.

## Typical Performance Characteristics

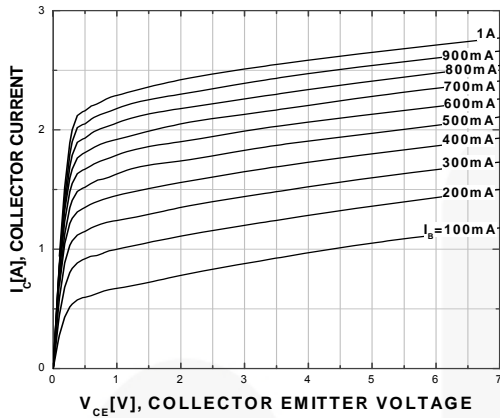


Figure 4. Static Characteristic

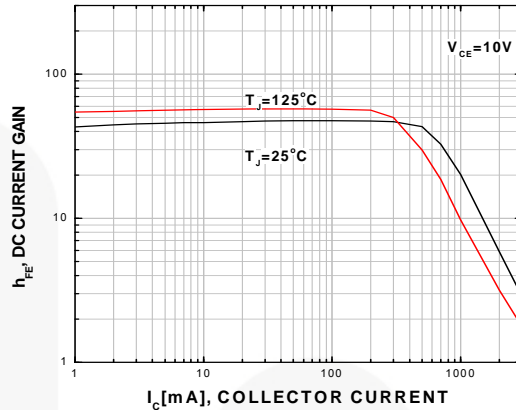


Figure 5. DC Current Gain

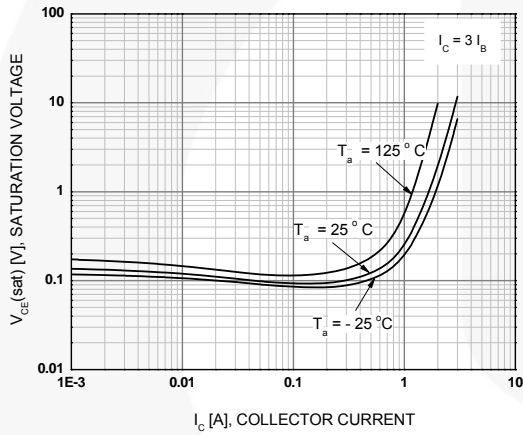


Figure 6. Collector-Emitter Saturation Voltage  
 $h_{FE}=3$

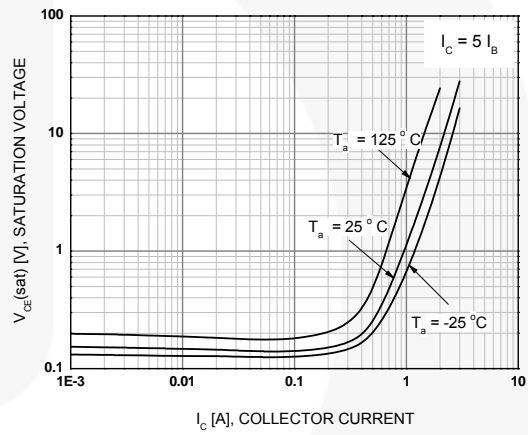


Figure 7. Collector-Emitter Saturation Voltage  
 $h_{FE}=5$

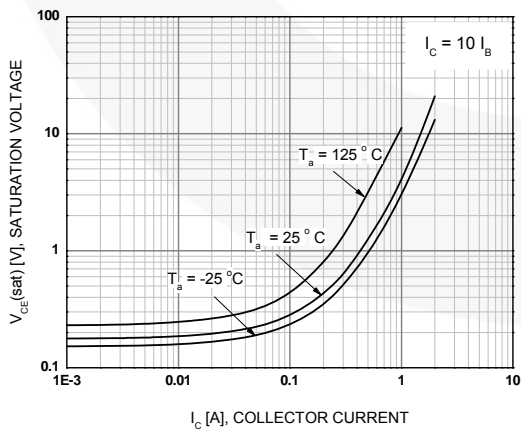


Figure 8. Collector-Emitter Saturation Voltage  
 $h_{FE}=10$

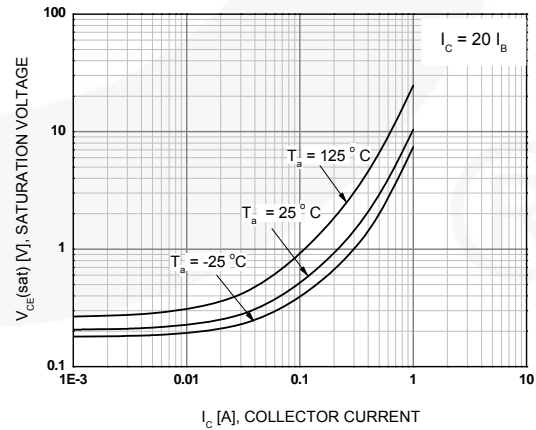
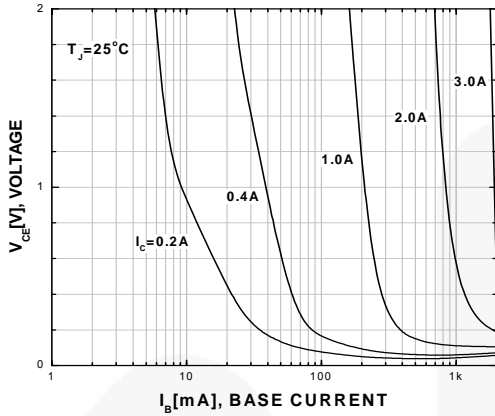
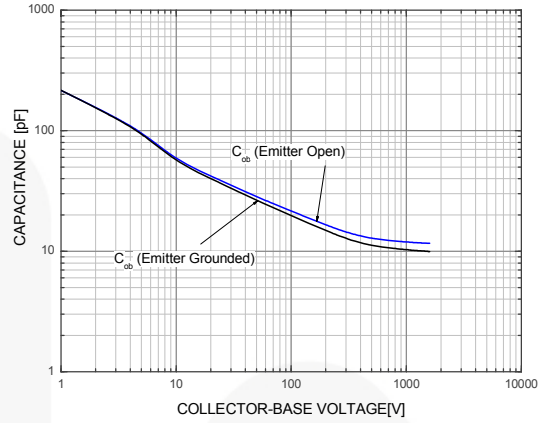


Figure 9. Collector-Emitter Saturation Voltage  
 $h_{FE}=20$

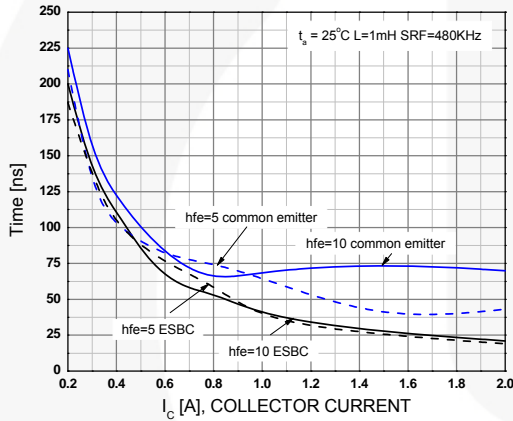
**Typical Performance Characteristics (Continued)**



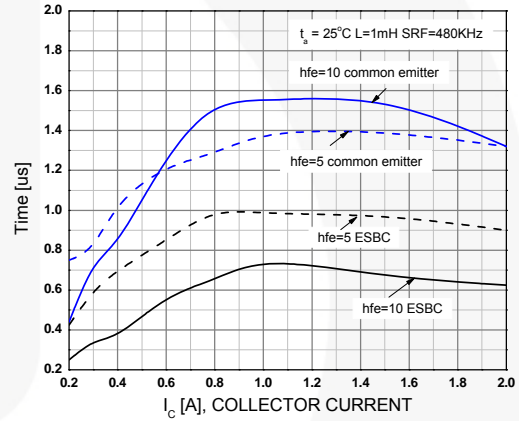
**Figure 10. Typical Collector Saturation Voltage**



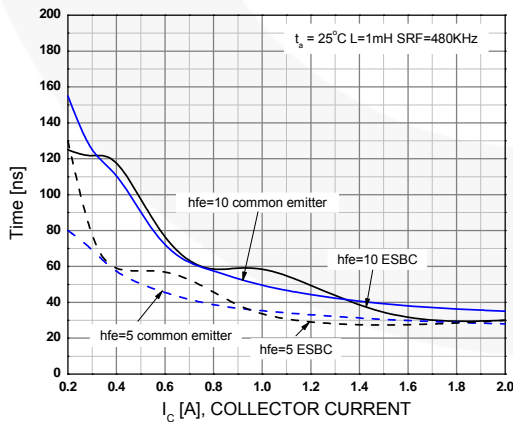
**Figure 11. Capacitance**



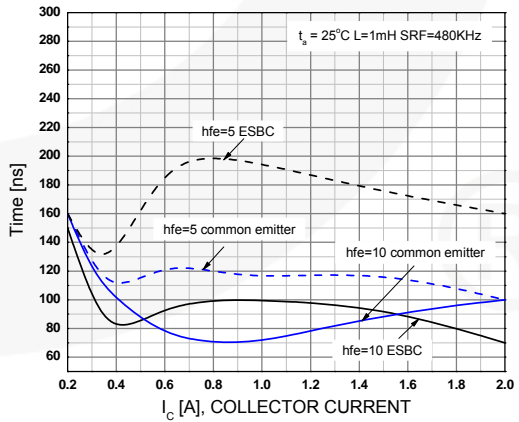
**Figure 12. Inductive Load Collector Current Fall-time ( $t_f$ )**



**Figure 13. Inductive Load Collector Current Storage time ( $t_{stg}$ )**

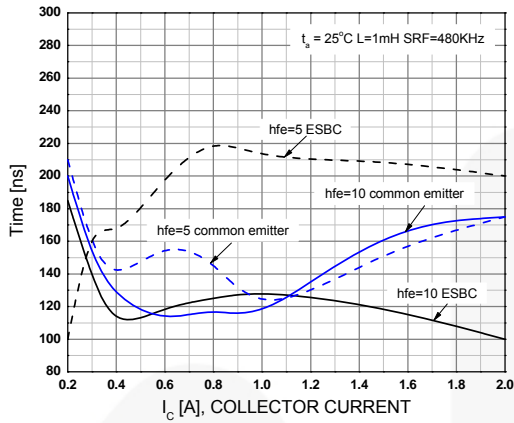


**Figure 14. Inductive Load Collector Voltage Fall-time ( $t_f$ )**

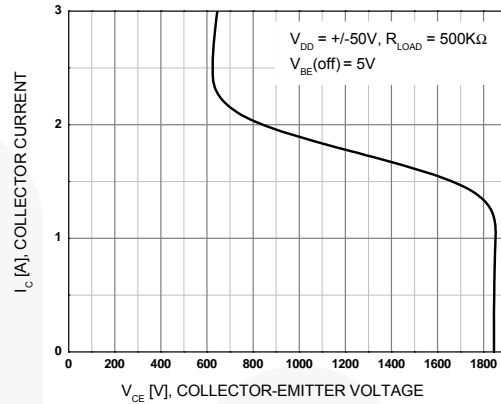


**Figure 15. Inductive Load Collector Voltage Rise-time ( $t_r$ )**

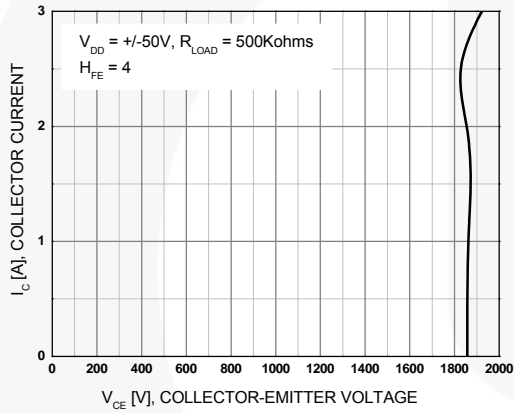
**Typical Performance Characteristics (Continued)**



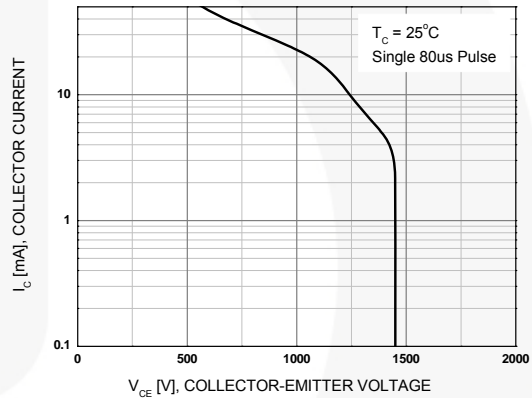
**Figure 16. Inductive Load Collector Current/Voltage Crossover ( $t_c$ )**



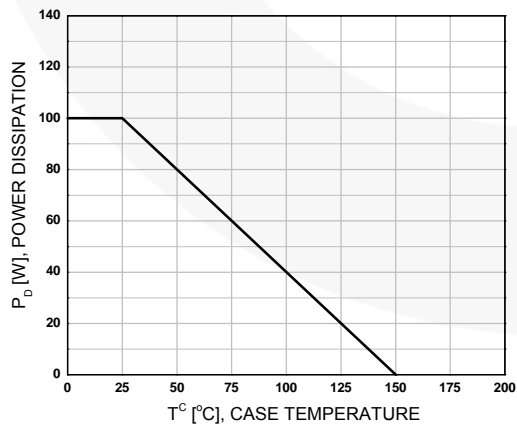
**Figure 17. BJT Reverse Bias Safe Operating Area**



**Figure 18. ESBC RBSOA**



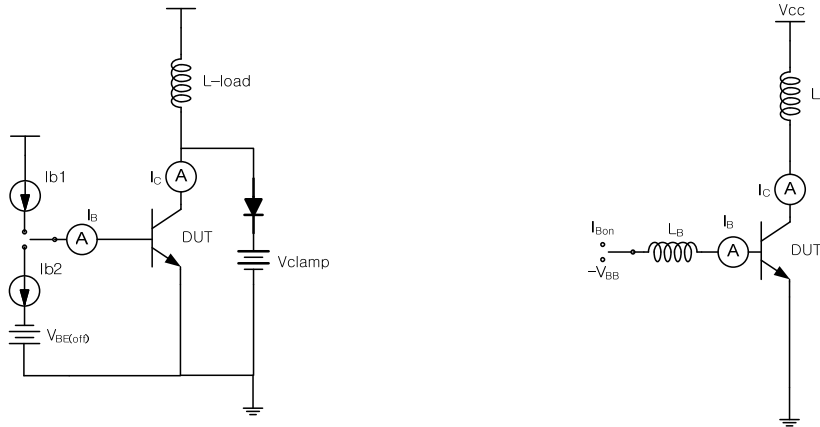
**Figure 19. Crossover Forward Bias Safe Operating Area**



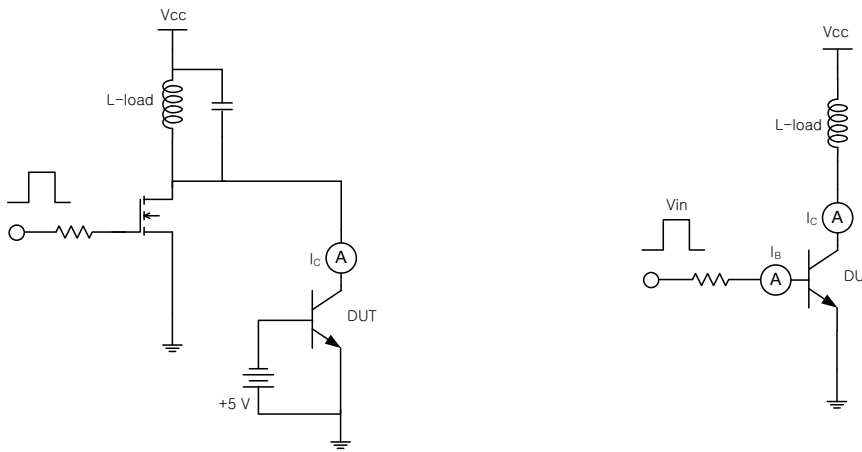
**Figure 20. Power Derating**



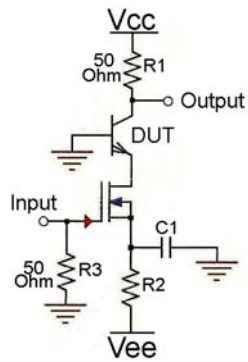
### Test Circuits



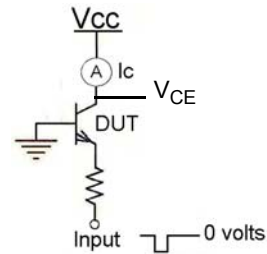
**Figure 21. Test Circuit For Inductive Load and Reverse Bias Safe Operating**



**Figure 22. Energy Rating Test Circuit**



**Figure 23. Ft Measurement**



**Figure 24. FBSOA**

Test Circuits (Continued)

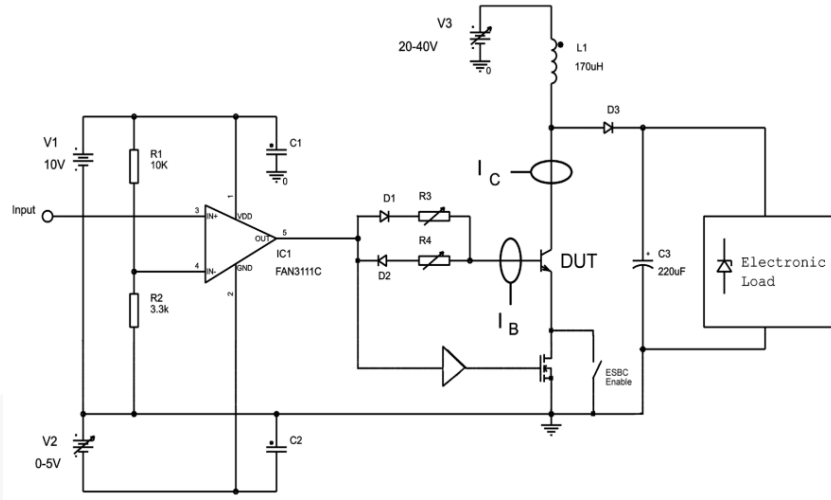


Figure 25. Simplified Saturated Switch Driver Circuit

Functional Test Waveforms

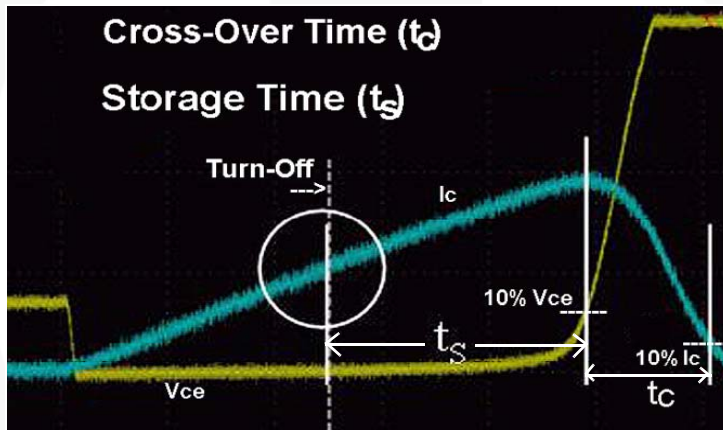


Figure 26. Crossover Time Measurement

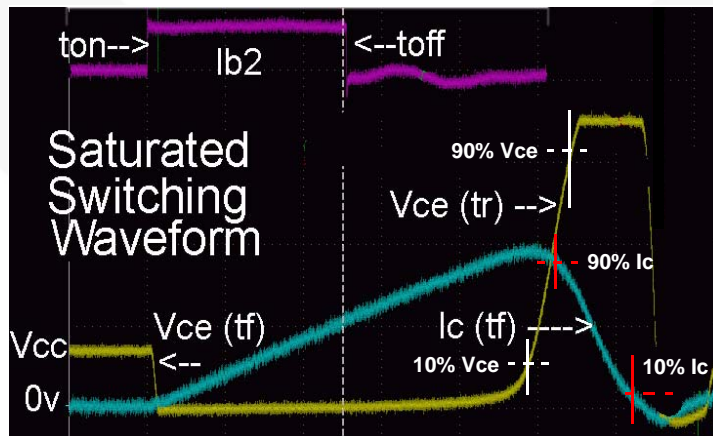


Figure 27. Saturated Switching Waveform

Functional Test Waveforms (Continued)

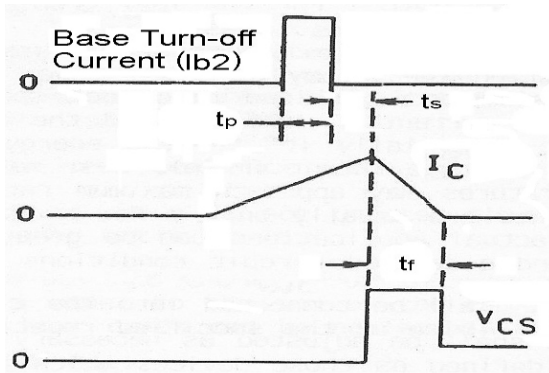


Figure 28. Storage Time - Common Emitter  
Base turn off ( $I_{b2}$ ) to  $I_c$  Fall-time

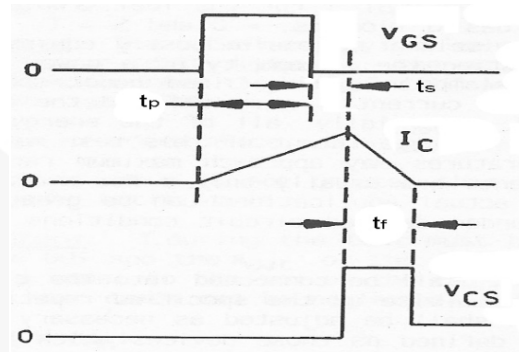


Figure 29. Storage Time - ESBC FET  
Gate (off) to  $I_c$  Fall-time





- NOTES:
- A) REFERENCE JEDEC, TO-220, VARIATION AB
  - B) ALL DIMENSIONS ARE IN MILLIMETERS.
  - C) DIMENSIONS COMMON TO ALL PACKAGE SUPPLIERS EXCEPT WHERE NOTED [ ].
  - D) LOCATION OF MOLDED FEATURE MAY VARY (LOWER LEFT CORNER, LOWER CENTER AND CENTER OF THE PACKAGE)
  - E) DOES NOT COMPLY JEDEC STANDARD VALUE.
  - F) "A1" DIMENSIONS AS BELOW:  
 SINGLE GAUGE = 0.51 - 0.61  
 DUAL GAUGE = 1.10 - 1.45
  - G) DRAWING FILE NAME: TO220B03REV9
  - H) PRESENCE IS SUPPLIER DEPENDENT
  - I) SUPPLIER DEPENDENT MOLD LOCKING HOLES IN HEATSINK.

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