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January 2016

FJP2160D — ESBC™ Rated NPN Silicon Transistor

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.

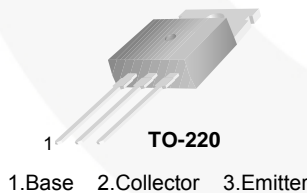


Figure 1. Pin Configuration

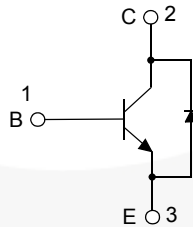


Figure 2. Internal Schematic Diagram

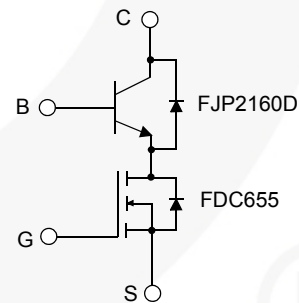


Figure 3. ESBC Configuration⁽²⁾

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⁽³⁾

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 μs , 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 | μA |
| I_{CEO} | Collector Cut-Off Current | $V_{CE} = 800\text{ V}, I_B = 0$ | | 0.01 | 100 | μA |
| I_{EBO} | Emitter Cut-Off Current | $V_{EB} = 12\text{ V}, I_C = 0$ | | 0.05 | 500 | μA |
| 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⁽⁴⁾

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 Ω |
| | | $V_{GS} = 4.5\text{ V}, I_D = 5.5\text{ A}$ | | 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

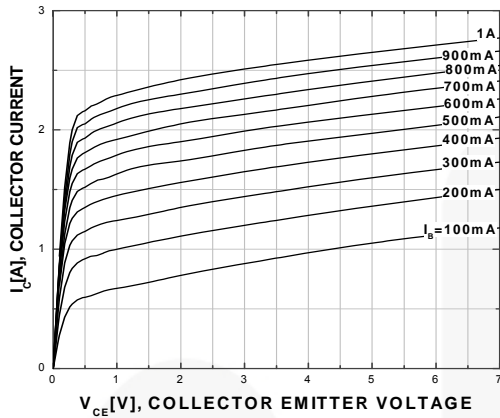


Figure 4. Static Characteristic

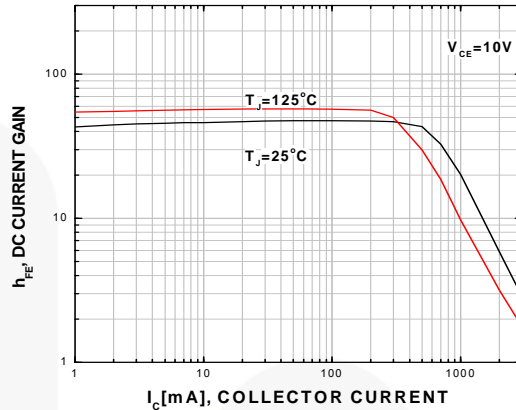


Figure 5. DC Current Gain

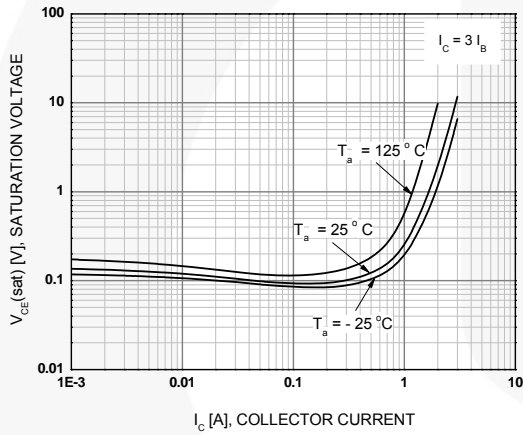


Figure 6. Collector-Emitter Saturation Voltage
 $h_{FE} = 3$

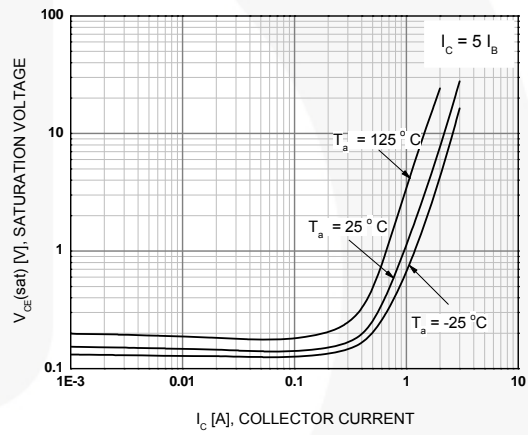


Figure 7. Collector-Emitter Saturation Voltage
 $h_{FE} = 5$

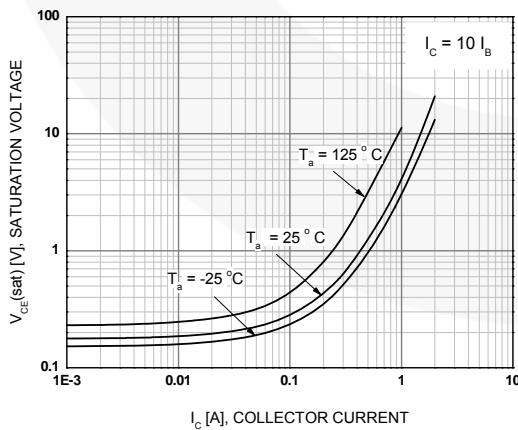


Figure 8. Collector-Emitter Saturation Voltage
 $h_{FE} = 10$

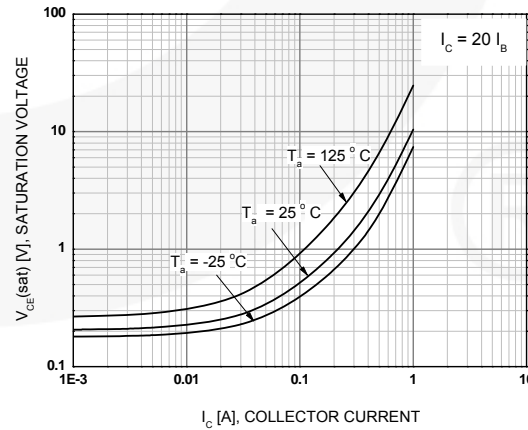


Figure 9. Collector-Emitter Saturation Voltage
 $h_{FE} = 20$

Typical Performance Characteristics (Continued)

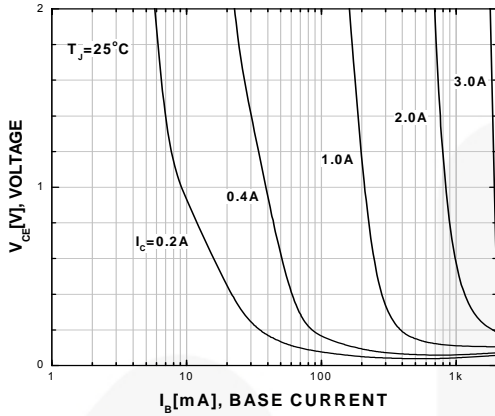


Figure 10. Typical Collector Saturation Voltage

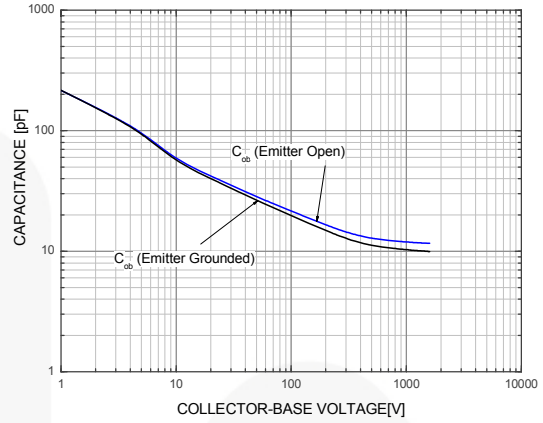
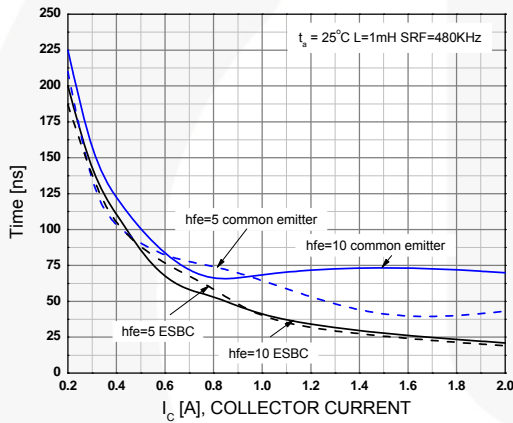
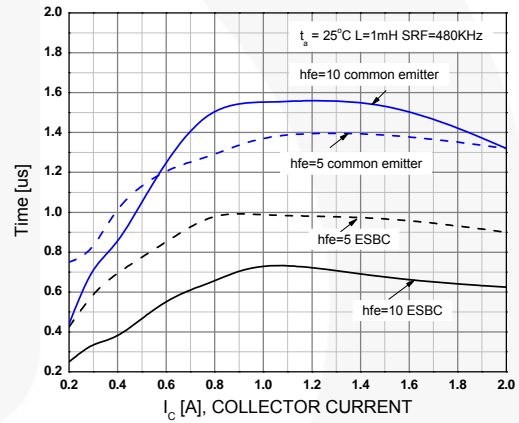


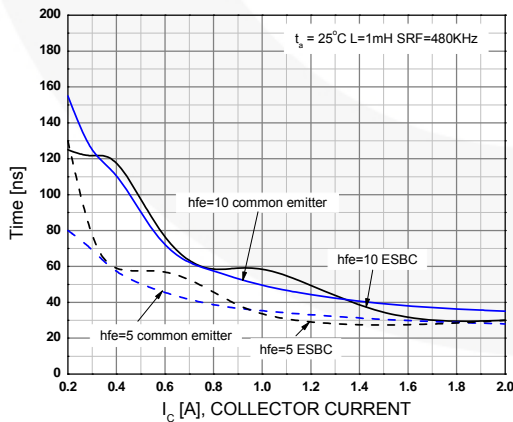
Figure 11. Capacitance



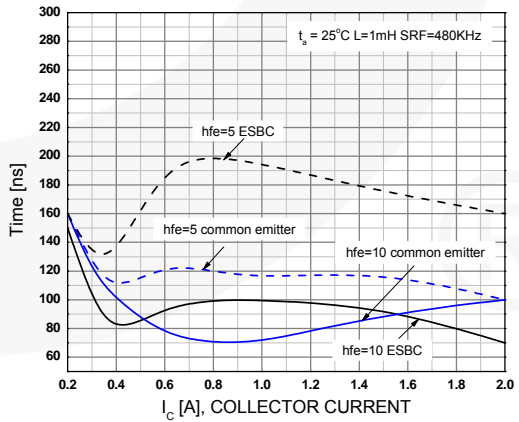
**Figure 12. Inductive Load
Collector Current Fall-time (t_f)**



**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)

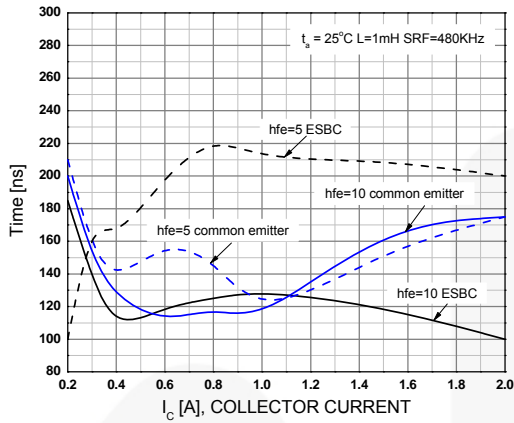


Figure 16. Inductive Load Collector Current/Voltage Crossover (t_c)

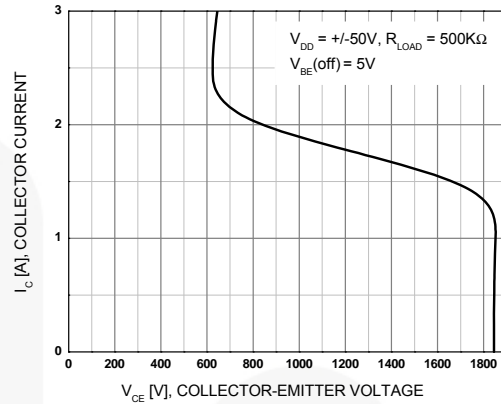


Figure 17. BJT Reverse Bias Safe Operating Area

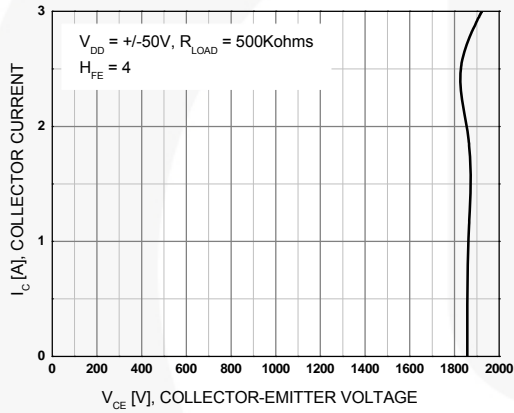


Figure 18. ESBC RBSOA

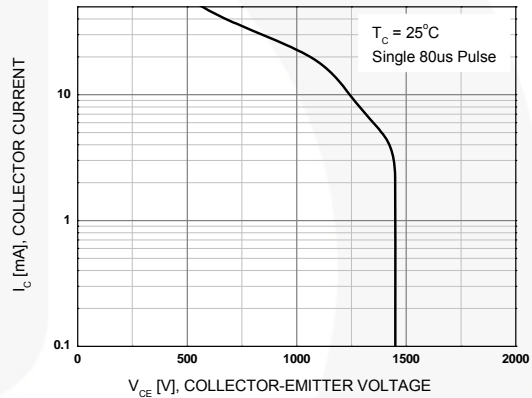


Figure 19. Crossover Forward Bias Safe Operating Area

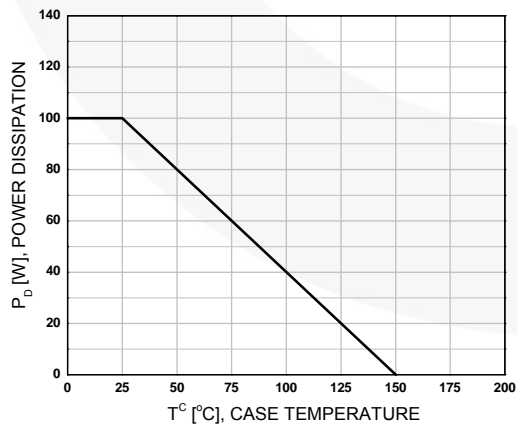


Figure 20. Power Derating

Test Circuits

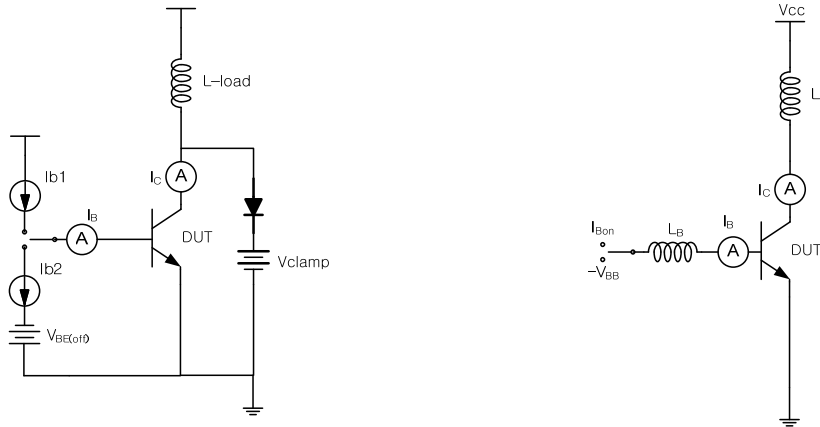


Figure 21. Test Circuit For Inductive Load and Reverse Bias Safe Operating

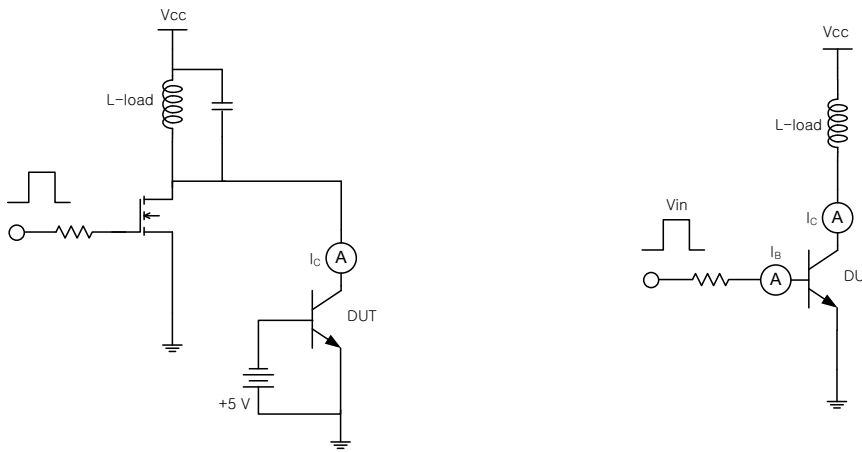


Figure 22. Energy Rating Test Circuit

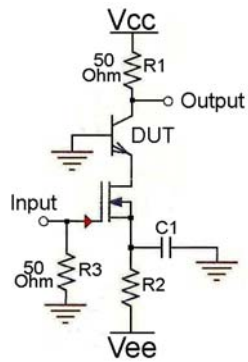


Figure 23. Ft Measurement

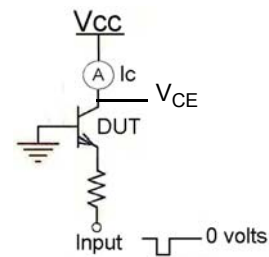


Figure 24. FBSOA

Test Circuits (Continued)

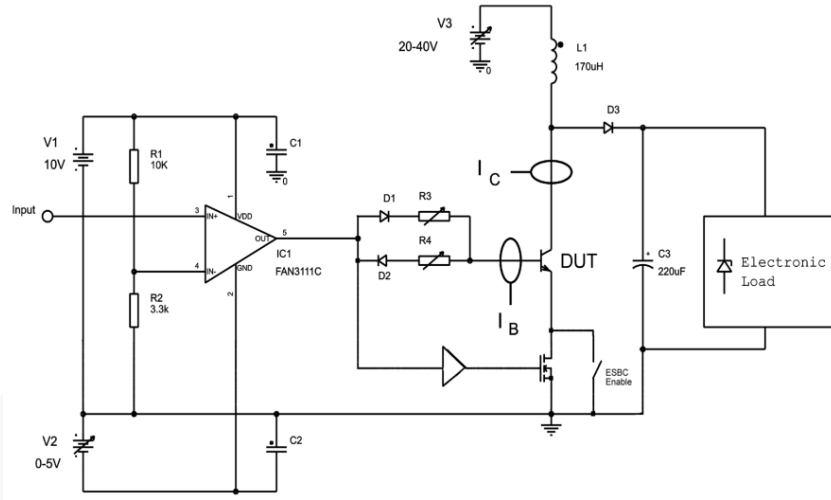


Figure 25. Simplified Saturated Switch Driver Circuit

Functional Test Waveforms

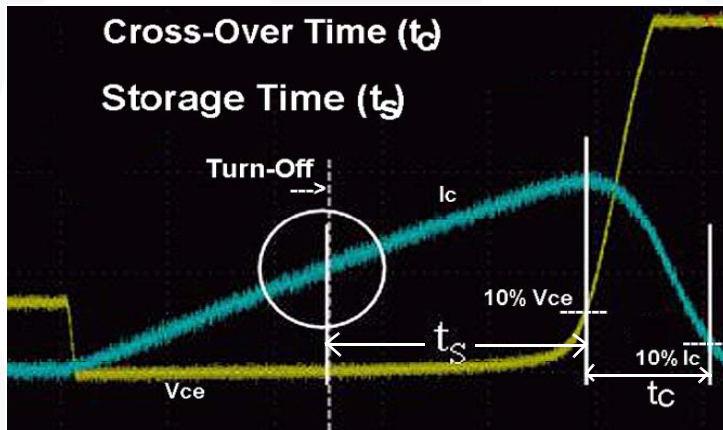


Figure 26. Crossover Time Measurement

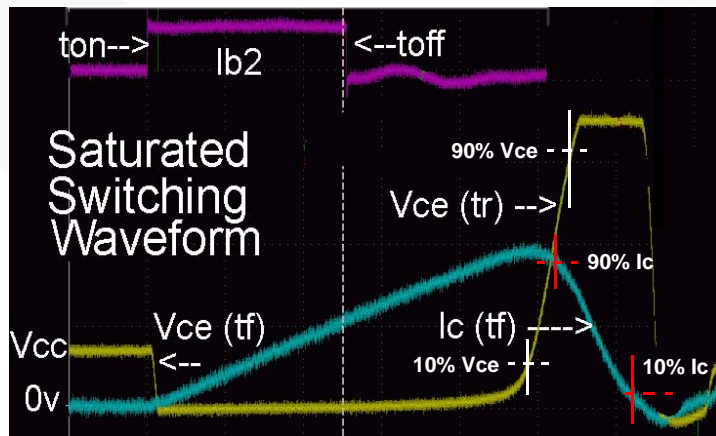


Figure 27. Saturated Switching Waveform

Functional Test Waveforms (Continued)

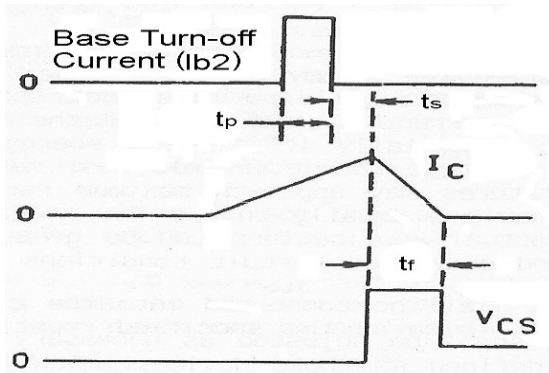


Figure 28. Storage Time - Common Emitter
Base turn off (I_{b2}) to I_c Fall-time

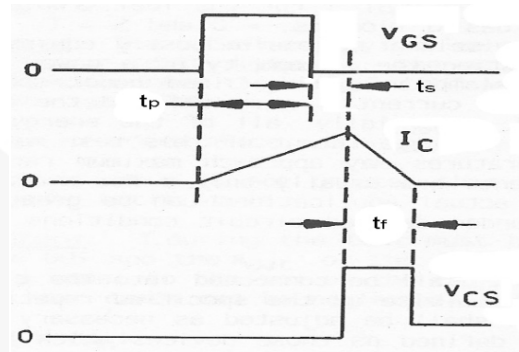
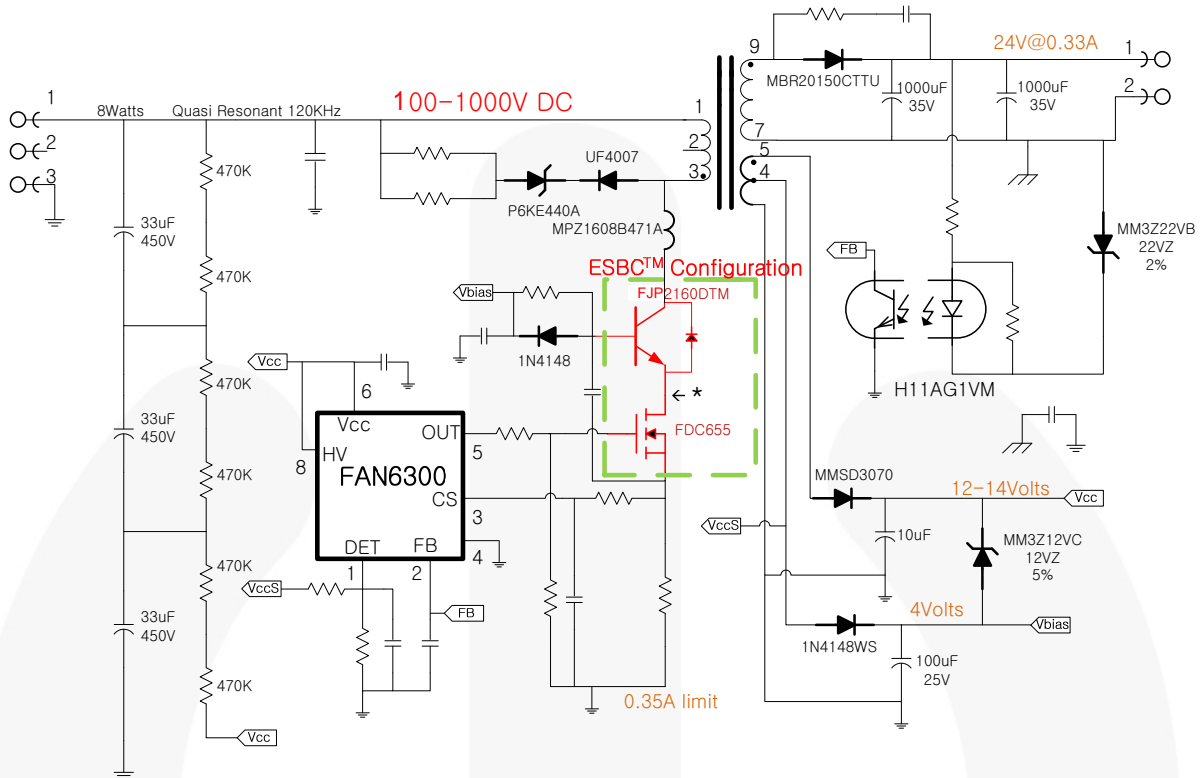


Figure 29. Storage Time - ESBC FET
Gate (off) to I_c Fall-time

Very Wide Input Voltage Range Supply

- 8watt; SecReg: 3 cap input; Quasi Resonant



* Make short as possible

Figure 30. Very Wide Input Voltage Range Supply

Driving ESBC Switches

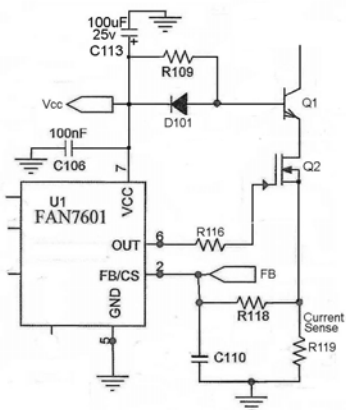


Figure 31. Vcc Derived

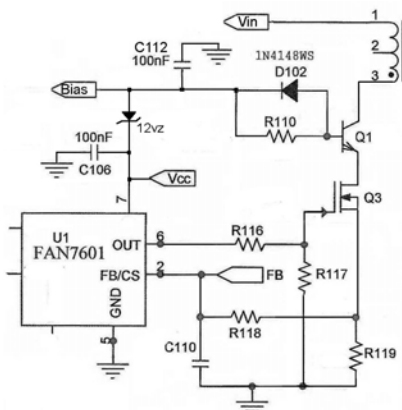


Figure 32. Vbias Supply Derived

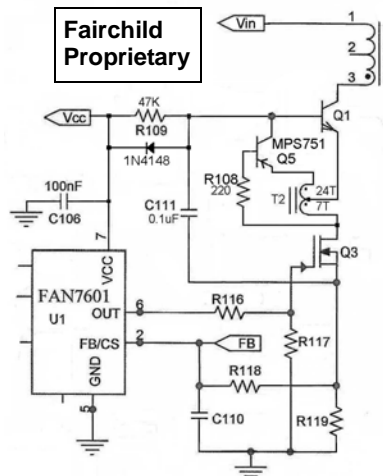


Figure 33. Proportional Drive



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