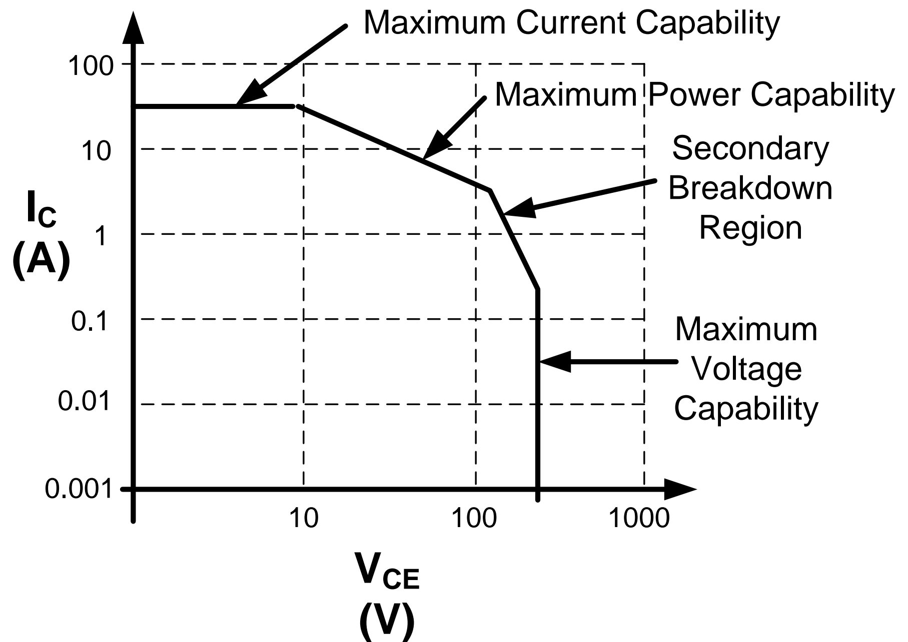
Thermal Testing Guidelines for Power Transistors

For power semiconductor device (such as BJT, MOSFET, or IGBT) a **Safe Operating Area** (SOA) is defined as the voltage and current conditions over which the device can be expected to operate without self-damage.

SOA is usually presented in transistor datasheets as a graph with V_{CE} (collector-emitter voltage) on the abscissa and I_{CE} (collector-emitter current) on the ordinate; the safe 'area' referring to the area under the curve. The SOA specification combines the various limitations of the device — maximum voltage, current, power, junction temperature, secondary breakdown — into one curve, as shown in general form below. Although this curve has parameters shown suitable for BJT and IGBT devices, it is very similar to the curve for MOSFET devices as well. This general curve is not specific to any one BJT part number but represents a set of high power specifications are typical of currently available high power devices.



Often, in addition to the continuous rating, separate SOA curves are provided for short duration conditions (1 ms pulse, 10 ms pulse etc.). The curve shown here is for the steady-state condition.

Thermal testing of high power transistors is usually performed in the high current region for several reasons. First, the high current applied during thermal testing provides the current density stresses normally occurring during actual operation. Second, the high applied current produces the Joule (i.e., resistive) heating associated with the electrical conductors (i.e., bond wires, etc.) needed for electrical connection to the semiconductor chip. The Joule heating is added to the dissipation in the device to produce the total power being generated in the semiconductor package. Third, this region maximizes the power that can be dissipated by thechip and package combination and represents a meaningful thermal resistance value for transistor applications. Fourth, operation in this region is safer from a testing point-of-view and potentially less dam-

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aging from a device point-of-view. Thermal measurements in the Secondary Breakdown Region or Maximum Voltage Capability Region are not useful from an applications point-of-view.

It is important to note that even though a transistor may have a very high voltage V_{CE} capability, very little power can be safely dissipated at high voltages, as shown in the curve above.

Although it is possible to have very high power transistors capable of dissipating hundreds of Watts, that dissipation can only occur within the SOA curve portions on the left where the current is maximized. Further, thermal testing of transistor modules in which several individual transistors are connected in parallel Is not recommended. The paralleled transistors are unlikely to be matched sufficiently at high power levels to avoid a "run-away" condition that will potentially destroy the weak device and potentially damage the thermal test system.

SOA specifications are incredibly useful to the design engineer working on linear power circuits such as amplifiers and power supplies as they allow him/her to quickly determine the conditions under which a design will catch fire, allowing the design of appropriate protection circuitry and/or selection of a more capable device. SOA curves are also important in the design of foldback circuits and in the design of switching circuits that operate between maximum current and maximum voltage.

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