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Don't Forget Temperature as an Important Design Criterion

Two articles in this issue have a strong emphasis on thermal performance. The article by Pengelly and Janke on a silicon carbide wideband amplifier notes that the high junction temperature capability of SiC devices allows the high quiescent currents required for these amplifiers. This allows an amplifier to be designed without using larger (and more expensive) power devices that must be operated well below their maximum ratings.

The article by Fejzuli, Kaarsberg and Roldan describes a device specifically designed to combine frequency and thermal equalization characteristics to maintain consistent amplifier gain over bandwidth and temperature.

Current applications in wireless telecommunications place high importance on thermal performance, as well. Outdoor-mounted base station equipment is exposed to a wide range of environmental conditions that require careful design of the power amplifier's mounting, heat sink and enclosure.

These considerations are even more critical when the equipment is to be tower mounted, where maintenance is difficult and costly. Similar installations that support public safety communications place yet another set of demands for high reliability over a wide range of temperatures.

Power Transistor Specifications

As an example, a high power transistor may have a junction-to-case thermal resistance of 0.5ºC/watt and a maximum operating junction temperature of 200ºC for continuous (CW) operation. Exceeding the allowable junction temperature will seriously degrade the lifetime of the device.

Let's say the maximum power dissipation of the device is 150 watts. Also, the mounting of the transistor (heat sink compound and mechanical connection) can add another 0.1ºC/W to the total thermal resistance. Under these conditions, the maximum temperature differential between junction and heat sink is:

$$\Delta T = [150 \times (0.5 + 0.1)] = 90^{\circ}C$$

Thus, the heat sink temperature cannot rise above 110ºC (200 – 90 degrees). With an ambient temperature of 25ºC (room temperature), the heat sink needs to be sized to handle an 85 degree temperature rise, but if the equipment is located inside an outdoor enclosure, the ambient temperature can easily reach 50ºC, which means that the heat sink must be larger, since the allowable temperature rise has been reduced to just 60 degrees.

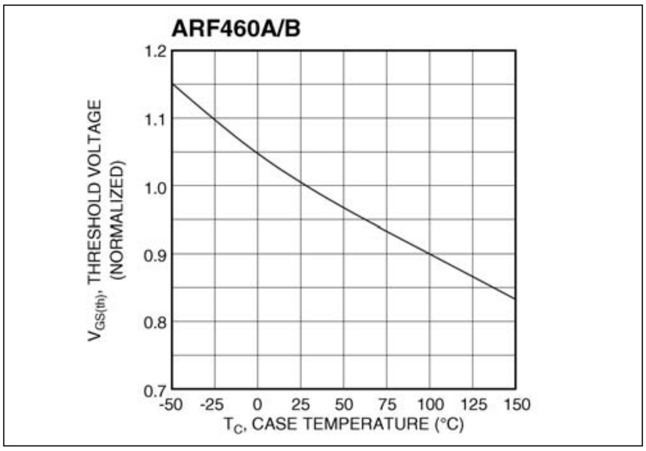

Figure 1 · Gate threshold voltage versus temperature for a Microsemi ARF460A/B power MOSFET.

In addition to reliability, maintaining the temperature of a power transistor is important for consistent RF performance. FET gate threshold voltage and bipolar device base current can change dramatically with temperature, with severe effects on linearity. Device manufacturers and amplifier designers spend plenty of time developing circuits to compensate for these variations, to allow the widest possible range of operating temperatures.

The magnitude of thermal effects on device parameters is illustrated in Figure 1, which shows the gate threshold voltage versus temperature curve for a Microsemi (formerly Advanced Power Technology) ARF460A/B power MOSFET. The curve is relatively linear, especially above 0ºC, so a first-order compensation network may accomplish the necessary bias correction. However, many of today's wireless transmission systems require very high linearity, and additional means of correction will likely be required.

Low Power Devices Need Attention, Too

This note emphasized power devices, but low power circuitry is also temperature-sensitive. Mechanical expansion/contraction and temperature coefficients of the various dielectric materials will combine to vary the operational parameters of the circuit. Handheld and portable equipment are clearly the most susceptible, but all equipment should be evaluated.