Solid-state physics convinces customers

I was working as a product engineer in the discrete division of a major semiconductor company in the early 1980s when the Big Three automotive companies—General Motors, Ford, and Chrysler—started to add many electronic accessories each model year. It was also when under-the-hood-temperature issues and reliability were major concerns, causing companies to change many 0 to 25°C specs to −40 to +125°C. Our customer rejected three shipments of 2N3906 transistors at incoming inspection, saying the parts had high leakage currents. I received some samples of the "defective" units but found nothing wrong. The problem reached my desk with only a week to resolve it before the automaker would have to shut down the production line. I flew out the next day with the returned units as well as some correlation units. Upon my arrival, the component engineer advised me that all the units were failing the 50-nA leakage test at 30V when he heated the units to 125°C. I had to close my gaping mouth when I realized he was applying the room-temperature specification across the full temperature range.

The engineer did not acknowledge that semiconductor performance should change with temperature. I pulled out my 1967 copy of *Physics and Technology of Semiconductor Devices* by Intel founder Andy Grove to show him how the leakage current increases with temperature (**Reference 1**). You can simplify the equations and graphs to the basic rule that leakage doubles for every 10°C increase in temperature. This explanation was not enough to release the product, so we went to the incoming-inspection lab to test my correlation units and production samples using a Tektronix 576 Curve Tracer and a TO-92 heating probe. All the parts showed the same leakage characteristics with temperature that you would expect from silicon.

After another meeting, the component engineer agreed to approve the shipments only after the lots had passed a large sampling plan. We expanded the 2N3906 limit of 50 nA at 25°C to 50 μA at 125°C and began to sample the lots.

During the final tests, the thermal heat probe failed and could not be used on the remaining lots. Once again, the engineer refused to approve the units based on a smaller sample and my solid-state-physics lessons. Not wanting to be any part of a department that caused a lines-down situation for one of the Big Three, I had to come up with a solution.

Again pulling out the textbook, I demonstrated how base-emitter voltage relates directly to the die temperature, as well. Again, you can simplify the equation when applying it to silicon, which reduces the saturated base-emitter voltage by 2 mV for every degree Celsius and translates to a 200-mV reduction in voltage for the added 100°C in temperature. Using the Tek 576 Curve Tracer, we could watch the voltage drop while heating the unit with my lighter. Once the unit met or exceeded temperature, we could change to leakage mode and confirm that the parts were good. I completed the sampling using this method, and the component engineer approved the parts. The next day, the production manager told me that he had to send out five 2N3906s per car to dealers, because that week's production of cars had been shipped without them. Mechanics at the dealership had to install the critical components, which drive the LEDs that light up when your door or trunk is ajar. EDN

REFERENCE

1. Grove, Andrew S, *Physics and Technology of Semiconductor Devices*, John Wiley and Sons, 1967.

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