3.5 Pulsed Measurements

3.5.1. Pulsed DC Measurements

When measuring transistors with higher Drain or Collector currents, self-heating may occur. This means for an output characteristics, for example, that the traces at high Collector or Drain voltages belong to a hotter device than those of low voltages. For modeling, the main problem hereby is that later, the simulator models assume a constant temperature TNOM over the full output characterization sweep (!), and what we measure as a selfheating would be possibly modeled by an avalanche effect!

Fig. 1 gives an example for a packaged bipolar transistor, measured with different pulse widths. It can be seen that only pulses in the millisecond range can lead to isothermal measurement results.

- As the pulse width increases, so does the current due to self-heating

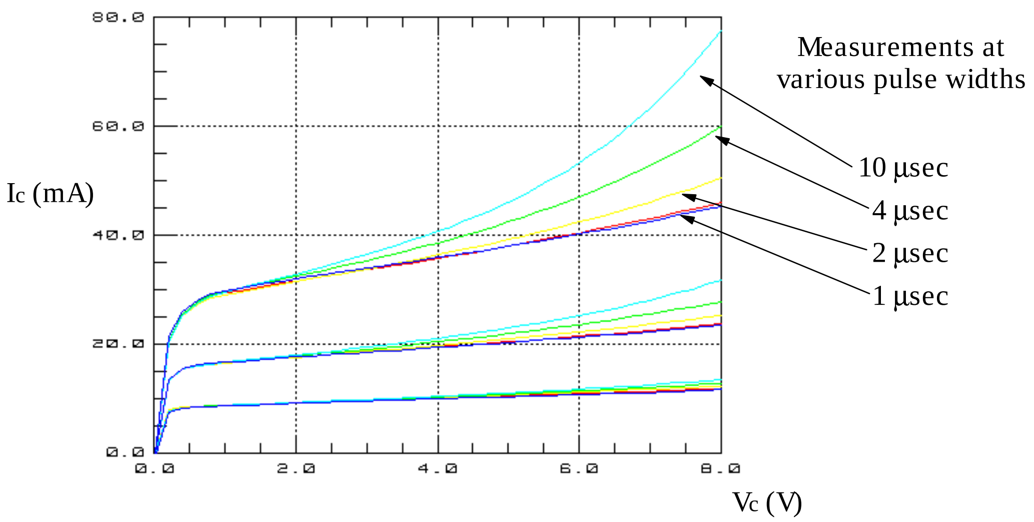

Fig.1: Thermal self-heating for pulsed bias measurements as a function of the pulse width

And this self-heating can cause a major challenge to modeling, because as a general rule, we have to account for self-heating effects already at currents above ~10mA (for typical Vmax = 5V) for packaged devices, and for on-chip measurements using a thermochuck, the critical current is about 50mA.

A solution is to apply pulsed DC measurements. This would give us isothermal measurement conditions, and would allow to extract really those model parameters which are correct for the modeling temperature TNOM. However, if these pulses exceed a few milliseconds, self-heating might already occur, see again fig.1 and fig.2.

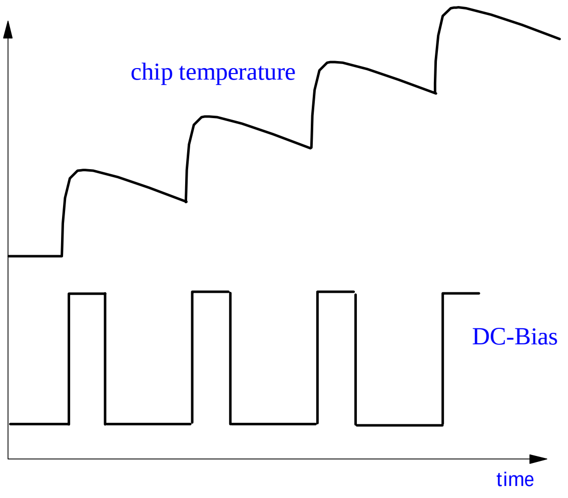

Fig.2: A self heating effect may occur even for pulsed bias conditions

To give an overview, fig.3 depicts possible temperature increase due to the bias power.

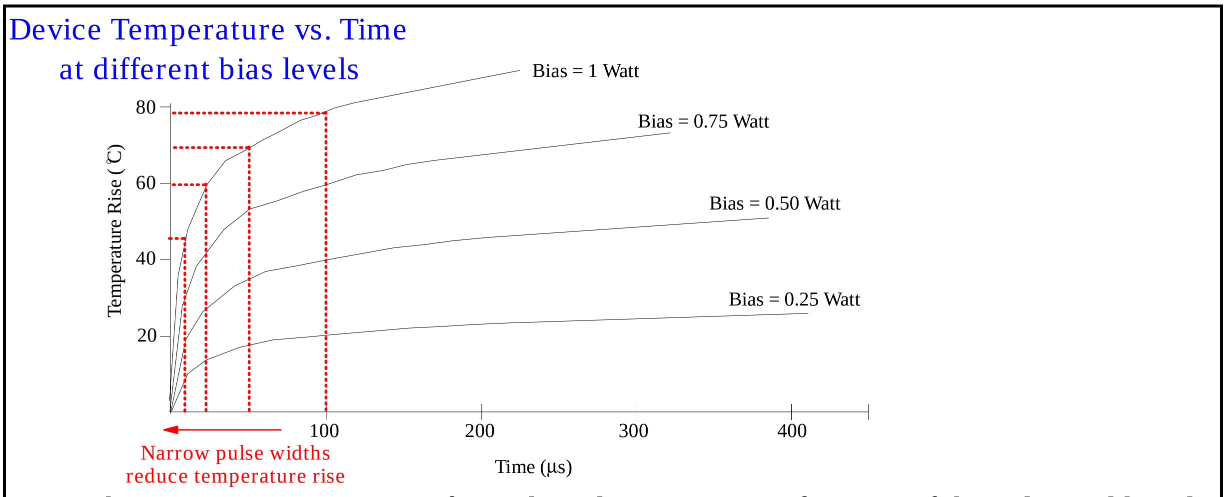

Fig.3: chip temperature increase of a packaged transistor as a function of the pulse width and the applied bias power. Pulse period is 1s.

Conclusions:

In order to avoid self-heating, the 100us of the Agilent 4142 and 415x are not short enough. This can be verified when measuring the BETA of bipolar transistors or ROUT of MOS transistors once with a forward sweep (from low to high voltage), and a second time in reverse sweep. If both traces are different, self-heating might have occurred (Import the data of setup 1<forward> into setup 2<reverse>). The same experiment can be performed when applying the 100us pulsed measurements to the device. If self-heating occurs, we might end up with 4 different beta curves, depending on the sweep and ulse conditions.

To prevent self-heating, we should doublecheck with the designers the operating conditions. When these include indeed the self-heating mode, and no isothermal measurement equipment with pulses in the 1us range is available (85124A pulsed modeling system), it might be better to sweep in 'long integration' mode rather than in 'short', in order to have the later application condition included in the modeling process.

Note:

The pulsed measurements of the 4142 and 415x are targeted for production test. For some of these tests, a CW mode would damage the device, and therefore, pulse measurements are performed instead. It is important to note that these pulsed measurements are not intended to prevent from self-heating, but rather from damaging the DUT! Therefore, these kind of pulsed measurements do usually not help much for modeling. If the DUT is later also measured by a NWA, it is even worse to apply these pulses for DC, because the device will definitively heat-up during the lengthy NWA measurements. And, in this case, the DC parameters apply to relatively cold (but not isothermal) measurements, while the biased NWA measurements are hot device measurements. In this case, it might no wonder when no curve fit can be achieved for both DC and S-parameters.