PCF50633HN N3B HTOL issue

MST Portable Power Solutions
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HTOL issue: Description

- The MBC block of the PCF50633/N3B shows failures after the HTOL test. The Charge & Play path is suffering from Negative Bias Temperature Instability (NBTI) degradation. NBTI degradation causes a shift in the Vt of a PMOST (especially at low Vgate and high temperatures).

- The NBTI degradation occurs especially in the "Play" paths (BAT-SYS and USB-SYS FET).
  1. For the BAT-SYS fet NBTI occurs in "Idle state", which is the default state when there is no USB and Adapter present.
  2. For the USB-SYS fet NBTI occurs in "USB-suspend mode" where the USB-SYS is switched ON.

- The effect of NBTI degradation in the BAT-SYS is that the adapter charge current decreases over time. This is proven with lab experiments. The NBTI degradation does not occur while charging via USB source.

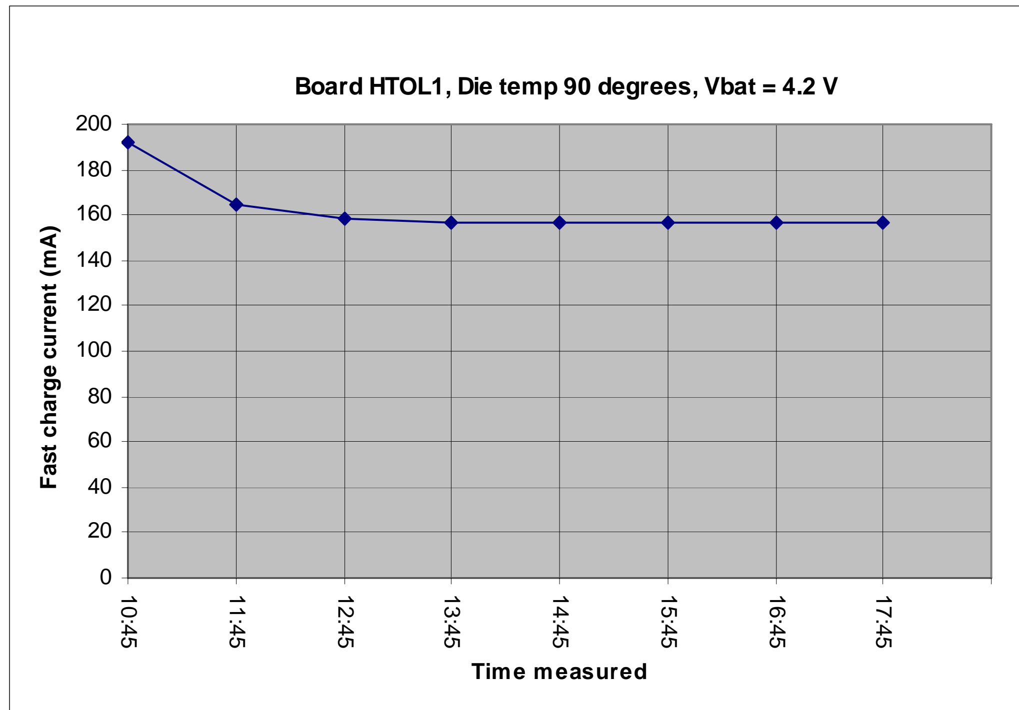
- The effect of NBTI degradation in the USB-SYS is that the USB current limit decreases over time. This is proven with lab experiments as well.

- Since use case (1) is the default state, end-users may notice this. E.g. the adapter charge current (@ 200mA setting) decreased about 18 % after using the product in "Idle state" for 7 hours at a die temperature of 90 °C.

- Use case (2) is not a default state and can even be avoided by programming USB-SYS OFF during USB suspend.

HTOL issue: The impact in the application

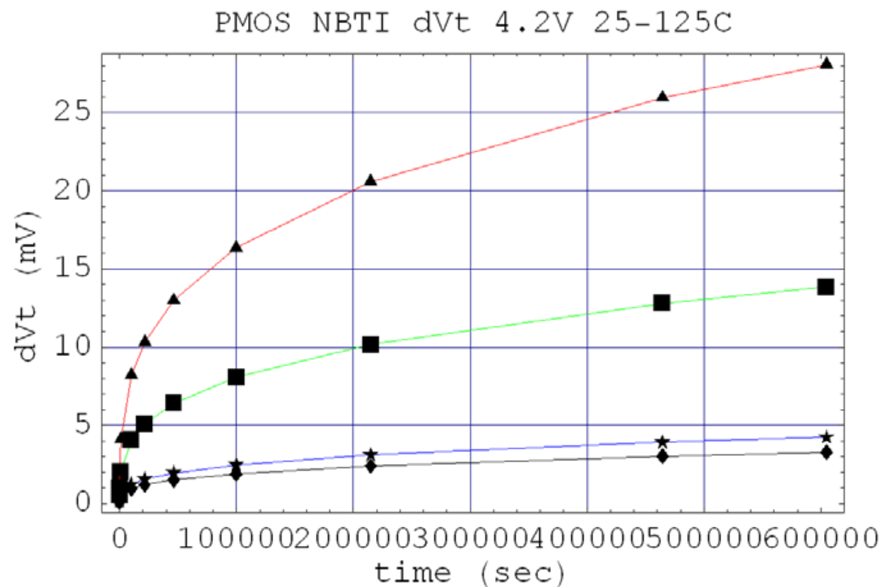
- The impact in the application is that the wall adapter charge current will decrease over time.
- This effect can be made visible by stressing the product in MBC-idle mode, at Vbat=4.2V and measure the adapter charge current each hour.



Vbat=4.2V: 18.2% reduction of adapter charge current after 7 hours @ 90 °C

HTOL issue: How to reduce the effect? - 1

- **Low die temperatures (so less power dissipation)**
  NBTI degradation also takes place at room temperature but the effect is bigger at high die temperature. In the picture below the shift in Vt is presented for different temperatures at Vbat=4.2V.



125 deg. Celsius

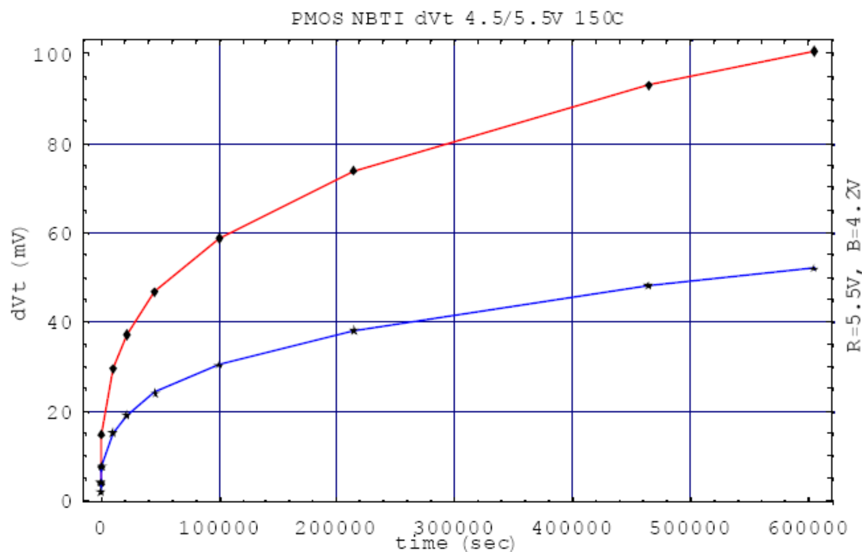
85 deg. Celsius: PMU in hot environment

35 deg. Celsius: PMU active

25 deg. Celsius: PMU standby

HTOL issue: How to reduce the effect? - 2

- **Low battery voltage**
  The shift in Vt is larger at higher BAT voltages. The NBTI degradation can be proved by applying two different voltages on the BAT node, while the charger is in Idle state.
  See plot of NBTI degradation at 4.2V and 5.5V @ 150 degrees Celsius:



Vbat=5.5V

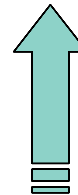
Vbat=4.2V

HTOL issue: How to reduce the effect? - 3

- **Higher charge current settings**
  NBTI degradation is less at higher charging current as depicted in the tables below.

Simulation results

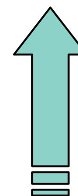
Simulation results		Vadapt=5V			
Sysbat FET		Vbat=3.6V			
Charge setting	Vt-shift=0	Vt-shift=50mV	Remaining charge current (%)	Vt-shift=100mV	Remaining charge current (%)
31	31.4	8.9	28.34	1.93	6.15
100	100.2	39.2	39.12	11.8	11.78
200	199.8	95.1	47.60	36.7	18.37
400	398.5	229.5	57.59	114.1	28.63
800	794.8	539.9	67.93	337.2	42.43



Larger deviation
at smaller charge currents

Lab results (HTOL samples)

Measured		Vadapt=5V		
Sysbat FET		Vbat=3.6V		
	Sample 3		Sample 4	
Charge setting	Actual charge current	Remaining charge current (%)	Actual charge current	Remaining charge current (%)
31	22.5	72.58	11	35.48
100	73.5	73.50	44.6	44.60
200	159.7	79.85	105	52.50
400	343.5	85.88	245.8	61.45



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