Application Report
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Configuring TPS65950/30/20 Backup State

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ABSTRACT

The TPS65930 and TPS65920 devices have the same backup state functionality as TPS65950 device. Hence the backup state functionality described for TPS65950 in this report also applies to TPS65930/20.

The TPS65950 uses a main battery and an optional backup battery. The backup battery powers up some modules of the TPS65950 when the main battery is removed or discharged below a certain level. This application note addresses topics related to TPS65950 BACKUP state and backup battery charging.

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1 TPS65950 BACKUP State Overview

The TPS65950 takes power from a main battery (VBAT) and an optional backup battery (BKBAT). This application note describes the BACKUP state configuration of the TPS65950 when a rechargeable backup battery is connected to it.

The TPS65950 operates in one of five power states:

- NO SUPPLY
- BACKUP
- WAIT-ON
- ACTIVE
- SLEEP

Note: This document uses VBACKUP to indicate the voltage level of the backup battery.

The VRTC power domain is powered by one of two internal low-dropout regulators (LDOs): VRRTC or

VBRTC. The VRTC is powered by the VRRTC LDO when VBAT > 2.7 V and it is powered by the VBRTC LDO when the TPS65950 is in BACKUP state. The input to VRRTC LDO is always VBAT, whereas the VBRTC LDO is supplied by the uninterrupted power rail (UPR). The UPR is connected to VBAT if VBAT > 2.85 V or (VBAT > 2.1 V and VBAT > VBACKUP); otherwise, the UPR is connected to BKBAT if it contains a valid supply (VBACKUP > 1.8 V).

The VRTC in the TPS65950 maintains registers and powers some modules:

- Internal 32-kHz clock
- Real-time clock (RTC)
- Twenty secure registers (SECURED_REG_x, x = A, B, …, S and SECURED_REG_U)
- Eight general-purpose (GP) registers (BACKUP_REG_x, x = A, …., H)
- Remaining Backup domain registers:
  - CFG_P1_TRANSITION
  - CFG_P2_TRANSITION
  - CFG_P3_TRANSITION
  - CFG_P123_TRANSITION
  - STS_BOOT
  - CFG_BOOT
  - BOOT_BCI
  - CFG_PWRANA1
  - CFG_PWRANA2
  - RTC_CTRL_REG
  - RTC_STATUS_REG

1.1 BACKUP State Transitions

Transitions between TPS65950 operating states are determined by external and internal events that can be hardware-generated or software-triggered.

Figure 1 shows the transition of the TPS65950 between BACKUP and other states. It does not show transitions between other states.

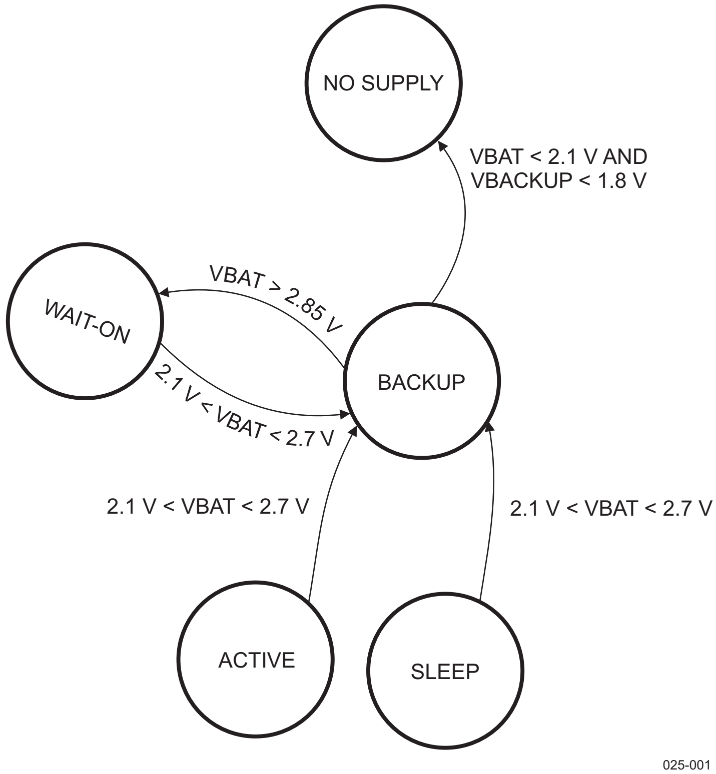

Figure 1. TPS65950 BACKUP State Transition

When the TPS65950 is in WAIT-ON, ACTIVE, or SLEEP states, it goes to BACKUP state when VBAT falls below 2.7 V. The TPS65950 remains in BACKUP state as long as VBAT > 2.1 V or VBACKUP > 1.8 V.

Note: One exception: when the user presses the PWRON (power-on) button for 8 seconds and removes the battery in the next 8 seconds, the TPS65950 enters NO SUPPLY state instead of BACKUP state, even if a valid backup battery is present. In such a situation, the backup domain registers are also reset, along with the VRRTC domain registers.

When the TPS65950 is in BACKUP state, it can move to WAIT-ON state when the VBAT level exceeds 2.85 V.

The TPS65950 moves from BACKUP state to NO SUPPLY state when VBAT < 2.1 V and VBACKUP < 1.8 V.

1.2 TPS65950-Supported Backup Batteries

The TPS65950 supports batteries or large capacitors to support backup battery functionality. Some examples of backup batteries are Manganese-Silicon-Lithium batteries (MS414) or electrochemical capacitors (XH414H).

Two of the most important parameters to consider before selecting a backup battery associated with TPS65950 are:

- Backup battery constant charging current
- Backup battery end-of-charge voltage

For information about the backup battery constant charging current and backup battery end-of-charge voltage supported by the TPS65950, see Reference 2 in Section A.1.

Note: When the backup battery is not used with the TPS65950, connect the BKBAT pin to electrical ground.

2 BACKUP State Configuration

As part of TPS65950 initialization, at boot time, the software running on the host processor must perform the following minimum steps related to backup domain configuration:

- If the value of the STS_BOOT BACKUP bit is 1:
  1. The system has previously been in BACKUP state and the software must take any required action and clear the BACKUP bit by setting it to 0.
  2. Software must ensure that the STS_BOOT SETUP_DONE_BCK bit is set to 1.
- If the value of the STS_BOOT BACKUP bit is 0, the system could be coming back from NO SUPPLY or WAIT-ON state. Thus, software must check the STS_BOOT SETUP_DONE_BCK bit (assuming that software always sets this bit after configuring the backup domain registers).
  – If the value of the STS_BOOT SETUP_DONE_BCK bit is 1, the backup domain register configuration has been retained and there is no need to reconfigure those registers.
  – If the value of the STS_BOOTSETUP_DONE_BCK bit is 0, software is returning from NO-SUPPLY state. Software must configure all backup domain registers and then set the SETUP_DONE_BCK bit to 1.

3 Backup Battery Charging

Figure 2 shows the TPS65950 backup charging scheme. A rechargeable backup battery connected to the TPS65950 can be charged by a programmable LDO powered by the main battery. The backup battery charger can be controlled by the BBCHEN, BBISEL, and BBSEL fields of the BB_CFG register.

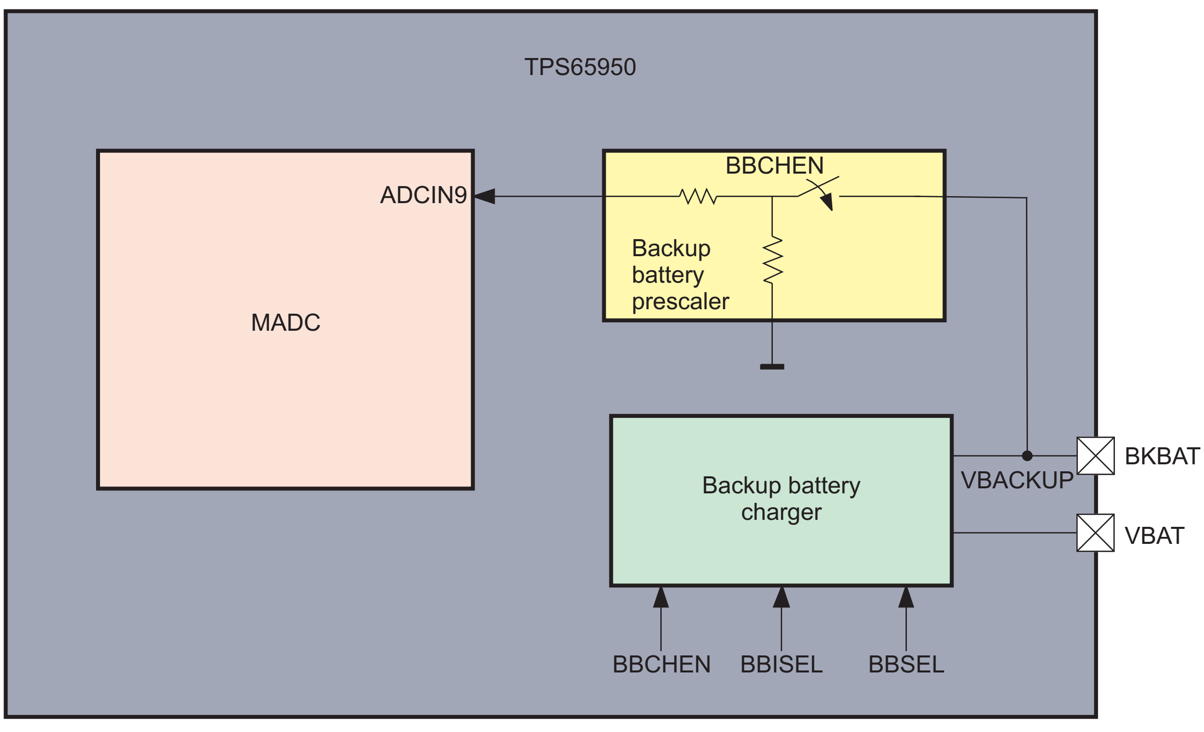

Figure 2. TPS65950 Backup Battery Charger

The BBISEL field lets the user specify the constant backup battery charging current. Table 1 lists typical values of backup battery charging current for different values of the BBISEL field. For minimum and maximum values of backup battery charging current for each value of the BBISEL field, see Reference 2 in Section A.1.

Table 1. BBISEL Field Mapping

BBISEL	Backup Battery Charging Current (μA)
00	25
01	150
10	500
11	1000

The BBSEL field lets the user specify the end-of-backup battery charging voltage. Table 2 lists typical values of backup battery charging voltage for different values of the BBSEL field. For minimum and maximum values of backup battery charging voltage limits for each value of the BBSEL field, see Reference 2 in Section A.1.

Table 2. BBSEL Field Mapping

BBSEL	End-of-Backup Battery Charging Voltage (V)
00	2.5
01	3.0
10	3.1
11	3.2

The host processor can identify the instantaneous backup battery voltage by connecting VBACKUP to the MADC ADCIN9 channel through a resistive prescaler (BB_CFG[BBCHEN] = 1) and then performing a software-triggered conversion on the ADCIN9 channel. For the monitoring ADC (MADC) configuration required for software-triggered conversion requests, see Reference 1 in Section A.1.

3.1 Automatic Backup Battery Charging

Automated backup battery charging is controlled by hardware. For automatic backup battery charging, perform the following steps:

1. Configure the backup battery charging current and end-of-backup battery charging voltage by programming the BBISEL and BBSEL fields, respectively. The values of these fields depend on the backup battery being used.
2. Enable backup battery charging by setting the BB_CFG BBCHEN bit to 1.

With this configuration, the backup battery starts charging automatically when VBAT > 3.2 V and VBAT > VBACKUP. Backup battery charging automatically stops when VBACKUP reaches the specified BBSEL voltage.

Even when the charging stops, the backup battery module is still enabled, because the BBCHEN bit is set to 1.

To reduce leakage in the backup battery charger after charging completes, software can measure VBACKUP using the MADC conversion. If VBACKUP has reached the desired voltage, the backup battery module can be disabled by setting the BBCHEN bit to 0.

3.2 Software-Controlled Backup Battery Charging

Software-controlled backup battery charging is used when the backup battery is to be charged to a voltage level different from the values mentioned in Table 2. For software-controlled backup battery charging, perform the following steps:

1. Configure the backup battery charging current and backup battery charging voltage limit by programming the BBISEL and BBSEL fields, respectively. The value of the battery end-of-charge voltage (the BBSEL field) selected must be greater than the required backup battery voltage.
2. Enable backup battery charging by setting the BB_CFG BBCHEN bit to 1. With this configuration, the backup battery starts charging automatically when VBAT > 3.2 V and VBAT > VBACKUP.
3. Request MADC conversion of VBACKUP periodically and compare the conversion results with the desired backup battery voltage.
4. When the conversion results are within some limits of desired backup battery voltage, stop backup battery charging by setting the BBCHEN bit to 0.

Note: The BBCHEN bit is reset when the TRITON_RESET resource in the TPS65950 is asserted. This resource is asserted when the default ACTIVE-to-WAIT-ON sequence executes in the TPS65950. The sample warm reset sequence provided in the TPS65950 TRM (Reference 1 in Section A.1) also asserts this resource when the system undergoes warm reset. That is, backup battery charging is automatically disabled when the TPS65950 enters WAIT-ON state or when a system warm reset occurs. Therefore, the host processor must enable backup battery charging (if needed) by setting the BBCHEN bit to 1 after the system returns to ACTIVE state from WAIT-ON state or after a warm reset.

4 Power Cut System Use Case

Power cut means a momentary disconnect of the main battery (for example, when the phone is dropped and the main battery is removed momentarily). In such a case, the capacitors connected to the main battery can keep the TPS65950 in ACTIVE state for some time, depending on the load on the application processor.

To support this feature, perform the following minimum steps:

1. Unmask the MBCHG interrupt of the TPS65950 power subchip by setting the PWR_IMR1 MBCHG bit to 0
2. The MBCHG interrupt is generated when VBAT falls below 3.0 V or rises above 3.2 V. Configure the MBCHG interrupt to be generated for both of these cases by setting the MBCHG_FALLING and MBCHG_RISING bits of the PWR_EDR2 register to 1.

If power is cut and if 2.7 V < VBAT < 3.0 V, the host processor receives the MBCHG interrupt. The host processor must take necessary action (save data, shut down applications, etc.). If the main battery is connected before the VBAT capacitors discharge below 2.7 V, the TPS65950 remains in ACTIVE state. If the VBAT level increases to more than 3.2 V, the same MBCHG interrupt is recognized by the host processor.

If the main battery remains disconnected for a longer period and the capacitors on the VBAT are discharged below 2.7 V, the TPS65950 enters BACKUP or NO SUPPLY state (assuming VBAT < 2.1 V and VBACKUP < 1.8 V).

5 Reducing Power Consumption in BACKUP State

To reduce power consumption in BACKUP state, the software can configure the 32-kHz clock to be in low-power mode by setting the CFG_BOOT CK32K_LOWPWR_EN bit to 1 when the TPS65950 is in ACTIVE state.

Note: The CFG_BOOT register is in the backup domain, so the value of the CK32K_LOWPWR_EN bit is retained as long as a valid battery source is present. That is, if the TPS65950 returns to ACTIVE state from BACKUP state without passing through NO SUPPLY state, the value of this bit is retained.

Note: The CK32K_LOWPWR_EN bit affects the 32-kHz clock only in BACKUP state. When the TPS65950 returns to ACTIVE state, the 32-KHz clock is in normal mode, even if the CK32K_LOWPWR_EN bit is set to 1.

Appendix A References

A.1 References

This document refers to the following related documents:

1. TPS65950 Technical Reference Manual (SWCU050A)
2. TPS65950 Data Manual (SWCS032)

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