F-RAM RTC Backup Supply (VBAK pin) and UL Compliance

About this document

Scope and purpose

AN404 discusses the F-RAM RTC processor companion's backup power sources, the internal charging circuit, and the associated issues.

Intended audience

It is intended for the users of RTC in F-RAM processor companions FM33xxx, FM31xxx.

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1 Overview

The FM31xx and FM33xx families are the Integrated Processor Companion devices that feature a real-time clock (RTC). The RTC provides the date/time information for the system and operates on either V_{DD} or V_{BAK} power. A battery or a capacitor is attached to the V_{BAK} backup power-supply pin. This application note discusses the backup power sources, the internal charging circuit, and the associated issues.

2 RTC Backup

The FM31xxx and FM33xxx RTCs are designed to operate over long periods of time without the main V_{DD} power supply. A backup power source can be provided by a non-rechargeable battery (lithium coin cell) or a large value supercapacitor as shown in **Figure 1**. Depending on the size and capacity, a lithium coin cell can provide continuous RTC operation for many years. When V_{DD} is powered up, the RTC and other associated circuits operate from the V_{DD} power source. There is essentially no current drawn from the backup source. If V_{DD} is powered down, the RTC is automatically switched over to the V_{BAK} power source.

The F-RAM RTC operates at very low current (<1 uA). A 3-V coin cell is typically used as the V_{BAK} power source. The expected life of a lithium cell in hours is calculated using the following equation:

Expected Life (in hours) = 1000 x Rated Battery Capacity (mAh)/Load Current (uA)

For example, a BR1225 rated at 48 mAh with a continuous load current of 1 uA (system powered down) will last 48,000 hours or nearly five and a half years. If V_{DD} is powered up for some time, then the battery will last longer because there is no backup current when V_{DD} is applied. During this time, the battery's self-discharge characteristic dominates the battery life.

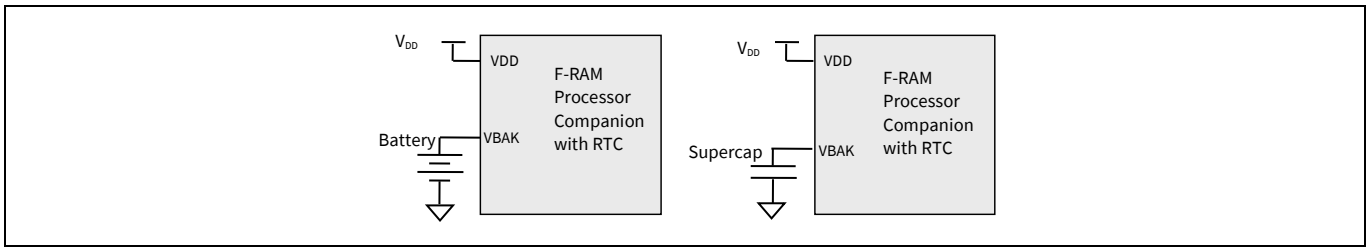

Figure 1 Two RTC Backup Options

In applications for which a battery cannot be used (due to space constraints, environmental restrictions, or added costs), a capacitor can be used as a backup power source. A large value capacitor, such as a supercapacitor, is generally used. The F-RAM companion devices have an integrated charging circuit that is used with the supercapacitor. This provides the user with cost savings, reduced board space, and convenience. The internal circuit charges the supercapacitor when V_{DD} is applied. No external components, such as protection diodes or current limiting resistors, are needed. The circuit provides a constant current to deliver charge to the capacitor. When V_{DD} is powered down, the RTC and other backed-up circuits are powered from the supercapacitor. See **Figure 2**.

RTC Backup

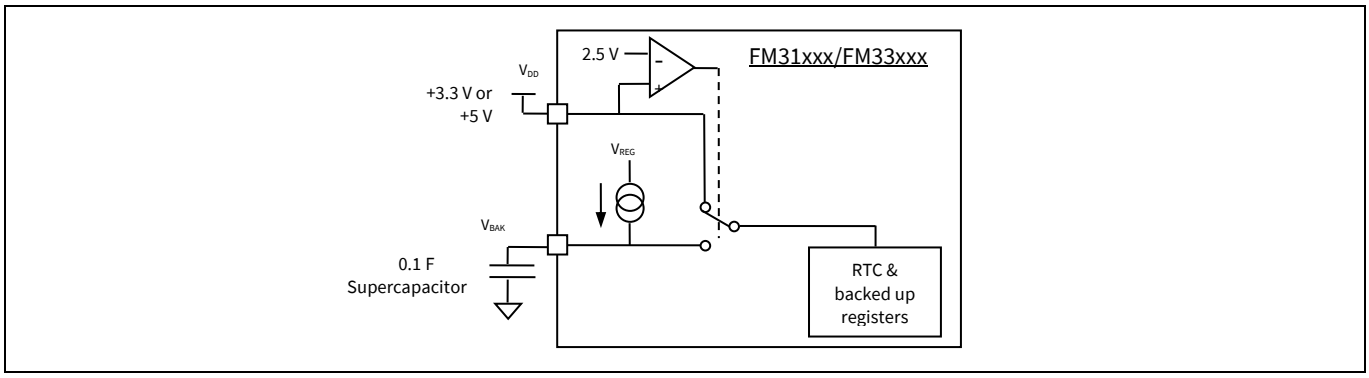

Figure 2 Simplified Diagram of Power Switch and V_{BAK} Trickle Charger

The length of time (in hours) that the RTC will run from the supercapacitor is calculated using the following equation:

Capacity of supercap (F) x ($V_{INITIAL}$ – 2.0 V) / (0.0036 x Load Current (uA))

In this equation:

- $V_{INITIAL}$ is the capacitor voltage that the V_{BAK} pin is charged to when V_{DD} is powered down.
- 2.0 V is the minimum operating RTC voltage as specified in the datasheet.
- The factor 0.0036 converts seconds to hours and amps to microamps.

A 0.1-F capacitor provides approximately two days of backup and a 1-F supercapacitor provides 20 days (this assumes $V_{INITIAL}$ is charged to the maximum voltage allowed for V_{BAK}). The VBC bit in the Companion Control Register (Register 0B, bit 2 for FM31256, FM3164, FM31278, FM31276, FM31L278, FM31L276 and Register 18, bit 3 for FM33256B) must be set high to activate the charging circuit. The supercapacitor charging voltage on V_{BAK} is provided by an internal regulator. Typically, systems run from either 3.3 V or 5 V. In the case of a 5-V system, the highest V_{BAK} voltage is 3.75 V, the internally regulated voltage. In the case of a 3.3-V system, the highest V_{BAK} is reduced to 3.3 V by V_{DD}.

The supercapacitor must be fully charged to get the maximum backup time during power down. The time (in hours) to fully charge a discharged capacitor is calculated as:

Capacity of the supercapacitor (F) x ($V_{CHARGED}$) / (0.0036 x Charge Current (uA))

In this equation:

- $V_{CHARGED}$ is the maximum V_{BAK} voltage. $V_{CHARGED}$ is 3.75 V for V_{DD} = 5 V and 3.3 V for V_{DD} = 3.3 V.
- The factor 0.0036 converts seconds to hours and amps to microamps.

For a capacitor = 0.1 F, V_{DD} = 5 V, and a charge current of 15 uA (charge current is 80 uA for FM31278, FM31276, FM31L278, FM31L276, FM33256B and 15 uA for FM31256, FM3164), it takes almost 7 hours to fully charge the supercapacitor. In the case of V_{DD} = 3.3 V, it takes approximately 6 hours to fully charge the supercapacitor.

Note: The FM31278 / FM31276 / FM31L278 / FM31L276 / FM33256B devices define a Fast Charge mode (FC bit – register 0Bh, bit 5), which is capable of sourcing approximately 1 mA.

3 UL Compliance

Users of primary batteries (non rechargeable) need assurance that the charging circuit has low reverse current when off and that it also has a protective resistor in series with the battery. This limits the charge current in the event of malfunction in the charging circuit that can cause excessive battery current. The circuit diagram in **Figure 3** shows two 1.3-kΩ resistors in series with the P-ch current source. There are no other elements in the path to the V_{BAK} pin. The trickle charger current is provided by the P-ch shown as I_{BAKTC} current and is activated only when the VBC bit is set. The RTC includes an Oscillator and Timekeeping Block, which holds the time/day/date values. If V_{DD} drops below 2.5 V, the RTC power is switched to the V_{BAK} source. Under this condition, the Oscillator and Timekeeping Block pulls no more than 1.4 uA (I_{BAK} maximum at V_{BAK} = 3.0 V), which is 100% tested at worst-case conditions.

When V_{DD} is within its normal operating range, there is no current into or out of the V_{BAK} pin, other than leakage current. Infineon F-RAM expects I_{BAK} to be < 1 nA under this condition.

Note: *If a primary battery is used, the VBC bit should not be set (charger off). If the VBC bit is set (charger on), the battery life may be reduced. The charge current provided by the FM31xxx/FM33xxx is low enough that it poses no safety risk, such as excessive heat. However this condition should be avoided.*

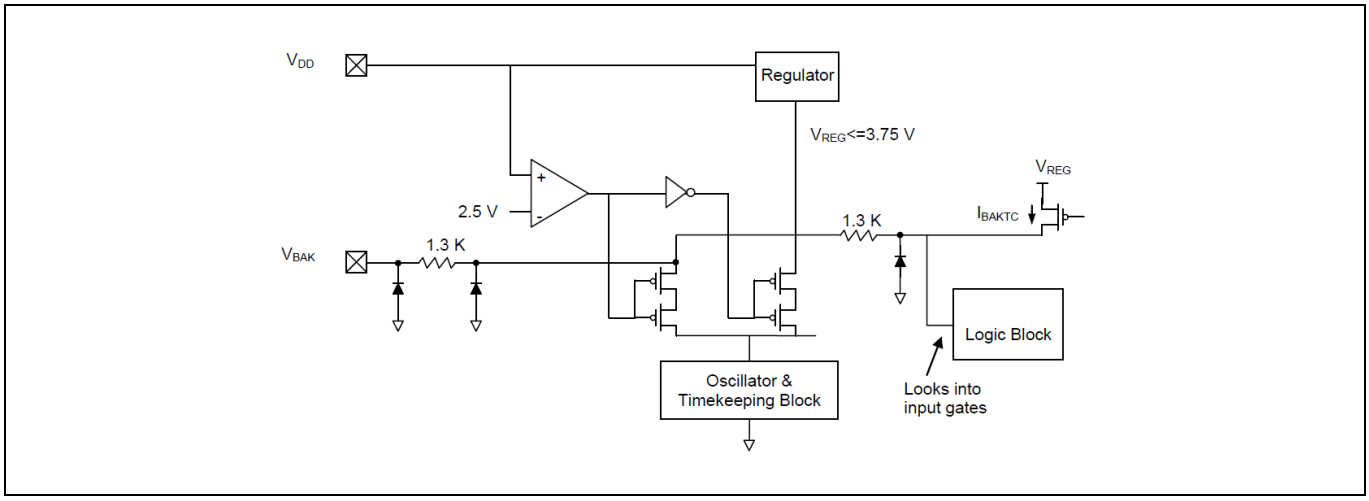

Figure 3 FM31xxx/FM33xxx Internal Circuits Relating to V_{DD} and V_{BAK}

4 Summary

AN404 describes the different backup source options for the F-RAM RTC processor companion. It explains the internal charging circuit and associated issues to be taken care of while designing systems with the F-RAM RTC processor companion.

5 Related Application Notes

You can refer to the following application notes for better understanding of the F-RAM Processor Companion devices.

- **AN407 - A Design Guide to I2C F-RAM Processor Companions – FM31278, FM31276, FM31L278, and FM31L276**
- **AN408 - A Design Guide to SPI F-RAM Processor Companion - FM33256B**
- **AN400 - Generating a Power-Fail Interrupt using the F-RAM Processor Companion**
- **AN401 - Charging Methods for the F-RAM RTC Backup Capacitor**
- **AN402 - F-RAM RTC Oscillator Design Guide**

Revision history

Document version	Date of release	Description of changes
**	2013-06-07	New Spec.
*A	2014-11-06	Changed the title from “F-RAM RTC Backup and UL Compliance” to “F-RAM RTC Backup Supply (V_{BAK} pin) and UL Compliance”. Added Fast Charge Mode related information in all instances across the document. Added Related Application Notes.
*B	2016-06-02	Updated to new template.
*C	2017-08-17	Updated logo and copyright.
*D	2021-05-27	Migrated to IFX template.

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