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APPLICATION NOTE 3693

Why Maxim Chose to Design the Single-Piece NV SRAM Modules

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Abstract: In order to understand the design criteria defining Maxim's new single-piece module package, it is first necessary to comprehend a bit of the history of battery-backed memory products.

Since the beginning of NV SRAM development, the intent has been to produce a hybrid memory product that could be handled exactly like an IC. Use of a commodity low-power SRAM with a lithium coin-cell battery mated CMOS wafer technology with a common, voltage-stable source for long-term memory backup power.

In order to understand the design criteria defining Maxim's new single-piece module (SPM) package, as well as the selection of Manganese Lithium (ML) secondary (rechargeable) battery chemistry for the energy source, it is first necessary to comprehend a bit of the history of battery-backed memory products. With understanding of the many issues that led to this battery chemistry selection, the answers become much more obvious, as well as technically justified.

It is recommended that the reader be familiar with the characteristics of primary (nonrechargeble) lithium coin-cell batteries used in nonvolatile applications, as outlined in application note 505, "Lithium Coin-Cell Batteries: Predicting an Application Lifetime."

The "Brick"—Through-Hole Components

Early hybrid module packaging concepts followed the traditional dual-in-line (DIP) footprint, as the marketing task was to capture EPROM sockets with a more application-flexible product solution. The modules are easy to connect, easy to use, and very reliable if properly handled during manufacturing processes.

A fundamental limitation with products containing primary lithium coin-cell batteries is that these coin cells cannot be exposed to temperatures above +85°C (+185°F). This processing limitation on high-volume circuit board assembly operations forced manufacturers to use special handling procedures when dealing with battery-backed modules. The battery manufacturers had limited familiarity with integrated circuit applications or printed-circuit-board assembly requirements, so the environmental issues associated with electronics manufacturing were essentially new and unknown to them. Design of a more thermally robust coin cell was not foremost on their developmental road map at that time.

To many users, the DIP module package is affectionately known as a "brick", but due to the physical size of the module, many potential users had difficulty finding the space for it.

The DIP module products occupy a fairly large board area based upon the traditional 600mil-wide pinout, and have an unusually tall package profile. With each memory-density upgrade, the circuit layout must be modified, adding pins and further increasing the board area required. With the fully potted construction, this additional mass could also influence the final board-vibration characteristics.

Common solutions to the temperature-exposure limitation were either to use a socket or hand-solder the module. But with either of these solutions, there is increased cost and/or inconvenience. The introduction of socket connectivity problems also surfaced as a system-reliability concern.

The result is a large, but highly reliable, self-contained memory subsystem, providing it is protected from any significant thermal exposure.

Low-Profile Modules Need Custom Sockets

To address the board area and height disadvantages of the DIP module, some packaging creativity led to a lower profile hybrid construction that was still unable to withstand direct-soldering operations. The height was cut in half and the board area was reduced, but the required use of a custom socket added piece-part cost to the system, and also necessitated additional end-of-line assembly labor to install the module after soldering the socket.

The low-profile modules (LPM) had the same field-proven reliability within the basic components as the brick, but could not be directly soldered in the customer's application. Connector integrity became the dominant field-reliability issue.

PowerCap—Almost SMT-Compatible

Based upon the reliability issues with sockets, further package development efforts focused on achieving an SMT-compatible replacement for the LPM. To protect the battery from any thermal exposure, the "product" was actually a two-piece solution in which the lithium cell was sold, stocked, and assembled as a separate item from the component base. Although the two-piece products achieved the goal of providing a high-volume, SMT-compatible product, the added logistics and labor to procure and assemble both pieces is not much different than with the LPM offering.

Additionally, introduction of connectors into the battery circuit transferred that field-reliability concern from the external socket into the product itself. Contact integrity issues, either from improper battery cap installation or vibration exposure in the field, demonstrated a weakness that was never experienced with fully soldered, one-piece constructions.

The PowerCap modules perform the same function as the brick, with the additional capability of sustaining a convection reflow assembly process. Based upon the custom footprint of the LPM, the lack of available pins for density expansion restricts any further product development in this package.

Lithium Coin-Cell Battery Issues

Any contract assembler that has ever tried to handle batteries quickly came to the realization that they cannot handle batteries like they handle ICs. Every metal work surface and grounded operator becomes a potential conduit to discharge production batteries. Simple use of metal tweezers or trays can have disastrous results on line yields without being an obvious culprit.

Products with exposed lithium batteries cannot tolerate aqueous cleaning operations. Water, in conjunction with bias, can lead to dendrite growth (metal migration) and prematurely discharged cells.

One constant question from the field is how to estimate the remaining battery capacity in a module, which is the primary focus of Application Note 505. Because the primary lithium coin-cell battery is a one-shot energy source, estimating the accumulative backup time of a module in a field installation is difficult, at best.

Aside from the previously mentioned limitation on soldering temperature exposure, lithium coin-cell batteries have some gradual loss of charge, or self-discharge, and is specified as percentage of charge lost per year. Improper storage conditions can significantly degrade the capability of the coin cell (refer to Application Note 505).

Single-Piece Modules

The single-piece module (SPM) package was specifically targeted to address the criticisms and weaknesses observed in the previous generations of NV SRAM products. Designed and developed under engineering control, none of the following items were considered to be any more or less critical than any other in answering the desires of the users:

The SPM, like the brick, is a **fully soldered, one-piece hybrid module**. In many ways, the primary function of the package has not changed—protect the battery from the user and the outside environment. The elimination of connectors, especially in the battery path, was a primary design requirement for this design effort. As an added benefit, the user can once again procure and stock only one item.

All of the SPM products use an **industry-standard, 27mm x 27mm, 256-ball PBGA footprint**. CAD designers will hopefully appreciate the departure from custom footprints.

The SPM products require a **minimized board area** (about $1in^2$) when compared to the PowerCap. The adjacent 'keep-out' area for battery-cap access is not applicable with this surface-mount package.

All of the SPM products are based upon a **standardized signal layout**. Every signal is routed through redundant ball connections, maximizing assembly line yields. Existing LPM or PowerCap board layouts containing memory densities up to 4Mb can execute a simple pad change to convert to an equivalent-density SPM.

The SPM products can be **handled with automated component placement equipment**, allowing for a fully automated board-assembly operation.

All of the SPM products are **convection reflow compatible**, based upon the soldering recommendations in the JEDEC J-STD-020 specification. All SPM reliability studies were initiated with a two-pass convection reflow preconditioning phase to emulate the customer's processing.

The SPM products can **tolerate aqueous cleaning solutions**, and are fully qualified for moisture sensitivity at MSL 3. SPM products are dry-packed and shipped in trays, ready for board assembly.

The SPM cavity package eliminates the need for potting, resulting in **reduced mass** of the component. This, in turn, reduces the product influence upon system vibration characteristics. A DS2065W (8Mb SPM) component's typical weight is 7.5g, compared to the DS1265W (8Mb brick) weight of 13.3g (approximately a 45% reduction).

The SPM package **allows for future product expansion**. Additional ball connections already exist for density expansion or custom product definitions.

The heart of the SPM is the ML-chemistry secondary battery. With any previous NV SRAM module, the primary lithium battery has a fixed charge capacity, and once that charge has been depleted, the battery must be replaced. As noted in Application Note 505, the useful service lifetime is based upon many factors, and estimating the remaining battery life of a module in a field installation can be difficult, at best. With the ML battery, the ability to occasionally replenish the battery charge can **extend the system service lifetime** to many decades.

The traditional lifetime expectation of a battery-backed memory product is based upon many years of accumulative battery backup. Realistically, most systems would not be powered off for consecutive years, assuming that the product was installed in the field and served some useful purpose in the first place. Whenever external V_{CC} power is applied to an SPM product, the nonvolatile controller/charger device will replenish the ML battery. Each recharge cycle provides up to three years of continuous battery backup. The highly regulated, float-charging function provided by the controller **virtually eliminates the self-discharge** phenomenon as a significant factor in battery-discharge calculations.

Conclusion

The SPM products have been designed to address the various issues associated with manufacturing and use of nonvolatile SRAMs, as voiced by the customer base. In every aspect, the SPM has significant advantages over packaging concepts previously introduced, as well as the technology leap brought about by the field application of rechargeable lithium coin-cell batteries. The ability to withstand soldering temperatures, as well as accept multiple recharge cycles, makes the ML coin cell a significant improvement over primary coin cells in most memory applications.

Questions/comments/suggestions concerning this application note can be sent to: MixedSignal.Apps@dalsemi.com.

Related Parts	
DS2030AB	Single-Piece 256kb Nonvolatile SRAM
DS2030L	3.3V Single-Piece 256Kb Nonvolatile SRAM
DS2030W	3.3V Single-Piece 256kb Nonvolatile SRAM
DS2030Y	Single-Piece 256kb Nonvolatile SRAM
DS2045AB	Single-Piece 1Mb Nonvolatile SRAM
DS2045L	3.3V Single-Piece 1Mb Nonvolatile SRAM
DS2045W	3.3V Single-Piece 1Mb Nonvolatile SRAM
DS2045Y	Single-Piece 1Mb Nonvolatile SRAM
DS2050W	3.3V Single-Piece 4Mb Nonvolatile SRAM
DS2065W	3.3V Single-Piece 8Mb Nonvolatile SRAM
DS2070W	3.3V Single-Piece 16Mb Nonvolatile SRAM
DS3030W	3.3V Single-Piece 256kb Nonvolatile SRAM with Clock
DS3045W	3.3V Single-Piece 1Mb Nonvolatile SRAM with Clock
DS3050W	3.3V Single-Piece 4Mb Nonvolatile SRAM with Clock

DS3065W	3.3V Single-Piece 8Mb Nonvolatile SRAM with Clock
DS3070W	3.3V Single-Piece 16Mb Nonvolatile SRAM with clock

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 3693: http://www.maximintegrated.com/an3693
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