Memory for Automotive In-Cabin and Under-the-Hood Applications

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The automotive market is well-known for adopting new technologies slowly and methodically. It often uses them initially in entertainment and navigation systems. As a technology matures, it may move into in-cabin applications - these are core automotive applications that are not subject to temperature extremes beyond those in other industrial electronics. The final step in a maturing technology is use in high-temperature automotive applications. FRAM (ferroelectric random-access memory) technology has been moving along this track.

As the most mature in a class of next-generation non-volatile memories, FRAM is increasingly aiding the automotive-design community through its fast write-speed and high-endurance characteristics. As such, FRAM is being designed into increasingly smarter in-cabin applications and is moving under the hood as more FRAM parts are being AEC-Q100 Grade 1-qualified to operate at between -40 and +125°C.

Smart-airbag systems

In the cabin, airbag technology is becoming increasingly smarter. In newer systems, "intelligence" is being added so that instead of deploying in the same way with all accidents, deployment force is determined by accident-event parameters such as the severity of the crash, the weight of the occupant, and the interaction with other safety systems within a vehicle. Vehicles are also being increasingly fitted with EDRs (event-data recorders) that collect crash information similar to an airplane "black box". The EDR function is normally included in the airbag ECU (electronic control unit). This is a natural architecture because the EDR does not have the survivability requirements of an airplane "black box" and because the airbag controller is the primary recipient of a variety of important sensor inputs. The recent decision by Hyundai Autonet to utilise non-volatile FRAM devices in its next-generation smart-airbag systems is further evidence of the growing recognition of the benefits of FRAM technology amongst leading automotive-system suppliers for use in such safety-critical applications. In this respect, Hyundai Autonet joins eight other automotive manufacturers across the United States, Asia, Japan and Europe who have opted for FRAM technology to provide the "intelligence" for smart-airbag systems and associated crash EDRs.

The parametric data that is sent to a vehicle's ECU is generated by sensors throughout a vehicle's interior, including sensors built into the seats that send data to the ECU so that the airbag can deploy "intelligently". As more and more sensors like these are added to cars, more data needs to be collected. FRAM allows automotive manufacturers to gather this data at higher frequencies, enabling a vehicle's systems to store and act on the timeliest information available. FRAM possesses key features for smart-airbag systems that floating-gate-memory devices such as EEPROM and Flash - previously predominant in automotive applications - cannot easily provide. These include non-volatility, unparalleled write endurance, and fast data collection. Non-volatility is important as crashes often result in a power outage, so at some point during the event the ECU will lose its connection to the battery. High endurance is desirable as the systems are required to collect a rolling window of data that is continuously overwritten with more up-to-date data. In addition to the EDR function, it is desirable to continuously record a data history from the occupant sensors. Fast write capability is also essential. As data requirements increase, the write speed becomes critical as power will most often soon fail. Currently, Ramtron's 16-kbit FM25C160 (Figure 1) is a popular choice among smart-airbag developers due to its 5V operating power and SPI interface.

Figure 1: Ramtron's FM25C160, now qualified to AEC-Q100 Grade 1.

Fast data capturing

In smart-airbag systems, it is not only necessary to store data in the event of a crash, but also desirable to store pre-crash data. To do this, a rolling log is used. In such cases, however, the low endurance of floating-gate-memory technology is problematic. Since airbag modules have large capacitors, which store sufficient energy to fire the airbag, there may be sufficient residual energy to write the data from a buffer after the squib has fired. The amount of data that can be written is limited by the energy available, i. e. the residual energy in the capacitor and the speed with which the memory can be written. A typical -kbyte floating-gate-memory device can write approximately 4bytes/5ms. To fill an entire floating-gate-memory device, therefore, can take more than a second. Using FRAM is less problematic; its endurance is high (1E12 and more), and its power requirement is significantly lower.

Extended data retention

The successful AEC-Q100 Grade 1 qualification of FRAM components is a technological milestone, which allows the technology to be more widely adopted across core automotive platforms. Significant interest already exists in high-temperature applications such as engine monitoring, steering, transmissions, and tyre-pressure monitoring, for example. These Grade 1 qualifications demonstrate operation at +125°C, even after a variety of qualification stresses. Component qualification uses stress to simulate the operating lifetime of a system. These stresses include high temperature, high voltage, low temperature, pressure, humidity, and rapid changes between extremes. Achieving this level of performance requires the demonstration of consistent reliability across the full temperature range. Grade 1 qualification is demanding for any component, but introduces additional challenges for a non-volatile memory. Beyond operation, a non-volatile memory must exhibit data retention over the system's lifetime. This is challenging because high temperature is a key accelerant of data loss, and the +125°C operating environment raises the bar considerably. For high-temperature automotive applications, the operating-temperature profile has two parts. When the vehicle is operating, the temperature is dictated by heat generators such as the engine, the transmission and the brakes. This temperature is much higher than with typical industrial or commercial applications. However, the total amount of time at elevated temperature is a small percentage of the total lifetime of a vehicle. The second part is non-operating time. Most of the vehicle's lifetime is non-operating, but this part must still be accounted for in the data-retention lifetime. In this situation, the range of temperatures is dictated by outdoor ambient temperature, so the average temperature is much lower than during operation. The FM25CL64-GA from Ramtron AEC-Q100 is a Grade 1-qualified part with upgraded data-retention specifications (Figure 2).

Figure 2: Ramtron's FM25CL64-GA: AEC-Q100 Grade 1-qualified part with upgraded data-retention specifications.

Under-the-hood applications

In order for FRAM technology to reach under-the-hood applications, a data-retention specification that considers the two-part profile needed to be developed. The first part is operating life; the second is the remainder of a vehicle's life. The high-temperature portion of its lifetime is based on a target of 250,000km of driving without major maintenance. Assuming an average speed of 56km/h, this leads to an operating time of just over 4400 hours. During this time, there is an elevated-operating-temperature profile, which ranges from the ambient temperature when the vehicle starts to +125°C. In some applications, there are excursions above this, but the time at such temperatures is critical and the excursions are insignificant. A model of a typical profile is shown in Figure 3. This model assumes 7400 operating hours rather than the expected 4400. In this profile there are roughly 3500 hours below +105°C and 3900 hours at or above +105°C. The average temperature of this profile is about +103°C. To accommodate this profile, the FRAM data-retention specification was set to 9000 hours at +125°C. Considering the reliability expectations of the automotive industry, this is a reasonable guard band.

Non-operating time

A vehicle's non-operating time is assumed to be roughly 14 years or 125,000 hours. The profile in Figure 4 is a typical temperature lifetime with an average of +38°C. In terms of data retention, the impact of 125,000 hours at an average of +38°C is a minimal burden compared to the high-temperature requirement. Note that the non-operating profile is skewed toward a very warm climate. For purposes of data retention, this is the most severe assumption. Once again, the FRAM specification is set with a generous guard band of 17 years at +55°C.

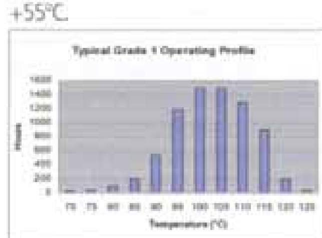

Figure 3: Typical Grade 1 operating profile.

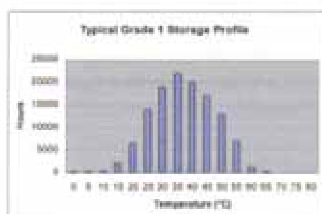

Figure 4: Typical Grade 1 storage profile.

Conclusion

As FRAM technology matures, the combination of the fastest write speed of any automotive-qualified non-volatile memory, a nearly unlimited write endurance, and low operating-power consumption provides automotive-system designers with significant new choices for data collection and storage.

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