Features

- 64-Kbit ferroelectric random access memory (F-RAM) logically organized as 8K × 8
  - High-endurance 10 trillion (10¹³) read/writes
  - 121-year data retention (See the Data Retention and Endurance table)
  - NoDelay™ writes
  - Advanced high-reliability ferroelectric process
- Very fast serial peripheral interface (SPI)
  - Up to 16 MHz frequency
  - Direct hardware replacement for serial flash and EEPROM
  - Supports SPI mode 0 (0, 0) and mode 3 (1, 1)
- Sophisticated write protection scheme
  - Hardware protection using the Write Protect (WP) pin
  - Software protection using Write Disable instruction
  - Software block protection for 1/4, 1/2, or entire array
- Low power consumption
  - 300 µA active current at 1 MHz
  - 6 µA (typ) standby current at +85 °C
- Low-voltage operation: VDD = 3.0 V to 3.6 V
- Automotive-E temperature: –40 °C to +125 °C
- 8-pin small outline integrated circuit (SOIC) package
- AEC-Q100 Grade 1 compliant
- Restriction of hazardous substances (RoHS) compliant

Functional Description

The FM25CL64B is a 64-Kbit nonvolatile memory employing an advanced ferroelectric process. A ferroelectric random access memory or F-RAM is nonvolatile and performs reads and writes similar to a RAM. It provides reliable data retention for 121 years while eliminating the complexities, overhead, and system level reliability problems caused by serial flash, EEPROM, and other nonvolatile memories.

Unlike serial flash and EEPROM, the FM25CL64B performs write operations at bus speed. No write delays are incurred. Data is written to the memory array immediately after each byte is successfully transferred to the device. The next bus cycle can commence without the need for data polling. In addition, the product offers substantial write endurance compared with other nonvolatile memories. The FM25CL64B is capable of supporting 10¹³ read/write cycles, or 10 million times more write cycles than EEPROM.

These capabilities make the FM25CL64B ideal for nonvolatile memory applications requiring frequent or rapid writes. Examples range from data collection, where the number of write cycles may be critical, to demanding industrial controls where the long write time of serial flash or EEPROM can cause data loss.

The FM25CL64B provides substantial benefits to users of serial EEPROM or flash as a hardware drop-in replacement. The FM25CL64B uses the high-speed SPI bus, which enhances the high-speed write capability of F-RAM technology. The device specifications are guaranteed over an automotive-E temperature range of –40 °C to +125 °C.

For a complete list of related resources, click here.

Logic Block Diagram
Contents

Pinout .................................................................3
Pin Definitions .......................................................3
Functional Overview ............................................4
Memory Architecture ..........................................4
Serial Peripheral Interface – SPI Bus .......................4
SPI Overview .......................................................4
SPI Modes ..........................................................6
Power Up to First Access .....................................6
Command Structure ..........................................6
WREN - Set Write Enable Latch ............................7
WRDI - Reset Write Enable Latch ...........................7
Status Register and Write Protection .....................7
RDSR - Read Status Register ................................8
WRSR - Write Status Register ................................8
Memory Operation .............................................9
Write Operation ................................................9
Read Operation ................................................9
HOLD Pin Operation ........................................10
Endurance .........................................................11
Maximum Ratings .............................................12
Operating Range ...............................................12
DC Electrical Characteristics .............................12
Data Retention and Endurance ............................13
Example of an F-RAM Life Time in an AEC-Q100 Automotive Application ..................13
Capacitance .........................................................13
Thermal Resistance .............................................13
AC Test Conditions ............................................13
AC Switching Characteristics .............................14
Power Cycle Timing ............................................16
Ordering Information ........................................17
Ordering Code Definitions ....................................17
Package Diagram ...............................................18
Acronyms ..........................................................19
Document Conventions ......................................19
Units of Measure ...............................................19
Document History Page .....................................20
Sales, Solutions, and Legal Information ..................21
Worldwide Sales and Design Support ....................21
Products ..........................................................21
PSoC® Solutions ................................................21
Cypress Developer Community ............................21
Technical Support ..............................................21
Figure 1. 8-pin SOIC pinout

<table>
<thead>
<tr>
<th>Pin</th>
<th>I/O Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>Input</td>
<td>Chip Select. This active LOW input activates the device. When HIGH, the device enters low-power standby mode, ignores other inputs, and tristates the output. When LOW, the device internally activates the SCK signal. A falling edge on CS must occur before every opcode.</td>
</tr>
<tr>
<td>SCK</td>
<td>Input</td>
<td>Serial Clock. All I/O activity is synchronized to the serial clock. Inputs are latched on the rising edge and outputs occur on the falling edge. Because the device is synchronous, the clock frequency may be any value between 0 and 16 MHz and may be interrupted at any time.</td>
</tr>
<tr>
<td>SI[1]</td>
<td>Input</td>
<td>Serial Input. All data is input to the device on this pin. The pin is sampled on the rising edge of SCK and is ignored at other times. It should always be driven to a valid logic level to meet IDD specifications.</td>
</tr>
<tr>
<td>SO[1]</td>
<td>Output</td>
<td>Serial Output. This is the data output pin. It is driven during a read and remains tristated at all other times including when HOLD is LOW. Data transitions are driven on the falling edge of the serial clock.</td>
</tr>
<tr>
<td>WP</td>
<td>Input</td>
<td>Write Protect. This active LOW pin prevents write operation to the Status Register when WPEN is set to ‘1’. This is critical because other write protection features are controlled through the Status Register. A complete explanation of write protection is provided in Status Register and Write Protection on page 8. This pin must be tied to VDD if not used.</td>
</tr>
<tr>
<td>HOLD</td>
<td>Input</td>
<td>HOLD Pin. The HOLD pin is used when the host CPU must interrupt a memory operation for another task. When HOLD is LOW, the current operation is suspended. The device ignores any transition on SCK or CS. All transitions on HOLD must occur while SCK is LOW. This pin must be tied to VDD if not used.</td>
</tr>
<tr>
<td>VSS</td>
<td>Power supply</td>
<td>Ground for the device. Must be connected to the ground of the system.</td>
</tr>
<tr>
<td>VDD</td>
<td>Power supply</td>
<td>Power supply input to the device.</td>
</tr>
</tbody>
</table>

Note
1. SI may be connected to SO for a single pin data interface.
Functional Overview

The FM25CL64B is a serial F-RAM memory. The memory array is logically organized as 8,192 × 8 bits and is accessed using an industry standard serial peripheral interface (SPI) bus. The functional operation of the F-RAM is similar to serial flash and serial EEPROMs. The major difference between the FM25CL64B and a serial flash or EEPROM with the same pinout is the F-RAM’s superior write performance, high endurance, and low power consumption.

Memory Architecture

When accessing the FM25CL64B, the user addresses 8K locations of eight data bits each. These eight data bits are shifted in or out serially. The addresses are accessed using the SPI protocol, which includes a chip select (to permit multiple devices on the bus), an opcode, and a two-byte address. The upper 3 bits of the address range are ‘don’t care’ values. The complete address of 13 bits specifies each byte address uniquely.

Most functions of the FM25CL64B are either controlled by the SPI interface or handled by on-board circuitry. The access time for the memory operation is essentially zero, beyond the time needed for the serial protocol. That is, the memory is read or written at the speed of the SPI bus. Unlike a serial flash or EEPROM, it is not necessary to poll the device for a ready condition because writes occur at bus speed. By the time a new bus transaction can be shifted into the device, a write operation is complete. This is explained in more detail in the interface section.

Note The FM25CL64B contains no power management circuits other than a simple internal power-on reset circuit. It is the user’s responsibility to ensure that VDD is within datasheet tolerances to prevent incorrect operation. It is recommended that the part is not powered down with chip enable active.

Serial Peripheral Interface – SPI Bus

The FM25CL64B is a SPI slave device and operates at speeds up to 16 MHz. This high-speed serial bus provides high-performance serial communication to a SPI master. Many common microcontrollers have hardware SPI ports allowing a direct interface. It is quite simple to emulate the port using ordinary port pins for microcontrollers that do not. The FM25CL64B operates in SPI Mode 0 and 3.

SPI Overview

The SPI is a four-pin interface with Chip Select (CS), Serial Input (Si), Serial Output (SO), and Serial Clock (SCK) pins.

The SPI is a synchronous serial interface, which uses clock and data pins for memory access and supports multiple devices on the data bus. A device on the SPI bus is activated using the CS pin.

The relationship between chip select, clock, and data is dictated by the SPI mode. This device supports SPI modes 0 and 3. In both of these modes, data is clocked into the F-RAM on the rising edge of SCK starting from the first rising edge after CS goes active.

The SPI protocol is controlled by opcodes. These opcodes specify the commands from the bus master to the slave device. After CS is activated, the first byte transferred from the bus master is the opcode. Following the opcode, any addresses and data are then transferred. The CS must go inactive after an operation is complete and before a new opcode can be issued. The commonly used terms in the SPI protocol are as follows:

SPI Master

The SPI master device controls the operations on a SPI bus. An SPI bus may have only one master with one or more slave devices. All the slaves share the same SPI bus lines and the master may select any of the slave devices using the CS pin. All of the operations must be initiated by the master activating a slave device by pulling the CS pin of the slave LOW. The master also generates the SCK and all the data transmission on SI and SO lines are synchronized with this clock.

SPI Slave

The SPI slave device is activated by the master through the Chip Select line. A slave device gets the SCK as an input from the SPI master and all the communication is synchronized with this clock. An SPI slave never initiates a communication on the SPI bus and acts only on the instruction from the master.

The FM25CL64B operates as an SPI slave and may share the SPI bus with other SPI slave devices.

Chip Select (CS)

To select any slave device, the master needs to pull down the corresponding CS pin. Any instruction can be issued to a slave device only while the CS pin is LOW. When the device is not selected, data through the SI pin is ignored and the serial output pin (SO) remains in a high-impedance state.

Note A new instruction must begin with the falling edge of CS.

Therefore, only one opcode can be issued for each active Chip Select cycle.

Serial Clock (SCK)

The Serial Clock is generated by the SPI master and the communication is synchronized with this clock after CS goes LOW.

The FM25CL64B enables SPI modes 0 and 3 for data communication. In both of these modes, the inputs are latched by the slave device on the rising edge of SCK and outputs are issued on the falling edge. Therefore, the first rising edge of SCK signifies the arrival of the first bit (MSB) of a SPI instruction on the SI pin. Further, all data inputs and outputs are synchronized with SCK.
Data Transmission (SI/SO)
The SPI data bus consists of two lines, SI and SO, for serial data communication. SI is also referred to as Master Out Slave In (MOSI) and SO is referred to as Master In Slave Out (MISO). The master issues instructions to the slave through the SI pin, while the slave responds through the SO pin. Multiple slave devices may share the SI and SO lines as described earlier.

The FM25CL64B has two separate pins for SI and SO, which can be connected with the master as shown in Figure 2. For a microcontroller that has no dedicated SPI bus, a general-purpose port may be used. To reduce hardware resources on the controller, it is possible to connect the two data pins (SI, SO) together and tie off (HIGH) the HOLD and WP pins. Figure 3 shows such a configuration, which uses only three pins.
Most Significant Bit (MSB)
The SPI protocol requires that the first bit to be transmitted is the Most Significant Bit (MSB). This is valid for both address and data transmission. The 64-Kbit serial F-RAM requires a 2-byte address for any read or write operation. Because the address is only 13 bits, the first three bits which are fed in are ignored by the device. Although these three bits are ‘don’t care’, Cypress recommends that these bits be set to 0s to enable seamless transition to higher memory densities.

Serial Opcode
After the slave device is selected with CS going LOW, the first byte received is treated as the opcode for the intended operation. FM25CL64B uses the standard opcodes for memory accesses.

Invalid Opcode
If an invalid opcode is received, the opcode is ignored and the device ignores any additional serial data on the SI pin until the next falling edge of CS, and the SO pin remains tristated.

Status Register
FM25CL64B has an 8-bit Status Register. The bits in the Status Register are used to configure the device. These bits are described in Table 3 on page 8.

SPI Modes
FM25CL64B may be driven by a microcontroller with its SPI peripheral running in either of the following two modes:
- SPI Mode 0 (CPOL = 0, CPHA = 0)
- SPI Mode 3 (CPOL = 1, CPHA = 1)
For both these modes, the input data is latched in on the rising edge of SCK starting from the first rising edge after CS goes active. If the clock starts from a HIGH state (in mode 3), the first rising edge after the clock toggles is considered. The output data is available on the falling edge of SCK.

The two SPI modes are shown in Figure 4 and Figure 5. The status of the clock when the bus master is not transferring data is:
- SCK remains at 0 for Mode 0
- SCK remains at 1 for Mode 3
The device detects the SPI mode from the status of the SCK pin when the device is selected by bringing the CS pin LOW. If the SCK pin is LOW when the device is selected, SPI Mode 0 is assumed and if the SCK pin is HIGH, it works in SPI Mode 3.

Power Up to First Access
The FM25CL64B is not accessible for a tpu time after power up. Users must comply with the timing parameter tpu, which is the minimum time from Vdd (min) to the first CS LOW.

Command Structure
There are six commands, called opcodes, that can be issued by the bus master to the FM25CL64B. They are listed in Table 1. These opcodes control the functions performed by the memory.

Table 1. Opcode commands

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Opcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>WREN</td>
<td>Set write enable latch</td>
<td>0000 0110b</td>
</tr>
<tr>
<td>WRDI</td>
<td>Write disable</td>
<td>0000 0100b</td>
</tr>
<tr>
<td>RDSR</td>
<td>Read Status Register</td>
<td>0000 0101b</td>
</tr>
<tr>
<td>WRSR</td>
<td>Write Status Register</td>
<td>0000 0001b</td>
</tr>
<tr>
<td>READ</td>
<td>Read memory data</td>
<td>0000 0011b</td>
</tr>
<tr>
<td>WRITE</td>
<td>Write memory data</td>
<td>0000 0010b</td>
</tr>
</tbody>
</table>
WREN - Set Write Enable Latch

The FM25CL64B will power up with writes disabled. The WREN command must be issued before any write operation. Sending the WREN opcode allows the user to issue subsequent opcodes for write operations. These include writing the Status Register (WRSR) and writing the memory (WRITE).

Sending the WREN opcode causes the internal Write Enable Latch to be set. A flag bit in the Status Register, called WEL, indicates the state of the latch. WEL = ‘1’ indicates that writes are permitted. Attempting to write the WEL bit in the Status Register has no effect on the state of this bit – only the WREN opcode can set this bit. The WEL bit will be automatically cleared on the rising edge of CS following a WRDI, a WRSR, or a WRITE operation. This prevents further writes to the Status Register or the F-RAM array without another WREN command. Figure 6 illustrates the WREN command bus configuration.

WRDI - Reset Write Enable Latch

The WRDI command disables all write activity by clearing the Write Enable Latch. The user can verify that writes are disabled by reading the WEL bit in the Status Register and verifying that WEL is equal to ‘0’. Figure 7 illustrates the WRDI command bus configuration.

Figure 6. WREN Bus Configuration

Figure 7. WRDI Bus Configuration
Status Register and Write Protection

The write protection features of the FM25CL64B are multi-tiered and are enabled through the status register. The Status Register is organized as follows. (The default value shipped from the factory for bits in the Status Register is ‘0’.)

Table 2. Status Register

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPEN</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>BP1</td>
<td>BP0</td>
<td>WEL</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 3. Status Register Bit Definition

<table>
<thead>
<tr>
<th>Bit</th>
<th>Definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit 0</td>
<td>Don’t care</td>
<td>This bit is non-writable and always returns ‘0’ upon read.</td>
</tr>
<tr>
<td>Bit 1 (WEL)</td>
<td>Write Enable Latch</td>
<td>WEL indicates if the device is write enabled. This bit defaults to ‘0’ (disabled) on power-up. WEL = ‘1’ --&gt; Write enabled WEL = ‘0’ --&gt; Write disabled</td>
</tr>
<tr>
<td>Bit 2 (BP0)</td>
<td>Block Protect bit ‘0’</td>
<td>Used for block protection. For details, see Table 4.</td>
</tr>
<tr>
<td>Bit 3 (BP1)</td>
<td>Block Protect bit ‘1’</td>
<td>Used for block protection. For details, see Table 4.</td>
</tr>
<tr>
<td>Bit 4-6</td>
<td>Don’t care</td>
<td>These bits are non-writable and always return ‘0’ upon read.</td>
</tr>
<tr>
<td>Bit 7 (WPEN)</td>
<td>Write Protect Enable bit</td>
<td>Used to enable the function of Write Protect Pin (WP). For details, see Table 5.</td>
</tr>
</tbody>
</table>

Bits 0 and 4–6 are fixed at ‘0’; none of these bits can be modified. Note that bit 0 (“Ready or Write in progress” bit in serial flash and EEPROM) is unnecessary, as the F-RAM writes in real-time and is never busy, so it reads out as a ‘0’. The BP1 and BP0 control the software write-protection features and are nonvolatile bits. The WEL flag indicates the state of the Write Enable Latch. Attempting to directly write the WEL bit in the Status Register has no effect on its state. This bit is internally set and cleared via the WREN and WRDI commands, respectively.

BP1 and BP0 are memory block write protection bits. They specify portions of memory that are write-protected as shown in Table 4.

Table 4. Block Memory Write Protection

<table>
<thead>
<tr>
<th>BP1</th>
<th>BP0</th>
<th>Protected Address Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1800h to 1FFFh (upper 1/4)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1000h to 1FFFh (upper 1/2)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0000h to 1FFFh (all)</td>
</tr>
</tbody>
</table>

The BP1 and BP0 bits and the Write Enable Latch are the only mechanisms that protect the memory from writes. The remaining write protection features protect inadvertent changes to the block protect bits.

The write protect enable bit (WPEN) in the Status Register controls the effect of the hardware write protect (WP) pin. When the WPEN bit is set to ‘0’, the status of the WP pin is ignored. When the WPEN bit is set to ‘1’, a LOW on the WP pin inhibits a write to the Status Register. Thus the Status Register is write-protected only when WPEN = ‘1’ and WP = ‘0’.

Table 5 summarizes the write protection conditions.

Table 5. Write Protection

<table>
<thead>
<tr>
<th>WEL</th>
<th>WPEN</th>
<th>WP</th>
<th>Protected Blocks</th>
<th>Unprotected Blocks</th>
<th>Status Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>X</td>
<td>X</td>
<td>Protected</td>
<td>Protected</td>
<td>Protected</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>X</td>
<td>Protected</td>
<td>Unprotected</td>
<td>Unprotected</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Protected</td>
<td>Unprotected</td>
<td>Protected</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Protected</td>
<td>Unprotected</td>
<td>Unprotected</td>
</tr>
</tbody>
</table>

RDSR - Read Status Register

The RDSR command allows the bus master to verify the contents of the Status Register. Reading the status register provides information about the current state of the write-protection features. Following the RDSR opcode, the FM25CL64B will return one byte with the contents of the Status Register.

WRSR - Write Status Register

The WRSR command allows the SPI bus master to write into the Status Register and change the write protect configuration by setting the WPEN, BP0 and BP1 bits as required. Before issuing a WRSR command, the WP pin must be HIGH or inactive. Note that on the FM25CL64B, WP only prevents writing to the Status Register, not the memory array. Before sending the WRSR command, the user must send a WREN command to enable writes. Executing a WRSR command is a write operation and therefore, clears the Write Enable Latch.
Memory Operation

The SPI interface, which is capable of a high clock frequency, highlights the fast write capability of the F-RAM technology. Unlike serial flash and EEPROMs, the FM25CL64B can perform sequential writes at bus speed. No page register is needed and any number of sequential writes may be performed.

Write Operation

All writes to the memory begin with a WREN opcode. The WRITE opcode is followed by a two-byte address containing the 13-bit address (A12–A0) of the first data byte to be written into the memory. The upper three bits of the two-byte address are ignored. Subsequent bytes are data bytes, which are written sequentially. Addresses are incremented internally as long as the bus master continues to issue clocks and keeps CS LOW. If the last address of 1FFFh is reached, the counter will roll over to 0000h. Data is written MSB first. The rising edge of CS terminates a write operation. A write operation is shown in Figure 10 on page 10.

Note When a burst write reaches a protected block address, the automatic address increment stops and all the subsequent data bytes received for write will be ignored by the device.

EEPROMs use page buffers to increase their write throughput. This compensates for the technology’s inherently slow write operations. F-RAM memories do not have page buffers because each byte is written to the F-RAM array immediately after it is clocked in (after the eighth clock). This allows any number of bytes to be written without page buffer delays.

Note If the power is lost in the middle of the write operation, only the last completed byte will be written.

Read Operation

After the falling edge of CS, the bus master can issue a READ opcode. Following the READ command is a two-byte address containing the 13-bit address (A12–A0) of the first byte of the read operation. The upper three bits of the address are ignored. After the opcode and address are issued, the device drives out the read data on the next eight clocks. The SI input is ignored during read data bytes. Subsequent bytes are data bytes, which are read out sequentially. Addresses are incremented internally as long as the bus master continues to issue clocks and CS is LOW. If the last address of 1FFFh is reached, the counter will roll over to 0000h. Data is read MSB first. The rising edge of CS terminates a read operation and tristates the SO pin. A read operation is shown in Figure 11 on page 10.
HOLD Pin Operation

The HOLD pin can be used to interrupt a serial operation without aborting it. If the bus master pulls the HOLD pin LOW while SCK is LOW, the current operation will pause. Taking the HOLD pin HIGH while SCK is LOW will resume an operation. The transitions of HOLD must occur while SCK is LOW, but the SCK and CS pin can toggle during a hold state.

Note

2. Figure shows HOLD operation for input mode and output mode.
Endurance

The FM25CL64B devices are capable of being accessed at least $10^{13}$ times, reads or writes. An F-RAM memory operates with a read and restore mechanism. Therefore, an endurance cycle is applied on a row basis for each access (read or write) to the memory array. The F-RAM architecture is based on an array of rows and columns of 1K rows of 64-bits each. The entire row is internally accessed once whether a single byte or all eight bytes are read or written. Each byte in the row is counted only once in an endurance calculation. Table 6 shows endurance calculations for a 64-byte repeating loop, which includes an opcode, a starting address, and a sequential 64-byte data stream. This causes each byte to experience one endurance cycle through the loop.

Table 6. Time to Reach Endurance Limit for Repeating 64-byte Loop

<table>
<thead>
<tr>
<th>SCK Freq (MHz)</th>
<th>Endurance Cycles/sec</th>
<th>Endurance Cycles/year</th>
<th>Years to Reach Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>18,660</td>
<td>$5.88 \times 10^{11}$</td>
<td>17.0</td>
</tr>
<tr>
<td>5</td>
<td>9,330</td>
<td>$2.94 \times 10^{11}$</td>
<td>34.0</td>
</tr>
<tr>
<td>1</td>
<td>1,870</td>
<td>$5.88 \times 10^{10}$</td>
<td>170.1</td>
</tr>
</tbody>
</table>
**Maximum Ratings**

Exceeding maximum ratings may shorten the useful life of the device. These user guidelines are not tested.

**Storage temperature** ............................................. –55 °C to +150 °C

**Maximum accumulated storage time**
- At 150 °C ambient temperature ................................. 1000 h
- At 125 °C ambient temperature ................................. 11000 h
- At 85 °C ambient temperature ................................. 121 Years

**Ambient temperature**
- with power applied ............................................ –55 °C to +125 °C
- Supply voltage on VDD relative to VSS ............. –1.0 V to +5.0 V
- Input voltage .................................................. –1.0 V to +5.0 V and V_IN < V_DD+1.0 V
- DC voltage applied to outputs
  - in High Z state ............................................. –0.5 V to V_DD + 0.5 V
  - Transient voltage (< 20 ns)
    - on any pin to ground potential .................. –2.0 V to V_DD + 2.0 V

**DC Electrical Characteristics**

Over the Operating Range

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_DD</td>
<td>Power supply</td>
<td></td>
<td>3.0</td>
<td>3.3</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>I_DD</td>
<td>V_DD supply current</td>
<td>V_DD = 0.3 V and V_SS = 0.3 V, SCK toggling between V_DD and V_SS, other inputs V_SS or V_DD = 0.3 V, SO = Open.</td>
<td>–</td>
<td>–</td>
<td>0.3</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>f_SCK = 1 MHz</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>f_SCK = 16 MHz</td>
<td>–</td>
<td>–</td>
<td>3</td>
<td>mA</td>
</tr>
<tr>
<td>I_SB</td>
<td>V_DD standby current</td>
<td>CS = V_DD, All other inputs V_SS or V_DD.</td>
<td>–</td>
<td>–</td>
<td>6</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TA = 85 °C</td>
<td>–</td>
<td>–</td>
<td>20</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TA = 125 °C</td>
<td>–</td>
<td>–</td>
<td>2</td>
<td>μA</td>
</tr>
<tr>
<td>I_IL</td>
<td>Input leakage current</td>
<td>V_SS ≤ V_IN ≤ V_DD</td>
<td>–</td>
<td>–</td>
<td>±1</td>
<td>μA</td>
</tr>
<tr>
<td>I_LO</td>
<td>Output leakage current</td>
<td>V_SS ≤ V_OUT ≤ V_DD</td>
<td>–</td>
<td>–</td>
<td>±1</td>
<td>μA</td>
</tr>
<tr>
<td>V_IH</td>
<td>Input HIGH voltage</td>
<td></td>
<td>0.75 VDD</td>
<td>–</td>
<td>V_DD + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>V_IL</td>
<td>Input LOW voltage</td>
<td></td>
<td>–</td>
<td>0.3</td>
<td>0.25 VDD</td>
<td>V</td>
</tr>
<tr>
<td>V_OH</td>
<td>Output HIGH voltage</td>
<td>I_OH = –2 mA</td>
<td>V_DD</td>
<td>–</td>
<td>–</td>
<td>V</td>
</tr>
<tr>
<td>V_OF</td>
<td>Output LOW voltage</td>
<td>I_OH = 2 mA</td>
<td>–</td>
<td>–</td>
<td>0.4</td>
<td>V</td>
</tr>
<tr>
<td>V_HYS[4]</td>
<td>Input Hysteresis (CS and SCK pin)</td>
<td></td>
<td>0.05 VDD</td>
<td>–</td>
<td>–</td>
<td>V</td>
</tr>
</tbody>
</table>

**Operating Range**

<table>
<thead>
<tr>
<th>Range</th>
<th>Ambient Temperature (TA)</th>
<th>V_DD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive-E</td>
<td>–40 °C to +125 °C</td>
<td>3.0 V to 3.6 V</td>
</tr>
</tbody>
</table>
Data Retention and Endurance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Test condition</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_{DR}</td>
<td>Data retention</td>
<td>T_{A} = 125 °C</td>
<td>11000</td>
<td>–</td>
<td>Hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_{A} = 105 °C</td>
<td>11</td>
<td>–</td>
<td>Years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_{A} = 85 °C</td>
<td>121</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>NV_{C}</td>
<td>Endurance</td>
<td>Over operating temp</td>
<td>10^{13}</td>
<td>–</td>
<td>Cycles</td>
</tr>
</tbody>
</table>

Example of an F-RAM Life Time in an AEC-Q100 Automotive Application

An application does not operate under a steady temperature for the entire usage life time of the application. Instead, it is often expected to operate in multiple temperature environments throughout the application’s usage life time. Accordingly, the retention specification for F-RAM in applications often needs to be calculated cumulatively. An example calculation for a multi-temperature thermal profiles is given below.

<table>
<thead>
<tr>
<th>Temperature T</th>
<th>Time Factor t</th>
<th>Acceleration Factor with respect to Tmax A [^5]</th>
<th>Profile Factor P</th>
<th>Profile Life Time L (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_1 = 125 °C</td>
<td>t_1 = 0.1</td>
<td>A_1 = 1</td>
<td>8.33</td>
<td>&gt; 10.46 Years</td>
</tr>
<tr>
<td>T_2 = 105 °C</td>
<td>t_2 = 0.15</td>
<td>A_2 = 8.67</td>
<td>8.33</td>
<td>&gt; 10.46 Years</td>
</tr>
<tr>
<td>T_3 = 85 °C</td>
<td>t_3 = 0.25</td>
<td>A_3 = 95.68</td>
<td>8.33</td>
<td>&gt; 10.46 Years</td>
</tr>
<tr>
<td>T_4 = 55 °C</td>
<td>t_4 = 0.50</td>
<td>A_4 = 6074.80</td>
<td>8.33</td>
<td>&gt; 10.46 Years</td>
</tr>
</tbody>
</table>

\[ A = \exp\left(\frac{\frac{1}{T} - \frac{1}{T_{\text{max}}}}{k \cdot T_{\text{max}}} \right) \]

\[ P = \frac{1}{\left(\frac{1}{A_1} + \frac{1}{A_2} + \frac{1}{A_3} + \frac{1}{A_4}\right)} \]

\[ L(P) = P \times L(T_{\text{max}}) \]

Capacitance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Test Conditions</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_O</td>
<td>Output pin capacitance (SO)</td>
<td>T_{A} = 25 °C, f = 1 MHz, V_{DD} = V_{DD}(typ)</td>
<td>8</td>
<td>pF</td>
</tr>
<tr>
<td>C_I</td>
<td>Input pin capacitance</td>
<td></td>
<td>6</td>
<td>pF</td>
</tr>
</tbody>
</table>

Thermal Resistance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Test Conditions</th>
<th>8-pin SOIC</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Theta_{JA})</td>
<td>Thermal resistance  (junction to ambient)</td>
<td>Test conditions follow standard test methods and procedures for measuring thermal impedance, per EIA/JESD51.</td>
<td>148</td>
<td>°C/W</td>
</tr>
<tr>
<td>(\Theta_{JC})</td>
<td>Thermal resistance  (junction to case)</td>
<td></td>
<td>48</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

AC Test Conditions

Input pulse levels .................................10% and 90% of V_{DD}
Input rise and fall times ..............................5 ns
Input and output timing reference levels ..........0.5 \times V_{DD}
Output load capacitance ............................30 pF

Notes
5. Where k is the Boltzmann constant 8.617 \times 10^{-5} eV/K, Tmax is the highest temperature specified for the product, and T is any temperature within the F-RAM product specification. All temperatures are in Kelvin in the equation.
6. This parameter is characterized and not 100% tested.
# AC Switching Characteristics

Over the Operating Range

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{SCK}$</td>
<td>SCK Clock frequency</td>
<td>0</td>
<td>16</td>
<td>MHz</td>
</tr>
<tr>
<td>$t_{CH}$</td>
<td>Clock HIGH time</td>
<td>25</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{CL}$</td>
<td>Clock LOW time</td>
<td>25</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{CSU}$</td>
<td>Chip select setup</td>
<td>10</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{CSH}$</td>
<td>Chip select hold</td>
<td>10</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{OD}^{[8, 9]}$</td>
<td>Output disable time</td>
<td>–</td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{ODV}$</td>
<td>Output data valid time</td>
<td>–</td>
<td>25</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{OH}$</td>
<td>Output hold time</td>
<td>0</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{D}$</td>
<td>Deselect time</td>
<td>60</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{R}^{[10, 11]}$</td>
<td>Data in rise time</td>
<td>–</td>
<td>50</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{F}^{[10, 11]}$</td>
<td>Data in fall time</td>
<td>–</td>
<td>50</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{SU}$</td>
<td>Data setup time</td>
<td>5</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{H}$</td>
<td>Data hold time</td>
<td>5</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{HS}$</td>
<td>HOLD setup time</td>
<td>10</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{HH}$</td>
<td>HOLD hold time</td>
<td>10</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{HZ}^{[8, 9]}$</td>
<td>HOLD LOW to HI-Z</td>
<td>–</td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{LZ}^{[9]}$</td>
<td>HOLD HIGH to data active</td>
<td>–</td>
<td>20</td>
<td>ns</td>
</tr>
</tbody>
</table>

**Notes**

7. Test conditions assume a signal transition time of 5 ns or less, timing reference levels of $0.5 \times V_{DD}$, input pulse levels of 10% to 90% of $V_{DD}$, and output loading of the specified $I_{OL}/I_{OH}$ and 30 pF load capacitance shown in AC Test Conditions on page 13.

8. $t_{OD}$ and $t_{ODZ}$ are specified with a load capacitance of 5 pF. Transition is measured when the outputs enter a high impedance state.

9. This parameter is characterized and not 100% tested.

10. Rise and fall times measured between 10% and 90% of waveform.

11. These parameters are guaranteed by design and are not tested.
Figure 13. Synchronous Data Timing (Mode 0)

Figure 14. HOLD Timing
## Power Cycle Timing

Over the Operating Range

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>t_{PU}</td>
<td>Power-up V_{DD(min)} to first access (CS LOW)</td>
<td>1</td>
<td>–</td>
<td>ms</td>
</tr>
<tr>
<td>t_{PD}</td>
<td>Last access (CS HIGH) to power-down (V_{DD(min)})</td>
<td>0</td>
<td>–</td>
<td>µs</td>
</tr>
<tr>
<td>t_{VR}</td>
<td>V_{DD} power-up ramp rate</td>
<td>30</td>
<td>–</td>
<td>µs/V</td>
</tr>
<tr>
<td>t_{VF}</td>
<td>V_{DD} power-down ramp rate</td>
<td>20</td>
<td>–</td>
<td>µs/V</td>
</tr>
</tbody>
</table>

**Figure 15. Power Cycle Timing**

Note 12. Slope measured at any point on V_{DD} waveform.
## Ordering Information

<table>
<thead>
<tr>
<th>Ordering Code</th>
<th>Package Diagram</th>
<th>Package Type</th>
<th>Operating Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM25CL64B-GA</td>
<td>51-85066</td>
<td>8-pin SOIC</td>
<td>Automotive-E</td>
</tr>
<tr>
<td>FM25CL64B-GATR</td>
<td>51-85066</td>
<td>8-pin SOIC</td>
<td>Automotive-E</td>
</tr>
</tbody>
</table>

All these parts are Pb-free. Contact your local Cypress sales representative for availability of these parts.

### Ordering Code Definitions

- Option: X = blank or TR
  - blank = Standard; TR = Tape and Reel
- Temperature Range:
  - A = Automotive-E (−40 °C to +125 °C)
- Package Type:
  - G = 8-pin SOIC
- Die revision: B
- Density: 64 = 64-Kbit
- Voltage: CL = 3.0 V to 3.6 V
- SPI F-RAM
- Cypress
Figure 16. 8-pin SOIC (150 Mils) Package Outline, 51-85066

1. DIMENSIONS IN INCHES[MM] MIN. MAX.

2. PIN 1 ID IS OPTIONAL, ROUND ON SINGLE LEADFRAME OR RECTANGULAR ON MATRIX LEADFRAME

3. REFERENCE JEDEC MS-012

4. PACKAGE WEIGHT 0.07gms

<table>
<thead>
<tr>
<th>PART #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOR, 15</td>
<td>STANDARD PKG</td>
</tr>
<tr>
<td>S Zo, 15</td>
<td>LEAD FREE PKG</td>
</tr>
<tr>
<td>S W, 15</td>
<td>LEAD FREE PKG</td>
</tr>
</tbody>
</table>

51-85066 *H
### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEC</td>
<td>Automotive Electronics Council</td>
</tr>
<tr>
<td>CPHA</td>
<td>Clock Phase</td>
</tr>
<tr>
<td>CPOL</td>
<td>Clock Polarity</td>
</tr>
<tr>
<td>EEPROM</td>
<td>Electrically Erasable Programmable Read-Only Memory</td>
</tr>
<tr>
<td>EIA</td>
<td>Electronic Industries Alliance</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>JEDEC</td>
<td>Joint Electron Devices Engineering Council</td>
</tr>
<tr>
<td>JESD</td>
<td>JEDEC Standards</td>
</tr>
<tr>
<td>LSB</td>
<td>Least Significant Bit</td>
</tr>
<tr>
<td>MSB</td>
<td>Most Significant Bit</td>
</tr>
<tr>
<td>F-RAM</td>
<td>Ferroelectric Random Access Memory</td>
</tr>
<tr>
<td>RoHS</td>
<td>Restriction of Hazardous Substances</td>
</tr>
<tr>
<td>SPI</td>
<td>Serial Peripheral Interface</td>
</tr>
<tr>
<td>SOIC</td>
<td>Small Outline Integrated Circuit</td>
</tr>
</tbody>
</table>

### Document Conventions

#### Units of Measure

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>degree Celsius</td>
</tr>
<tr>
<td>Hz</td>
<td>hertz</td>
</tr>
<tr>
<td>kHz</td>
<td>kilohertz</td>
</tr>
<tr>
<td>KΩ</td>
<td>kilohm</td>
</tr>
<tr>
<td>Kbit</td>
<td>kilobit</td>
</tr>
<tr>
<td>kV</td>
<td>kilovolt</td>
</tr>
<tr>
<td>MHz</td>
<td>megahertz</td>
</tr>
<tr>
<td>μA</td>
<td>microampere</td>
</tr>
<tr>
<td>μs</td>
<td>microsecond</td>
</tr>
<tr>
<td>mA</td>
<td>milliampere</td>
</tr>
<tr>
<td>ms</td>
<td>millisecond</td>
</tr>
<tr>
<td>ns</td>
<td>nanosecond</td>
</tr>
<tr>
<td>Ω</td>
<td>ohm</td>
</tr>
<tr>
<td>%</td>
<td>percent</td>
</tr>
<tr>
<td>pF</td>
<td>picofarad</td>
</tr>
<tr>
<td>V</td>
<td>volt</td>
</tr>
<tr>
<td>W</td>
<td>watt</td>
</tr>
</tbody>
</table>
### Document History Page

#### Document Title: FM25CL64B, 64-Kbit (8K × 8) Serial (SPI) Automotive F-RAM
#### Document Number: 001-86149

<table>
<thead>
<tr>
<th>Rev.</th>
<th>ECN No.</th>
<th>Orig. of Change</th>
<th>Submission Date</th>
<th>Description of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>**</td>
<td>3912930</td>
<td>GVCH</td>
<td>02/25/2013</td>
<td>New data sheet.</td>
</tr>
<tr>
<td>*A</td>
<td>3985108</td>
<td>GVCH</td>
<td>05/07/2013</td>
<td>Updated SOIC package marking scheme.</td>
</tr>
<tr>
<td>*C</td>
<td>4724164</td>
<td>PSR</td>
<td>04/14/2015</td>
<td>Updated <strong>Functional Description:</strong> Added &quot;For a complete list of related resources, click here.&quot; at the end. Updated <strong>Package Diagram:</strong> spec 51-85066 – Changed revision from *F to *G. Updated to new template.</td>
</tr>
<tr>
<td>*D</td>
<td>4835587</td>
<td>SDHK</td>
<td>07/13/2015</td>
<td>Updated <strong>Memory Operation:</strong> Updated <strong>Read Operation</strong> (Updated formatting only).</td>
</tr>
<tr>
<td>*E</td>
<td>4884720</td>
<td>ZSK / PSR</td>
<td>08/14/2015</td>
<td>Updated <strong>Maximum Ratings:</strong> Updated ratings of &quot;Storage temperature&quot; (Replaced “+125 °C” with “+150 °C”). Removed &quot;Maximum junction temperature&quot;. Added &quot;Maximum accumulated storage time&quot;. Added &quot;Ambient temperature with power applied&quot;.</td>
</tr>
<tr>
<td>*F</td>
<td>5747680</td>
<td>SDHK / GVCH</td>
<td>05/24/2017</td>
<td>Updated <strong>Ordering Code Definitions under Ordering Information:</strong> Fixed typo (Replaced “Density: 04 = 4-Kbit” with “Density: 64 = 64-Kbit”). Updated <strong>Package Diagram:</strong> spec 51-85066 – Changed revision from *G to *H. Updated to new template.</td>
</tr>
</tbody>
</table>
Sales, Solutions, and Legal Information

Worldwide Sales and Design Support
Cypress maintains a worldwide network of offices, solution centers, manufacturer’s representatives, and distributors. To find the office closest to you, visit us at Cypress Locations.

Products

<table>
<thead>
<tr>
<th>Category</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARM® Cortex® Microcontrollers</td>
<td>cypress.com/arm</td>
</tr>
<tr>
<td>Automotive</td>
<td>cypress.com/automotive</td>
</tr>
<tr>
<td>Clocks &amp; Buffers</td>
<td>cypress.com/clocks</td>
</tr>
<tr>
<td>Interface</td>
<td>cypress.com/interface</td>
</tr>
<tr>
<td>Internet of Things</td>
<td>cypress.com/iot</td>
</tr>
<tr>
<td>Memory</td>
<td>cypress.com/memory</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>cypress.com/mcu</td>
</tr>
<tr>
<td>PSoC</td>
<td>cypress.com/psoc</td>
</tr>
<tr>
<td>Power Management ICs</td>
<td>cypress.com/pmic</td>
</tr>
<tr>
<td>Touch Sensing</td>
<td>cypress.com/touch</td>
</tr>
<tr>
<td>USB Controllers</td>
<td>cypress.com/usb</td>
</tr>
<tr>
<td>Wireless Connectivity</td>
<td>cypress.com/wireless</td>
</tr>
</tbody>
</table>

PSoC® Solutions

<table>
<thead>
<tr>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSoC 1</td>
</tr>
</tbody>
</table>

Cypress Developer Community

<table>
<thead>
<tr>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forums</td>
</tr>
</tbody>
</table>

Technical Support

cypress.com/support