**Introduction**

Electrically Erasable Programmable Read-Only Memory (EEPROM) devices are often used by end applications to store relatively small amounts of data which are retained when power is not supplied to the system. This type of data storage is valuable to applications requiring calibration data, unit identification, or backup information. Such an operation can be emulated by using ferroelectric random access memory (FRAM) available on select MSP430™ microcontrollers (MCUs). The ultra-low-power nature of FRAM makes it a great option for EEPROM emulation enabling nonvolatile writes for a fraction of the power used by conventional memories. Furthermore, FRAM offers practically unlimited write cycles and is not stressed from constantly logging data or saving system information. 48 bytes of FRAM are allocated to EEPROM functionality on the MSP430FR2000 MCU, a cost-effective FRAM device that has only 512 bytes of main memory, but larger devices can be substituted for more data storage or added functionality. To get started, download project files and a code example demonstrating this functionality.

**Implementation**

EEPROM emulation is configured to use SPI protocol in slave mode. A host processor acting as the master should be connected so that it can write or read data from the MSP430 MCU. Beyond the typical SPI bus (SCLK, MOSI, MISO, and CS) a write protect (WP) line is also used. Figure 1 shows the SPI block diagram interface.

![Figure 1. EEPROM SPI Block Diagram](image)

The CS pin determines if the SPI is enabled and is active low by default. Communication is achieved by sending an op code followed by an 8-bit address, after which the EEPROM can be written to or read from until the memory space allocation has been exceeded or the CS line resets the SPI. The two op-code values are 0x02 (write) and 0x03 (read) but can be changed to the user's preference. Up to 256 bytes of EEPROM memory can be utilized on FRAM devices that exceed 512 bytes of total memory, but additional space will require changes to the code, because it accounts for only 8-bit addressing. The EEPROM page is protected from write commands until the WP line is driven low but read commands can be performed at any time. Figure 2 and Figure 3 show an interface example between a host device and MSP430 FRAM EEPROM emulator, in which a word is written starting at 0x0F and then read from 0x10.

![Figure 2. EEPROM Write Word Sequence](image)
As seen in Figure 2, the "write" op-code (0x02) is followed by the desired address (0x0F), after which the word 0xCEB4 is supplied. A "read" op code (0x03) quickly follows with the address 0x10, and the MSP430 MCU responds with the 0x1B value that was previously given as well as the preset value (0x11) stored at the memory address 0x11. Further investigation reveals that 0xCE has been properly written to address 0x0F as well. After the op code and address are given, writes or reads can continue repeatedly until the end of the memory page has been reached, at which point further instructions are ignored.

**Performance**

Using the MSP430FR2000 MCU has certain restrictions due to the 0.5KB of memory. For example, Figure 3 shows that a 75 µs delay is required between the high-to-low transition of the CS/EN pin and the start of the system clock (SCLK). 150 µs must also pass between the read address and reading from the EEPROM memory, and the CS/EN pin must remain high for at least 100 µs between SPI sequences.

Upgrading to one kilobyte of memory with the MSP430FR2100 MCU or reducing the necessary EEPROM page size allows enough additional memory space for increasing the operating frequency for faster response times. For a fuller featured and larger EEPROM memory, other MSP430 FRAM MCUs can be used with the TIDM-FRAM-EEPROM reference design, which uses the 256KB MSP430FR5994 device.

The firmware operates in low-power mode 3 (LPM3) when the SPI is not active but consumes 20 µA of current at 3 V, some of which is due to the internal pullup resistance on the CS pin. 15 µA is required to drive the internal trimmed low-frequency reference oscillator (REFO), but less than 2 µA is achievable by populating an external crystal and sourcing to the auxiliary clock (ACLK). Overall current consumption averages from active SPI communication depend on the number of bytes written to the FRAM during each transaction and the frequency to which the EEPROM is accessed. Use cases therefore need to be further evaluated by the user.

**Device Recommendations**

The device used in this example is part of the MSP430 Value Line Sensing portfolio of low-cost MCUs, designed for sensing and measurement applications. This example can be used with the devices shown in Table 1 with minimal code changes. For more information on the entire Value Line Sensing MCU portfolio, visit www.ti.com/MSP430ValueLine.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Key Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP430FR2000</td>
<td>0.5KB FRAM, 0.5KB RAM, eComp</td>
</tr>
<tr>
<td>MSP430FR2100</td>
<td>1KB FRAM, 0.5KB RAM, 10-bit ADC, eComp</td>
</tr>
<tr>
<td>MSP430FR2110</td>
<td>2KB FRAM, 1KB of RAM, 10-bit ADC, eComp</td>
</tr>
<tr>
<td>MSP430FR2111</td>
<td>3.75KB FRAM, 1KB RAM, 10-bit ADC, eComp</td>
</tr>
</tbody>
</table>

(1) MSP430 is a trademark of Texas Instruments.
(2) All other trademarks are the property of their respective owners.
## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<table>
<thead>
<tr>
<th>Changes from September 16, 2017 to April 20, 2018</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Corrected direction of MOSI and MISO in Figure 1, EEPROM SPI Block Diagram</td>
<td>1</td>
</tr>
</tbody>
</table>
IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI’s provision of TI Resources does not expand or otherwise alter TI’s applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT. AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED “AS IS” AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include, without limitation, TI’s standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated