

Using the Undervoltage Lockout Detection Feature on SPI Serial EEPROMs

Author: *Martin Kvasnicka*
Microchip Technology Inc.

INTRODUCTION

A voltage drop in the system supply may cause unintentional data writes to a SPI Serial EEPROM memory. Microchip's 25CSXXX Series offers a feature to prevent erroneous write operations during a voltage drop event.

The Undervoltage Lockout Detection (UVLO) feature incorporates a programmable voltage detection circuit that allows the user to choose a voltage level at which the device will no longer accept any write commands. It serves as additional write protection when an under-voltage event is detected.

In an application, the minimum power supply voltage for each component typically varies and may be higher than that of the Serial EEPROMs on the board (typically 1.6V to 1.8V). By setting the UVLO at or slightly above the minimum operating voltage of the application, as determined by the system designer, the UVLO circuit can detect when voltages are below the application's expected operating voltage range and block any spurious writes that may be issued unintentionally, preventing data corruption.

The UVLO circuit works by monitoring the VCC level of the EEPROM at the time in which a write command is to be initiated, specifically, at the rising edge of \overline{CS} after a valid write command has been transmitted to the SPI device.

If an undervoltage situation is observed, the UVLO circuit will prevent the EEPROM from writing by aborting the write command currently being attempted. As an indication that an undervoltage condition has been detected, the Write Lockout State (WLS) bit in the STATUS register will be set to a logic '1'. This bit allows the user to know when an undervoltage write event has been detected. The UVLO circuit will inhibit writes to any of the nonvolatile memory locations and includes the following commands: WRITE, WRSR, WREX, LOCK, WMPR, PPAB, FRZR, and WUVL.

UVLO OPERATIONS

In order to successfully use the programmable UVLO feature, there are several SPI commands that need to be reviewed.

The two new commands⁽¹⁾ unique to the UVLO feature on the new SPI devices are Write Undervoltage Lockout Register (WUVL) and Read Undervoltage Lockout Register (RUVL).

In addition to those two new commands, there are two other commands⁽¹⁾ involved that are more familiar to traditional SPI EEPROM users. These commands are the Write Enable (WREN) command and the Read STATUS Register (RDSR) command.

To accommodate UVLO and other new features, the 25CSXXX devices utilize a 2-byte STATUS register.

Note 1: For more information about the new commands, refer to any 25CSXXX product data sheet available from the Microchip website (www.microchip.com).

Choosing a Voltage

Since UVLO features a programmable voltage level, the first step in using UVLO is choosing the minimum programming voltage that will still allow the application to program normally when voltages are in the "desired" voltage range. Referring to Table 2 as an example, UVLO can be programmed in 100 mV increments from 1.5V to 4.6V typically.

This gives 32 different programmable UVLO settings to choose from. Table 1 presents the voltage settings that are used to evaluate the UVLO circuit.

TABLE 1: VOLTAGE SETTINGS

| Voltage Settings | Voltage Value |
|------------------|---------------|
| Nominal Vcc | 5.0V |
| UVLO circuit | 4.0V |
| Undervoltage VCC | 3.8V |

A setting of 4.0V for the UVLO will give 1.0V below the nominal VCC voltage and 200mV higher than the example VCC undervoltage condition of 3.8V. Per Table 2, this means that the setting VUVL<4:0> = '11001' must be programmed for an undervoltage lockout level of 4.0V.

**TABLE 2: UNDERVOLTAGE LOCKOUT
DETECTION LEVEL**

| UVLO Voltage | Binary Value |
|--------------|-------------------|
| 1.5 | VUVL<4:0> = 00000 |
| 1.6 | VUVL<4:0> = 00001 |
| 1.7 | VUVL<4:0> = 00010 |
| 1.8 | VUVL<4:0> = 00011 |
| 1.9 | VUVL<4:0> = 00100 |
| 2.0 | VUVL<4:0> = 00101 |
| 2.1 | VUVL<4:0> = 00110 |
| 2.2 | VUVL<4:0> = 00111 |
| 2.3 | VUVL<4:0> = 01000 |
| 2.4 | VUVL<4:0> = 01001 |
| 2.5 | VUVL<4:0> = 01010 |
| 2.6 | VUVL<4:0> = 01011 |
| 2.7 | VUVL<4:0> = 01100 |
| 2.8 | VUVL<4:0> = 01101 |
| 2.9 | VUVL<4:0> = 01110 |
| 3.0 | VUVL<4:0> = 01111 |
| 3.1 | VUVL<4:0> = 10000 |
| 3.2 | VUVL<4:0> = 10001 |
| 3.3 | VUVL<4:0> = 10010 |
| 3.4 | VUVL<4:0> = 10011 |
| 3.5 | VUVL<4:0> = 10100 |
| 3.6 | VUVL<4:0> = 10101 |
| 3.7 | VUVL<4:0> = 10110 |
| 3.8 | VUVL<4:0> = 10111 |
| 3.9 | VUVL<4:0> = 11000 |
| 4.0 | VUVL<4:0> = 11001 |
| 4.1 | VUVL<4:0> = 11010 |
| 4.2 | VUVL<4:0> = 11011 |
| 4.3 | VUVL<4:0> = 11100 |
| 4.4 | VUVL<4:0> = 11101 |
| 4.5 | VUVL<4:0> = 11110 |
| 4.6 | VUVL<4:0> = 11111 |

Setting the UVLO Register

In order to write to the UVLO register, as with all SPI write commands, a Write Enable (\overline{WREN}) command needs to be issued to set the Write Enable Latch.

When writing the UVLO register, the enable bit can be set at the same time as the UVLO threshold, or the Enable Undervoltage Lockout Function (UVLOEN) bit can be set later. For this example, the UVLOEN bit is set at the same time as the threshold, so once the write command is complete the UVLO will be active and set to 4.0V.

The UVLO register (see [Register 1](#)) is 8 bits wide, but the two Most Significant bits are unused and always read as logic '0'. Combining the detection level of 19h for 4.0V with the UVLOEN bit yields a data value of 39h to be programmed into the UVLO register.

[Figure 1](#) shows an example of the Write Undervoltage Lockout Register (\overline{WUVL}) command. Chip Select is brought low (active) and the opcode 11h is clocked in followed by the data payload. After the last bit of data has been clocked in, the \overline{CS} pin is brought high (inactive) starting the internal write cycle to program the UVLO register.

Note: Setting the undervoltage lockout level (VUVL) above VCC will cause all write sequences to be ignored. VCC must be above the VUVL in order to program the VUVL.

REGISTER 1: UNDERVOLTAGE LOCKOUT DETECTOR REGISTER

| U-0 | U-0 | R/W | R/W | R/W | R/W | R/W | R/W | |
|-------|-----|--------|-------|-------|-------|-------|-------|-------|
| — | — | UVLOEN | VUVL4 | VUVL3 | VUVL2 | VUVL1 | VUVL0 | |
| bit 7 | | | | | | | | bit 0 |

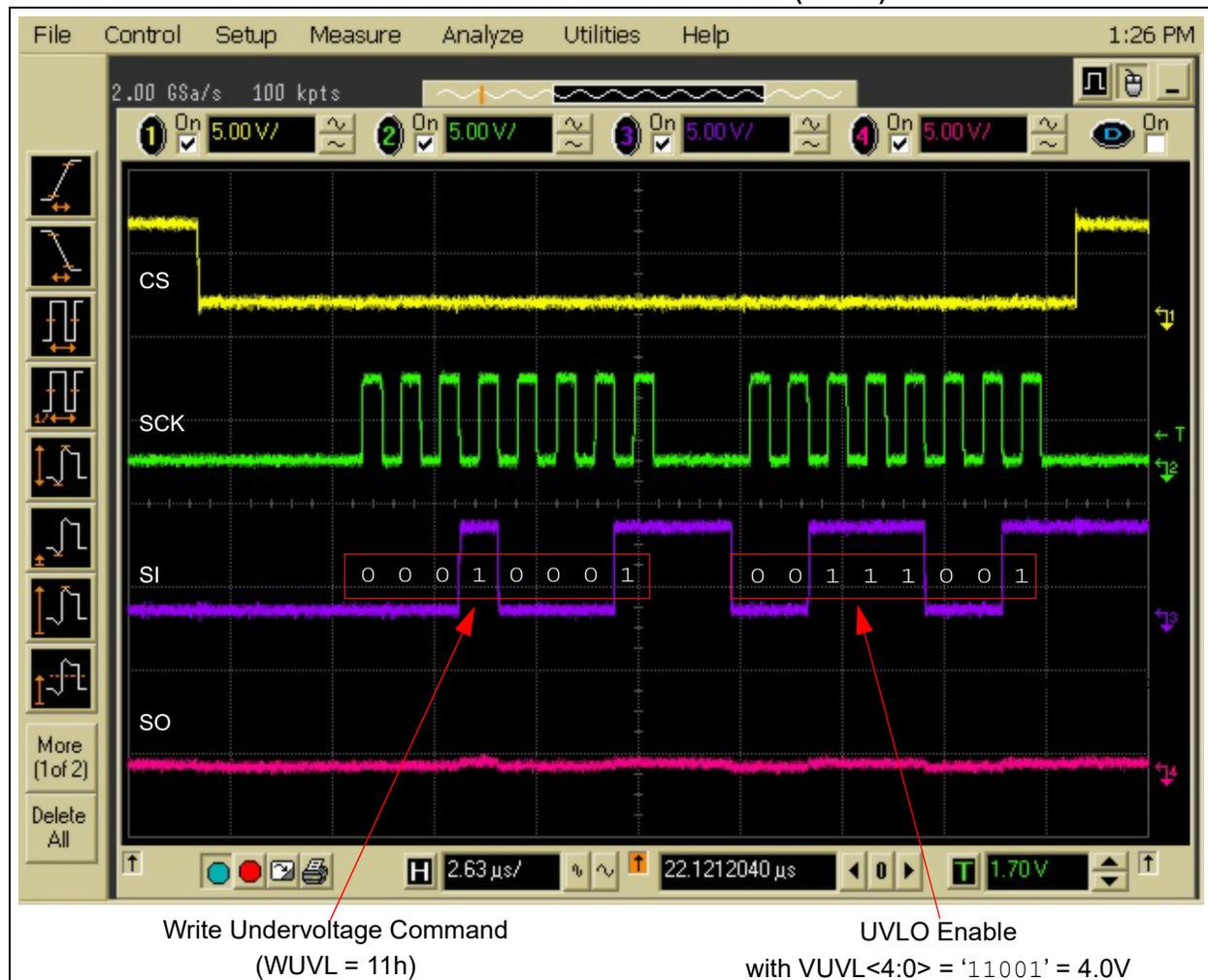
Legend:

R = Readable bit W = Writable bit U = Unimplemented bit, read as '0'
 -n = Value at POR '1' = Bit is set '0' = Bit is cleared x = Bit is unknown

- bit 7-6 **Unimplemented:** Read as '0'
- bit 5 **UVLOEN:** Enable Undervoltage Lockout Function
 1 = UVLO is enabled
 0 = UVLO is not enabled
- bit 4-0 **VUVL<4:0>:** Undervoltage Lockout Detection Level⁽¹⁾
 00000 = Minimum
 ...
 11111 = Maximum

Note 1: For specific UVLO levels, refer to [Table 2](#).

FIGURE 1: WRITE UNDERVOLTAGE LOCKOUT REGISTER (WUVL)



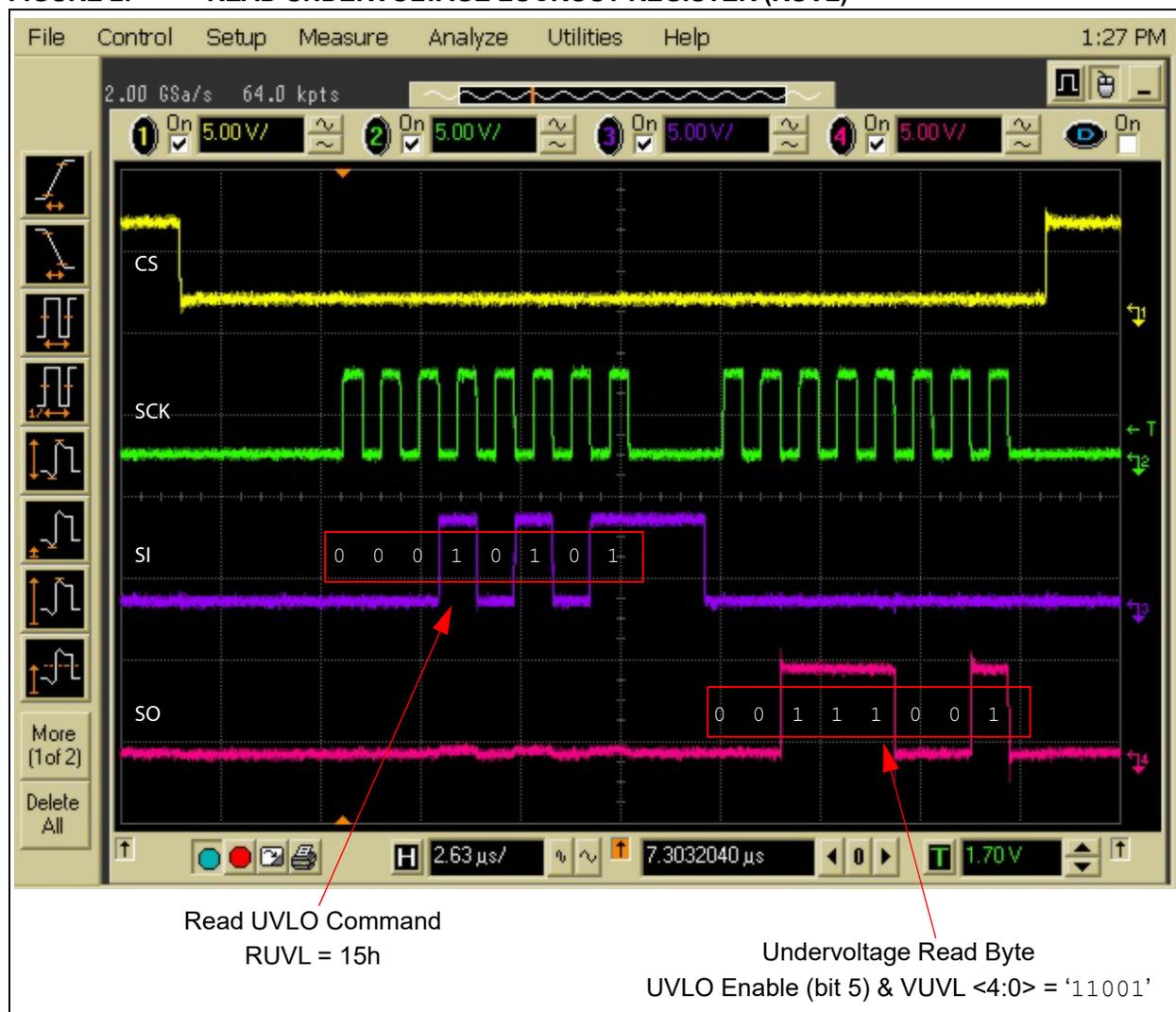
Reading the UVLO Register

After writing to the UVLO register, the contents of the register should be read to confirm it is correct for the application. This is done by issuing the Read Undervoltage Lockout Register (R_{UVL}) command (15h).

Figure 2 shows an example of the Read Undervoltage Lockout Register command. Once again the device is selected and the opcode (15h) is sent.

The UVLO register data is shifted out on the Serial Output pin. A value of 39h shows that the UVLO is enabled with a detection level of 4.0V ($V_{UVL<4:0>} = '11001'$).

FIGURE 2: READ UNDERVOLTAGE LOCKOUT REGISTER (RUVL)



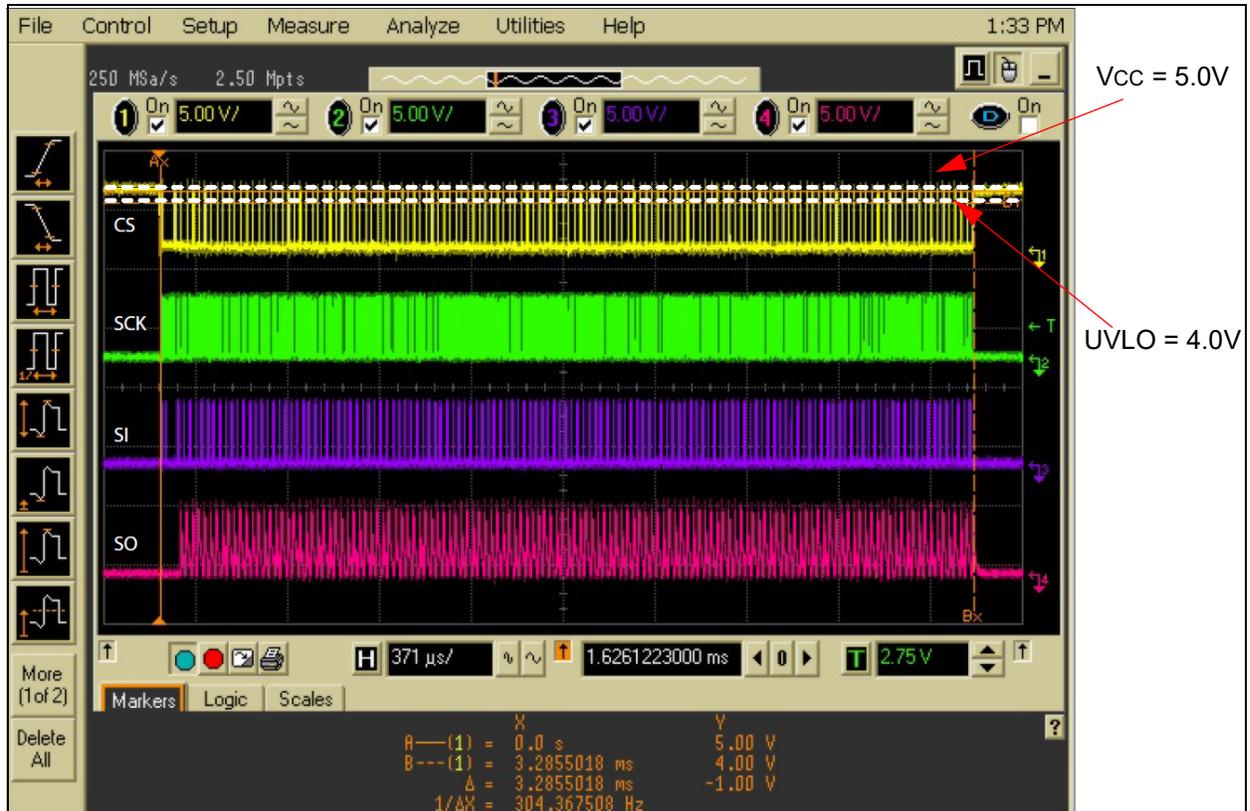
Executing a Valid Write Command

In order to demonstrate the UVLO feature, a write command will first be attempted with the voltage at a “good” VCC setting of 5.0V. The purpose of this write is to verify that the device is operating correctly.

Figure 3 shows an example of a valid memory array write command followed by a polling routine. As noted earlier, when invoked, the UVLO will prevent the write cycle from occurring. As shown in Figure 3, the write

cycle takes roughly 4 ms to complete, which illustrates that the write operation occurred successfully and was not blocked by the UVLO function.

FIGURE 3: VALID WRITE COMMAND WITH VCC AT 5.0V



Write Inhibited by UVLO

After a valid write command has been shown, the voltage is lowered to observe what happens when a write is attempted at a voltage below the UVLO detect threshold. For this write command, the application VCC is set at 3.8V and the same memory array write command as earlier will be issued. Since the UVLO detect threshold is set at 4.0V, this command is blocked by the UVLO detect circuit. In this scenario, the device will attempt the write command and the polling routine will initiate, but unlike the previous attempt at programming, the polling routine would stop immediately because the command was blocked by the UVLO circuit. In order to ensure this is the case, the Read Status Register (RDSR) command will need to be issued.

Note: If the STATUS register is read during the UVLO detection time (T_{UVL}), the 25CS640 will report a busy state indicated by RDY/BSY = 1. If the write is inhibited due to the UVLO, the RDY/BSY bit will clear and the WLS bit will be set.

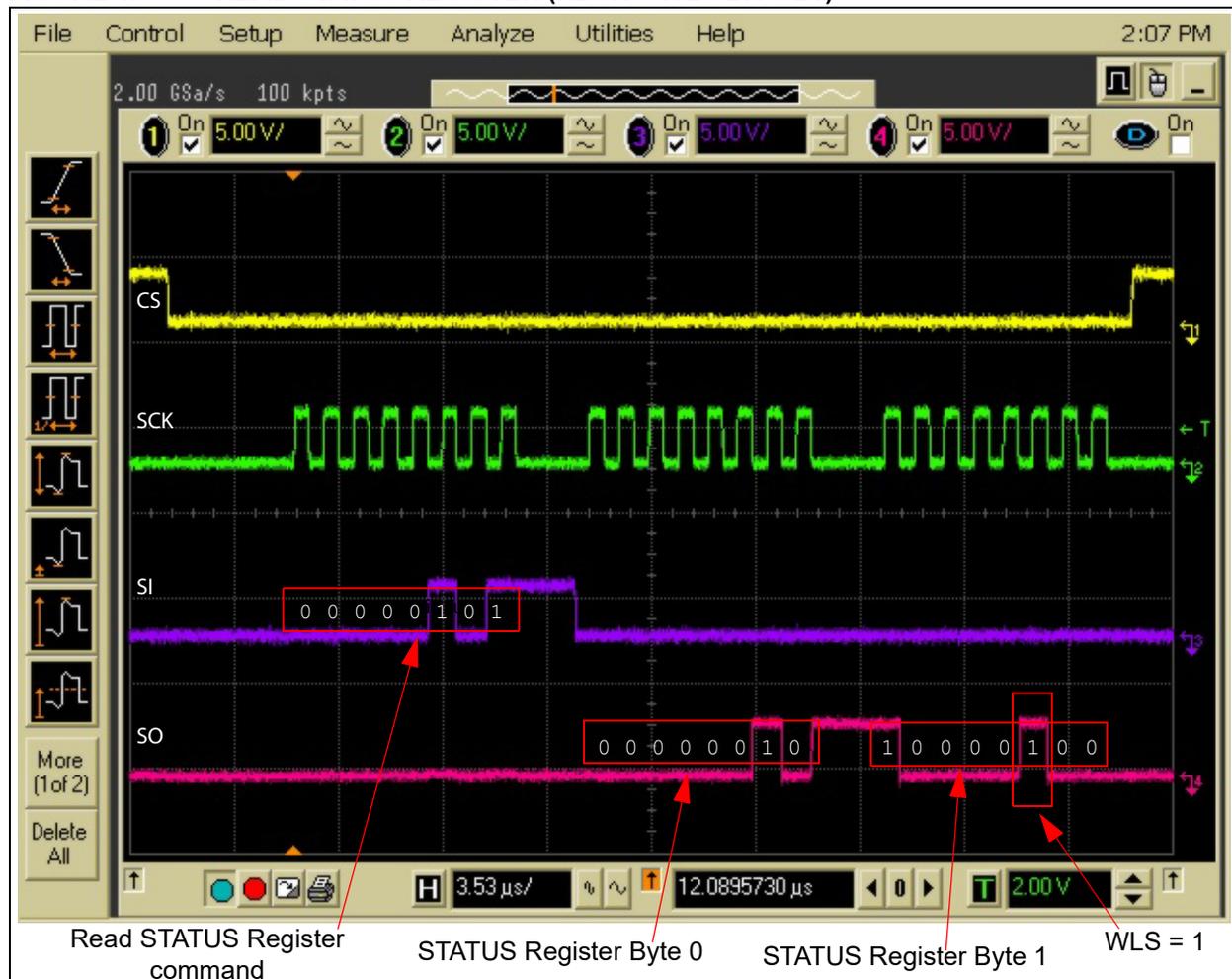
Read STATUS Register (RDSR – WLS Bit Set)

Since the previous write cycle was aborted, the Write Lockout State (WLS) bit in the STATUS register can be checked to confirm that UVLO blocked the write. The WLS bit is bit 2 of the STATUS Register Byte 1. Figure 4 shows that this bit is set to a logic '1', indicating that the previous write attempt was blocked by the UVLO detect circuit.

The WLS bit will remain set until the device is issued a new programming command that is successful and is not blocked by the UVLO detect circuit.

Note: The WLS bit will clear if a Power-on Reset (POR) event or Software Device Reset (SRST) command is sent to the device.

FIGURE 4: READ STATUS REGISTER (RDSR – WLS BIT SET)



CONCLUSION

The UVLO feature is an undervoltage lockout detection circuit that can be used to detect undervoltage events or device VCC power supply levels that are outside the expected operating range of the application. UVLO can prevent spurious writes or data corruption by blocking any write attempts when the device voltage dips below the setting of the UVLO threshold.

This application note presents how to select, enable and set a UVLO voltage. It also explains how to read the UVLO register to ensure that the circuit is enabled and set to the proper voltage level. In addition, it shows examples of “good” and “bad” writes with the circuit enabled, and how to read the STATUS register and the Write Lockout State (WLS) bit that gets reported every time a low-voltage write attempt has been detected and blocked by the UVLO circuit.

APPENDIX A: REVISION HISTORY

Revision B (3/2021)

Added note about UVLO detection time (T_{UVL}) to Figure 4.

Revision A (3/2020)

Initial release of this document.

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable." Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication is provided for the sole purpose of designing with and using Microchip products. Information regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL OR CONSEQUENTIAL LOSS, DAMAGE, COST OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, HELDO, IGL00, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzr, PackeTime, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AgileSwitch, APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, FlashTec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, Augmented Switching, BlueSky, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, IdealBridge, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, Inter-Chip Connectivity, JitterBlocker, maxCrypto, maxView, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, RTAX, RTG4, SAM-ICE, Serial Quad I/O, simpleMAP, SimpliPHY, SmartBuffer, SMART-I.S., storClad, SQI, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, TSHARC, USBCheck, VariSense, VectorBlox, VeriPHY, ViewSpan, WiperLock, XpressConnect, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2020-2021, Microchip Technology Incorporated, All Rights Reserved.

ISBN: 978-1-5224-7836-2

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.



MICROCHIP

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
[http://www.microchip.com/
support](http://www.microchip.com/support)
Web Address:
www.microchip.com

Atlanta

Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX

Tel: 512-257-3370

Boston

Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago

Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas

Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit

Novi, MI
Tel: 248-848-4000

Houston, TX

Tel: 281-894-5983

Indianapolis

Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles

Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC

Tel: 919-844-7510

New York, NY

Tel: 631-435-6000

San Jose, CA

Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto

Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880-3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4485-5910
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-72400

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7288-4388

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820