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Using C and a Hardware Module to Interface Texas Instruments' MSP430XXXX MCUs with SPI Serial EEPROMs

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INTRODUCTION

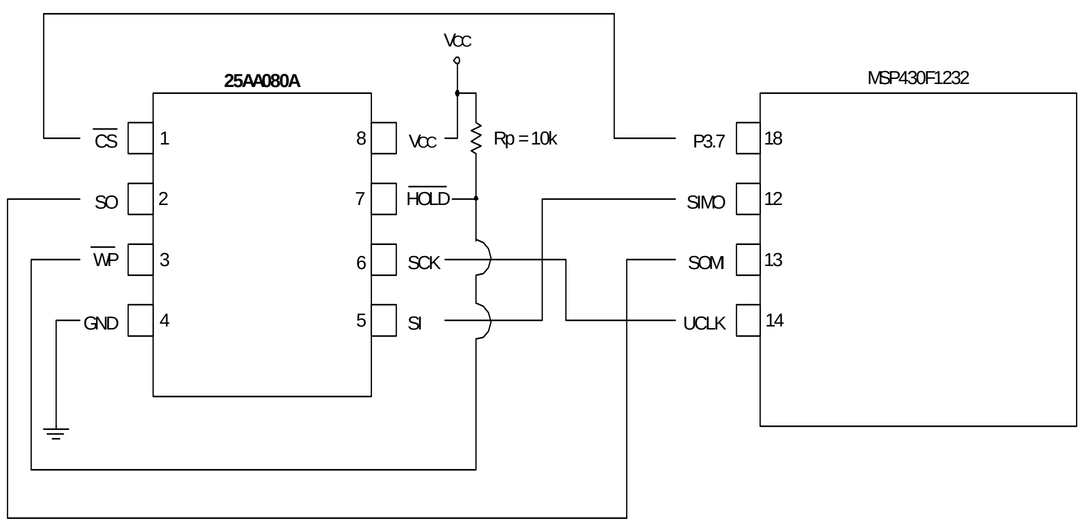
The 25XXX series serial EEPROMs from Microchip Technology support a half-duplex SPI protocol. The bus is controlled by the microcontroller (master), which accesses the 25XXX serial EEPROM (slave). The bus signals required consist of a clock input (SCK) plus separate data in (SI) and data out (SO) lines. Access to the 25XXX serial EEPROM is controlled through a Chip Select ($\overline{\text{CS}}$) input. Maximum clock frequencies range from 3 MHz to 20 MHz. Communication to the 25XXX serial EEPROM can be paused via the hold pin ($\overline{\text{HOLD}}$). While the EEPROM is paused, transitions on its inputs are ignored, except for the $\overline{\text{CS}}$, allowing the MCU to service higher priority interrupts. After releasing the $\overline{\text{HOLD}}$ pin, the operations resume from the point when the hold was asserted.

The main features of the 25XXX serial EEPROMs are:

- SPI-compatible serial interface bus
- EEPROM densities range from 1 Kbits to 1 Mbits
- Bus speed from 3 MHz to 20 MHz
- Voltage range from 1.8V to 5.5V
- Low-power operation
- Temperature range from -40°C to +125°C
- Over 1,000,000 erase/write cycles
- Built-in write protection

This application note is part of a series that provide source code to help users implement the protocol with minimal effort. Figure 1 is the hardware schematic depicting the interface between Microchip's 25XXX series serial EEPROMs and the MSP430F1232 based MCU from Texas Instruments. The schematic shows the necessary connections between the MCU and the serial EEPROM. The $\overline{\text{WP}}$ and $\overline{\text{HOLD}}$ pins are tied to VCC through a resistor, as they are not used in the examples provided.

FIGURE 1: CIRCUIT FOR MSP430XXXX AND 25XXX SERIAL EEPROM



Note: A 100 nF decoupling capacitor should be connected between VCC and GND.

FIRMWARE DESCRIPTION

This application note offers designers a set of examples for the read and write functions for the Microchip SPI serial EEPROM (byte read/write and page read/write) using internal hardware peripheral and C language.

The main routine writes a string in the SPI serial EEPROM, reads it back and compares the two strings, displaying a success or error message on the 4 onboard LEDs of the evaluation board. The firmware was written in C language for the MSP430F1232 MCU, using the IAR™ – IDE and the related C compiler. It was developed on the Softbaugh™ ES1232 evaluation board and debugged through the MSP430 USB debug interface, MSP-FET430UIF, from Texas Instruments. The code was tested using the 25AA080A serial EEPROM.

Oscilloscope screen shots are shown in this application note. All timings are based on the internal RC oscillator of the MCU (~ 8 MHz). If another clock is used, the code must be modified to generate the correct delays (mainly the 5 milliseconds delay, which is an alternative to the polling of the WIP flag, also presented in the application note) for the EEPROM write cycle. The bus speed in these examples is of ~ 200 kHz. If desired, the bus speed may be changed in the initialization routine (`ini_spi`) by modifying the U0BR0 and U0BR1 registers. (Please refer to the **Section "Initialization"**).

INITIALIZATION

Initialization consists of three routines: `ini_gpio`, `ini_spi` and `ini_memspi`.

The `ini_gpio` routine sets the SPI pins for their functions P3.3 = UCLK (SPI CLK), P3.2 = SOMI0 (Slave Out Master In), P3.1 = SIMO0 (Slave In Master Out). The P3.7 pin is used as GPIO output, driving the $\overline{CS}$ pin of the SPI memory.

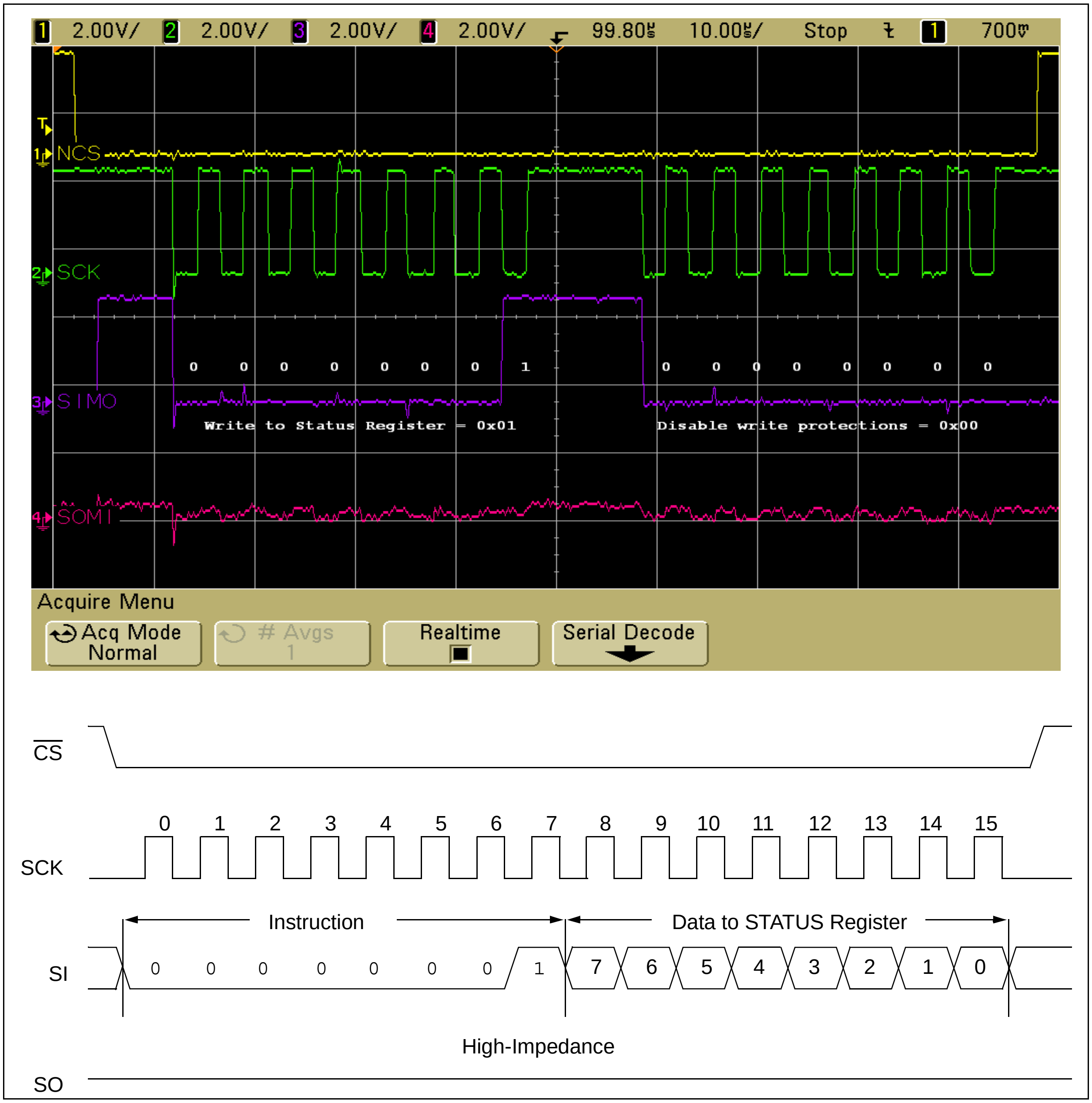
In addition, the function sets as GPIO outputs P1.3, P1.2, P1.1 and P1.0, driving the 4 onboard LEDs in order to display success or error messages.

The `ini_spi` routine prepares the MCU for communication with the serial EEPROM, using the hardware peripheral and setting the following registers: U0CTL, U0TCTL, ME, U0BR1 and U0BR0. The internal part will be configured for: 8-bits character, USART = SPI master, SCK = Idle high, SPICLK = SMCLK: 16, 3 wires scheme, enable SPI module.

If another speed is desired, the U0BR0 and U0BR1 registers must be set to other values.

The third routine, `ini_memspi`, prepares the memory for further writes. It sends to the device a 0x00 byte in order to disable all write protections. The scope plot showing this operation is depicted in Figure 2.

FIGURE 2: WRITE TO STATUS REGISTER



WRITE ENABLE

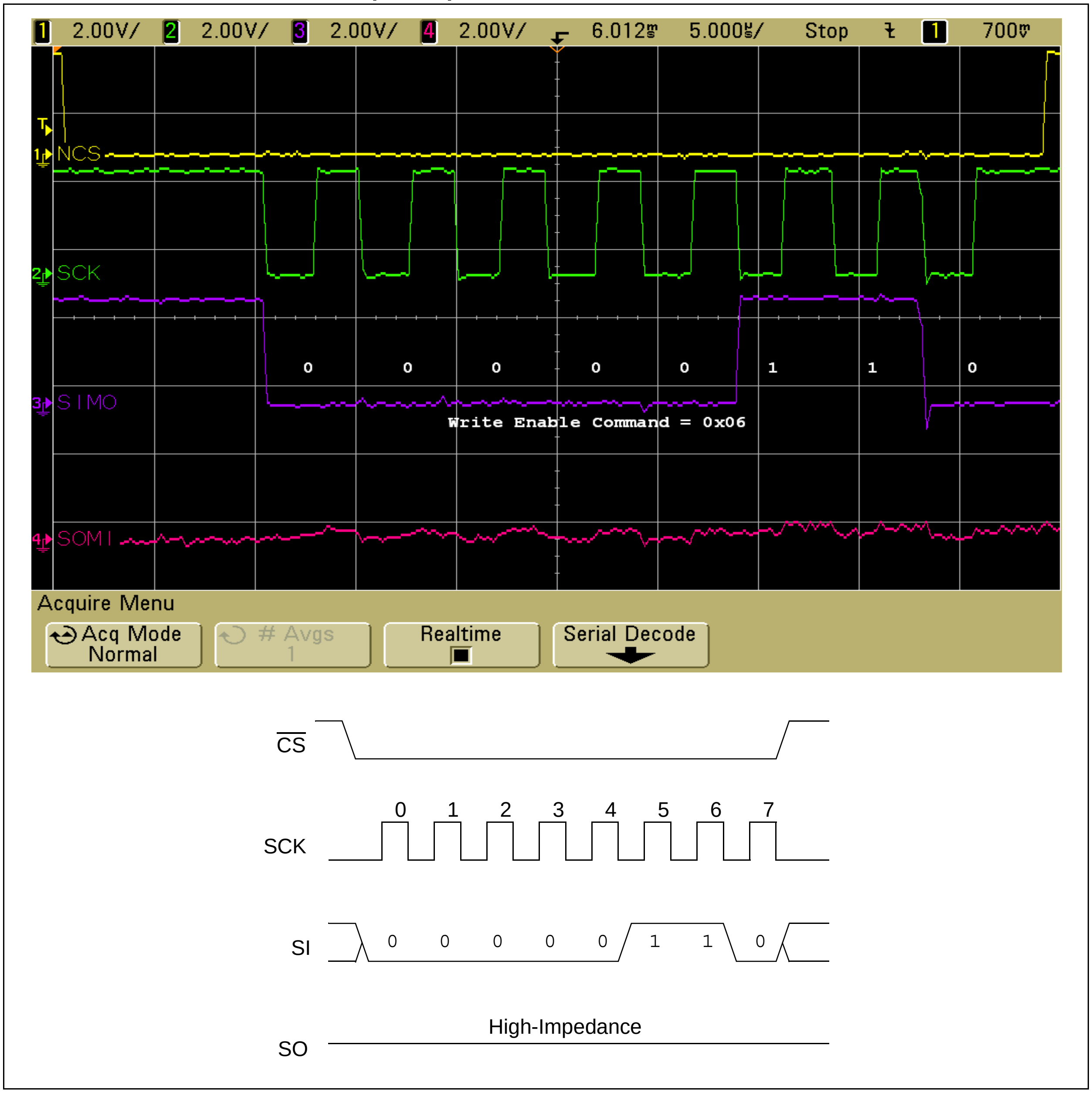
Before any write operation can occur, the MCU must set the Write Enable Latch (WEL).

This is done by issuing a WREN command.

The MCU clears the WEL bit by issuing a Write Disable (WRDI) command. The WEL bit is also automatically reset if the serial EEPROM is powered down and when a write cycle is completed.

Figure 3 shows the WREN command.

FIGURE 3: WRITE ENABLE (WREN)

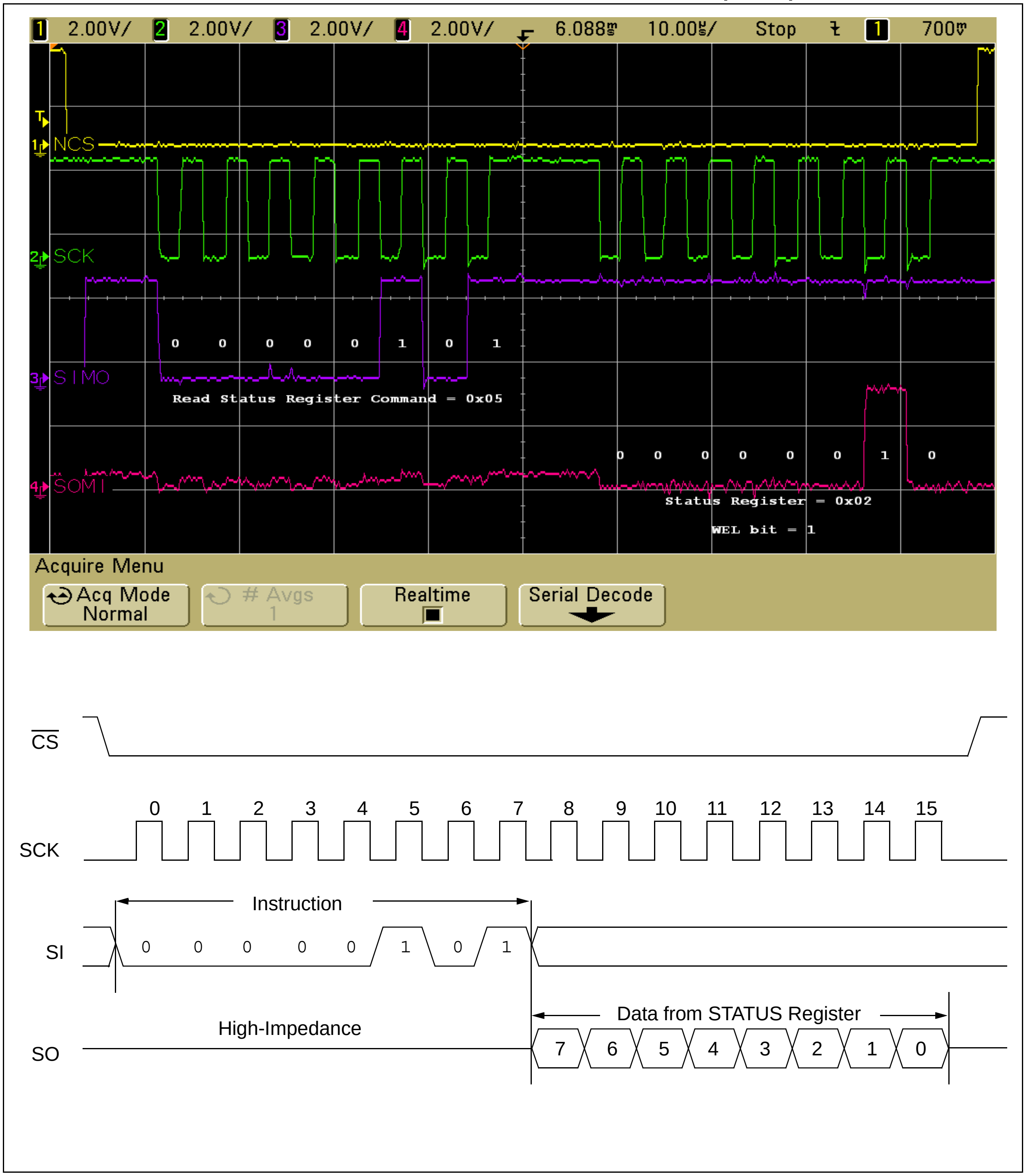


READ STATUS REGISTER TO CHECK FOR WEL BIT

Figure 4 shows an example of the Read Status Register command to check for the WEL bit. This bit must be set before a write is attempted either to the STATUS register or the array. Before attempting to write, a good programming practice is to check the WEL bit. Once again, the device is selected and the opcode for a Read Status Register is sent.

The STATUS register is shifted out on the Serial Out pin. A value of 0x02 shows that the WEL bit in the STATUS register has been set. The device is now ready to do a write.

FIGURE 4: READ STATUS REGISTER TO CHECK FOR WEL BIT (RDSR)

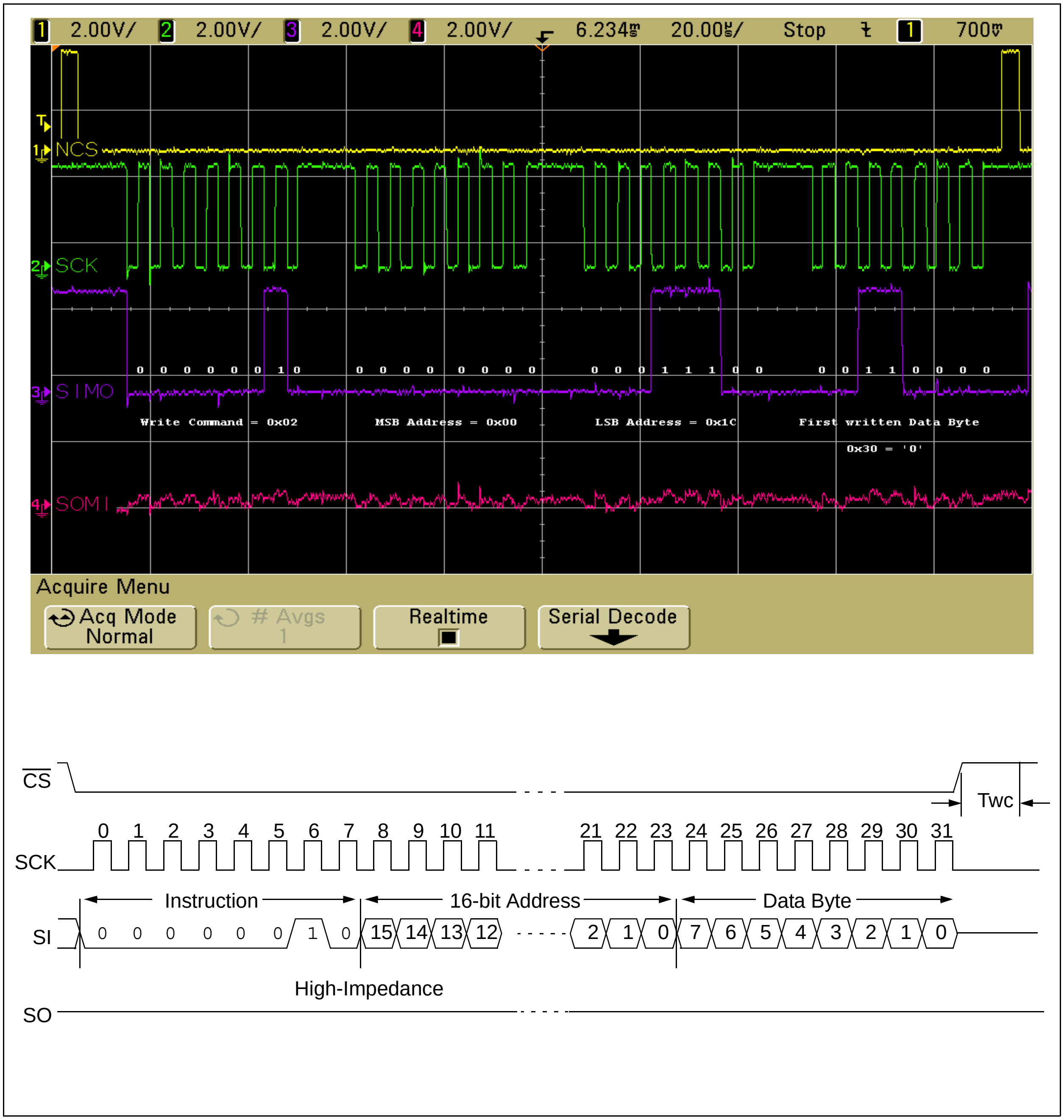


BYTE WRITE SEQUENCE

The byte write operation consists of the MCU sending the Write command, followed by the word address and the data byte. The word address for the 25XX080A is a 16-bit value, so, two bytes must be transmitted for the entire word address, with the Most Significant Byte (MSB) sent first. Note that the WREN command is not illustrated in this section but is still required to initiate the operation.

Figure 5 shows the following sequence: Write command (0x02), MSB address (0x00), LSB address (0x1C) and the first written byte (0x30 = 0).

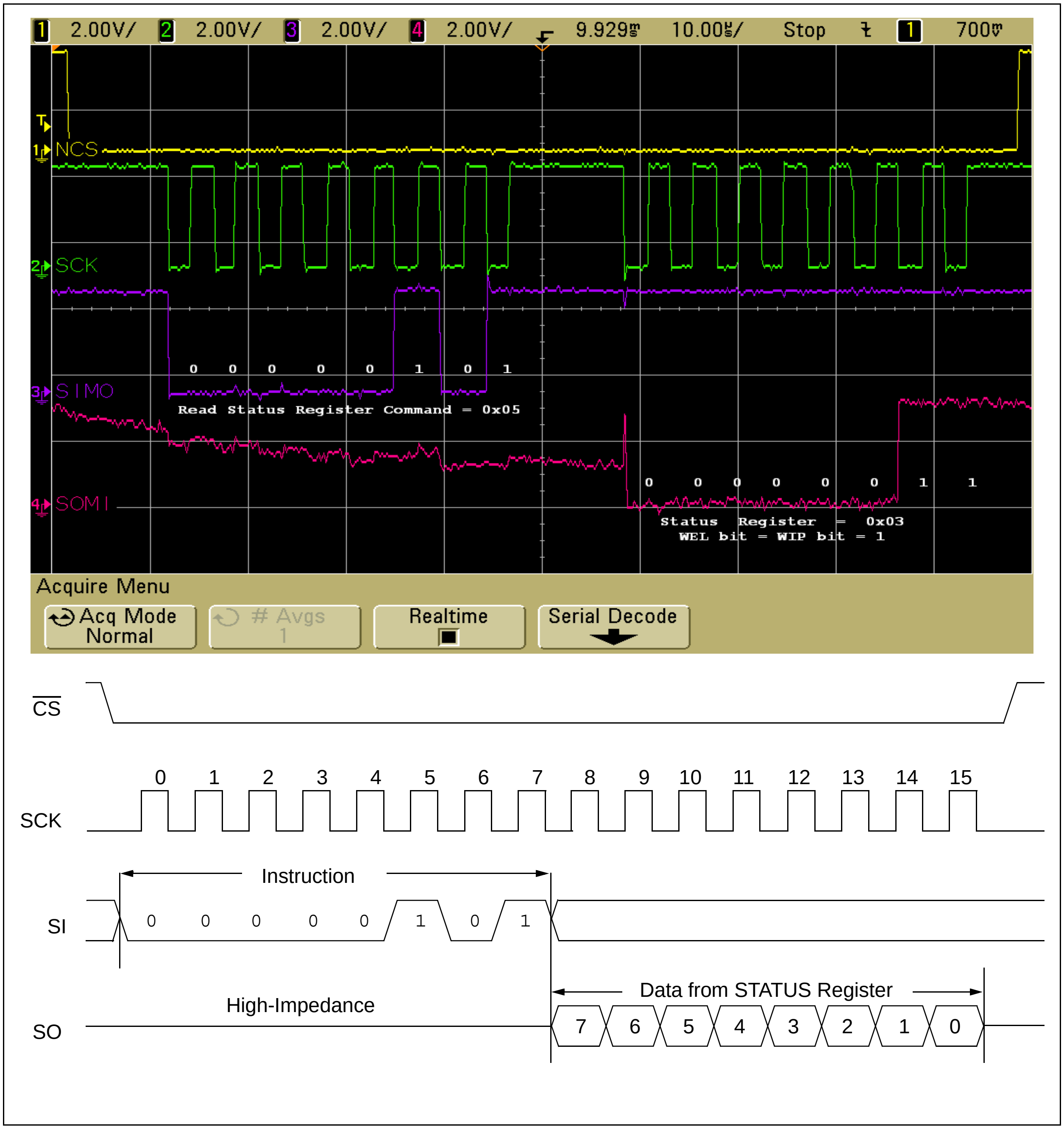
FIGURE 5: BYTE WRITE COMMAND, ADDRESS AND DATA



RDSR – CHECK FOR WIP SET

After the MCU issues a Write command, the STATUS register may be read to check if the internal write cycle has been initiated, and it can be continuously monitored to look for the end of the write cycle. The MCU selects the serial EEPROM and sends the Read Status Register command (RDSR) (`00000101` or 0x05), as shown in Figure 6. The STATUS register is then shifted out on the Serial Out (SO) pin, resulting in a value of `00000011` or 0x03, also shown in Figure 6. Both the WEL bit (bit 1) and the WIP bit (bit 0) are set (`1`), indicating that the write cycle is in progress.

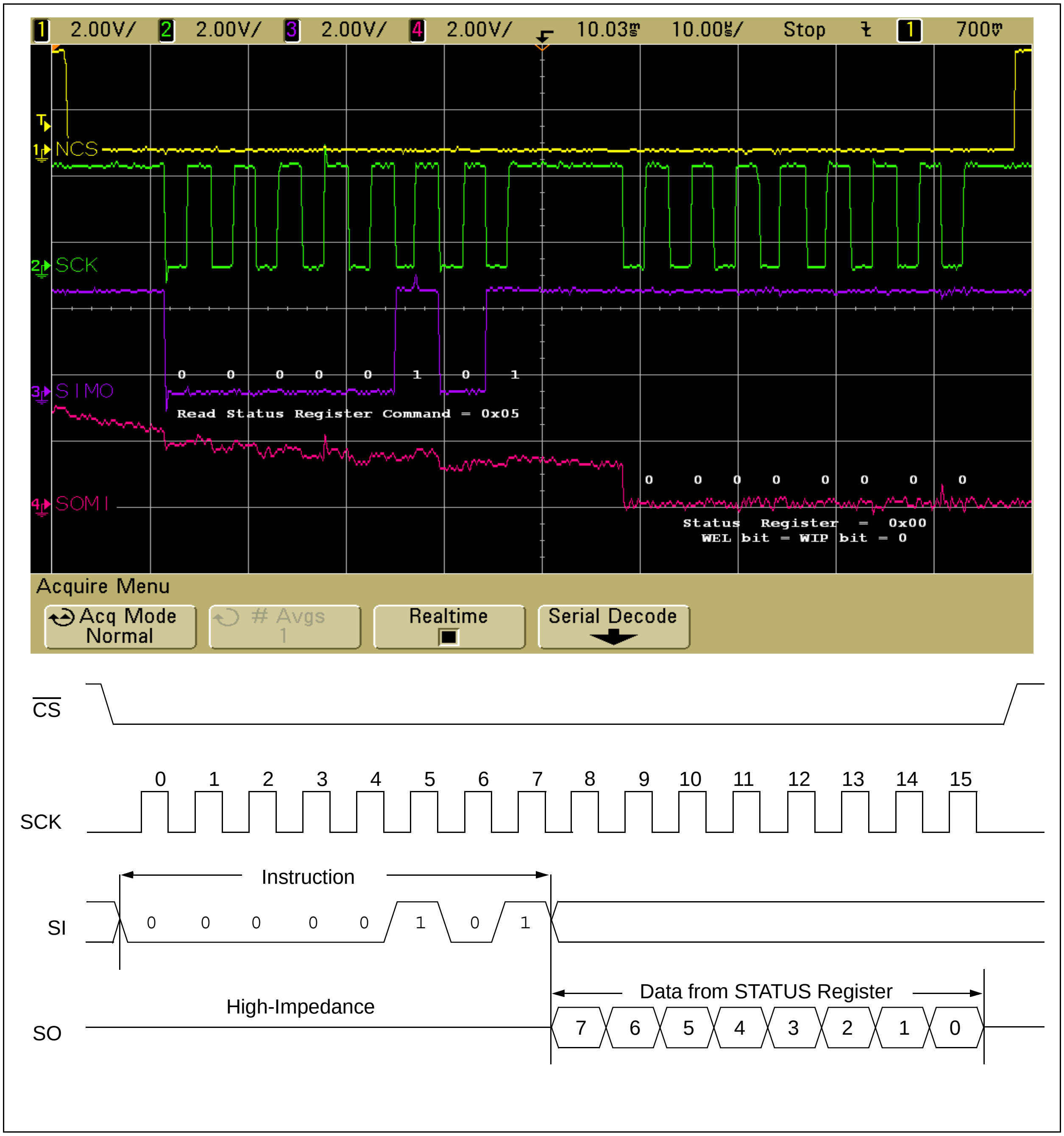
FIGURE 6: READ STATUS REGISTER TO CHECK FOR WIP BIT SET



RDSR – WIP BIT CLEARED

The firmware remains in a continuous loop and the WIP status is evaluated until the WIP bit is cleared ('0'). Figure 7 shows the RDSR command. This is followed by a value of 0x00 being shifted out on the SO pin, indicating that the write cycle has finished and the serial EEPROM is ready to receive additional commands. The WEL bit is also cleared at the end of a write cycle, which serves as additional protection against unwanted writes.

FIGURE 7: READ STATUS REGISTER – WIP BIT CLEARED



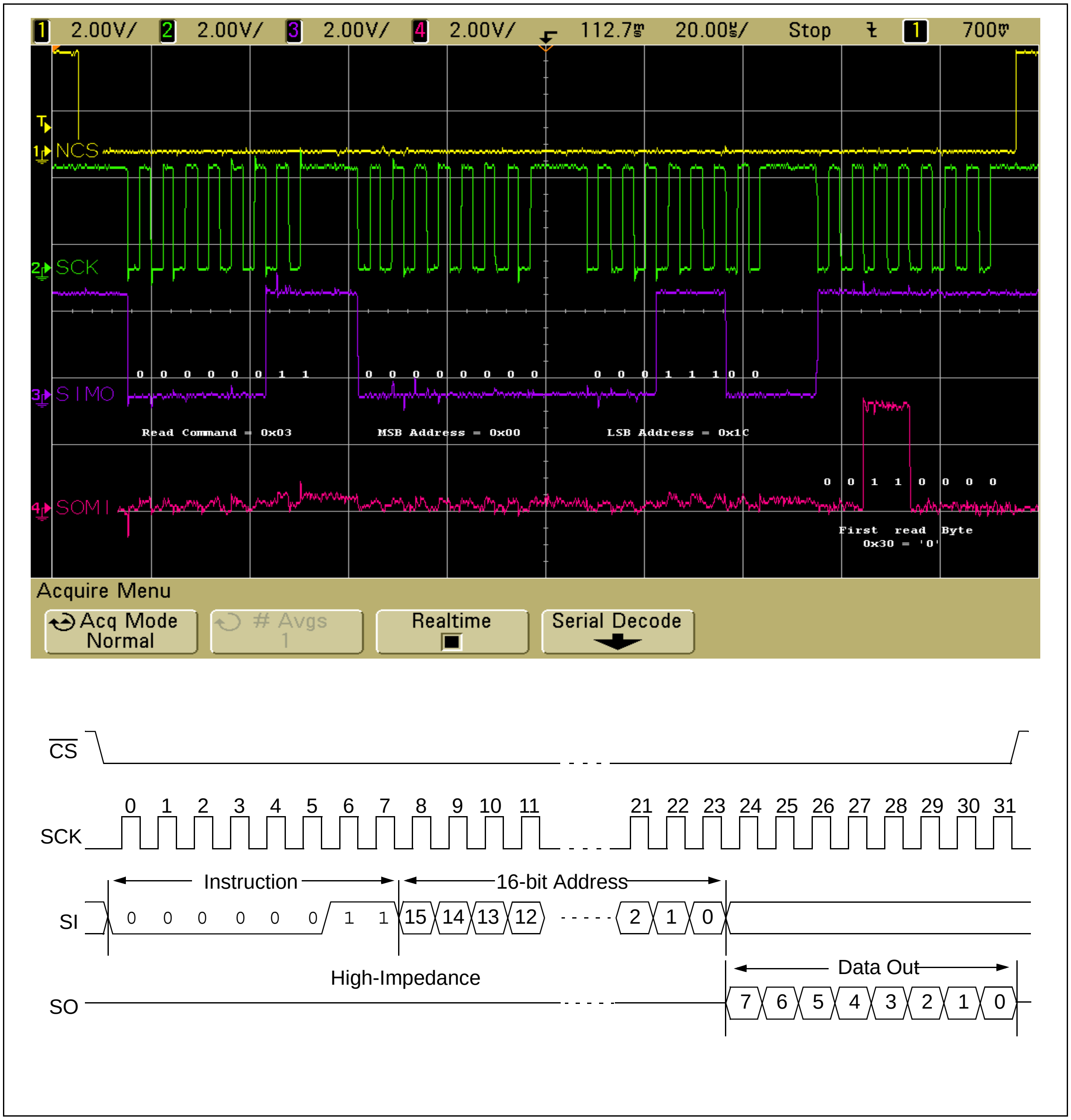
READ BYTE SEQUENCE

The byte read operation can be used to read data from the serial EEPROM.

The MCU transmits the Read command byte (0x03) followed by the word address bytes (MSB = 0x00, LSB = 0x1C) to the serial EEPROM.

Figure 8 shows an example of the Read command, followed by the MSB and LSB address bytes, and the first read byte (0x30 = 0). After the MCU reads the data byte, it will raise up the $\overline{CS}$ signal in order to end the command.

FIGURE 8: READ COMMAND, ADDRESS AND DATA



PAGE WRITE SEQUENCE

Page write operations provide a technique for increasing throughput when writing large blocks of data. The 25XX080A serial EEPROM features a 16-bytes page. Up to 1 full page of data can be written consecutively by using the page write feature.

It is important to note that page write operations are limited to writing bytes within a single physical page, regardless of the number of bytes actually written. Physical page boundaries start at addresses that are integer multiples of the page size and end at addresses that are [integer multiples of the page size] minus 1. Attempts to write across a page boundary result in the data being wrapped back at the beginning of the current page, thus overwriting any data previously stored there.

The page write operation is very similar to the byte write operation. The serial EEPROM automatically increments the internal Address Pointer to the next higher address with receipt of each byte. It starts with the same 3 bytes: Write command, MSB address, LSB address. Comparing to the byte write function, the only difference is that the page write routine stops the communication after several data bytes (not after the first one) by raising up the $\overline{CS}$ signal.

Figure 9 shows the last 2 written characters during a page write operation (0x4F = O and 0x50 = P).

The firmware of this application note presents a useful feature: the string write function (`spi_wrstr`).

The routine has the following tasks:

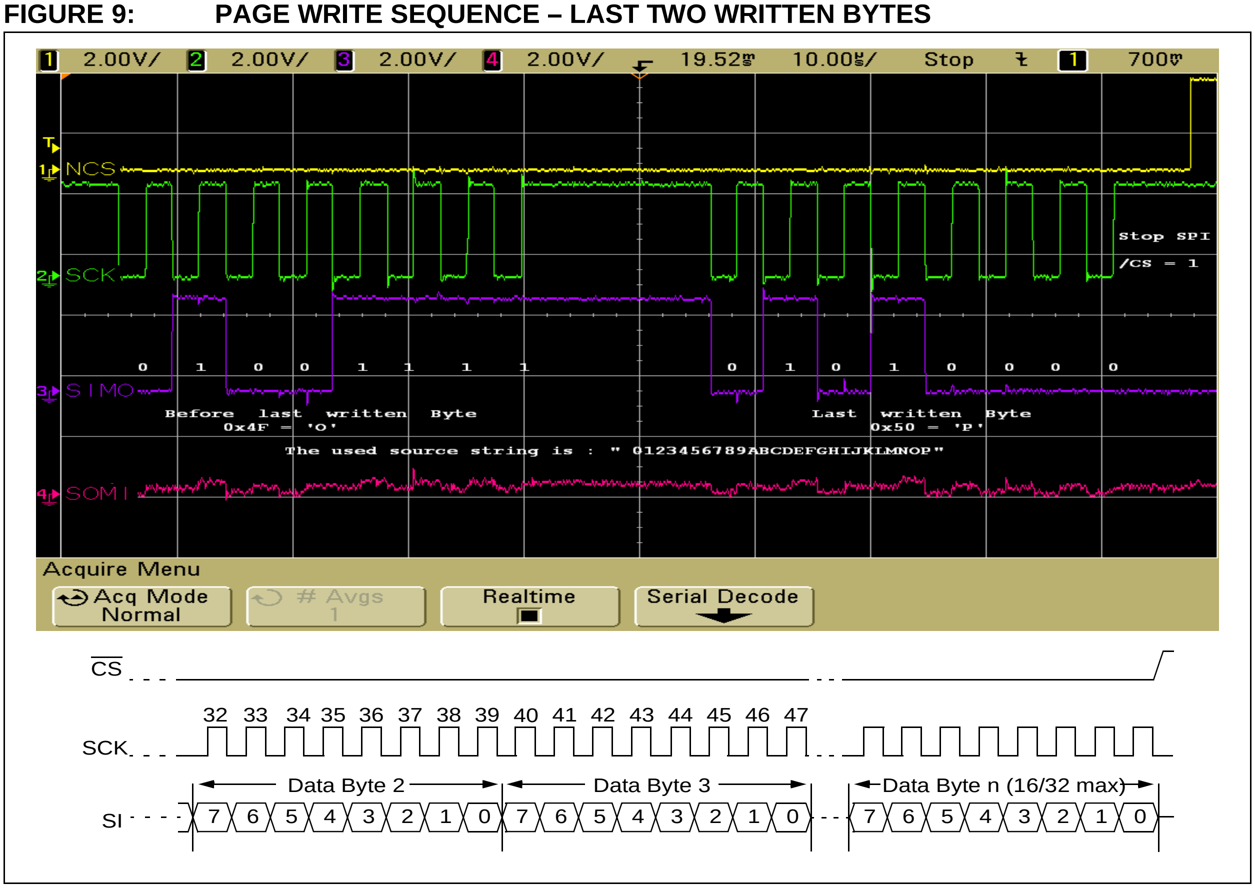
- calculates the length of the string to be written in the memory
- calculates the size of the substrings to be written inside an individual page
- splits accordingly the initial string in the related substrings
- inserts after each substring the related write cycle time (delay or polling of the WIP flag)
- re-initializes the start address for each substring (page)
- for all of these, it calls several times the page write function = `spi_wrpg`

Also, it features the following advantages:

- the most general method to write strings
- the fastest method (minimum of Twc periods)
- the most economical: saves memory space, by overriding page boundaries
- (no breaks between strings)
- increases the lifetime of the NV memory

Accordingly, by using this routine, the programmer must pass to the function only the name of the string to be written and the memory start address.

FIGURE 9: PAGE WRITE SEQUENCE – LAST TWO WRITTEN BYTES

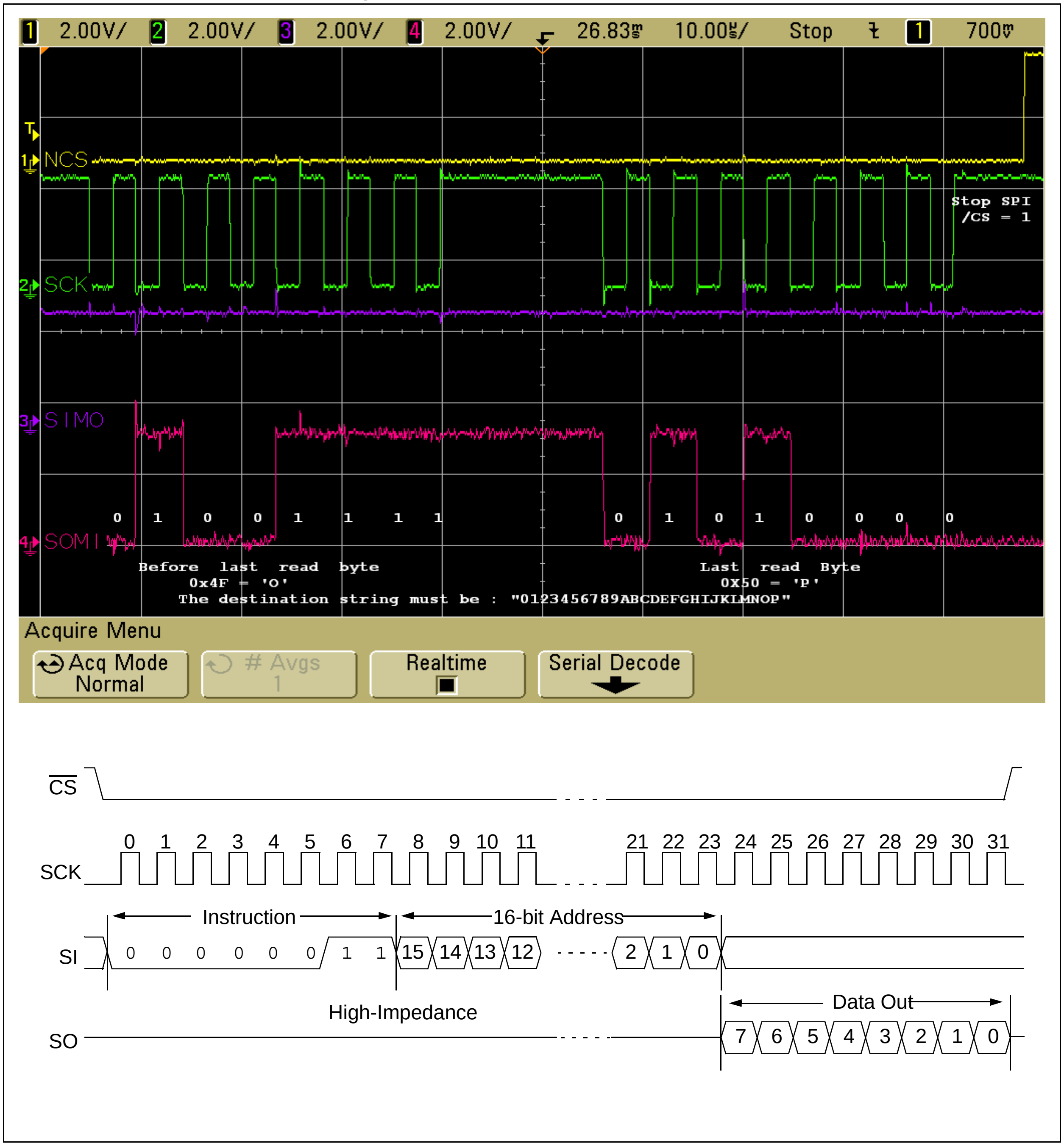


PAGE READ SEQUENCE

Page read operations read a complete string, starting with the specified address. In contrast to the page write operations described on the previous page, there is no maximum length for the page read.

After 1 Kbyte has been read, the internal address counter rolls over to the beginning of the array. Figure 10 depicts the last two read bytes, as the start of the command (Read command, word address, first read byte) is the same as in the case of the read byte sequence.

FIGURE 10: PAGE READ SEQUENCE – LAST TWO BYTES



CONCLUSION

This application note offers designers a set of firmware routines to access Microchip's SPI serial EEPROMs using a hardware peripheral. The code demonstrates byte and page operations. All routines were written using the C compiler from IAR, included in the IDE of the same company. All experiments were performed on the ES-1232 evaluation board from Softbaugh, equipped with an MSP430F1232 MCU from Texas Instruments.

The code was debugged using the USB debug interface, MSP-FET430UIF, available from Texas Instruments

The firmware was tested using the schematic shown in Figure 1.

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