Using a Hardware Module to Interface 8051 MCUs with SPI Serial EEPROMs

Author: Alexandru Valeanu
Microchip Technology Inc.

INTRODUCTION

The 25XXX series serial EEPROMs from Microchip Technology support a half-duplex protocol that functions on a master-slave paradigm that is ideally suited to data stream applications. The bus is controlled by the microcontroller (master), which accesses the 25XXX serial EEPROM (slave) via a simple Serial Peripheral Interface (SPI) compatible serial bus. Bus signals required are 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 ($\overline{\text{HOLD}}$) if the clock line is shared with other peripherals on the SPI bus. While the EEPROM is paused, transitions on its inputs are ignored, with the exception of $\overline{\text{CS}}$, allowing the MCU to service higher priority interrupts. After releasing the $\overline{\text{HOLD}}$ pin, operations resume from the point when the hold was asserted.

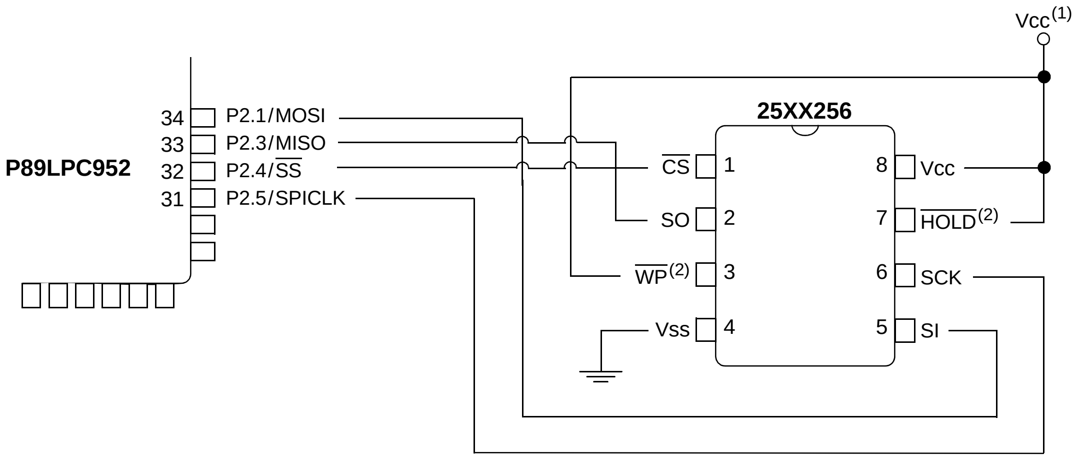
The main features of the 25XXX serial EEPROMs are:

- SPI-compatible serial interface bus
- EEPROM densities from 128 bits to 512 Kbits
- 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 the Microchip 25XXX series serial EEPROMs and NXP's P89LPC952 8051-based MCU. The schematic shows the connections necessary between the MCU and the serial EEPROM as tested. The software was written assuming these connections. The $\overline{\text{WP}}$ and $\overline{\text{HOLD}}$ pins are tied to VCC through resistors, because the write-protect and hold features are not used in the examples provided.

FIGURE 1: CIRCUIT FOR P89LPC952 MCU AND 25XXX SERIAL EEPROM



Note 1: A decoupling capacitor (typically 0.1 µF) should be used to filter noise on VCC.
2: $\overline{\text{WP}}$ and $\overline{\text{HOLD}}$ pins should have pull-up resistors (2 kΩ to 10 kΩ).

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 parts and a main routine. The main routine writes a string in the SPI serial EEPROM, reads it back and compares the two strings, displaying the results on LEDs on an evaluation board. Moreover, the main routine sends the results of the read to the UART to verify the correctness of operations.

The firmware was written in assembly language for NXP's P89LPC952 MCU using the Keil™ µVision3® IDE and was developed on the Keil MCB950 evaluation board.

The code was tested using the 25XX256 serial EEPROM. The EEPROM features 32K x 8 (256 Kbit) of memory and 64-byte pages. Oscilloscope screen shots are shown in this application note. All timings are based on the internal RC oscillator of the MCU (7.373 MHz). If a faster clock is used, the code must be modified to generate the correct delays.

The bus speed in these examples is ~1.8 MHz. As explained in the applicable SPI serial EEPROM data sheets, the maximum allowed bus speed depends on the EEPROM's operating voltage. If desired, the bus speed may be changed in the initialization routine (`ini_spi`) by modifying the SPR1 and SPR0 bits in the SPI control register (SPCTL) (refer to the section titled **"Initialization"**).

INITIALIZATION

Initialization consists of three routines: `ini_str`, `ini_spi` and `ini_memspi`. The `ini_str` routine creates the 16-byte string to be written to the serial EEPROM.

The `ini_spi` routine does two things: it prepares the MCU for communication with the serial EEPROM using the hardware peripheral, and it initializes the SPCTL register. The values of the bits in the SPCTL register are now:

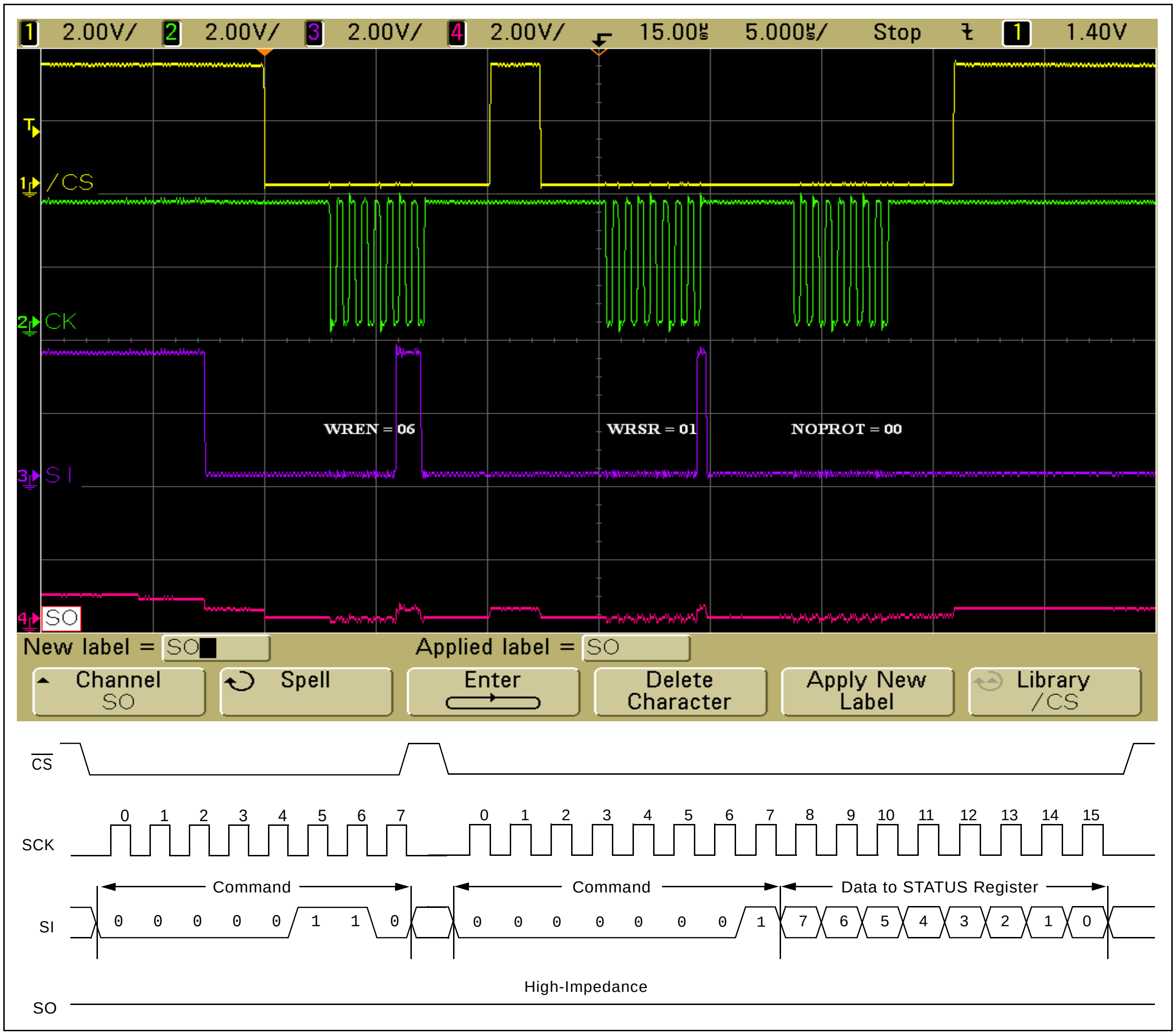
- SSIG = SPEN = MSTR = `1` (this enables the SPI port and sets the block as master)
- DORD = `0` (MSb first)
- CPOL = CPHA = `1` (CK = Idle '`1`', drive on first edge, sample on second edge)
- SPR1 = SPR0 = `0` (sets the maximum speed `F_spi_ck` = `main_ck`:4 ~ 7.373 MHz: 4 ~ 1.8 MHz)

If another speed is desired, the SPR1 and SPR0 bits must be set to other values.

The third routine, `ini_memspi`, prepares the serial EEPROM for further writes.

The structure of the initialization operation is as follows: Write Enable (`WREN`) + Write STATUS Register (`WRSR`) + `WRITE (#NOPROT = 00)`. The scope plot showing this operation appears in Figure 2.

FIGURE 2: WRITE TO STATUS REGISTER



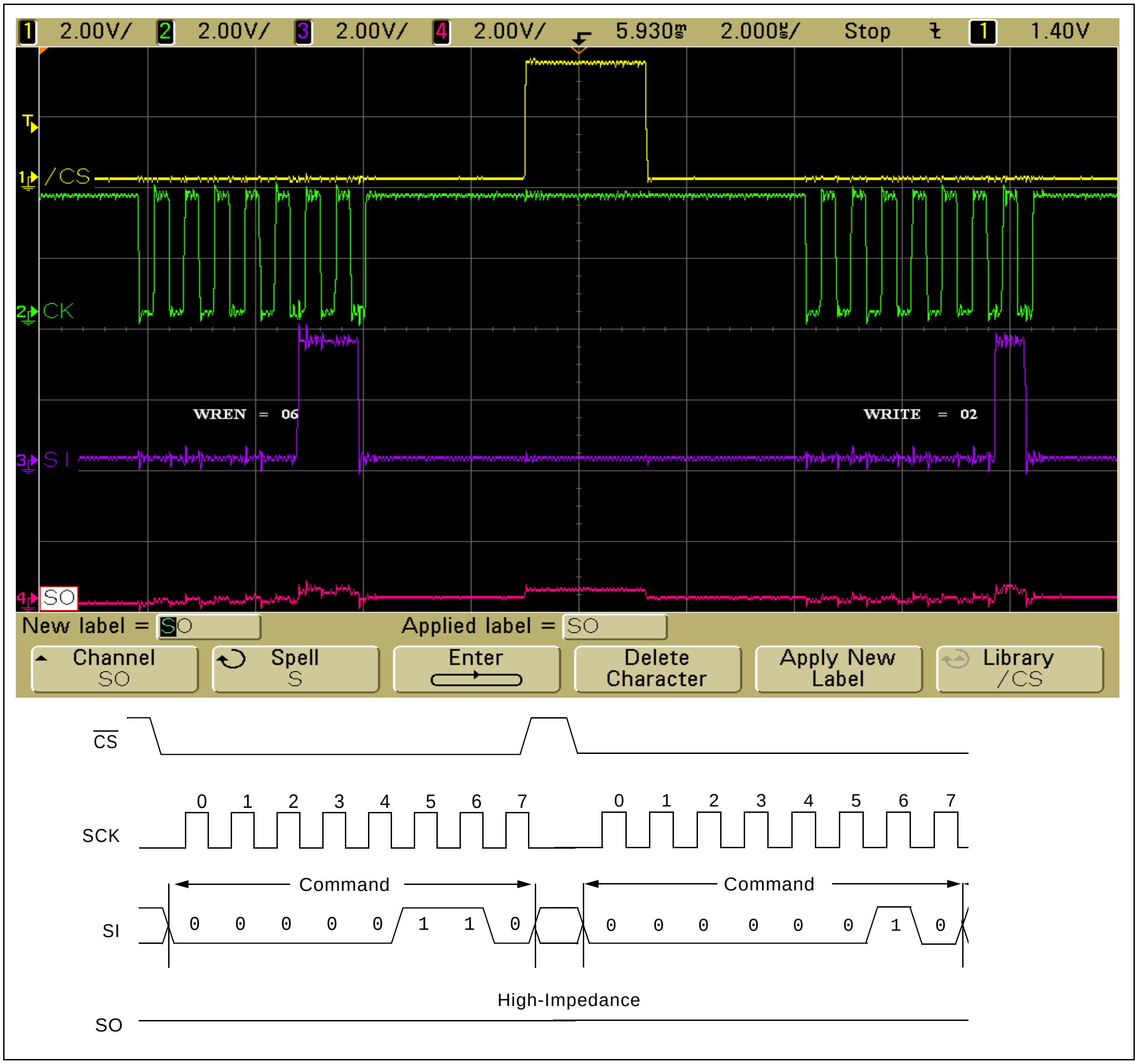
WRITE ENABLE

Before a write operation to the array 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 or if a write cycle is completed.

Figure 3 shows the `WREN` and `WRITE` pair of commands.

FIGURE 3: WRITE ENABLE AND WRITE COMMANDS

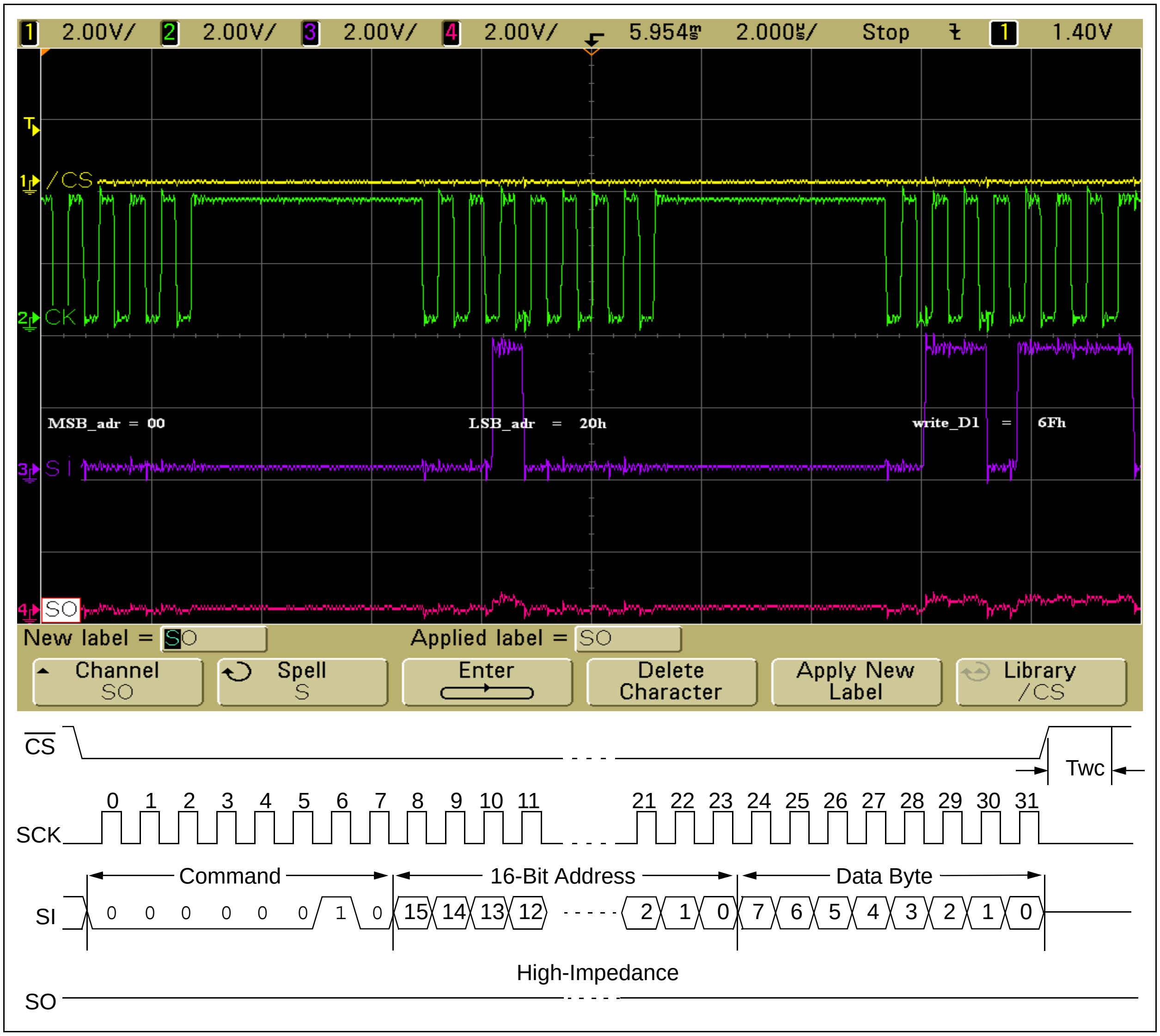


BYTE WRITE

The byte write operation consists of the MCU sending the WRITE command followed by the word address and data byte. The word address for the 25XX256 is a 16-bit value, so two bytes must be transmitted for the entire word address, with the Most Significant Byte sent first. Note that the WREN command is not illustrated in this section but is still required to initiate the operation.

Figure 4 shows the sequence MSB address (00), LSB address (20h) and the first written byte (6Fh).

FIGURE 4: WRITE COMMAND AND WORD ADDRESS

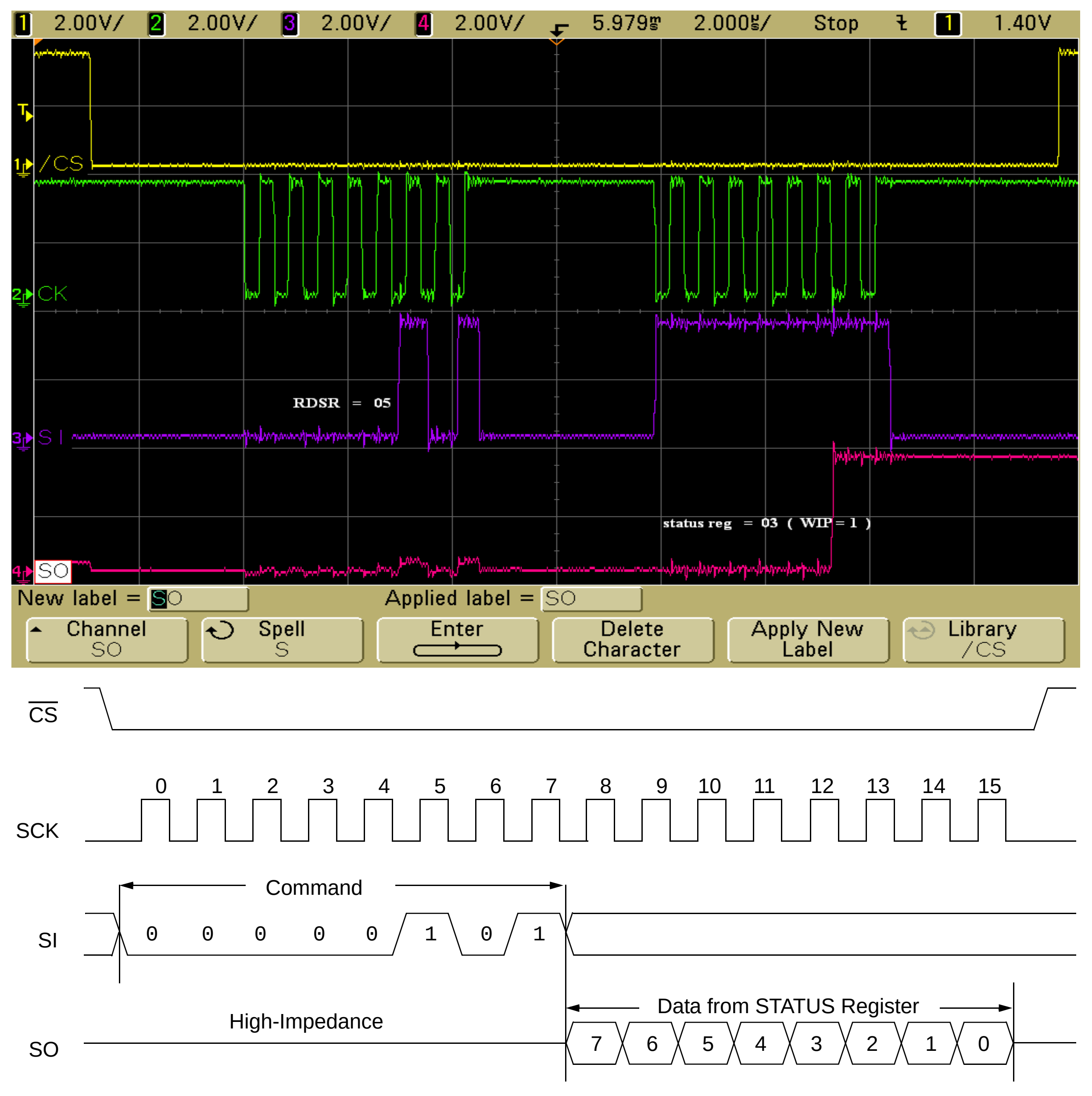


DATA POLLING (RDSR – CHECK FOR WIP SET)

After the MCU issues a `WRITE` command, it reads the STATUS register to check if the internal write cycle has been initiated. The STATUS register can be continuously monitored to look for the end of the write cycle.

When the write operation has ended, the MCU selects the serial EEPROM and sends the Read STATUS Register command (`RDSR`) (‘`00000101`’ or 0x05), as shown in Figure 5. 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 5. Both the WEL bit (bit 1) and the WIP bit (bit 0) are set (‘1’), indicating that the write cycle is in progress.

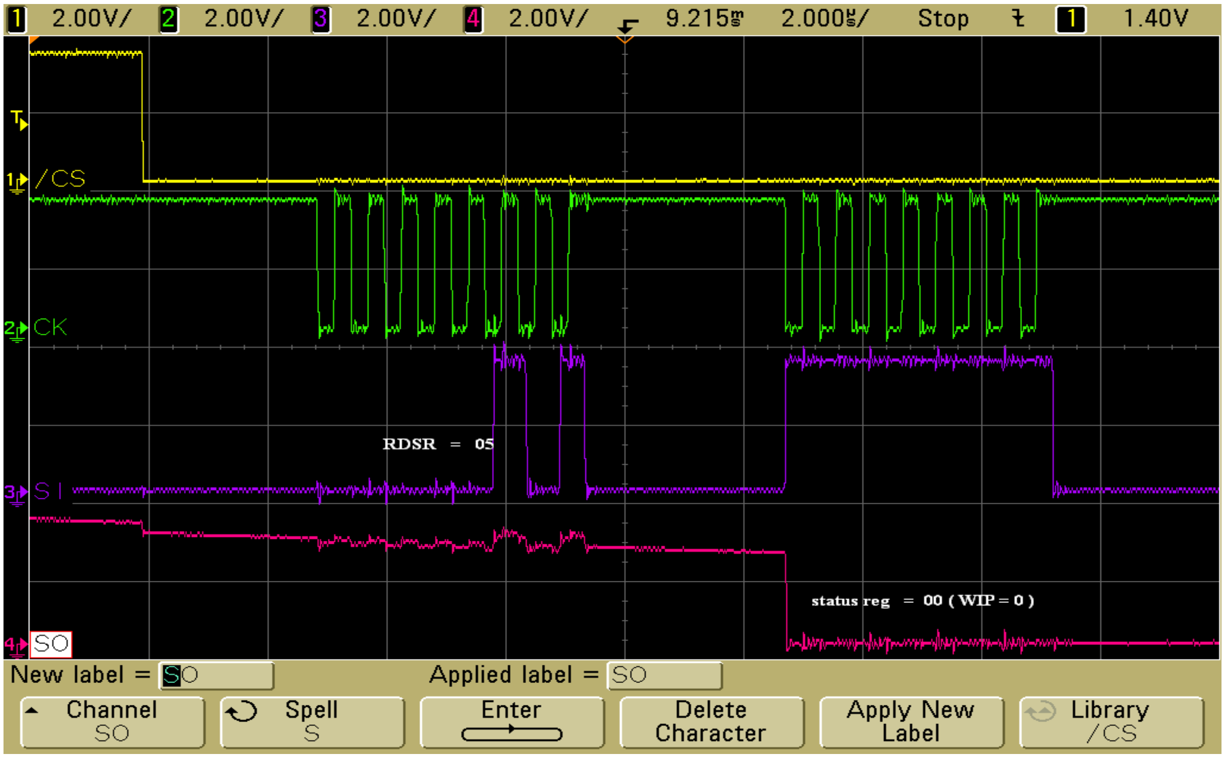
FIGURE 5: DATA POLLING (READ STATUS REGISTER TO CHECK WIP BIT)



DATA POLLING FINISHED (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 6 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 6: DATA POLLING FINISHED (RDSR – WIP AND WEL BITS CLEARED)



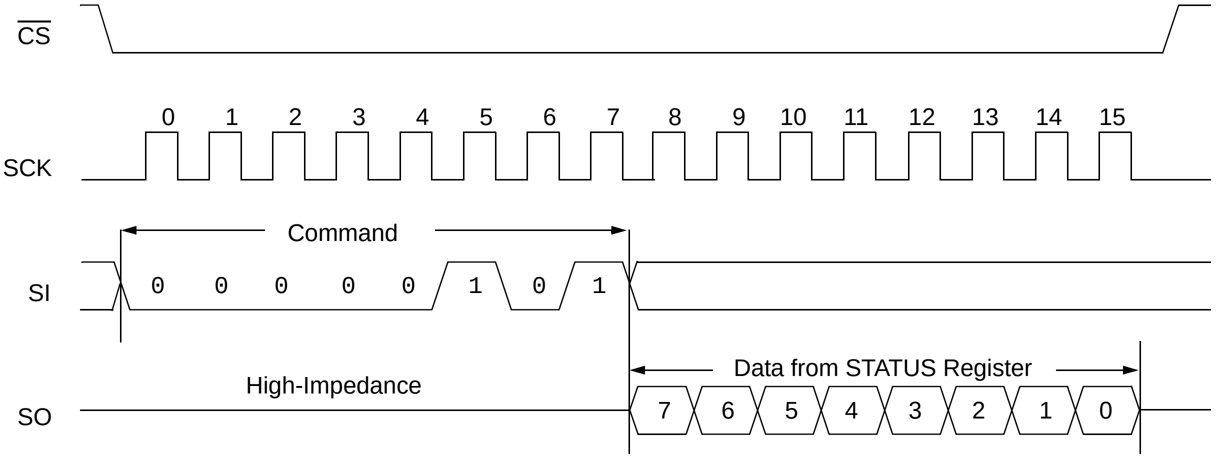
1 2.00V/ 2 2.00V/ 3 2.00V/ 4 2.00V/ 9.215ms 2.000us/ Stop 1 1.40V

RDSR = 05

status reg = 00 (WIP = 0)

New label = SO

Applied label = SO

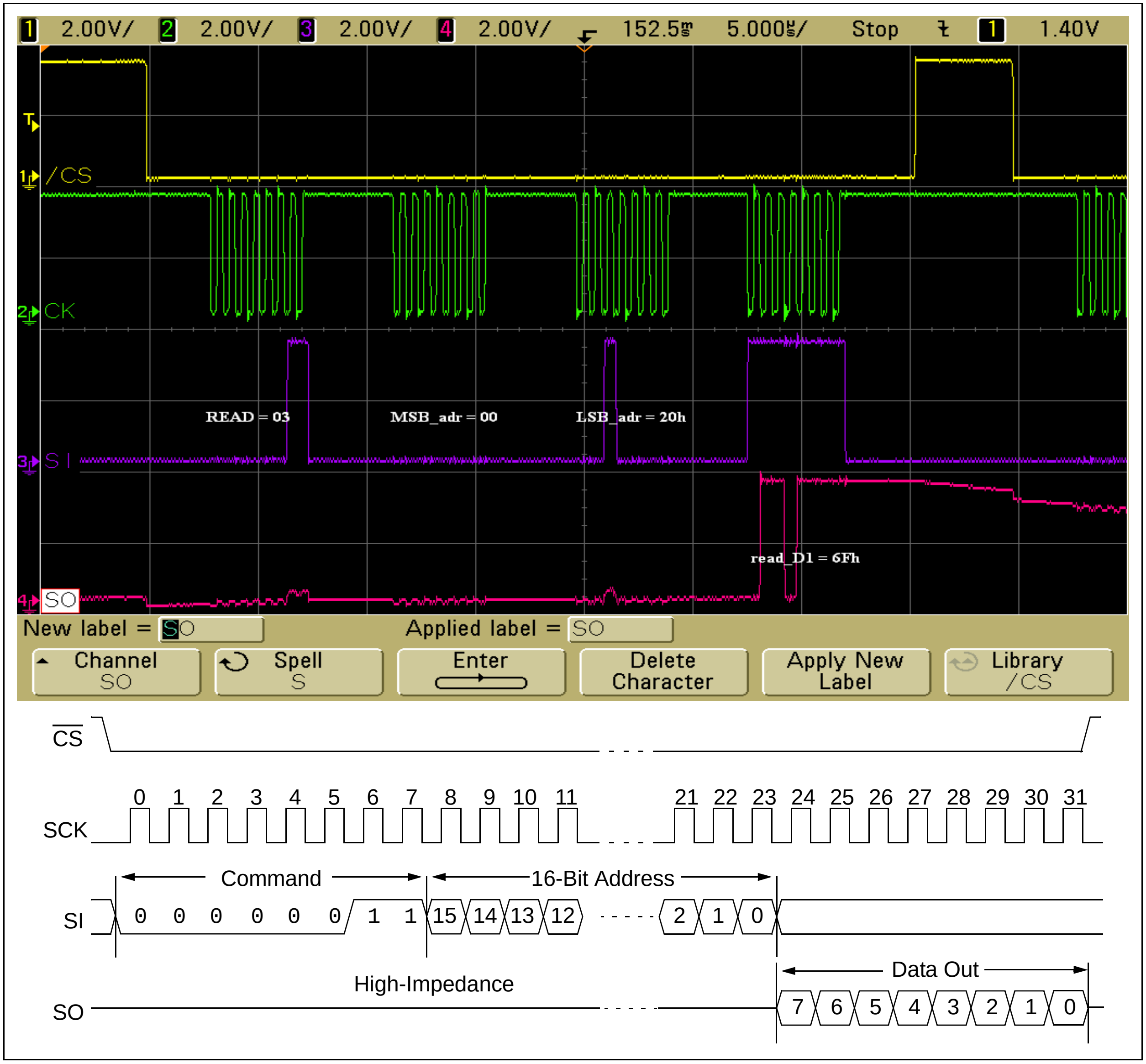


BYTE READ

The byte read operation can be used to read data from the serial EEPROM. The MCU transmits the command byte followed by the word address bytes to the serial EEPROM.

Figure 7 shows an example of the READ command, followed by the MSB and LSB address bytes, followed by the first read byte. After the MCU reads the data byte, the SO line relaxes and goes to a high impedance state.

FIGURE 7: BYTE READ (COMMAND BYTE, WORD ADDRESS AND FIRST READ BYTE)



1 2.00V/ 2 2.00V/ 3 2.00V/ 4 2.00V/ 152.5㎲ 5.000㎲/ Stop 1 1.40V

New label = SO

Applied label = SO

PAGE WRITE

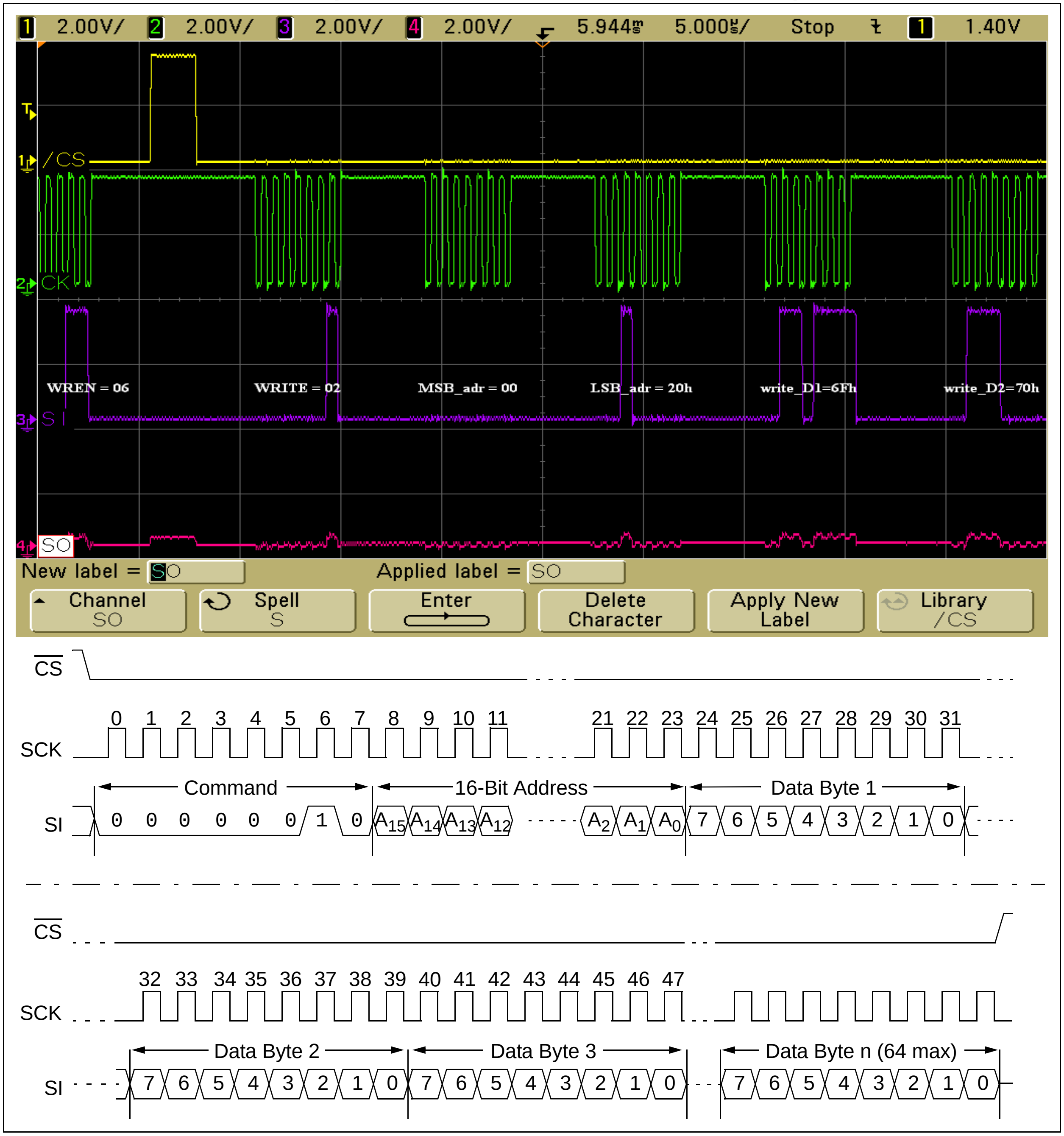
Page write operations provide a technique for increasing throughput when writing large blocks of data. The 25XX256 serial EEPROM features a 64-byte page. By using the page write feature, up to 1 full page of data can be written consecutively.

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 to 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.

Figure 8 shows four consecutive data bytes during a page write operation.

FIGURE 8: PAGE WRITE (FIRST FOUR CONSECUTIVE DATA BYTES)

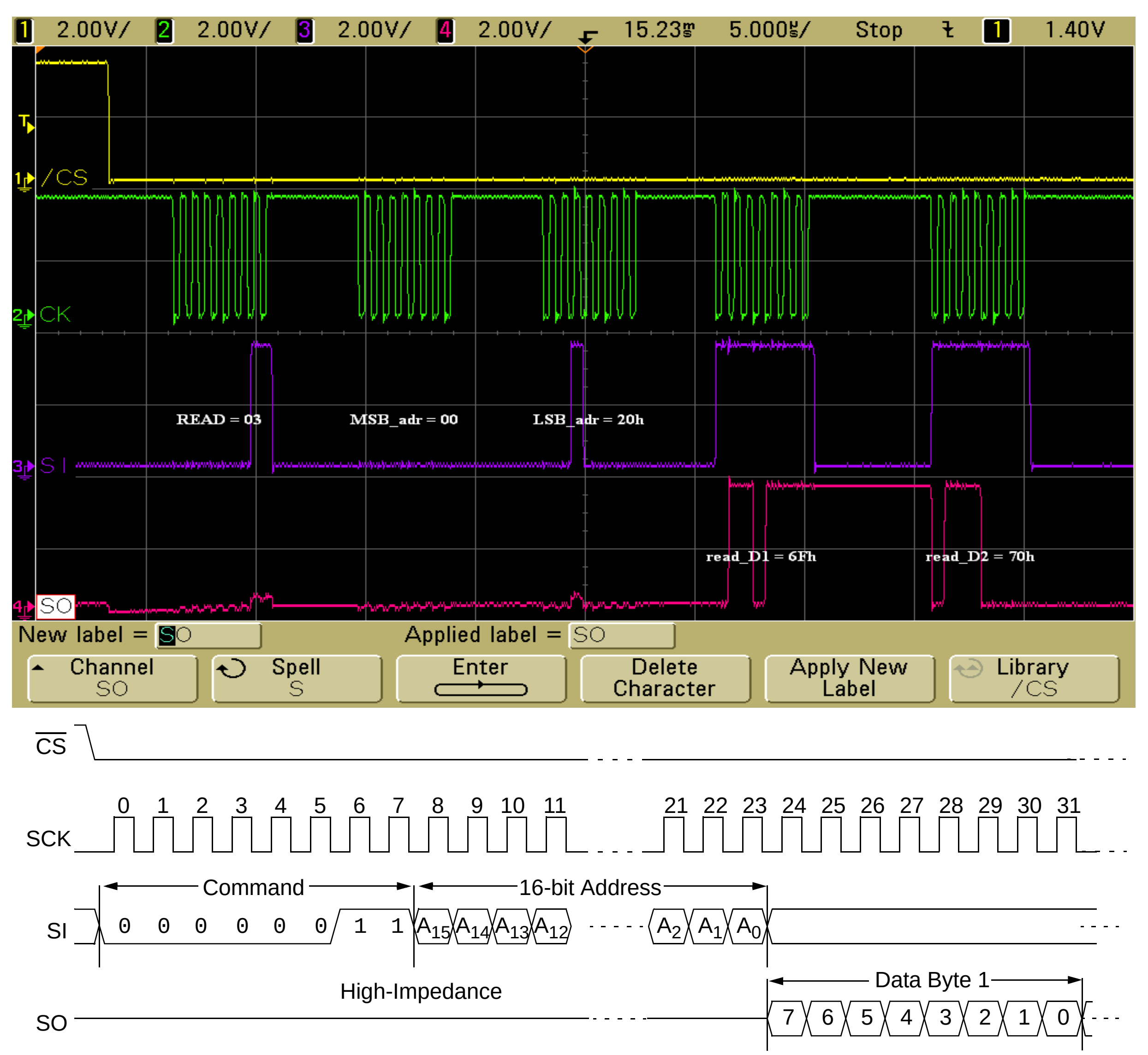


PAGE READ

Page read operations read a complete string, starting with the specified address. In contrast to page write operations described on the previous page, there is no maximum length for page read. After 64 Kbytes have been read, the internal address counter rolls over to the beginning of the array.

Figure 9 depicts the entire sequence of commands necessary to perform the page read operation. For clarity, only the first two read bytes are shown.

FIGURE 9: PAGE READ (FIRST TWO READ BYTES)



BYTE WRITE VERSUS PAGE WRITE

At first glance, the page write method appears superior to the byte write method: it’s simpler and faster. However, a careful analysis shows that the byte write method has a major advantage over page write owing to the roll-over phenomenon (see Note).

> **Note:** Page write operations are limited to writing bytes within a single physical page, regardless of the number of bytes actually being written. Physical page boundaries start at addresses that are integer multiples of the page buffer size (or page size), and they end at addresses that are integer multiples of [page `size-1`]. If a `Page Write` command attempts to write across a physical page boundary, the result is that the data wraps around to the beginning of the current page (overwriting data previously stored there) instead of being written to the next page as might be expected. It is therefore necessary for the application software to prevent page write operations that would attempt to cross a page boundary.

As a consequence of the roll-over phenomenon, applications that write long strings to the SPI serial EEPROM risk overlapping the page boundary in the middle of a string. In such instances, the firmware should use byte write to avoid this condition. The disadvantage of doing this is the slower speed involved in writing the entire string: every byte write cycle time is approximately 5 ms.

The following summarizes the differences between the byte write and page write methods.

Byte Write

- Is slower – It needs a 5 ms write cycle time for each byte.
- Is more general – It may write a string of any length.

Page Write

- Is faster – It needs only one write cycle time for the whole page.
- Care must be taken to observe page boundaries during page writes.

CONCLUSION

This application note offers designers a set of firmware routines to access SPI serial EEPROMs using a hardware peripheral. The code demonstrates byte and page operations. All routines were written in the assembly language for an 8051-based MCU.

The code was developed on the Keil MCB950 evaluation board using the schematic shown in Figure 1. It was tested using the NXP P89LPC952 MCU and debugged using the Keil µVision3 IDE.

NOTES:

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