AN1186

Using C and a Timer to Interface MSP430 MCUs with UNI/O® Bus-Compatible Serial EEPROMs

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INTRODUCTION

As embedded systems become smaller, a growing need exists to minimize I/O pin usage for communication between devices. Microchip has addressed this need by developing the UNI/O® bus, a low-cost, easy-to-implement solution requiring only a single I/O pin for bidirectional communication.

UNI/O bus-compatible serial EEPROMs can be used to enhance any application facing restrictions on available I/O. Such restrictions can potentially stem from connectors, board space or from the microcontroller itself.

The 11XXX family is the newest addition to Microchip Technology's broad serial EEPROM product line, and is compatible with the newly developed UNI/O bus.

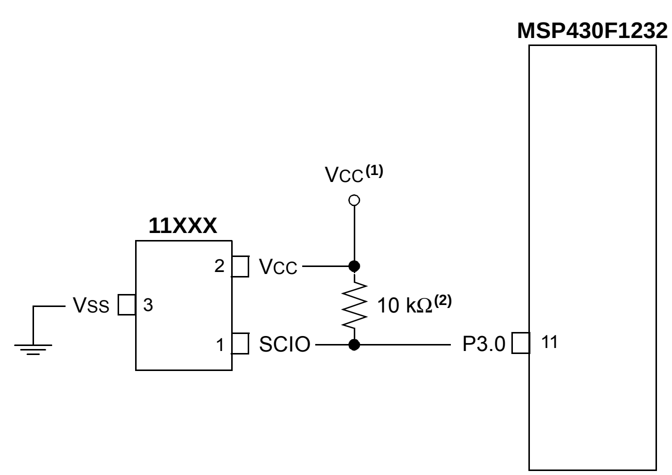
Some of the main features of 11XXX serial EEPROMs are:

- Single I/O pin used for communication
- EEPROM densities from 1 Kbits to 16 Kbits
- Extremely small packages
- Bus speed from 10 kHz up to 100 kHz
- 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

This application note is part of a series that provide source code to help the user implement the protocol with minimal effort.

Figure 1 is the hardware schematic depicting the interface between the Microchip 11XXX series of UNI/O bus-compatible serial EEPROMs and Texas Instrument's MSP430 MCUs. The schematic shows the connections necessary between the MCU and the serial EEPROM as tested. Additional components used for testing and debugging are not shown but are detailed in the firmware files. The software was written assuming these connections. The single I/O connection between the MCU and the serial EEPROM includes a recommended pull-up resistor. A decoupling capacitor across VCC and VSS is also recommended.

FIGURE 1: CIRCUIT FOR MSP430F1232 MCU AND 11XXX SERIAL EEPROM



Note 1: A decoupling capacitor (typically 0.1 µF) should be used to filter noise on VCC.
2: A pull-up resistor (typically 10 kΩ) on SCIO is recommended to ensure bus idle during power-up.

FIRMWARE DESCRIPTION

The purpose of the firmware is to show how to generate specific UNI/O bus transactions using a generic I/O pin on the microcontroller. The focus is to provide the designer with a strong understanding of communication with the 11XXX series serial EEPROMs, thus allowing for more complex programs to be written in the future.

The firmware was written using the IAR™ IDE and the related C compiler. It was developed on a SoftBaugh™ ES1232 evaluation board that was connected to a PC through an MSP-FET430UIF USB debug interface from Texas Instruments. The code can easily be modified to use any available I/O line.

The firmware consists of a single file that includes declarations, definitions, and the main function. The code is organized into the following sections:

- Initialization
- Write Enable
- Byte Write
- Write-in-Process Polling
- Byte Read
- Page Write

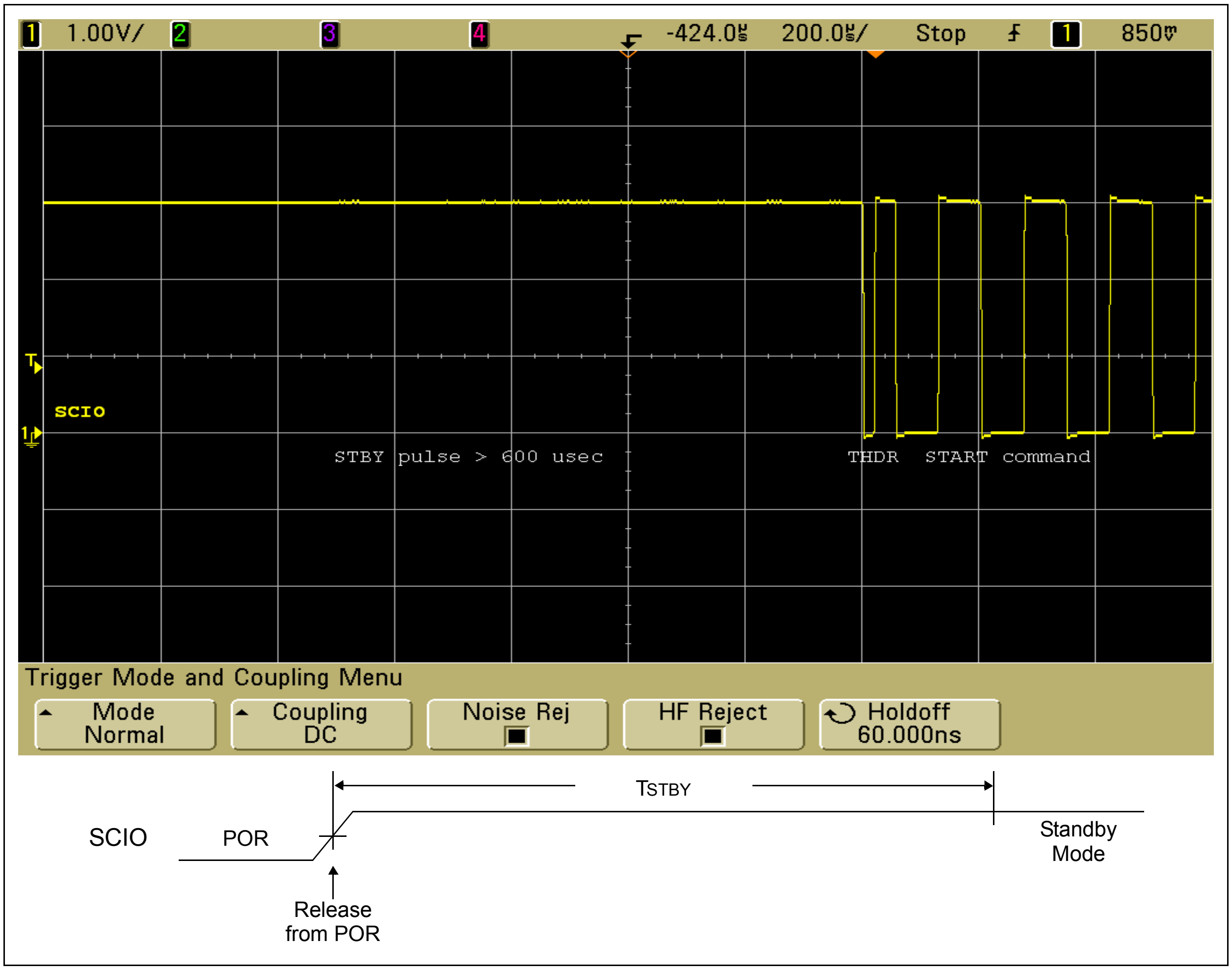
The code was tested using the 11XX160 serial EEPROM. The EEPROM features 2K x 8 (16 Kbit) of memory and 16-byte pages. Oscilloscope screen shots are shown in this application note. All timings are based on the 10 MHz internal RC oscillator of the MCU.

INITIALIZATION

Before initiating communication with the serial EEPROM, the MCU must generate a low-to-high edge on the SCIO to release the serial EEPROM from Power-on Reset (POR). Because bus idle is high, the MCU must create a high-low-high pulse on the SCIO. Once the serial EEPROM has been released from POR, a standby pulse with a minimum timing of T_{STBY} is performed to place the serial EEPROM into Standby mode, as shown in Figure 2.

Note that once a command has successfully executed – indicated by the reception of a Slave Acknowledgment (SAK) following the No Master Acknowledgment (NoMAK) – the serial EEPROM enters Standby mode immediately and a standby pulse is not necessary. In this case, only the start header setup time (T_{SS}) must be observed before the MCU may initiate another command to the same serial EEPROM.

FIGURE 2: STANDBY PULSE



WRITE ENABLE

Before a write operation to the array or the STATUS register can occur, the Write Enable Latch (WEL) bit must be set. This is done by issuing a Write Enable (WREN) command.

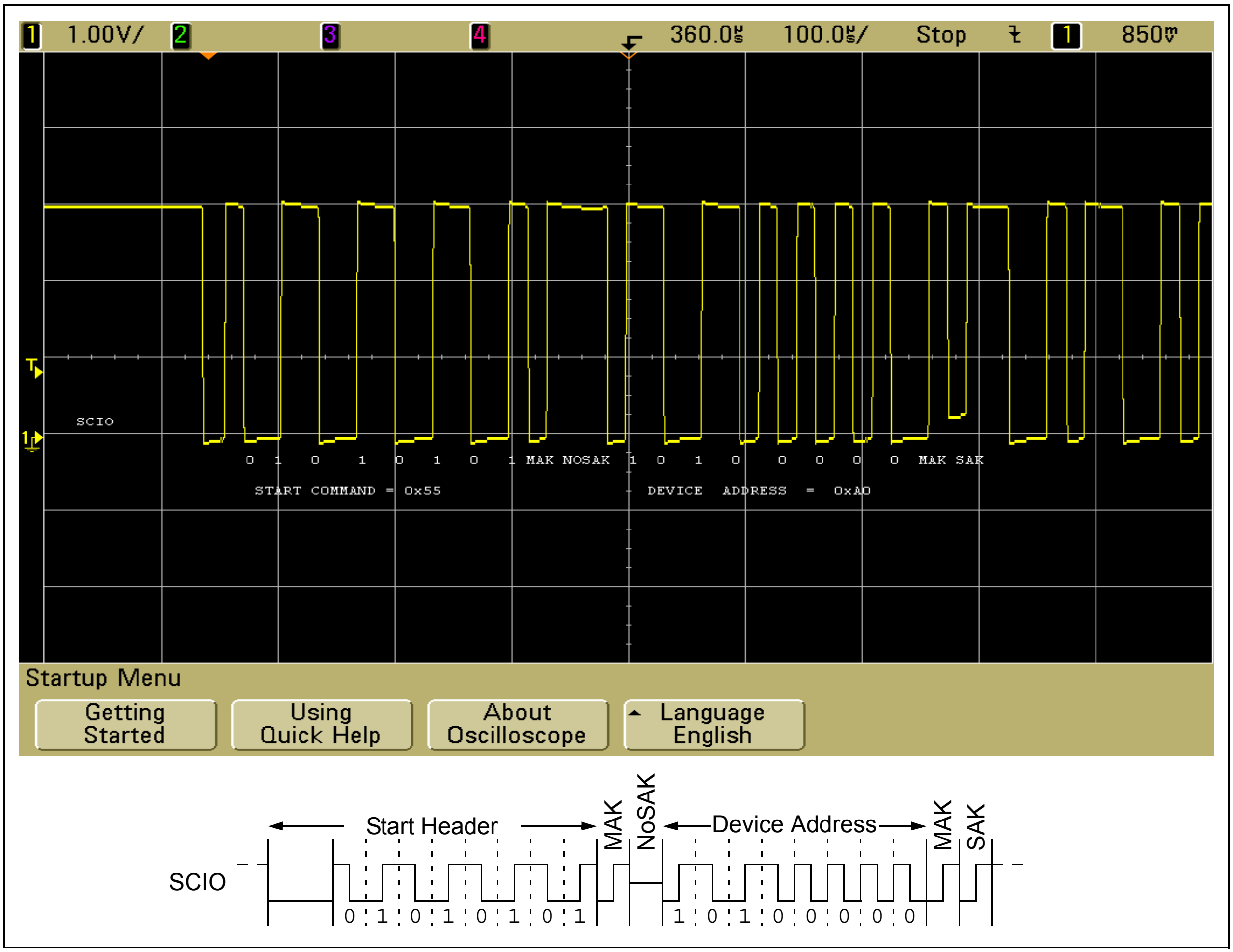
The WEL bit can be cleared by issuing a Write Disable (WRDI) command. It is also cleared upon termination of a write cycle to either the array or the STATUS register, and upon POR.

The write enable operation consists of the following components: the start header, which is followed by the device address and the command byte.

Start Header and Device Address

To issue a WREN command, the MCU transmits the start header. This consists of a low pulse (T_{HDR}) followed by '01010101', and a Master Acknowledge (MAK) followed by a NoSAK. Next, the MCU transmits the device address ('10100000') and another MAK. The serial EEPROM then responds with a SAK if the start header and device address were received correctly. Figure 3 shows the details of the start header and the device address.

FIGURE 3: START HEADER AND DEVICE ADDRESS

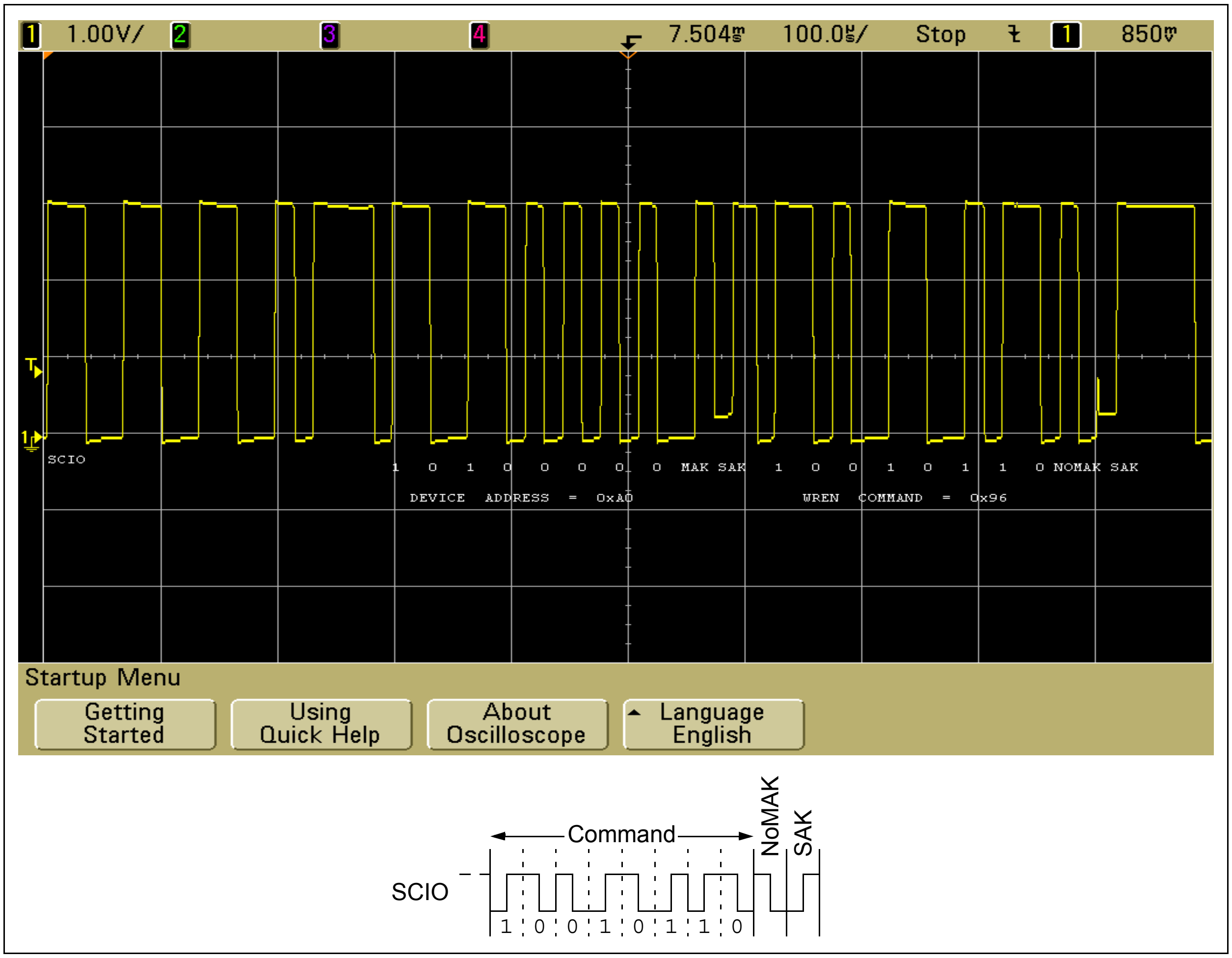


Write Enable (WREN) Command Byte

Once the SAK is received following the device address, the MCU sends the WREN command (‘`10010110`’ or 0x96) and performs a final Acknowledge sequence. During this last sequence, the MCU sends a NoMAK to signal the end of the operation. Once again, the serial EEPROM responds with a SAK, indicating it received the byte successfully.

Figure 4 shows an example of the WREN command.

FIGURE 4: WRITE ENABLE COMMAND



BYTE WRITE

The byte write operation consists of the following components: the write command followed by the word address and data byte. Note that the start header and device address are not illustrated in this section but are still required to initiate the operation.

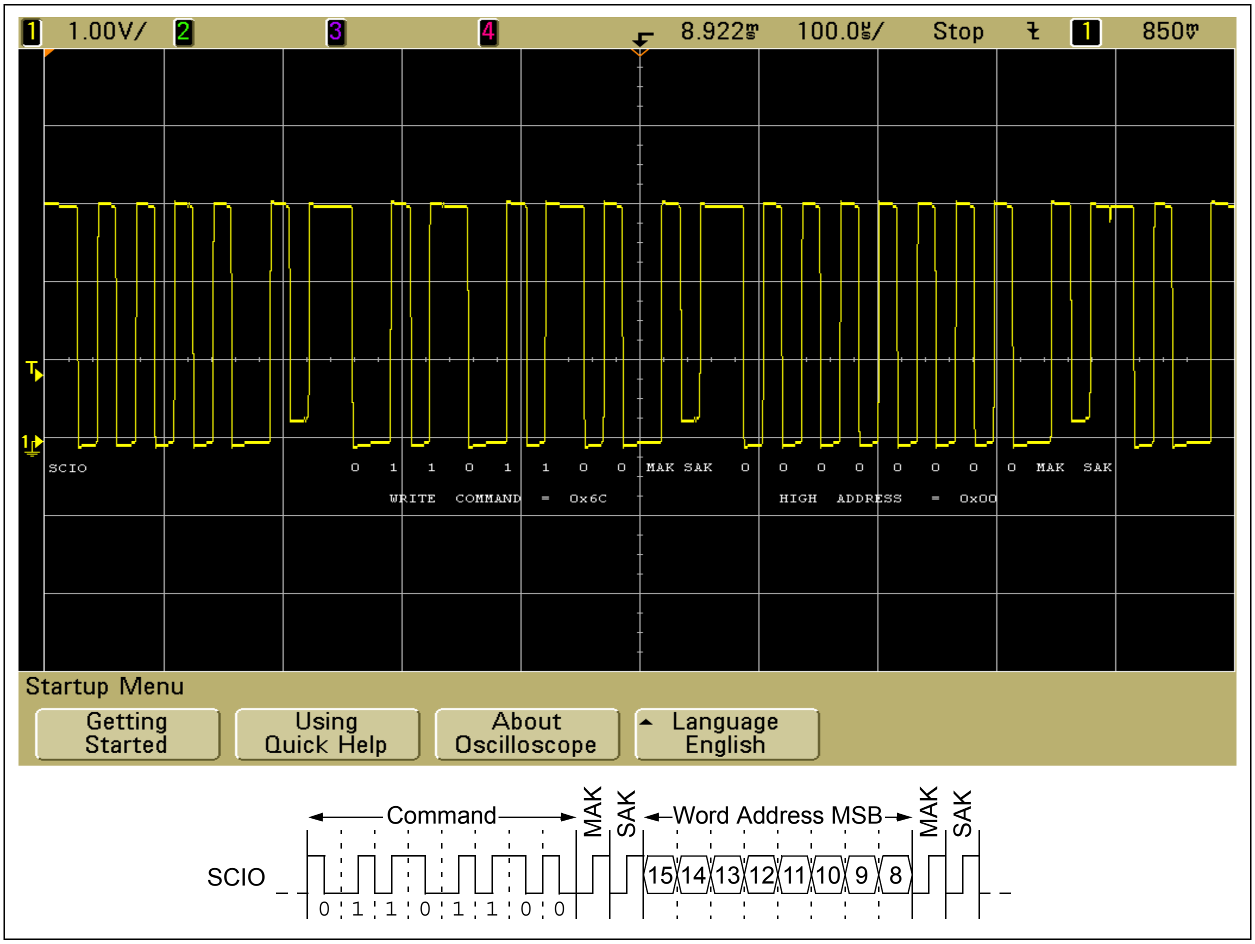
The acknowledge scheme is included as part of the provided functions but will be shown as part of the commands. Please consult the device data sheet for more information.

Sending the Write Command and Word Address

After the EEPROM device has acknowledged the start header and device address, the MCU sends the write command, followed by the word address. The write command is '`01101100`' or 0x6C. The word address for the 11XX160 is a 16-bit value, so two bytes must be transmitted for the entire word address, with the Most Significant Byte sent first. After the command byte and the word address bytes have been sent, the MCU generates a MAK; the serial EEPROM responds with a SAK if there are no errors.

Figure 5 shows the command byte, the MSB address byte and the corresponding MAK/SAK. The LSB address byte is shown in Figure 6.

FIGURE 5: WRITE COMMAND AND WORD ADDRESS



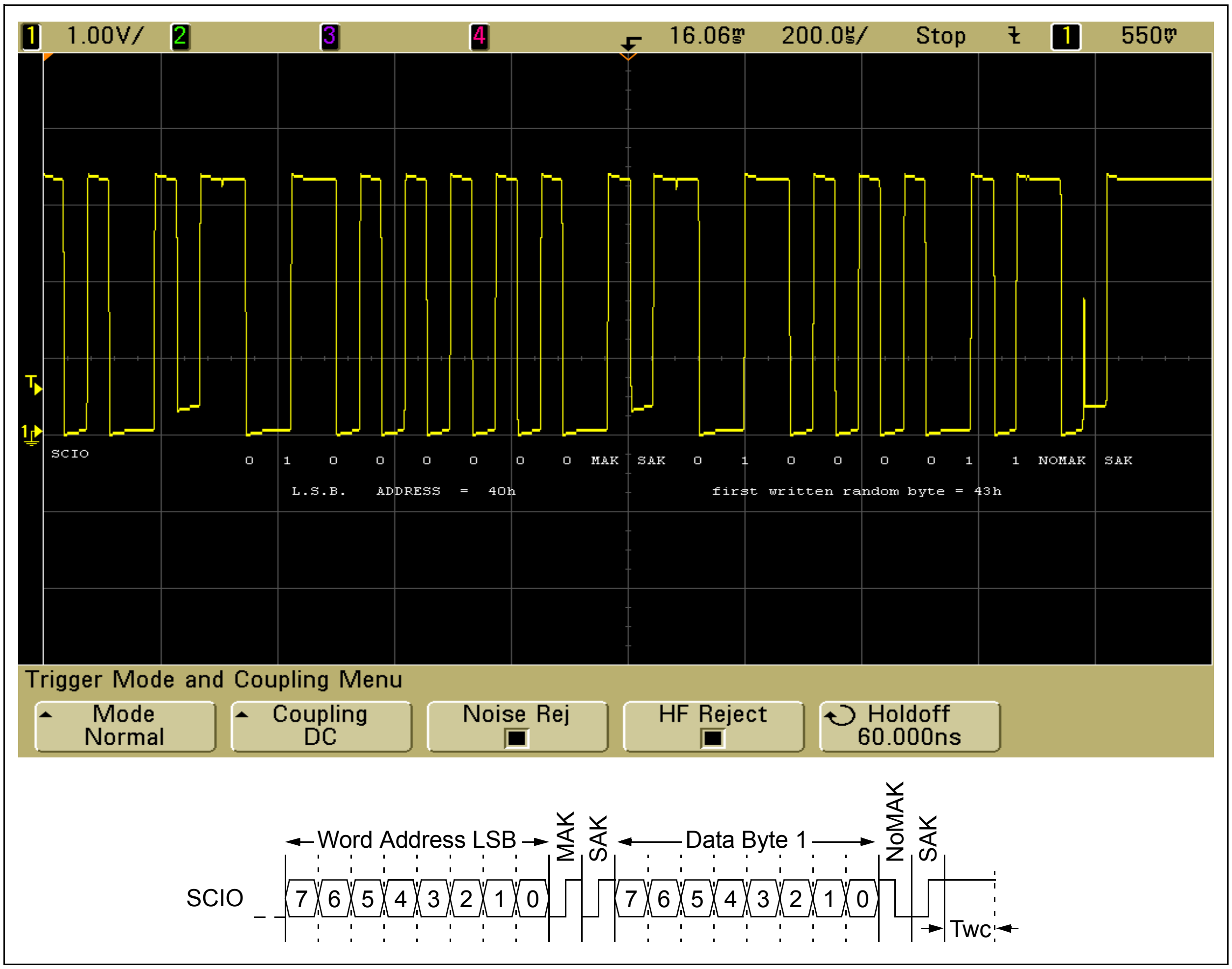
Data Byte and Command Termination

Once the word address has been transmitted and the last SAK received, the MCU sends the data byte.

After sending the data byte, the MCU terminates the command by generating a NoMAK in place of the MAK, and the serial EEPROM again responds with a SAK. This also initiates the internal write cycle (TWC).

Figure 6 shows the transmission of the LSB address byte and the data byte, as well as the NoMAK and SAK.

FIGURE 6: LSB ADDRESS BYTE, DATA BYTE AND STOP BIT



WRITE-IN-PROCESS POLLING

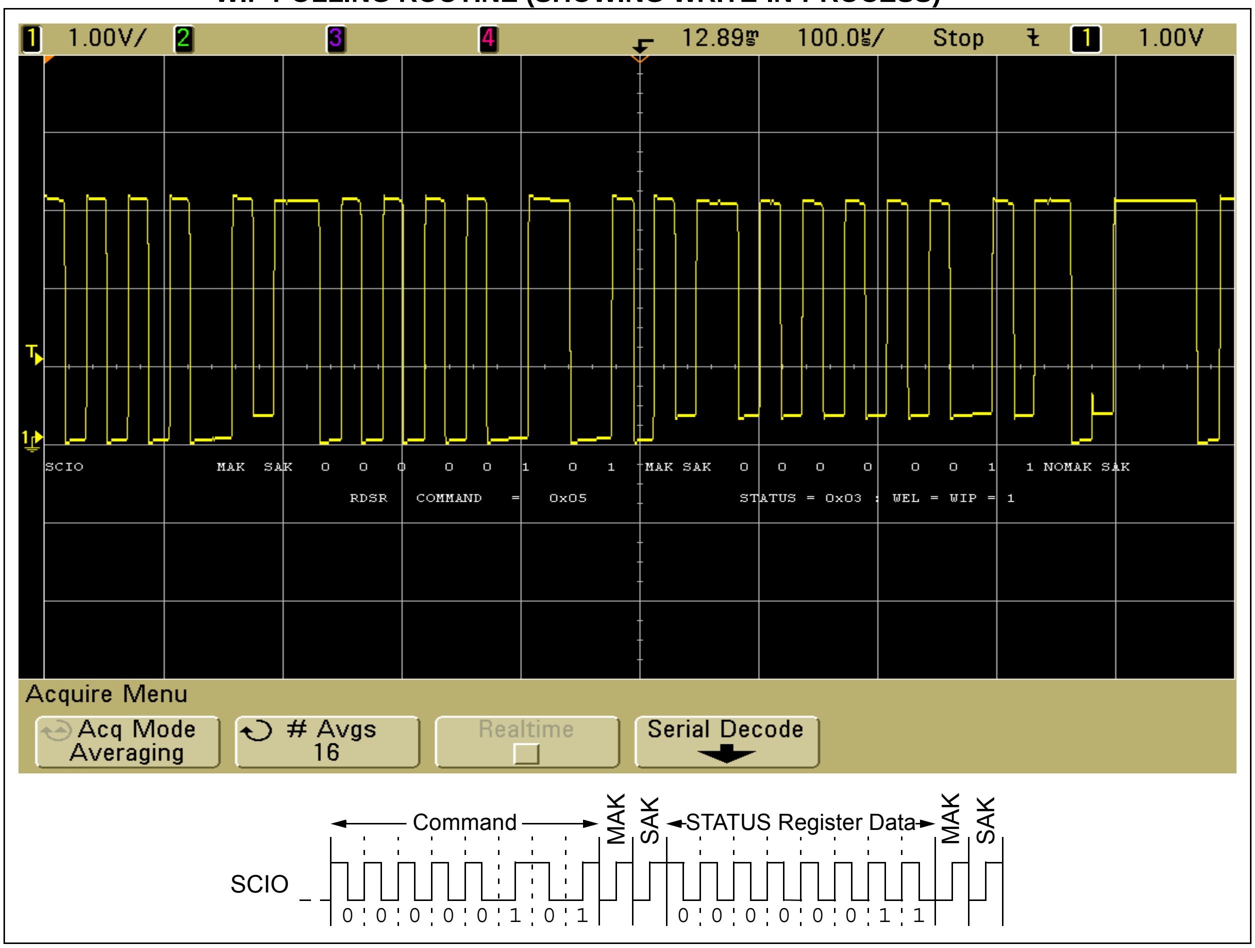
After an array or STATUS register `WRITE` instruction is executed, the MCU must observe a write cycle time (TWC). Write cycle time is a maximum, so the actual time required is typically less. Therefore, to transfer data as efficiently as possible, using the Write-In-Process (WIP) polling feature is highly recommended. Because the STATUS register can be read during a write cycle, the WIP bit can be continuously monitored to determine the completion of the write cycle.

Write-In-Process Polling Routine

The process of WIP polling consists of the MCU sending a start header and device address after observing the TSS period. The MCU follows this by sending the Read Status Register (RDSR) command (‘`00000101`’ or 0x05) and MAK. After sending the subsequent SAK, the serial EEPROM transmits the STATUS register. At this point, the STATUS register can be requested again by sending a MAK. The WEL and WIP values sent are updated dynamically, so the MCU can continuous check the STATUS register. Sending a NoMAK terminates the command.

Figure 7 shows an example of WIP polling to check if a write operation has finished. In this example, the WIP bit is set (‘`1`’), indicating that the write cycle has not yet completed.

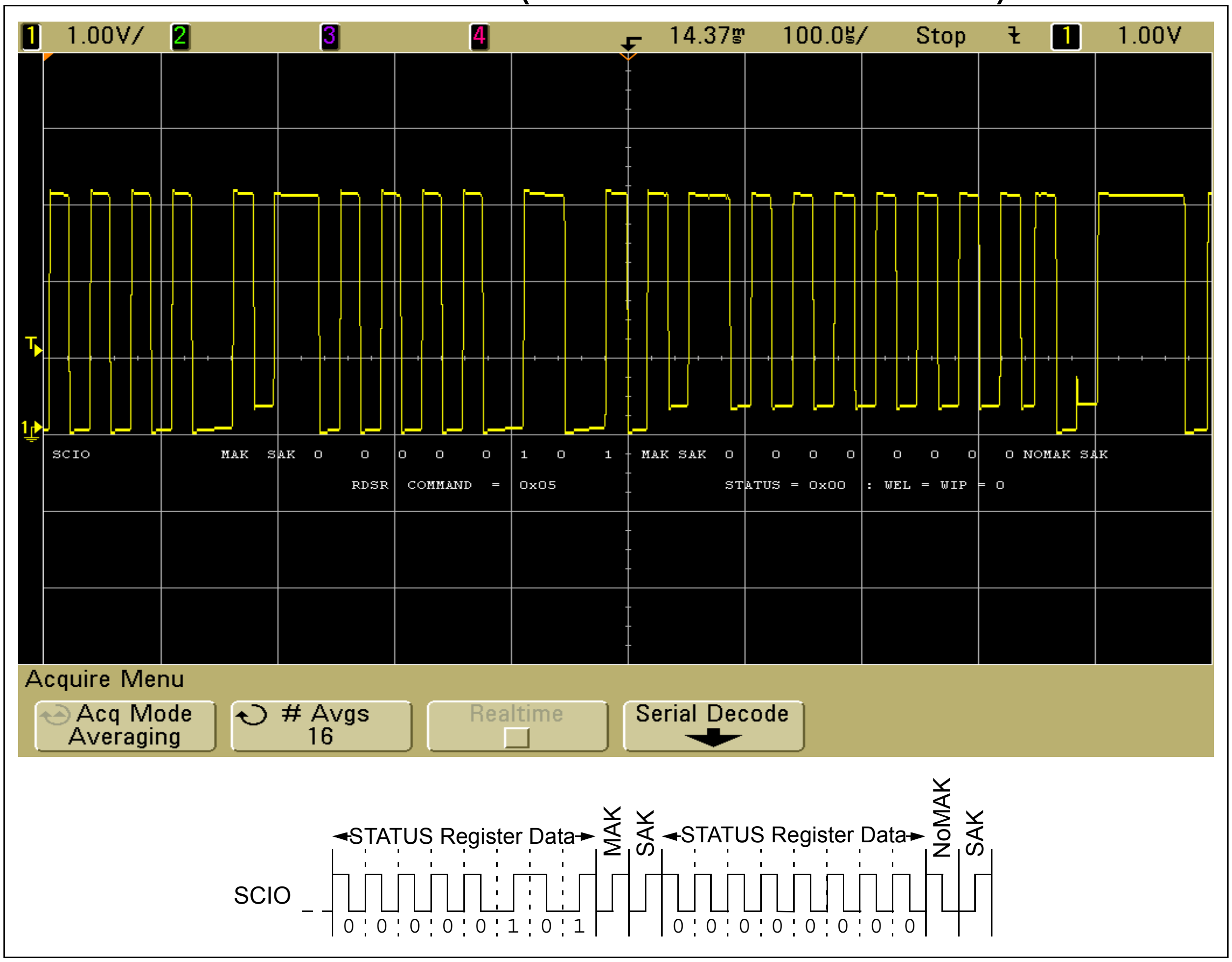
FIGURE 7: WIP POLLING ROUTINE (SHOWING WRITE-IN-PROCESS)



WIP Polling Complete

Figure 8 shows the final read of the STATUS register after the page write operation, in which the WIP bit is clear (‘0’). This indicates that the write cycle is complete and the serial EEPROM is ready to continue.

FIGURE 8: WIP POLLING FINISHED (SHOWING WRITE CYCLE COMPLETE)



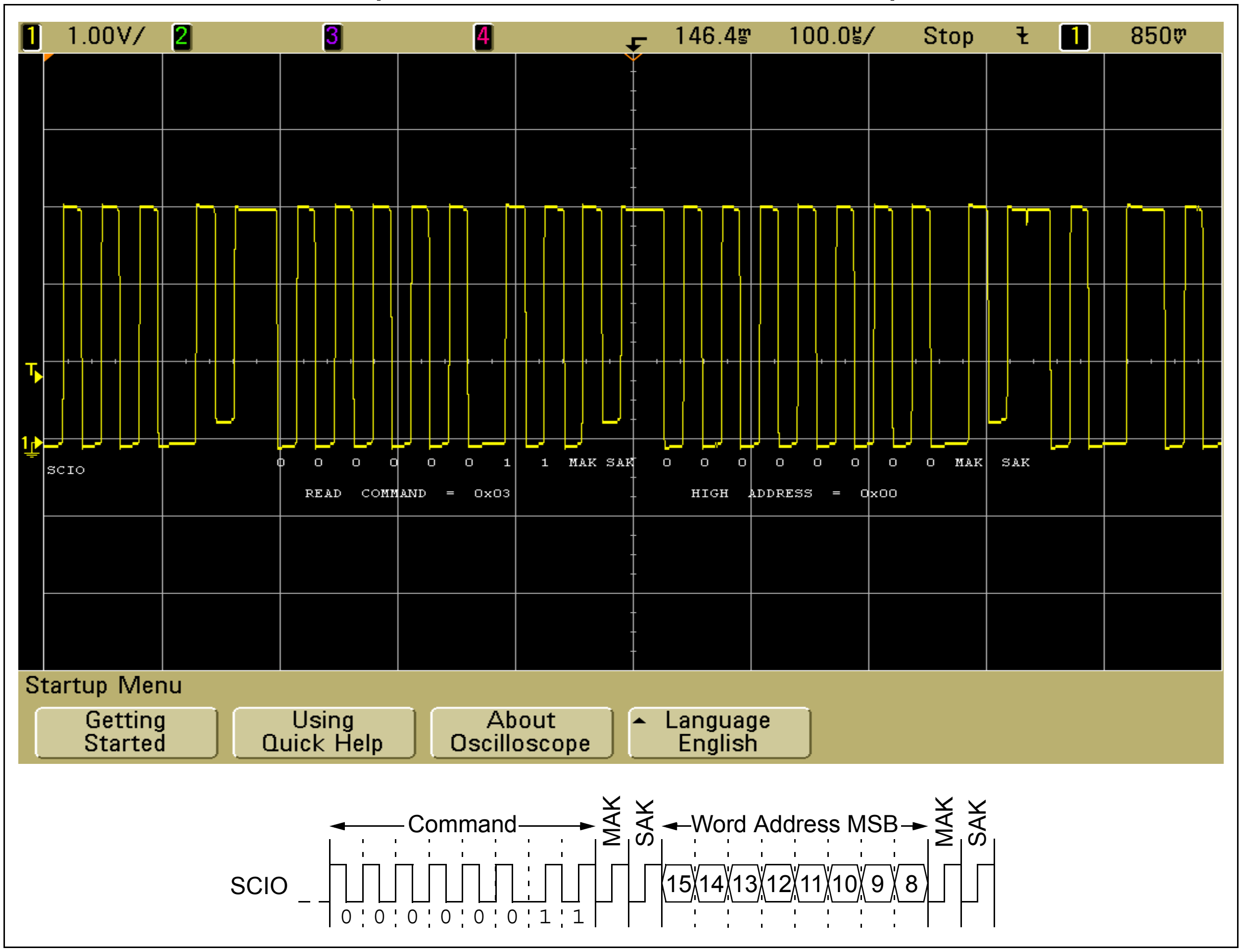
BYTE READ

The byte read operation can be used to read data from the serial EEPROM. The start header and device address must first be sent as in a byte write operation; they have been omitted from this section. The MCU transmits the command byte followed by the word address bytes to the serial EEPROM. The MCU generates a MAK after each byte, and this is followed by a SAK if there are no errors.

Command and Word Address for Read

Figure 9 shows an example of the read command '00000011' or 0x03, followed by the MSB address byte. The LSB address byte has been omitted from this example.

FIGURE 9: BYTE READ (COMMAND BYTE AND WORD ADDRESS)



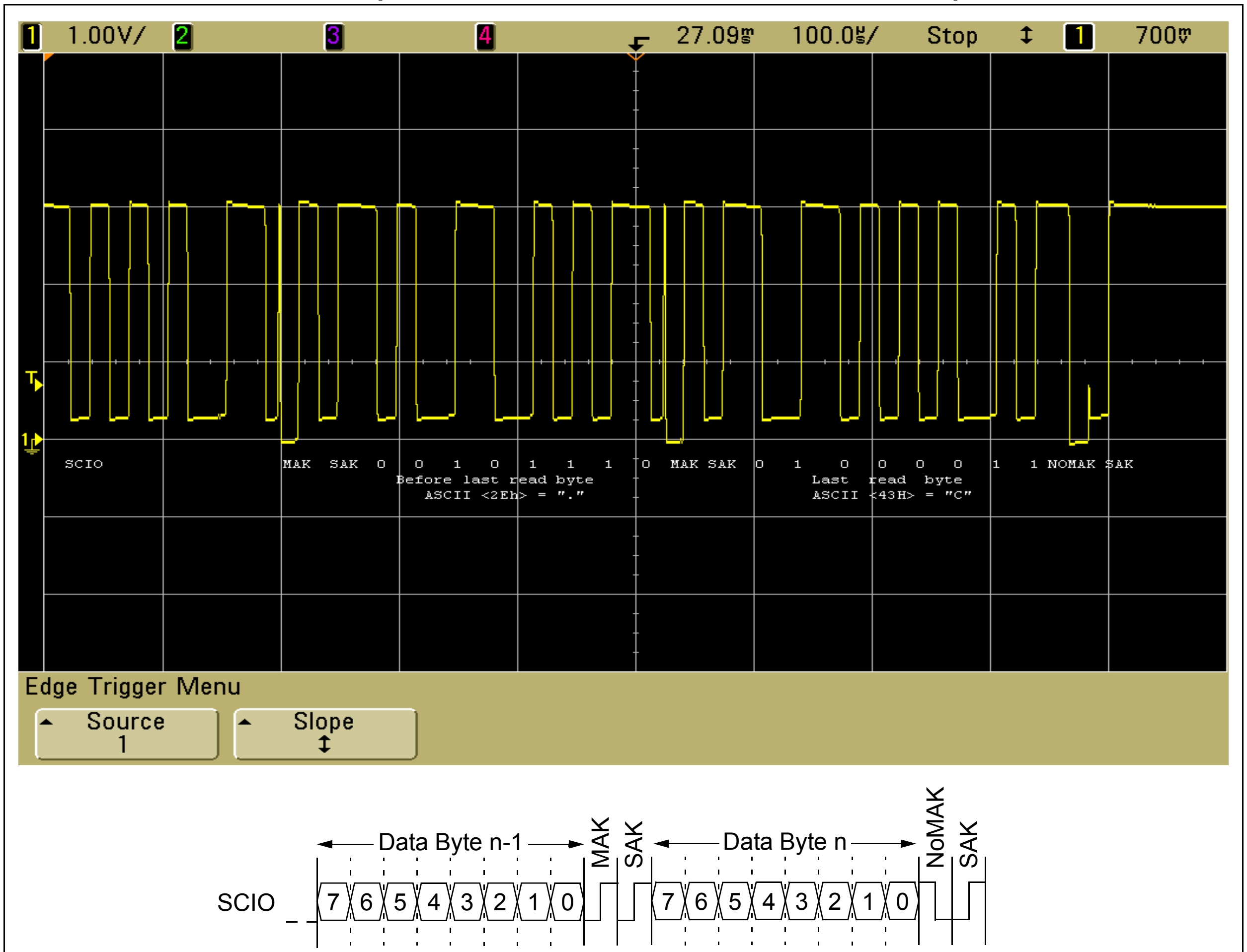
Reading Data Bytes Back

After the read command and word address have been sent and acknowledged, the serial EEPROM starts to send the data from the array starting at the address specified.

To read a single byte, the MCU generates a NoMAK after the byte is read. To continuously read the array, the MCU generates a MAK after each data byte. The serial EEPROM responds with a SAK if there are no errors.

Figure 10 shows the MCU reading two bytes of data. The MCU sends a NoMAK after the second byte to indicate that no more data is requested and to terminate the command.

FIGURE 10: BYTE READ (DATA BYTES AND COMMAND TERMINATION)



PAGE WRITE

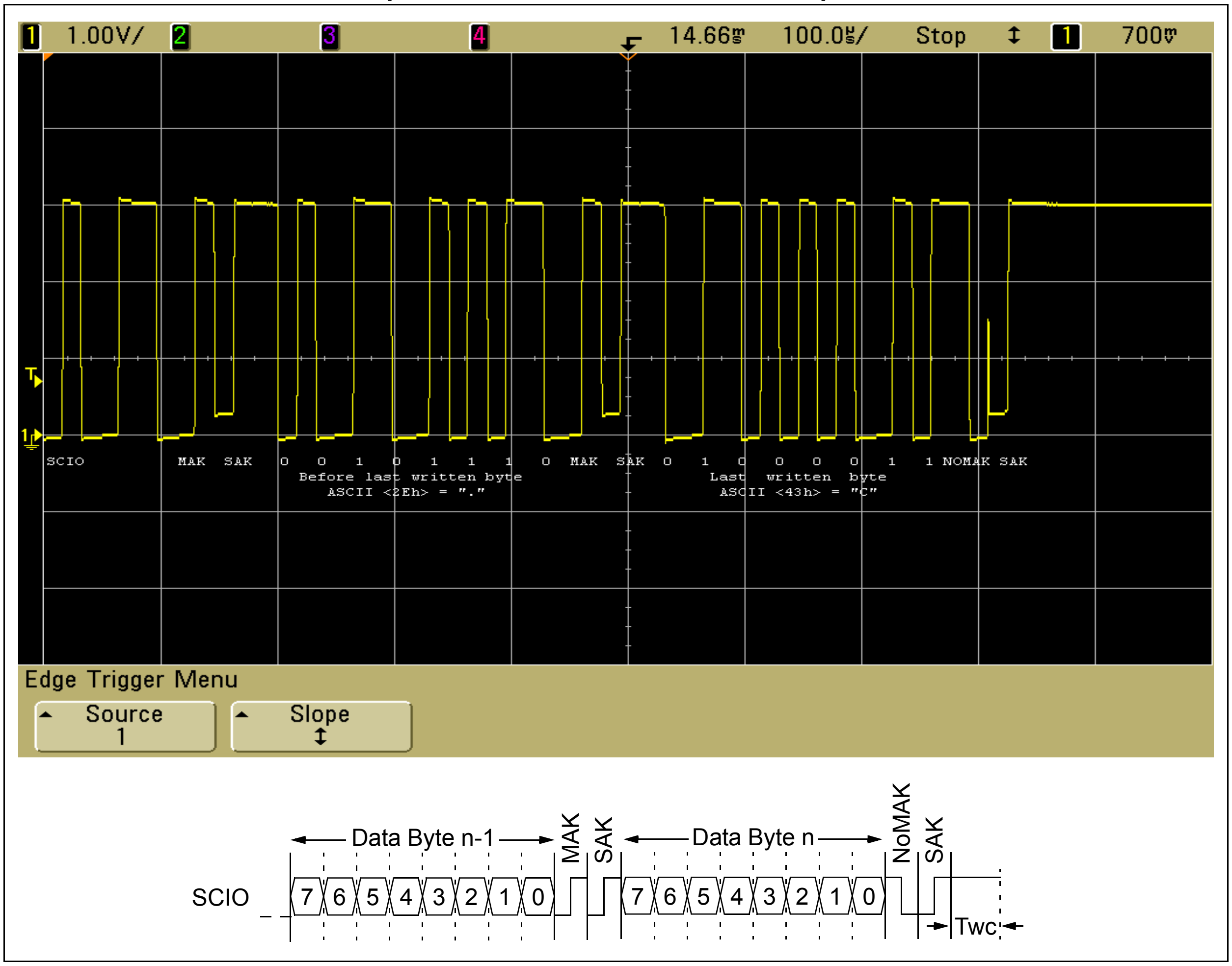
Page write operations provide a technique for increasing throughput when writing large blocks of data. The serial EEPROM features a 16-byte page. By using the page write feature, up to 1 full page of data can be written consecutively, with the start header, device address, command and word address bytes being transmitted only once. It is important to point out, however, that 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 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. However, instead of generating a NoMAK after the first data byte has been transmitted, the MCU continues to send more data bytes, up to 1 page total. The serial EEPROM automatically increments the internal Address Pointer with receipt of each byte. As with the byte write operation, the internal write cycle (TWC) is initiated by the NoMAK generated by the MCU.

Sending Multiple Bytes Successively

Figure 11 shows two consecutive data bytes during a page write operation. Notice that a MAK is sent after the first byte of data and a NoMAK is sent after the last byte of data.

FIGURE 11: PAGE WRITE (TWO CONSECUTIVE DATA BYTES)



CONCLUSION

This application note offers designers a set of firmware routines to access UNI/O serial EEPROMs using a generic I/O pin on the MCU. The code demonstrates byte and page operations. All routines were written in C for an MSP430-based MCU.

The code was developed on an ES1232 evaluation board from SoftBaugh using the schematic shown in Figure 1. It was tested using an MSP-FET430UIF USB debug interface from Texas Instruments.

NOTES:

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