

# Using quad and octal ADCs in SPI mode

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## Introduction

This article describes the steps required to interface a microprocessor-based system using a serial peripheral interface (SPI) port of the quad and octal family of serial analog-to-digital converters (ADCs) listed in Table 1.

Table 1. TI ADC features

DEVICE	CHANNELS	SUPPLY VOLTAGE (V)	RESOLUTION (bits)	INTERNAL CONVERSION CLOCK
TLV1504	4	2.7 to 5.5	10	Yes
TLV1508	4	2.7 to 5.5	10	Yes
TLV1544	4	2.7 to 5.5	10	Yes
TLV1548	8	2.7 to 5.5	10	Yes
TLV2544	4	2.7 to 5.5	12	Yes
TLV2548	8	2.7 to 5.5	12	Yes
TLC1514	4	5.0	10	No
TLC1518	8	5.0	10	No
TLC2554	4	5.0	12	No
TLC2558	8	5.0	12	No

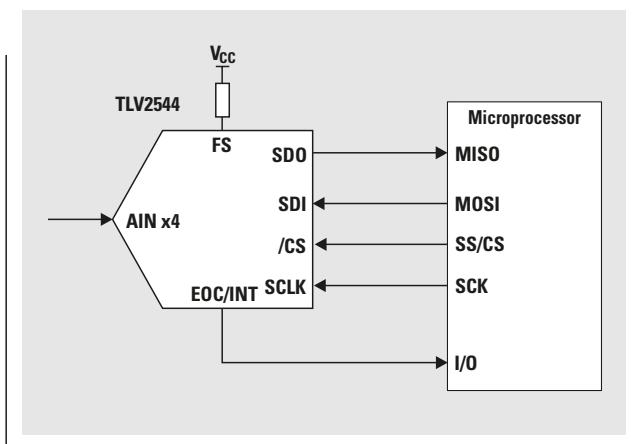
## Serial ADC interface

Serial communication with this family of devices is accomplished through three serial inputs and a tri-state serial output: chip select (/CS), serial input clock (SCLK), and serial data input (SDI), and serial data output (SDO). These 4 pins provide a direct 4-wire interface to most microprocessors. Figure 1 shows a typical ADC-to-microprocessor interface.

## Frame sync and EOC/INT

A frame sync (FS) pin is provided for a typical DSP interface and is normally tied high when used in microprocessor applications. This family of devices also features a programmable end-of-conversion/interrupt (EOC/INT) pin. When programmed as EOC, the output goes from a high to low state at the falling edge of the 16th clock, indicating that

Figure 1. Four-wire microprocessor interface



the sampling process has been completed. EOC returns to a high state upon the completion of the conversion process. When programmed as /INT, it can act as an interrupt to the host processor. /INT goes from a high to low state at the end of the conversion process and is cleared automatically on the following /CS falling edge.

## ADC read and write cycles

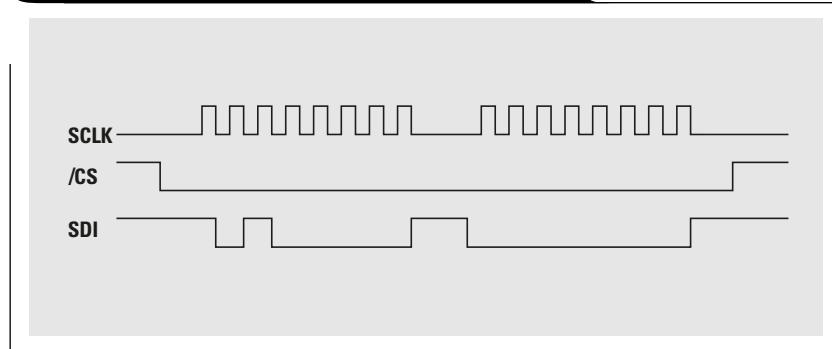
Many microprocessors offer an SPI port that transmits and receives data in 8-bit packets. The ADCs, however, use a 16-bit data string for configuration and provide serial data output in a 16-bit format.

Configuring the ADC requires the microprocessor to issue back-to-back data transfers while holding the SS/CS line low. The processor's transmit buffer is loaded first with the upper byte of configuration data, sending the SS/CS line low and starting the SCLK, which transmits the serial data to the ADC. The processor's SPI interrupt flag is then cleared, the transmit buffer is loaded with the lower byte of configuration data, and the transfer process begins again. Figure 2 shows the host mode configuration cycle (write 0xA000 to ADC).

The same sequence could be used to read the contents of the configuration register or the contents of the FIFO. The serial data output would simply be configured to perform the requested read operation (write 0x9000 or 0xE000).

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Figure 2. The host mode configuration cycle



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### ADC sample and convert cycles

Each sample/convert cycle requires the user to issue a valid channel select command in the upper nibble of the SDI string. The valid channel selection codes consist of the hex values 0x0000 through 0x9000. FIFO Read (0xE000) will also allow a conversion cycle to take place.

Hex commands 0xA000 through 0xD000 and 0xF000 are reserved for access to the configuration register and internal test modes. More information about these commands can be found in the respective device data sheets listed under References at the end of this article.

Another factor to consider when using these devices in the microprocessor mode is the sample and conversion time. When the TLV2544 is operated in short sampling with the internal conversion clock, for instance, sampling is not complete until the 16th falling edge of SCLK (see Figure 3). Another 3.5  $\mu$ s are required for the conversion to take place. If chip select is asserted low before the conversion cycle is complete (EOC going Hi), the current conversion data will be lost.

If the microprocessor is set to clock polarity = 1 and clock phase = 1 as shown in Figure 4, the ADC requires the user to issue a third, or "null data," transfer to the SPI port. Since the ADC samples, converts, and shifts data out on the rising edge of the clock, the first falling edge is ignored. As shown in Figure 4, the EOC signal appears on the 16th falling clock edge after the *first* rising. The length of conversion time and number of dummy write transfers the processor has to make is dependent upon the mode in which the ADC is being used, and the clock phase and polarity settings of the SPI port.

The TLC series of devices does not contain an internal conversion clock and depends on SCLK throughout the entire sample/conversion process. This requires that additional "null data" SPI transfers be conducted. The total number of clock cycles is dependent upon the operating mode of the ADC being used. The TLC2544 (in single-shot mode), for example, would require 16 clocks for channel selection and sampling, plus an additional 16 clocks for conversion. A minimum of four 8-bit SPI blocks would be needed.

### Reading valid data

The serial data out from these devices is pre-released by 1/2 clock cycle, plus a delay. What this means is that while valid output data is available on the rising edge of SCLK, the rising edge also triggers the shifting out of the next data bit. With low clock speeds, it may appear as if data is changing when it should be valid. A processor's setup and hold time requirements may affect its ability to read correctly the data presented by the converter. Figures 5 and 6 show the relationship between SCLK, SDO, and SDI with a 4-MHz and 20-MHz clock, respectively.

Figure 3. Sample/convert cycle

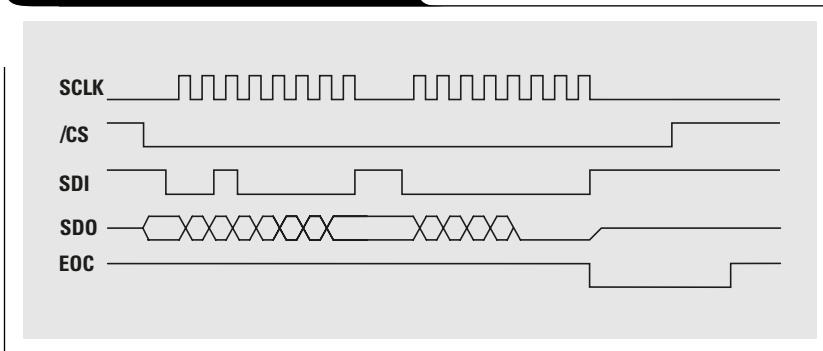
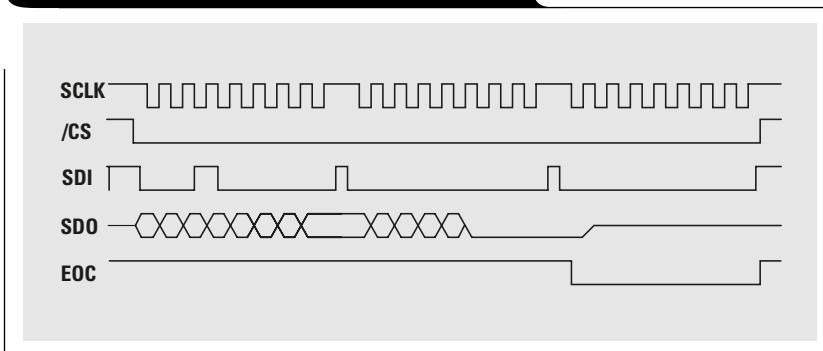


Figure 4. Alternate sample/convert cycle



The code example at the bottom of the next page was written for the Motorola 68HC912 and was assembled using ASM12.EXE. The code samples and stores data from channel 0 of a TLV2544.

### References

For more information related to this article, you can download an Acrobat Reader file at [www-s.ti.com/sc/techlit/litnumber](http://www-s.ti.com/sc/techlit/litnumber) and replace "litnumber" with the **TI Lit. #** for the materials listed below.

#### Document Title

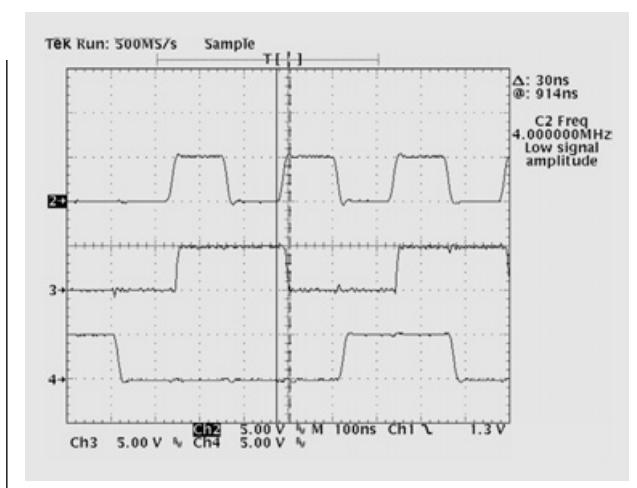
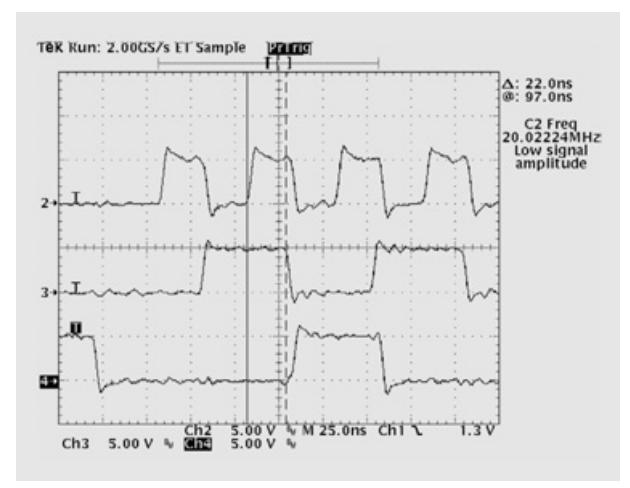
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1. TLV1504/1508/1544/2544/2548, TLC1514/1518/2554/2558 10-Bit and 12-Bit ADC EVM User's Guide	.....slau029
2. TLV1504, TLV1508 Data Sheet	.....slas251
3. TLV1544, TLV1548 Data Sheet	.....slas139
4. TLV2544, TLV2548 Data Sheet	.....slas198
5. TLC1514, TLC1518 Data Sheet	.....slas252
6. TLC2554, TLC2558 Data Sheet	.....slas220

### Related Web sites

[www.dataconverter.com](http://www.dataconverter.com)

[www.ti.com/sc/docs/products/analog/device.html](http://www.ti.com/sc/docs/products/analog/device.html)

Replace *device* with tlc1514, tlc1518, tlc2554, tlc2558, tlv1504, tlv1508, tlv1544, tlv2544, or tlv2548

**Figure 5. SCLK = 4 MHz****Figure 6. SCLK = 20 MHz****Code example**

```

; SPI program using the 68HC912 uP and a TLV2544 ADC with Frame Sync hi via SP3
;* _____;
;* Equates and Variables
;* _____;

SP0CR1:    equ $D0      ;SPI 0 Control Register 1
SP0CR2:    equ $D1      ;SPI 0 Control Register 2
SP0BR:     equ $D2      ;SPI 0 Baud Rate Register
SP0SR:     equ $D3      ;SPI 0 Status Register
SP0DR:     equ $D5      ;SPI 0 Data Register
PORTS:     equ $D6      ;Port S Data Register
DDRS:      equ $D7      ;Port S Data Direction Register

; User Variables

Upper_Byte: EQU $0B00
Lower_Byte: EQU $0B01
Upper_CFIG: EQU $0B02
Lower_CFIG: EQU $0B03
;* _____;
;* MAIN PROGRAM
;* _____;
ORG      $0800  ; User code data area,
               ; start main program at $0800
DATA    FCB     00,01  ; Set up 16 bit Output DATA
MAIN:
      BSR     INIT    ; Subroutine to initialize SPI registers
      JSR     SAMPLE ; Subroutine to start transmission

```

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**Code example (Continued)**

```

;* _____ Initialization Subroutine
;* _____
;
INIT:
    BSET DDRS, #\$11101100      ; Configure PORT S input/ouput:
    BSET SP0BR, #\$00            ; SS/CS, SCK, MOSI, MISO, PS3, PS2, TXD, RXD
    MOVB #\$50, SP0CR1          ; Set Baud Rate
    MOVB #\$00, SP0CR2          ; Configure SPI(SP0CR1)
    MOVB #\$88, PORTS           ; SPIE, SPE, SWOM, MSTR, CPOL, CPHA, SSOE, LSBF
    BCLR PORTS, #\$10000000      ; Configure SPI(SP0CR2):
    MOVB #\$A0, Upper_CFIG      ; -, -, -, -, -, SSWAI, SPCO
    MOVB Upper_CFIG, SP0DR      ; Sets ADC CS Hi, FS Hi
    JSR FLAG                   ; Select ADC
    MOVB #\$04, Lower_CFIG      ; Configure ADC
    MOVB Lower_CFIG, SP0DR      ; Write 0xA000 to set up Host Communication.
    JSR FLAG                   ; Put data in XMIT Buffer
    MOVB #\$80, PORTS           ; Clear SPI Flag
    BSET PORTS, #\$80            ; Select EOC Mode
    MOVB #\$00, UPPER_BYTE       ; Clear SPI Flag
    MOVB #\$00, LOWER_BYTE       ; Sets ADC CS Hi
    RTS                         ; Set initial values
    MOVB #\$00, LOWER_BYTE       ; Set initial values
    RTS

;* _____ Sample / Convert
;* _____
;
SAMPLE:
    MOVB #\$08, PORTS           ; Sets ADC CS Low
    MOVB #\$20, SP0DR            ; Tell ADC what channel to read and generate SCLK for ADC
    JSR FLAG                   ; Clear SPI Flag
    LDAA SP0DR                 ; Store received data
    MOVB #\$00, SP0DR            ; Load first ADC Sample
    JSR FLAG                   ; Write zero value to data register to generate SCLK for ADC
    LDAB SP0DR                 ; Clear SPI Flag
    STD DATA                   ; Load second ADC Sample
    STD DATA                   ; Store ACCA and ACCB in Data

    NOP                         ; Extra time for conversion
    MOVB #\$88, PORTS           ; Sets ADC CS Lo
    JMP SAMPLE                 ; Go back and do it again

;* _____ Clear SPI Flag Subroutine
;* _____
;
FLAG:  BRCLR SP0SR, #\$80, FLAG ; Wait for flag.
    RTS
.end

```

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