INTRODUCTION
This application note details the interface of Crystal Semiconductor’s CS5525/6/9 Analog-to-Digital Converter (ADC) to a Motorola 68HC05 microcontroller. This note takes the reader through a simple example describing how to communicate with the ADC. All algorithms discussed are included in the Appendix at the end of this note.

ADC DIGITAL INTERFACE
The CS5525/6/9 interfaces to the 68HC05 through either a three-wire or a four-wire interface. Figure 1 depicts the interface between the two devices. Though this software was written to interface to the SPI™ on the 68HC05, the algorithms can be easily modified to work in the four-wire format.

The ADC’s serial port consists of four control lines: CS, SCLK, SDI, and SDO.

CS, Chip Select, is the control line which enables access to the serial port.

SCLK, Serial Clock, is the bit-clock which controls the shifting of data to or from the ADC’s serial port.

SDI, Serial Data In, is the data signal used to transfer data from the 68HC05 to the ADC.

SDO, Serial Data Out, is the data signal used to transfer output data from the ADC to the 68HC05.

SOFTWARE DESCRIPTION
This note presents algorithms to initialize the 68HC05 and the CS5525/6/9, perform a self-offset calibration, modify the CS5525/6/9’s gain register, and acquire a conversion. Figure 2 depicts a block

![Diagram](image-url)
diagram. While reading this application note, please refer to the Appendix for the code listing.

**Initialize**

*Initialize* is a subroutine that configures the SPI™ on the 68HC05 and places the CS5525/6/9 in the command-state. Figure 1 depicts how the interface is configured (for more information on configuring the SPI™ refer to Motorola’s M68HC05 Application Guide). After configuring the SPI™, the controller enters a delay state to allow time for the CS5525/6/9’s power-on-reset and oscillator to start-up (oscillator start-up time is typically 500 mS). The last step is to reinitialize the serial port on the ADC (reinitializing the serial port is unnecessary here, the code was added for demonstration purposes only). This is implemented by sending the converter sixteen bytes of logic 1’s followed by one final byte, with its LSB at logic 0. Once sent, the sequence places the serial port of the ADC into the command-state, where it awaits a valid command.

After returning to main, the software demonstrates how to calibrate the converter’s offset.

![Diagram](image)

**Self-Offset Calibration**

*Calibrate* is a subroutine that calibrates the converter’s offset. *Calibrate* first sends 0x000001 (Hex) to the configuration register. This instructs the converter to perform a self-offset calibration. Then the Done Flag (DF) bit in the configuration register is polled until set. Once DF is set, it indicates that a valid calibration is performed. To minimize digital noise (while performing a calibration or a conversion), many system designers may find it advantageous to add a software delay equivalent to a conversion or calibration cycle before polling the DF bit.

**Read/Write Gain Register**

To modify the gain register the command-byte and data-byte variables are first initialized. This is accomplished with the LDA and STA opcodes. The subroutine *write_register* uses these variables to set the contents of the gain register in the CS5525/6/9 to 0x800000 (HEX). To do this, *write_register* calls *send_spi* four times (once for the command-byte and three additional times for the 24 bits of data). *Send_spi* is a subroutine used to transfer a byte of information from the 68HC05 to the CS5525/6/9 via the SPI™. A byte is transferred one bit at a time, MSB (most significant bit) first. Figure 3 depicts the timing diagram for the write-cycle in the CS5525/6/9’s serial port. This algorithm demonstrates how to write to the gain register. It does not perform a gain calibration. To perform a gain calibration, follow the procedures outlined in the data sheet.

To verify if 0x800000(HEX) was written to the gain register, *read_register* is called. It duplicates the read-cycle timing diagram depicted in Figure 4. *Read_register* calls *send_spi* once to transfer the command-byte to the CS5525/6/9. This places the converter into the data-state where it waits until data is read from its serial port. *Read_register* calls *receive_spi* three times and transfers three bytes of data.
information from the CS5525/6/9 to the 68HC05 via the SPI™. Similar to send_spi, receive_spi receives a byte one bit at a time MSB first. When the transfer is complete, highbyte, midbyte, and low-byte byte contain the CS5525/6/9’s 24-bit gain register.

**Acquire Conversion**

To acquire a conversion the subroutine convert is called. Convert sends the command-byte 0x0C to the converter instructing it to perform a single conversion. Then the Done Flag bit in the configuration register is polled. When DF is set, it indicates that a conversion was performed. The 68HC05 then reads the conversion data register to acquire the conversion. Figure 6 depicts how 16-bit and 20-bit conversion words are stored in the 68HC05.

An alternate method can be used to acquire a conversion. By setting the Port Flag bit (PF, the fifth bit in the configuration register), SDO’s function is modified to fall to logic 0 when a conversion is complete (refer to Figure 5). By tying SDO to the controller’s interrupt pin, conversions can be acquired via an interrupt service routine.

![Figure 3. Write-Cycle Timing](image_url)

![Figure 4. Read-Cycle Timing](image_url)
MAXIMUM SCLK RATE

A machine cycle in the 68HC05 consists 2 oscillator periods or 500 ns if the microcontroller’s oscillator frequency is 4 MHz. Since the CS5525/6/9’s maximum SCLK rate is 2MHz, additional no-operation (NOP) delays may be necessary to reduce the transfer rate if the microcontroller system requires higher rate oscillators.

CONCLUSION

This application note presents an example of how to interface the CS5525/6/9 to the 68HC05. It is divided into two main sections: hardware and software. The hardware section illustrates both a three-wire and a four-wire interface. The three-wire interface is SPI™ and MICROWIRE™ compatible. The software section illustrates how to initialize the converter and microcontroller, calibrate the converters offset, write to and read from the ADC’s internal register, and acquire a conversion. The software is modularized and illustrates important subroutines, e.g. write_register and read_register. The software described in this note is included in the Appendix at the end of this document.

SPI™ is a trademark of Motorola.

MICROWIRE™ is a trademark of National Semiconductor.
APPENDIX

68HC05 Microcode to Interface to the CS5525/6/9

*****************************************************************************
* File: 55266805.asm
* Date: November 1, 1996
* Programmer: Keith Coffey
* Revision: 0
*
* Processor: 68HC05
*
* Program entry point at routine "main". The entry point is address $100
*****************************************************************************
*
* This program is designed as an example of interfacing a 68HC05 to a CS5525/6/9
* ADC. The program interfaces via SPI (i.e. port D) which controls the
* serial communications, calibration, and conversion signals. Other ADC's
* (16-bit and 20-bit) in the product family can be used.
*****************************************************************************
******** Memory Map Equates
PORTA EQU $00 ; General Purpose I/O Port
DDRA EQU $04 ; Data Direction Control For Port A
SPCR EQU $0A ; Serial Peripheral Control Register
SPSR EQU $0B ; Serial Peripheral Status Register
SPDR EQU $0C ; Serial Peripheral Data I/O Register
SPIF EQU 7 ; Serial Peripheral Data Transfer Flag

******** RAM Values
ORG $50

******** Ram Memory Equates
HIGHBYTE RMB 1 ; Upper 8 bits of Conversion Register
MIDBYTE RMB 1 ; Middle 8 bits of Conversion Register
LOWBYTE RMB 1 ; Lowest 8 bits of Conversion Register
COMMANDBYTE RMB 1 ; One byte RAM storage location
ORG $0100

* Routine - Main
* Input - none
* Output - none
* This is the entry point to the program.

MAIN EQU * ; Start from Reset Vector

******* Initialize System and Perform SELF OFFSET Calibration
JSR initialize ; Initialize the system
JSR calibrate ; Calibrate the ADC Offset

******* Write to the GAIN Register
LDA #$82 ; Prepare COMMANDBYTE
STA COMMANDBYTE
LDA #$80 ; Prepare HIGHTBYTE
STA HIGHTBYTE
CLR MIDBYTE ; Prepare MIDBYTE
CLR LOWBYTE ; Prepare LOWBYTE
JSR write_register ; Write to Gain Register

******* Read from the GAIN Register
LDA #$92 ; Prepare COMMANDBYTE
STA COMMANDBYTE
JSR read_register ; Read the Gain Register

******* Perform Single Conversions
LOOP JSR convert ; Convert Analog input
JMP LOOP ; Repeat Loop

******* End MAIN
************************************************************************************
*       Subroutines
************************************************************************************

* Routine - initialize
* Input   - none
* Output  - none
* This subroutine initializes port D for interfacing to the CS5525/6/9 ADC.
* It provides a time delay for oscillator start-up/wake-up period.
* A typical start-up time for a 32768 Hz crystal, due to high Q, is 500 ms.
* Also 1003 XIN clock cycles are allotted for the ADC’s power on reset.

initialize LDA #%01010000     ; Load ACCA with for SPSC
            STA SPCR            ; Setup SPI
            LDA #40             ; Load ACCA with delay count
            JSR delay          ; Delay, Power on Reset 1003 XIN
            LDA #220            ; Load ACCA with delay count
            JSR delay          ; Delay, Oscillator start-up 170 mS
            JSR delay          ; Delay, Oscillator start-up 170 mS
            JSR delay           ; Delay, Oscillator start-up 170 mS
            LDX #$0F            ; Reset Serial Port on ADC
            LDA #%11111110      ; Load ACCA with last byte
            JSR send_spi        ; Move $FF to SPDR

loop            JSR  send_spi        ; Move $FF to SPDR
            DECX                    ; Decrement the counter
            BNE loop            ; Repeat loop is counter not zero
            LDA #%11111110      ; Load ACCA with last byte
            JSR send_spi        ; Move $FE to SPDR
            RTS                     ; Exit subroutine

************************************************************************************
* Routine - calibrate
* Input   - none
* Output  - none
* This subroutine instructs the CS5525/6/9 to perform self-calibration.

calibrate       LDA #$84            ; set command byte for config write
            STA COMMANDBYTE    ; set COMMAND BYTE
            CLR HIGHBYTE       ; clear HIGHBYTE
            CLR MIDBYTE        ; clear MIDBYTE
            LDA #$01            ; get ready for self offset cal
            STA LOWBYTE         ; set LOWBYTE
            JSR write_register  ; Write to Config Register

            LDA #$94           ; set command byte for config read
            STA COMMANDBYTE    ; set COMMAND BYTE
            JSR read_register   ; Poll done flag until cal complete

poll_done:     BRCLR 3,LOWBYTE,poll_done; repeat if flag not set
            RTS                     ; Exit subroutine
************************************************************************************
* Routine - convert
* Input   - none
* Output  - Conversion results in memory locations HIGHBYTE, MIDBYTE and
*           LOWBYTE. This algorithm performs only single conversions. If
*           continuous conversions are needed the routine needs to be
*           modified. Port flag is zero.
*           HIGHBYTE          MIDBYTE           LOWBYTE
*           7 6 5 4 3 2 1 0   7 6 5 4 3 2 1 0   7 6 5 4 3 2 1 0
* 16-bit results MSB                                   LSB 1 1 1 0 0 OD OF
* 20-bit results MSB                                           LSB 0 0 OD OF
* This subroutine initiates a single conversion.
************************************************************************************
convert  LDA #$C0            ; Set COMMANDBYTE for single CONV
         STA COMMANDBYTE
         JSR send_spi ; Transmit command out SPI
         LDA #$94           ; Set command byte for config read
         STA COMMANDBYTE     ; Send COMMAND BYTE
         JSR read_register   ; Poll done flag until CONV complete
         BRCLR   3,LOWBYTE,done1 ; Repeat if Done Flag not Set
         LDA #$96            ; Set Byte to Read Conversion Reg.
         STA COMMANDBYTE     ; Store COMMAND BYTE
         JSR read_register ; Acquire the Conversion
         RTS ; Exit subroutine

************************************************************************************
* Routine - write_register
* Input   - COMMANDBYTE, HIGHBYTE, MIDBYTE, LOWBYTE
* Output  - none
* This subroutine instructs the CS5525/6/9 to write to an internal register.
************************************************************************************
write_register  LDA COMMANDBYTE     ; Load ACCA with COMMANDBYTE
                JSR send_spi ; transfer byte
                LDA HIGHBYTE ; Load ACCA with HIGHBYTE
                JSR send_spi ; transfer byte
                LDA MIDBYTE ; Load ACCA with MIDBYTE
                JSR send_spi ; transfer byte
                LDA LOWBYTE ; Load ACCA with LOWBYTE
                JSR send_spi ; transfer byte
                RTS ; Exit Subroutine
* Routine - read_register
* Input   - COMMANDBYTE
* Output  - HIGHBYTE, MIDBYTE, LOWBYTE
*
* This subroutine reads an internal register of the ADC.
**************************************************************************************
read_register   LDA COMMANDBYTE     ; Load ACCA with COMMANDBYTE
                JSR send_spi        ; transfer byte
                JSR receive_spi    ; receive byte
                STA HIGHBYTE      ; Move ACCA with HIGHBYTE
                JSR receive_spi    ; receive byte
                STA MIDBYTE       ; Move ACCA with MIDBYTE
                JSR receive_spi    ; receive byte
                STA LOWBYTE       ; Move ACCA with LOWBYTE
                RTS ; Exit Subroutine
**************************************************************************************
* Routine - send_spi
* Input   - Byte to be transmitted is placed in ACCA
* Output  - none
*
* This subroutine sends a byte to the ADC.
**************************************************************************************
send_spi:      STA SPDR            ; Move ACCA to SPDR
wait0          BRCLR SPIF,SPSR,wait0 ; Loop until byte is transmitted
                RTS                     ; Exit Subroutine
**************************************************************************************
* Routine - receive_spi
* Input   - none
* Output  - Byte received is placed in ACCA
* This subroutine receives a byte from the ADC.
**************************************************************************************
receive_spi:   CLRA                    ; Load ACCA register with Zero
                STA SPDR            ; Initiate a transfer of all Zero’s
wait1          BRCLR SPIF,SPSR,wait1 ; Reset Flag SPIF bit
                LDA SPDR            ; Move SPDR to ACCA
                RTS ; Exit Subroutine
**************************************************************************************
* Routine - delay
* Input   - Count in register A
* Output  - none

* This subroutine delays by using count from register A. The 68HC05
* development board uses a 4.0MHz clock (E = 2.0 MHz), thus each cycle is
* 500 nS. This delay is equivalent to (500ns)*(1545)*(count value),
* (a count of 720 provides a 556ms delay).

```
delay
outlp           CLRX ; X used as inner loop count
innlp           DECX ; 0-FF, FF-FE, FE-FD, ....1-0  256 loops
NOP             ; 2 cycles
NOP             ; 2 cycles
BNE  innlp       ; 10 cycles*256*500ns=1.28 ms
DECA            ; Countdown the accumulator
BNE  outlp       ; 2569 cycles*500ns*A
RTS             ; Exit subroutine
```