Interfacing the CS5521/22/23/24/28 to the 68HC05

1. INTRODUCTION

This application note details the interface of Cirrus Logic’s Crystal® CS5521/22/23/24/28 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 Section 6. “APPENDIX: 68HC05 Microcode to Interface to the CS5521/22/23/24/28” on page 6.

2. ADC DIGITAL INTERFACE

The CS5521/22/23/24/28 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 three-wire 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.

![Figure 1. 3-Wire and 4-Wire Interfaces](image-url)
3. SOFTWARE DESCRIPTION

This note presents algorithms to initialize the 68HC05 and the CS5521/22/23/24/28, modify the CS5521/22/23/24/28’s internal registers, perform calibrations, and acquire conversions. Figure 2 depicts a block diagram of the program structure. While reading this application note, please refer to Section 6. “APPENDIX: 68HC05 Microcode to Interface to the CS5521/22/23/24/28” on page 6 for the code listing.

3.1 Initialize

Initialize is a subroutine that configures the SPI on the 68HC05 and places the CS5521/22/23/24/28 into the command state. The SPI is configured as depicted in Figure 1 by selecting the 68HC05 as the master. To function properly with the CS5521/22/23/24/28, the SPI must be set up to use a clock which idles low, and begins clocking data with a rising edge in the center of the first bit (for more information on configuring the SPI refer to Motorola’s 68HC05 Application Guide). After configuring the SPI, the controller enters a delay state to allow time for the CS5521/22/23/24/28’s power-on-reset and oscillator to start-up (oscillator start-up time for a 32.768 KHz crystal is typically 500 ms). The last step is to reinitialize the serial port on the ADC (reinitializing the serial port is unnecessary here, and the code is for demonstration purposes only). This is implemented by sending the converter fifteen bytes of logic 1’s followed by one final byte, with its LSB at logic 0. This sequence places the serial port of the ADC into the command state, where it waits for a valid command.

3.2 Write Channel Setup Registers

The subroutine write_csrs is an example of how to write to the CS5521/22/23/24/28’s Channel Setup Registers (CSRs). For this example, two CSRs (four Setups) are written. The number of CSRs to be accessed is determined by the Depth Pointer bits (DP3-DP0) in the configuration register. The Depth Pointer bits are set to “0011” to access the two CSRs. The value “0011” is calculated by tak-
ing the number of Setups to be accessed and subtracting 1. Because each CSR holds two Setups, this number must always be an odd value, that is, DP0 must always be logic 1 when reading and writing the CSRs. To modify the Depth Pointer bits, the configuration register is read to prevent corruption of other bits. After the `read_register` routine is run with the command 0x0B (HEX), the DP3-DP0 bits are masked to “0011”. Then, the updated information is written back into the ADC with the command 0x03 (HEX) using the `write_register` routine.

After the depth pointer bits are set correctly, the CSR information is written to the ADC. The command 0x05 (HEX) is sent to the ADC to begin the write sequence (to read the CSRs, the command would be 0x0D). At this point, the ADC is expecting to receive information for two 24-bit CSRs, or 48 bits, based on the Depth Pointer bits. The first CSR is written with a value of 0x000000 (HEX). This sets Setup 1 and Setup 2 both to convert bipolar, 100mV signals on physical channel 1 (PC1) at an output word rate (OWR) of 15 Hz, and latch pins A1-A0 equal to “00”. The second CSR is written with the value 0x4C0105 (HEX). This sets Setup 3 to convert a bipolar, 100mV signal on PC2 at a 101.1 Hz OWR, with latch pins A1-A0 at “01”. This also sets Setup 4 to convert a unipolar, 25mV input signal at 15 Hz on PC3, with output latch pins A1-A0 set to “00”.

### 3.3 Self-Offset Calibration

`Calibrate` is a subroutine that performs a self-offset calibration using Setup 1. `Calibrate` does this by sending the command 0x81 (HEX) to the ADC through the SPI. This tells the ADC to perform a self-offset calibration using Setup 1 (see the CS5522/24/28 and CS5521/23 Data Sheets for information on performing offset or gain calibrations using other Setups). Once the command has been sent, the controller polls MISO (SDO) until it falls, indicating that the calibration is complete. Note that although calibrations are done using a specific Setup, the offset or gain register that is modified belongs to the physical channel referenced by that Setup.

### 3.4 Read/Write Gain Register

The routine `rwgain` provides an example of how to modify the ADC’s internal gain registers. To modify the gain register the command byte and data byte variables are written with the appropriate information. `rwgain` then calls the subroutine `write_register`, which uses these variables to set the contents of Physical Channel 1 (PC1)’s gain register to 0x800000 (HEX). The `write_register` routine calls the `send_spi` algorithm four times, once to send the command byte, and three more times to send the three data bytes. `Send_spi` is a subroutine which transfers data to the CS5521/22/23/24/28 MSB-first through the SPI. Figure 3 depicts the timing diagram for the write-cycle in the CS5521/22/23/24/28’s serial port. It is important to note here that this section of the code demonstrates how to write to the gain register of PC1. It does not perform a gain calibration. To write to the other internal registers of the ADC, follow the procedures outlined in the CS5522/24/28 and CS5521/23 data sheets.

To read the value in the gain register of PC1, the command byte is loaded with the value 0x0A (HEX), and the `read_register` routine 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 CS5521/22/23/24/28. This places the converter into the data state where it waits until data is read from its serial port. `Read_register` then calls `receive_spi` three times and transfers three bytes of information from the CS5521/22/23/24/28 to the 68HC05. Similar to `send_spi`, `receive_spi` acquires a byte one bit at a time, MSB-first from the SPI. When the transfer is complete, the variables `high_byte`, `mid_byte`, and `low_byte` contain the value present in PC1’s 24-bit gain register.
3.5 Acquiring Conversions

To acquire a conversion the subroutine `convert` is called. For single conversions on one physical channel, the MC (multiple conversion) and the LP (loop) bits in the configuration register must be logic 0. To prevent corruption of the configuration register, `convert` instructs the 68HC05 to read and save the contents. This information is stored in the variables HIGHBYTE, MIDBYTE and LOWBYTE. Then the MC, LP, and RC (read convert) bits are masked to logic 0, and the new information is written back to the ADC’s configuration register. A conversion is initiated using Setup 1 by sending the command 0x80 to the converter. At this time, the controller polls MOSI (SDO) until it falls to a logic 0 level (see Figure 5). After SDO falls, `convert` calls `send_spi` to send one byte of all 0’s to the converter to clear the SDO flag. The 68HC05 then reads the conversion data word by calling `receive_spi` three times. Figure 6 depicts how the 16 and 24-bit data words are stored in the memory locations HIGHBYTE, MIDBYTE, and LOWBYTE.

4. MAXIMUM SCLK RATE

A machine cycle in the 68HC05 consists of 2 oscillator periods or 500 ns if the microcontroller’s oscillator frequency is 4 MHz. Since the CS5521/22/23/24/28’s maximum SCLK rate is 2 MHz, additional no operation (NOP) delays may be necessary to reduce the transfer rate if the microcontroller system requires higher rate oscillators.
5. CONCLUSION

This application note presents an example of how to interface the CS5521/22/23/24/28 to the 68HC05. It is divided into two main sections: hardware and software. The hardware interface illustrates both 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, write to the CSRs, write and read the ADC’s internal registers, perform calibrations, and acquire conversions. The software is modularized and provides important subroutines such as write_register, read_register, write_csrs and convert, which were all written in 68HC05 assembly language.

The software described in the note is included in Section 6. “APPENDIX: 68HC05 Microcode to Interface to the CS5521/22/23/24/28” on page 6.
6. APPENDIX: 68HC05 MICROCODE TO INTERFACE TO THE CS5521/22/23/24/28

;*****************************************************************************
;* File: 5526805.ASM
;* Date: September 23, 1998
;* Revision:0
;* Processor:68HC05
;*
;* Program entry point at routine 'main'. Entry point address is $100
;*
;* This program is an example on how to interface a 68HC05 Microcontroller
;* to a CS5521/22/23/24/28 ADC. The program interfaces via the SPI port (Port D)
;* on the microcontroller, which controls the serial communications,
;* calibration, and conversion cycles.
;*****************************************************************************

;*** Memory Map Equates ***
PORTA EQU $00 ;General Purpose I/O Port
DDRA EQU $04 ;Data Direction Control for Port A
PORTD EQU $03 ;Port D Direct Pin Access (Input)
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
HIGHBYTE RMB 1 ;Upper 8 bits of Conversion Register
MIDBYTE RMB 1 ;Middle 8 bits of Conversion Register
LOWBYTE RMB 1 ;Lower 8 bits of Conversion Register
COMMAND RMB 1 ;Command Byte storage location

;*****************************************************************************
;* Program Code
;*****************************************************************************
ORG $100

;*****************************************************************************
;* Routine - main
;* Input - none
;* Output - none
;* This is the entry point and the main loop of the program.
;*****************************************************************************
MAIN EQU * ;Start from reset vector

;*** Initialize and Calibrate the system ***
JSR initialize ;Initialize the System
JSR write_csrs ;Modify the Channel Setup Registers
JSR calibrate ;Calibrate ADC Offset
JSR rwgain ;Write and read gain register

;*** Continuously perform single conversions ***
mloop: JSR convert ;Obtain a conversion from the ADC
JMP mloop ;Keep Looping

;*** End MAIN ***

;******************************************************************************
;* Subroutines
;******************************************************************************

;******************************************************************************
;* Routine - initialize
;* Input - none
;* Output - none
;* This subroutine initializes Port D as a SPI port to interface to the
;* CS5521/22/23/24/28 ADC.
;* A time delay for the ADC oscillator start-up period is provided, as well
;* as a delay for the ADC's power-on reset.
;* Typically, a 32.768 KHz crystal has a start-up time of about 500ms. After
;* this delay, an additional 1003 XIN cycles are delayed for the ADC reset.
;* The ADC's serial port is also reset at this time
;******************************************************************************

initialize LDA #%01010000 ;Load ACCA with values for SPCR
STA SPCR ;Setup SPI Port
LDX #$0F ;Value of 15 for first 15 Bytes
LDA #$FF ;Load ACCA with all 1's
sloop: JSR send_spi ;Send info to ADC
DECX ;Decrement Counter
BNE sloop ;Repeat loop if counter isn’t zero
LDA #%11111110 ;Load ACCA with last byte
JSR send_spi ;Send final byte to ADC
RTS ;Exit routine

;*****************************************************************************
;* Routine - write_csrs
;* Input - none
;* Output - none
;* This subroutine is used to write to the Channel Setup Registers. It first
;* changes the depth pointer bits in the configuration register to reflect
;* the number of CSRs to be written, and then writes information to the
;* appropriate number of CSRs.
;*****************************************************************************

write_csrs LDA #$0B ;Command to read config. register
STA COMMAND ;Prepare command byte
JSR read_register;Read the configuration register

;*** Mask DP3-DP0 to access two CSRS (four Setups) ***
LDA MIDBYTE ;Get Middle Byte in ACCA
AND #$3F ;Mask DP3-DP2 low
ORA #$30 ;Mask DP1-DP0 high
STA MIDBYTE ;Put info back into Middle Byte location
LDA #$03 ;Command to write back to config Register
STA COMMAND ;Prepare Command Byte
JSR write_register;Write Configuration Register

;*** Write to CSRs - note, the ADC expects information for the number of
; CSR's indicated in the Depth Bits (DP3-DP0 in the configuration
; register) so all of the CSRs must be written at this time.
LDA #$05 ;Command to write CSRs
JSR send_spi ;send command to ADC

;*** Setup CSR #1 - Setups 1 and 2
; Sets both Setups to a default value of '000'
; (A1-A0 = 00, Physical Channel = 1, OWR = 15Hz,
; Input V-range = 100mV, Bipolar Measurement Mode)
LDA #$00 ;Load ACCA with zeros
JSR send_spi ;One byte of zero...
JSR send_spi ;Two bytes of zero...
JSR send_spi ;Three bytes of zero.

;*** Setup CSR #2 - Setups 3 and 4
; Sets Setup 3 to '4C0' and Setup 4 to '105'
; Setup 3 Settings - (A1-A0 = 01, Physical Channel = 2, OWR = 101.1Hz,
; input V-range = 100mV, Bipolar)
Setup 4 Settings - (A1-A0 = 00, Physical Channel = 3, OWR = 15Hz, input V-range = 25mV, Unipolar)

LDA #$4C ;Load ACCA with first byte of CSR #2
JSR send_spi ;Send byte number one
LDA #$01 ;Load ACCA with second byte of CSR #2
JSR send_spi ;Send byte number two
LDA #$05 ;Load ACCA with third byte of CSR #2
JSR send_spi ;Send byte number three
RTS ;Exit subroutine

*****************************************************************************
* Routine - calibrate
* Input - none
* Output - none
* This subroutine instructs the CS5521/22/23/24/28 to perform a self-calibration on
* Setup 1.
*****************************************************************************
calibrate LDA #$81 ;Command for Self-Offset Cal, Setup 1
JSR send_spi ;Send Self-Cal command to ADC
poll_sdo1 BRSET 2,PORTD, poll_sdo1 ;Wait for SDO to fall
RTS ;Exit Routine

*****************************************************************************
* Routine - rwgain
* Input - none
* Output - contents of gain register on PC1 in HIGH, MID and LOW bytes
* This subroutine first writes, and then reads back the value of the gain
* register on Physical Channel 1
*****************************************************************************
rwgain LDA #$02 ;Command to Write Gain Register of PC 1
STA COMMAND ;Prepeare COMMAND byte
LDA #$80 ;Value for High Byte
STA HIGHBYTE ;Prepare HIGHBYTE
CLR MIDBYTE ;Prepare MIDBYTE
CLR LOWBYTE ;Prepare LOWBYTE
JSR write_register;Write to Gain Register

RTS ;Return
;*****************************************************************************
;* Routine - convert
;* Input - none
;* Output - conversion results in memory locations HIGHBYTE, MIDBYTE and
;* LOWBYTE. This algorithm performs single conversions on
;* Setup 1. See the CS5521/22/23/24/28 data sheet for multiple
;* conversions or conversions on other channels.
;* This subroutine performs a Single conversion using Setup 1
;*****************************************************************************

convert

;Command to read Configuration Register
LDA #$0B

;Prepare COMMAND byte
STA COMMAND

;Read Config. Register
JSR read_register

;Get High Byte in ACCA
LDA HIGHBYTE

;Mask MC, LP and RC bits to 0
AND #$F8

;Put info back into High Byte location
STA HIGHBYTE

;Command to write back to config Register
LDA #$03

;Prepare Command Byte
STA COMMAND

;Write Configuration Register
JSR write_register


;*** Receive Conversion Data ***

;Command to convert on Setup 1
LDA #$80

;Send Command to ADC
JSR send_spi

;Wait for SDO to fall
BRSET 2,PORTD,poll_sdo2

;Load A with all 0's
LDA #$00

;Send all 0's to ADC
JSR send_spi

;Get high conversion byte
JSR receive_spi

;Move info to High Byte location
STA HIGHBYTE

;Get middle conversion byte
JSR receive_spi

;Move info to Middle Byte location
STA MIDBYTE

;Get low conversion byte
JSR receive_spi

;Move info to Low Byte location
STA LOWBYTE

;Return
RTS

;*****************************************************************************
;* Routine - write_register
;* Input - COMMAND, HIGHBYTE, MIDBYTE, LOWBYTE
;* Output - none
;* This subroutine is used to write information to the internal registers of
;* the CS5521/22/23/24/28
;*****************************************************************************

write_register

;Load ACCA with COMMAND
LDA COMMAND

;Transfer command byte
JSR send_spi

;Load ACCA with HIGHBYTE
LDA HIGHBYTE

;Transfer high byte
JSR send.spi

;Load ACCA with MIDBYTE
LDA MIDBYTE

;Transfer middle byte
JSR send_spi

;Load ACCA with LOWBYTE
LDA LOWBYTE

;Return
RTS
<table>
<thead>
<tr>
<th>Label</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSR send_spi</td>
<td>;Transfer low byte</td>
<td></td>
</tr>
<tr>
<td>RTS</td>
<td>;Return</td>
<td></td>
</tr>
</tbody>
</table>

;*****************************************************************************
;* Routine - read_register
;* Input - COMMAND
;* Output - HIGHBYTE, MIDBYTE, LOWBYTE
;* This subroutine is used to read from the internal registers of the
;* CS5521/22/23/24/28
;*****************************************************************************
read_register
<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDA COMMAND</td>
<td>Load ACCA with COMMAND</td>
</tr>
<tr>
<td>JSR send_spi</td>
<td>Send command byte</td>
</tr>
<tr>
<td>JSR receive_spi</td>
<td>Receive a byte</td>
</tr>
<tr>
<td>STA HIGHBYTE</td>
<td>Store value in HIGHBYTE</td>
</tr>
<tr>
<td>JSR receive_spi</td>
<td>Receive a byte</td>
</tr>
<tr>
<td>STA MIDBYTE</td>
<td>Store value in MIDBYTE</td>
</tr>
<tr>
<td>JSR receive_spi</td>
<td>Receive a byte</td>
</tr>
<tr>
<td>STA LOWBYTE</td>
<td>Store value in LOWBYTE</td>
</tr>
<tr>
<td>RTS</td>
<td>Return</td>
</tr>
</tbody>
</table>

;*****************************************************************************
;* Routine - send_spi
;* Input - Byte to be send is placed in ACCA
;* Output - none
;* This subroutine sends a byte to the ADC using the SPI port.
;*****************************************************************************
send_spi
<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STA SPDR</td>
<td>Move ACCA to the SPI Data Register</td>
</tr>
<tr>
<td>BRCLR SPIF,SPSR,wait0</td>
<td>Loop until byte has been transmitted</td>
</tr>
<tr>
<td>RTS</td>
<td>Return</td>
</tr>
</tbody>
</table>

;*****************************************************************************
;* Routine - receive_spi
;* Input - none
;* Output - Received byte is placed in ACCA
;* This subroutine receives a byte from the ADC using the SPI port.
;*****************************************************************************
receive_spi
<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLRA</td>
<td>Load ACCA Register with all Zeros</td>
</tr>
<tr>
<td>STA SPDR</td>
<td>Transfer 8 0's to clock next byte</td>
</tr>
<tr>
<td>BRCLR SPIF,SPSR,wait1</td>
<td>Reset SPIF bit</td>
</tr>
<tr>
<td>LDA SPDR</td>
<td>Get received information</td>
</tr>
<tr>
<td>RTS</td>
<td>Return</td>
</tr>
</tbody>
</table>
;* Routine - delay
;* Input - count in ACCA
;* Output - none
;* This routine delays by using the count specified in ACCA. The 68HC05
;* Development Board uses a 4.0MHz clock (E = 2.0MHz), thus each cycle is
;* 500ns. 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  ;256 loops on inner
;         NOP   ;2 cycles
;         NOP   ;2 cycles
;         BNE  innlp ;10 cycles*256*500ns=1.28ms
;         DECA ;countdown accumulator
;         BNE  outlp ;2569 cycles*500ns*ACCA
;         RTS  ;Return

;**********************************************************************

;* Interrupt Vectors
;**********************************************************************

; NOT_USEDRTI
; ORG $1FF4  ;Return from interrupt
; FDB NOT_USED  ;SPI interrupt
; FDB NOT_USED  ;SPI interrupt
; FDB NOT_USED  ;SPI interrupt
; FDB NOT_USED  ;SPI interrupt
; FDB NOT_USED  ;SPI interrupt
; FDB MAIN    ;Reset interrupt - power on reset