

Application Note

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

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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: \overline{CS} , SCLK, SDI, and SDO.

\overline{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.

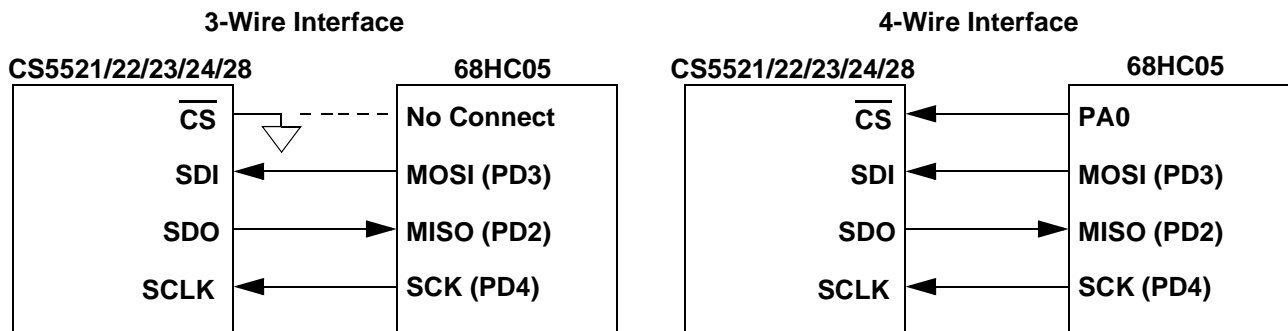


Figure 1. 3-Wire and 4-Wire Interfaces

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-

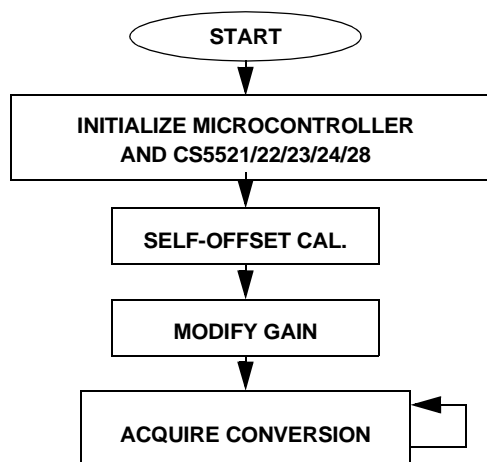


Figure 2. CS5521/22/23/24/28 Software Flowchart

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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, *con-*

vert 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.

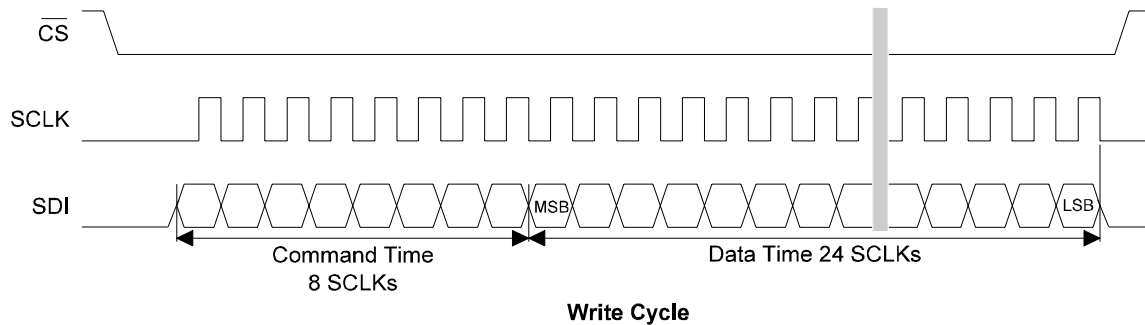


Figure 3. Write-Cycle Timing

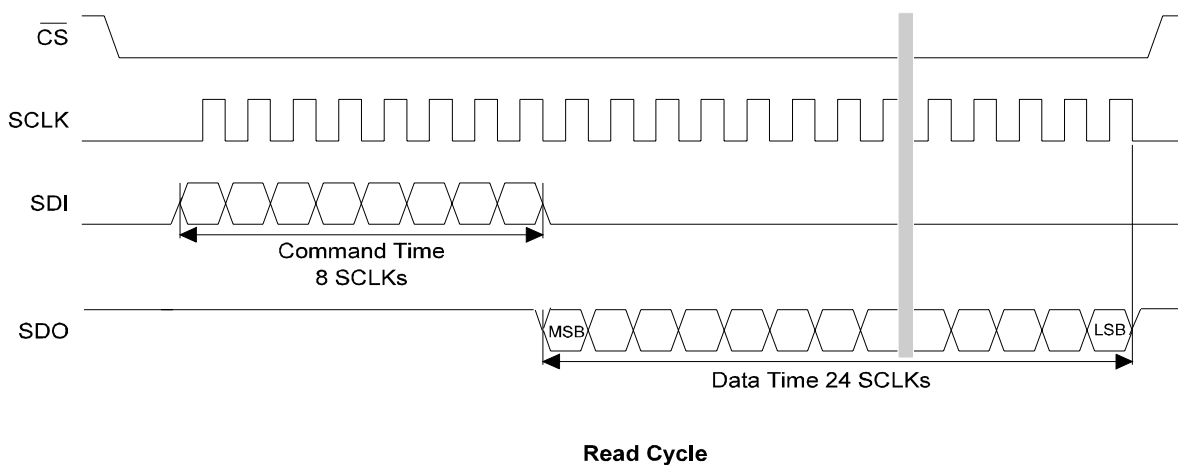
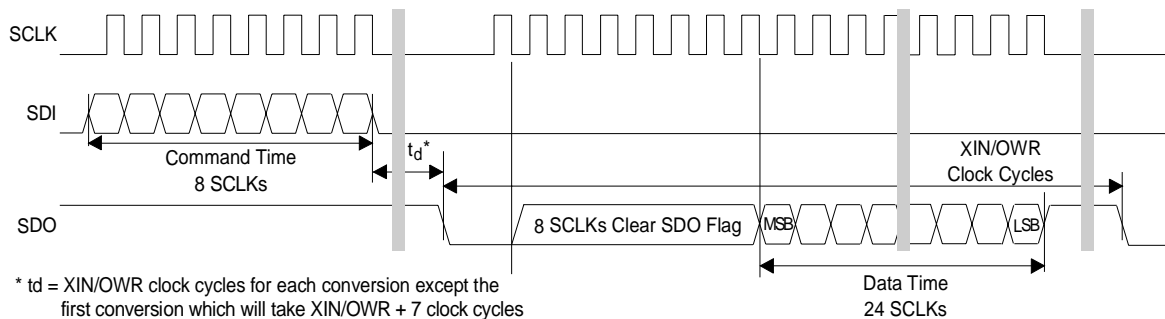


Figure 4. Read-Cycle Timing



* t_d = XIN/OWR clock cycles for each conversion except the first conversion which will take XIN/OWR + 7 clock cycles

Data SDO Continuous Conversion Read

Figure 5. Conversion/Acquisition Cycle Timing

MSB								High-Byte							
D23	D22	D21	D20	D19	D18	D17	D16	D15	D14	D13	D12	D11	D10	D9	D8

Mid-Byte							
D15	D14	D13	D12	D11	D10	D9	D8

Low-Byte							
D7	D6	D5	D4	D3	D2	D1	D0

A) 24-Bit Conversion Data Word (CS5522/24/28)

MSB								High-Byte							
D15	D14	D13	D12	D11	D10	D9	D8								

Mid-Byte							
D7	D6	D5	D4	D3	D2	D1	D0

Low-Byte							
1	1	1	0	CI1	CI0	OD	OF

B) 16-Bit Conversion Data Word (CS5521/23)

0- always zero, 1- always one,

CI1, CI0 - Channel Indicator Bits

OD - Oscillation Detect, OF - Overflow

Figure 6. Bit Representation/Storage in 68HC05

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*TM 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: 55226805.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
                LDA          #$40         ;Load ACCA with delay count value
                JSR          delay        ;Delay 1003 XIN for power-on reset
                LDA          #220        ;Load ACCA with delay count value
                JSR          delay        ;Delay for oscillator start-up 170ms
                JSR          delay        ;Delay for oscillator start-up 170ms
                JSR          delay        ;Delay for oscillator start-up 170ms

;*** Initialize ADC serial 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
;
;       CSRs 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
;*****

```

```

;*** Write to Gain Register of 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

```

```

;*** Read From Gain Register of Physical Channel 1 ***
               LDA          #$0A          ;Command to Read Gain Register of PC 1
               STA          COMMAND      ;Prepare COMMAND byte
               JSR          read_register;Read from 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          LDA      #$0B          ;Command to read Configuration Register
                 STA      COMMAND      ;Prepare COMMAND byte
                 JSR      read_register;Read Config. Register
                 LDA      HIGHBYTE     ;Get High Byte in ACCA
                 AND      #$F8         ;Mask MC, LP and RC bits to 0
                 STA      HIGHBYTE     ;Put info back into High Byte location
                 LDA      #$03         ;Command to write back to config Register
                 STA      COMMAND      ;Prepare Command Byte
                 JSR      write_register;Write Configuration Register

```

```

;*** Receive Conversion Data ***

```

```

poll_sdo2:      LDA      #$80          ;Command to convert on Setup 1
                 JSR      send_spi     ;Send Command to ADC
                 BRSET    2,PORTD,poll_sdo2 ;Wait for SDO to fall
                 LDA      #$00         ;Load A with all 0's
                 JSR      send_spi     ;Send all 0's to ADC
                 JSR      receive_spi  ;Get high conversion byte
                 STA      HIGHBYTE     ;Move info to High Byte location
                 JSR      receive_spi  ;Get middle conversion byte
                 STA      MIDBYTE     ;Move info to Middle Byte location
                 JSR      receive_spi  ;Get low conversion byte
                 STA      LOWBYTE     ;Move info to Low Byte location
                 RTS                    ;Return

```

```

;*****
;* 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  LDA      COMMAND      ;Load ACCA with COMMAND
                 JSR      send_spi     ;Transfer command byte
                 LDA      HIGHBYTE     ;Load ACCA with HIGHBYTE
                 JSR      send_spi     ;Transfer high byte
                 LDA      MIDBYTE     ;Load ACCA with MIDBYTE
                 JSR      send_spi     ;Transfer middle byte
                 LDA      LOWBYTE     ;Load ACCA with LOWBYTE

```

```

JSR    send_spi    ;Transfer low byte
RTS

```

```

;*****
;* 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      LDA    COMMAND    ;Load ACCA with COMMAND
                  JSR    send_spi    ;Send command byte
                  JSR    receive_spi ;Receive a byte
                  STA    HIGHBYTE    ;Store value in HIGHBYTE
                  JSR    receive_spi ;Receive a byte
                  STA    MIDBYTE     ;Store value in MIDBYTE
                  JSR    receive_spi ;Receive a byte
                  STA    LOWBYTE     ;Store value in LOWBYTE
                  RTS

```

```

;*****
;* 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          STA    SPDR        ;Move ACCA to the SPI Data Register
wait0:           BRCLR  SPIF,SPSR,wait0 ;Loop until byte has been transmitted
                  RTS                ;Return

```

```

;*****
;* 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      CLRA                ;Load ACCA Register with all Zeros
                  STA    SPDR        ;Transfer 8 0's to clock next byte
wait1:          BRCLR  SPIF,SPSR,wait1 ;Reset SPIF bit
                  LDA    SPDR        ;Get received information
                  RTS                ;Return

```

```

;*****

```

```

;* 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          NOP
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   ;Return from interrupt
               ORG          $1FF4 ;Int Vector location
               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

```

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