

Application Note

Interfacing the CS5521/22/23/24/28 to the PIC16C84

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1. INTRODUCTION

This application note details the interface of Crystal Semiconductor's CS5521/22/23/24/28 Analog-to-Digital Converter (ADC) to the Microchip PIC16C84 microcontroller. This note takes the reader through a simple example which demonstrates how to communicate between the microcontroller and the ADC. All algorithms discussed are included in Section 8. "APPENDIX: PIC16C84 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 PIC16C84 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 Port A (RA) on the PIC16C84 with a four-wire interface, the algorithms can be easily modified to work with the three-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 PIC16C84 to the ADC.

SDO, Serial Data Out, is the data signal used to transfer output data from the ADC to the PIC16C84.

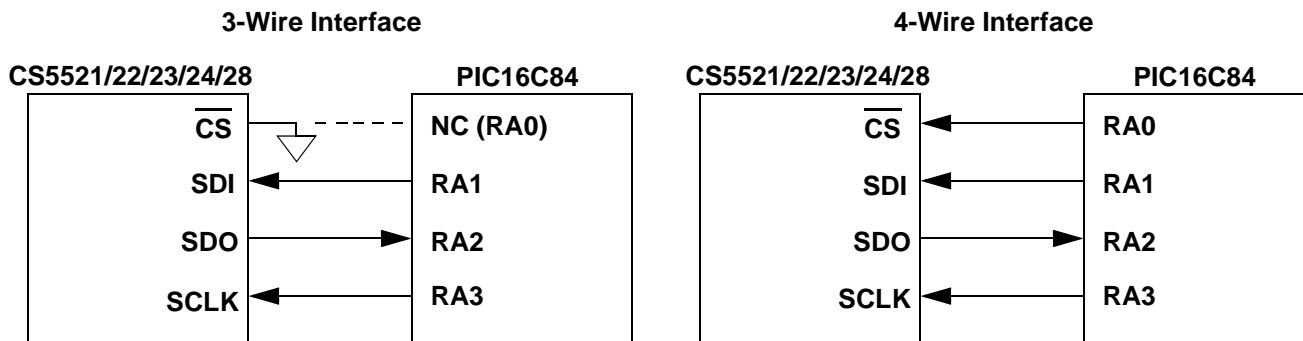


Figure 1. 3-Wire and 4-Wire Interfaces

3. SOFTWARE DESCRIPTION

This note presents algorithms to initialize the PIC16C84 and the CS5521/22/23/24/28, perform calibrations, modify the CS5521/22/23/24/28's internal registers, and acquire a conversion. Figure 2 depicts a block diagram of the main program structure. While reading this application note, please refer to Section 8. "APPENDIX: PIC16C84 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 Port A (RA) on the PIC16C84 and places the serial port of the CS5521/22/23/24/28 into the command state. RA's data direction is configured as depicted in Figure 1 by writing to the TRISA register (for more information on configuring ports, see the PIC16C84 Data Sheet). The controller then enters a number of delay states to allow the appropriate time for the ADC's oscillator to start up and stabilize (oscillator start-up time for a 32.768 KHz crystal is typically about 500ms). Finally, the ADC's serial port is reset by sending fifteen bytes of logic 1's followed by a single byte with its LSB at logic 0 to SDI (the serial port is initialized after any power-on reset, and this software re-initialization is for demonstration purposes) Once the proper sequence of bits has been received, the serial port on the

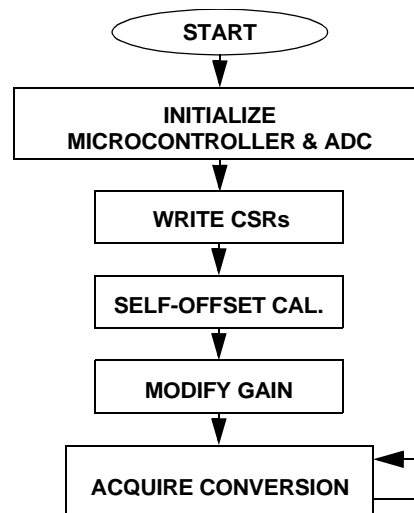


Figure 2. CS5521/22/23/24/28 Software Flowchart

ADC is in 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 taking 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,

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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. This tells the ADC to perform a self-offset calibration using Setup 1 (see the CS5521/22/23/24/28 Data Sheet for information on performing offset or gain calibrations using other Setups). Once the command has been sent, the controller polls RA2 (SDO) until it falls, indicating that the calibration is complete. Note that although calibrations are done on 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 *modify_gain* 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. *Modify_gain* 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_byte* algorithm four times, once to send the command byte, and three more times to send the three data bytes. *Send_byte* is a subroutine used to ‘bit-bang’ a byte of information from the PIC16C84 to the CS5521/22/23/24/28. A byte is transferred one bit at a time, MSB (most significant bit) first, by placing a bit of information on RA1 (SDI) and then pulsing RA3 (SCLK). The byte is transferred by repeating this process eight times. 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 CS5521/22/23/24/28 data sheet.

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* asserts \overline{CS} (RA0). Then it calls *send_byte* 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_byte* three times and transfers three bytes of information from the CS5521/22/23/24/28 to the PIC16C84. Similar to *send_byte*, *receive_byte* acquires a byte one bit at a time, MSB first. 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 Acquire Conversion

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 PIC16C84 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 on Setup 1 by sending the command 0x80 to the converter. At this time, the controller polls RA2 (SDO) until it falls to a logic 0 level (see Figure 5). After SDO falls, *convert* applies a logic 0 to RA1 (SDI) and pulses RA3 (SCLK) eight times to initiate the data transfer

from the ADC. The PIC16C84 then reads the conversion data word by calling *receive_byte* three times. Figure 6 depicts how the 16 or 24-bit data word is stored in the memory locations HIGHBYTE, MIDBYTE, and LOWBYTE.

4. MAXIMUM SCLK RATE

An instruction cycle in the PIC16C84 consists of four oscillator periods, or 400ns if the microcontroller's oscillator frequency is 10 MHz. Since the CS5521/22/23/24/28'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.

5. SERIAL PERIPHERAL INTERFACE

When using a built-in Serial Peripheral Interface (SPI) port, the designer must pay special attention to how the port is configured. Most SPI ports allow

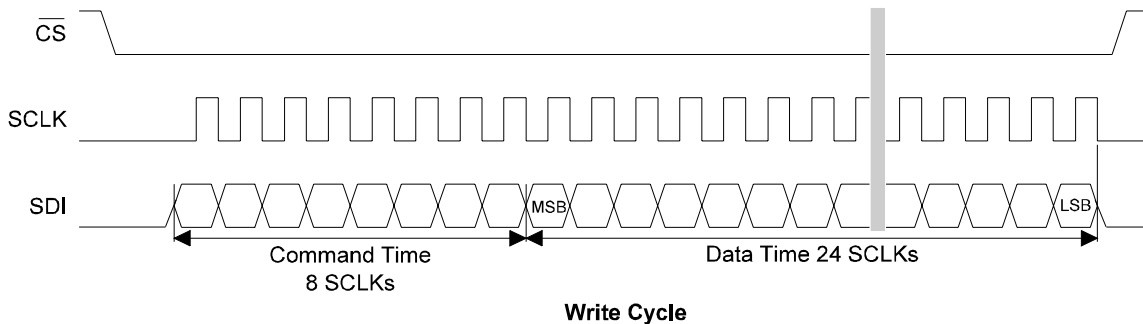


Figure 3. Write-Cycle Timing

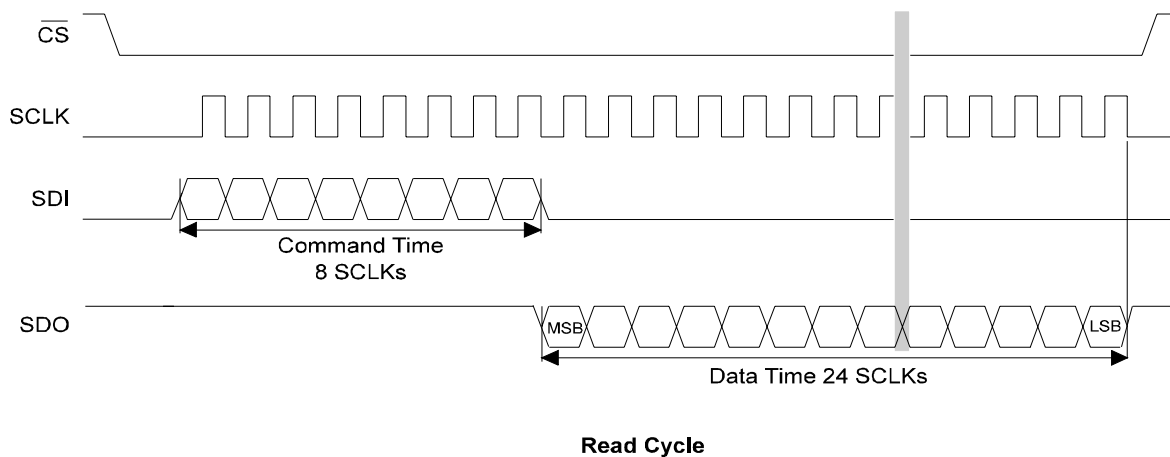
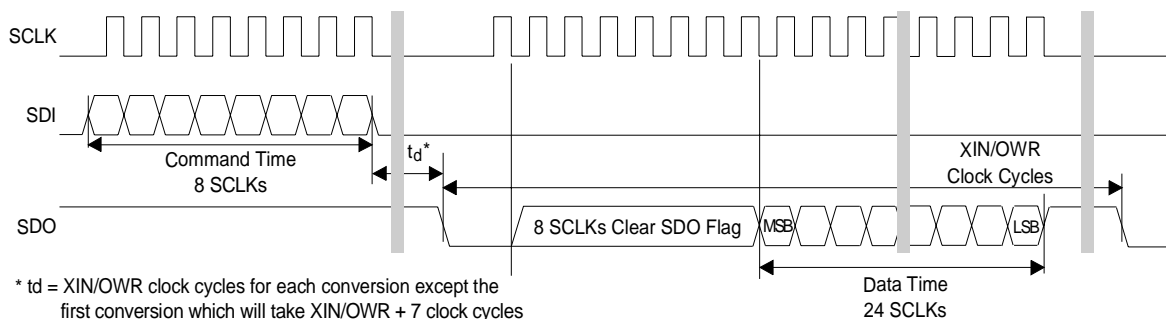


Figure 4. Read-Cycle Timing


Data SDO Continuous Conversion Read
Figure 5. Conversion/Acquisition Cycle Timing

MSB				High-Byte			
D23	D22	D21	D20	D19	D18	D17	D16
Mid-Byte							
D15	D14	D13	D12	D11	D10	D9	D8
Low-ByteLSB							
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 1

CI1, CI0 - Channel Indicator Bits

OD - Oscillation Detect, **OF** - Overflow

Figure 6. Bit Representation/Storage in the PIC16C84 for a selectable clock polarity. However, many do not have the capability to select the clock's phase. When using a microcontroller with both features, the clock polarity should be set to idle low, and the clock phase should be set to begin clocking in the middle of the data bits. For an SPI port without the variable clock phase feature to function properly with the CS5521/22/23/24/28, the clock polarity needs to be set to idle high, and the ADC's serial port must be re-initialized anytime new information is transmitted between the microcontroller and the converter.

6. DEVELOPMENT TOOL DESCRIPTION

The code in this application note was developed with *MPLAB™*, a development package from Microchip, Inc. It was written in Microchip assembly and compiled with the *MPASM™* assembler.

7. CONCLUSION

This application note presents an example of how to interface the CS5521/22/23/24/28 to the PIC16C84. 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, developed using tools from Microchip, Inc., 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 PIC assembly language.

The software described in the note is included in Section 8. "APPENDIX: PIC16C84 Microcode to Interface to the CS5521/22/23/24/28" on page 6.

8. APPENDIX: PIC16C84 MICROCODE TO INTERFACE TO THE CS5521/22/23/24/28

```

;*****
;* File:    55221684.ASM
;* Date:    November 1, 1999
;* Revision: 1
;* Processor:PIC16C84
;* Program entry point at routine "main". Entry point address is 0x05.
;*****
;* This program is designed to provide examples of how to interface the
;* CS5521/22/23/24/28 ADCs to a PIC16C84 Microcontroller. The software handles all
;* of the serial communications between the controller and the ADC to perform
;* system calibration and acquire 24 and 16-bit conversion words.
;*****

;*** Memory Map Equates ***

STATUS      equ    0x03      ; STATUS register
PORTA       equ    0x05      ; I/O Port A address
TRISA       equ    0x85      ; Port A Data Direction Control Latch
CARRY       equ    0x00      ; Carry Bit in STATUS
RP0         equ    0x05      ; Register Bank Select Bit in STATUS
CS          equ    0x00      ; Port A bit 0 - Chip Select
SDI         equ    0x01      ; Port A bit 1 - Serial Data In
SDO         equ    0x02      ; Port A bit 2 - Serial Data Out
SCLK        equ    0x03      ; Port A bit 3 - Serial Clock
HIGHBYTE    equ    0X0C      ; Upper 8 Bits of Conversion Register
MIDBYTE     equ    0x0D      ; Middle 8 Bits of Conversion Register
LOWBYTE     equ    0x0E      ; Lowest 8 bits of Conversion Register
COMMAND     equ    0x0F      ; Command Byte RAM location
TEMP        equ    0x10      ; Temporary Data storage RAM location
COUNT      equ    0x11      ; Software Counter RAM location
SERI_DATA   equ    0x12      ; Serial Data RAM location

;*****
;* Program Code
;*****

        processor    16C84      ; Set Processor Type
        org          0x00      ; Reset Vector Location
        goto         main      ; Start at "main" routine

```

```

;*****

```

```

;* Routine - main
;* Input - none
;* Output - none
;* This is the entry point to the program, as well as the central loop.
;*****

                org           0x05           ; program memory beginning location
main

;*** Initialize and Calibrate System ***
                CALL          initialize     ; Initialize the System

                CALL          write_csrs    ; Modify the Channel Setup Registers

                CALL          calibrate     ; Calibrate ADC Offset

                CALL          modify_gain   ; Write and Read gain register

;*** Loop to perform continuous single conversions ***
mloop:         CALL          convert       ; Obtain conversions from ADC
                goto         mloop        ; Keep looping

;*** End main ***

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

;*****
;* Routine - initialize
;* Input - none
;* Output - none
;* This subroutine initializes Port A to interface to the CS5521/22/23/24/28 ADC.
;* A time delay is provided to allow for the ADC oscillator to power up.
;* Typically, a 32.768 KHz crystal has a start-up time of about 500ms.
;* Additionally, 1003 XIN cycles are delayed for the ADC's power-on reset
;* after the crystal has stabilized. The total delay is 660ms upon system
;* power-up, assuming that the microcontroller has no start-up delay.
;*****

initialize     CLRF          PORTA         ; Clear Port A Output data latches
                BSF          STATUS, RP0   ; Select Register Bank 1 - control
                MOVLW        0x04         ; Directional Values for Port A:
                MOVWF        TRISA        ; RA2 = input, RA0-1 & 3-4 = output

                BCF          STATUS, RP0   ; Select Register Bank 0 - normal
                MOVLW        0x32         ; Load W for delay count
                CALL          delay        ; Delay 1003 XIN cycles

```

```

MOVW 0xFF      ; Load W for new delay count
CALL delay     ; Delay for Oscillator start-up 158ms
CALL delay     ; Delay for Oscillator start-up 158ms
CALL delay     ; Delay for Oscillator start-up 158ms
CALL delay     ; Delay for Oscillator start-up 158ms

```

```

;*** ADC Serial Port Initialization ***

```

```

MOVW 0x0F      ; Load W with a value of 15
MOVWF TEMP     ; Loop count variable = TEMP
BCF  PORTA, CS ; Clear CS to enable ADC
loop:
MOVW 0xFF      ; Load W with all 1's
CALL send_byte ; send all 1's to ADC
DECFSZ TEMP, 1 ; loop through to send 15 bytes of all 1's
goto  loop
MOVW 0xFE      ; Load W with last byte - '11111110'
CALL send_byte ; send final initialize byte to ADC
BSF  PORTA, CS ; Set CS to disable ADC
RETURN         ; Exit to "main"

```

```

;*****
;* Routine - calibrate
;* Input - none
;* Output - none
;* This subroutine tells the ADC to perform self-offset calibration on Setup 1
;*****

```

```

calibrate      MOVW 0x81      ; Command for Self-Offset Calibration
               BCF  PORTA, CS ; Enable ADC
               CALL send_byte ; Send Calibration Command to ADC
poll_sdo1:     BTFSC PORTA, SDO ; Wait until SDO falls to indicate
               goto  poll_sdo1 ; calibration completion.
               BSF  PORTA, CS ; Disable ADC
               RETURN         ; Exit to "main"

```

```

;*****
;* Routine - modify_gain

```



```

;* Input - none
;* Output - none
;* This subroutine writes to and reads from the gain register on physical
;* channel 1.
;*****

```

```

modify_gain      MOVLW  0x02          ; Command to write Gain register
                 MOVWF  COMMAND      ; Set command byte
                 MOVLW  0x80          ; High byte information
                 MOVWF  HIGHBYTE     ; Set high byte
                 CLRF   MIDBYTE      ; Set middle byte
                 CLRF   LOWBYTE      ; Set low byte
                 CALL   write_register ; Write 0x800000 to Gain Register

                 MOVLW  0x0A          ; Command to read Gain Register
                 MOVWF  COMMAND      ; Set Command byte
                 CALL   read_register  ; Read data from the Gain Register

                 RETURN               ; Exit

```

```

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

```

```

write_csrs       MOVLW  0x0B          ; Command to read Config. Register
                 MOVWF  COMMAND      ; set command byte
                 CALL   read_register ; read the config. register

;*** Mask DP3-DP0 to access two CSRs (four Setups) ***
                 MOVLW  0x3F          ; mask DP3-DP2 low
                 ANDWF  MIDBYTE, 1    ; change DP3 and DP2
                 MOVLW  0x30          ; mask DP1-DP0 high
                 IORWF  MIDBYTE, 1    ; change DP1 and DP0

                 MOVLW  0x03          ; Command to write config. register
                 MOVWF  COMMAND      ; set command byte
                 CALL   write_register ; Change Depth Pointer Bits

;*** Write to CSRs - note, the ADC expects information for the
;
;      number CSRs indicated in the Depth Bits (DP3-0 in the
;      configuration register) so all of the CSRs are
;      written at this time ***

```

```
        MOVLW 0x05      ; Command to write CSRs
        BCF     PORTA, CS ; select the ADC
        CALL   send_byte ; send command byte to ADC

;*** Setup CSR #1 - Setups 1 and 2
;
;   setting both to default value of '000'
;   (A1-A0 = 00, Physical Channel = 1, OWR = 15Hz,
;   input V-range = 100mV, Bipolar Measurement mode) ***

        MOVLW 0x00      ; all zeros
        CALL   send_byte ; send first byte
        CALL   send_byte ; send second byte
        CALL   send_byte ; send third byte

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

        MOVLW 0x4C      ; first byte of info
        CALL   send_byte ; send first byte
        MOVLW 0x01      ; second byte of info
        CALL   send_byte ; send second byte
        MOVLW 0x05      ; third byte of info
        CALL   send_byte ; send last byte

        BSF     PORTA, CS ; de-select the ADC
        RETURN          ; exit
```

```

;* Routine - convert
;* Input - none
;* Output - 24-bit Conversion Results in memory locations HIGHBYTE, MIDBYTE
;*           and LOWBYTE.
;* The Algorithm itself will only perform a single
;* conversion using Setup 1. For multiple continuous
;* conversions, or for conversions using other setups, the routine
;* must be modified. (see the CS5521/22/23/24/28 data sheet for more info)
;*****

```

```

convert          MOVLW 0x0B          ; Command to read Configuration Reg.
                 MOVWF COMMAND      ; Set Command Byte
                 CALL  read_register ; Read Config. Register Information
                 MOVLW 0xF8          ; Load mask info into W
                 ANDWF HIGHBYTE, 1 ; Mask MC, LP, and RC to 0
                 MOVLW 0x03         ; Command to write Configuration Reg.
                 MOVWF COMMAND      ; Set Command Byte
                 CALL  write_register ; Write Config. Register with new info

```

```

;           *** Receive Conversion Data ***

```

```

                 BCF    PORTA, CS    ; Enable ADC
                 MOVLW 0X80          ; Command for conversion using Setup 1
                 CALL  send_byte     ; send command byte
poll_sdo2: BTFSC PORTA, SDO; Wait until SDO falls to indicate
                 goto   poll_sdo2   ; conversion completion
                 MOVLW 0X00          ; Command to start data output
                 CALL  send_byte     ; send command
                 CALL  receive_byte  ; Receive data...
                 MOVWF HIGHBYTE     ; High Byte 1st..
                 CALL  receive_byte
                 MOVWF MIDBYTE      ; then the Middle Byte..
                 CALL  receive_byte
                 MOVWF LOWBYTE      ; and finally the Low Byte.
                 BSF    PORTA, CS    ; Disable ADC
                 RETURN              ; Exit to "main"

```

```

;*****

```

```

;* Routine - write_register
;* Input - COMMAND, HIGHBYTE, MIDBYTE, LOWBYTE
;* Output - none
;* This subroutine writes to the internal registers of the CS55/2122/23/24/28
;*****

```

```

write_register      BCF      PORTA, CS    ; Enable ADC
                   MOVF     COMMAND, 0; Load W with Command byte
                   CALL     send_byte    ; Send command info
                   MOVF     HIGHBYTE, 0; Load W with high byte
                   CALL     send_byte    ; Send high byte first..
                   MOVF     MIDBYTE, 0 ; Load W with middle byte
                   CALL     send_byte    ; Then the middle byte..
                   MOVF     LOWBYTE, 0 ; Load W with low byte
                   CALL     send_byte    ; .. and then the low byte last.
                   BSF      PORTA, CS    ; Disable ADC
                   RETURN    ; Exit Subroutine

```

```

;*****
;* Routine - read_register
;* Input - COMMAND
;* Output - HIGHBYTE, MIDBYTE, LOWBYTE
;* This subroutine reads from the internal registers of the CS5521/22/23/24/28
;*****

```

```

read_register      BCF      PORTA, CS    ; Enable ADC
                   MOVF     COMMAND, 0; Load W with Command Byte
                   CALL     send_byte    ; Send Command info
                   CALL     receive_byte ; receive High byte first..
                   MOVWF    HIGHBYTE    ; Move W to HIGHBYTE
                   CALL     receive_byte ; and then the middle byte..
                   MOVWF    MIDBYTE     ; Move W to MIDBYTE
                   CALL     receive_byte ; and finally the Low byte.
                   MOVWF    LOWBYTE     ; Move W to LOWBYTE
                   BSF      PORTA, CS    ; Disable ADC
                   RETURN    ; Exit Subroutine

```

```

;*****

```

```

;* Routine - send_byte
;* Input - Byte stored in W register
;* Output - none
;* This subroutine sends a byte, one bit at a time, MSB first, to the ADC
;*****

```

```

send_byte      MOVWF  SERI_DATA  ; Move W to SERI_DATA
               MOVLW  0x08      ; Set COUNT to 8
               MOVWF  COUNT     ; to transmit each bit individually

```

```

bitloop1:     RLF      SERI_DATA, 1      ; Rotate SERI_DATA to send MSB first
               BTFSC   STATUS, CARRY    ; If bit is low, skip next instruction
               BSF    PORTA, SDI       ; If high, set SDI
               BTFSS  STATUS, CARRY    ; If bit is high, skip next instr.
               BCF    PORTA, SDI       ; If low, clear SDI
               BSF    PORTA, SCLK      ; Toggle SCLK High
               BCF    PORTA, SCLK      ; Toggle SCLK Low
               DECFSZ COUNT, 1         ; Go to next bit unless done
               goto   bitloop1
               BCF    PORTA, SDI       ; Return SDI to low state
               RETURN                  ; Exit Subroutine

```

```

;*****
;* Routine - receive_byte
;* Input - none
;* Output - Byte stored in W register
;* This subroutine receives a byte, one bit at a time, MSB first, from the ADC
;*****

```

```

receive_byte   MOVLW  0x08          ; Set COUNT to 8
               MOVWF  COUNT        ; to receive each bit individually

```

```

bitloop2:     BTFSC   PORTA, SDO       ; If Bit is low, skip next instruction
               BSF    STATUS, CARRY    ; Otherwise, set carry bit
               BTFSS  PORTA, SDO       ; If Bit is high, skip next instruction
               BCF    STATUS, CARRY    ; Otherwise, clear carry bit
               RLF    SERI_DATA, 1     ; Rotate Carry into SERI_DATA, MSB first
               BSF    PORTA, SCLK      ; Toggle SCLK High
               BCF    PORTA, SCLK      ; Toggle SCLK Low
               DECFSZ COUNT, 1         ; Go to next bit unless finished
               goto   bitloop2
               MOVF   SERI_DATA, 0     ; Put received byte into W
               RETURN                  ; Exit Subroutine

```

```

;*****

```

```

;* Routine - delay
;* Input - Count in W register
;* Output - none
;* This subroutine delays by using a count value stored in register W. This
;* example was tested using a 10MHz clock (E = 2.5 MHz), thus each
;* cycle is 400ns. This delay is approximately equivalent to:
;* (400ns)*(1536)*(count value in W) - A count of 720 provides a 445ms delay
;*****

```

```

delay      MOVWF  COUNT      ; Move delay value to COUNT
outlp:     CLRF   TEMP      ; TEMP used for inner loop counter
innlp:     NOP             ; 1 cycle - 400ns
           NOP             ; 2 cycles - 800ns
           NOP             ; 3 cycles - 1.2 us
           NOP             ; 4 cycles - 1.6 us
           DECFSZ  TEMP, 1   ; Decrement TEMP and loop 256 times
           goto    innlp
           DECFSZ  COUNT, 1  ; Decrement COUNT and loop
           goto    outlp
           RETURN          ; Exit delay

```

```

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

```

```

NOT_USEDRETFIE
           ORG     0x04      ; originate interrupt vector here
           goto   NOT_USED  ; no interrupts enabled
end       ; end program listing

```

• **Notes** •

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