configuration data for each channel [7]-[8]. The Programming of ADC chip is an off-line operation and it is configured in such a manner as to load this data automatically in power-up onto its configuration registers. These ADCs have different gain values and is based on the internal reference voltage and differential input voltage of the ADC [9]. Different gain settings of ADC are shown in Table 2.

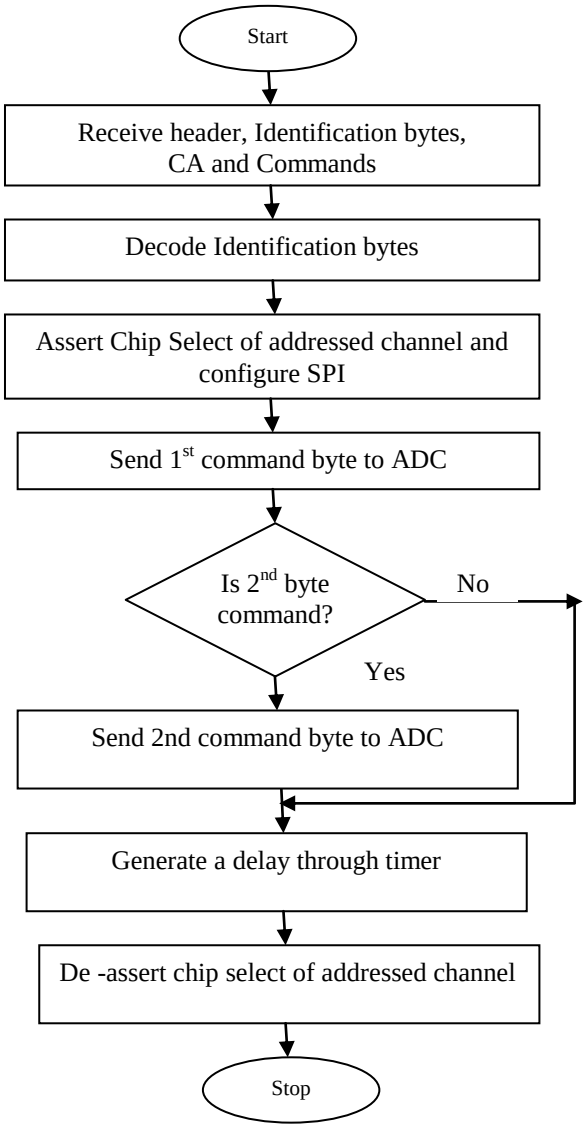

Figure 2: Flowchart for program mode operation

3.2 Data Acquisition Mode

In this mode, the A DCs are polled continuously. The 16-bit data is read from ADC and stored in the data memory of microcontroller .It is possible through SPI routine and this process continuous until the microcontroller receives a command from Processing Unit. This command request is handled using interrupts and the interrupt service routine handles the posting of reply to Processing Unit. It is possible through UART routine. After sending the reply, the microcontroller returns to ADC polling [10].

Table 2: Gain settings of ADC

V ref	Differential input Voltage range	Gain
2.5V	0-2.5V	1
2.5V	0-1.25V	2
2.5V	0-0.625V	4
2.5V	0-312.5mV	8
2.5V	0-156.25mV	16
2.5V	0-78.125mV	32
2.5V	0-39.0625mV	64
2.5V	0-19.53mV	128
1.25V	0-10mV	128

3.2.1 SPI routine

The communication between MCU and ADC is possible through SPI by means of five hand shaking signals ,the Chip Select(CS),Data Ready(DRDY),SCLK(Serial Clock),Data Input(DI) and Data Output(DO)lines. Figure 3 shows the flow diagram for SPI routine. The individual ReaDY (DRDY) signal corresponding to each chip is used to check the data validity before reading the corresponding channel. The CS lines are individually supplied to each chip when corresponding channel is to be accessed. The data transfer is synchronised with a SCLK of 1MHz.The microcontroller polls channel sequentially, selects the ADC if data is ready, issues a Read Data (RDATA) command and reads the data over the SPI port.

SPI operating frequency is calculated using equation 1.

$$FSCK = \frac{FCY}{\mathrm{Pr}imaryprescale * Secondaryprescale} \quad (1)$$

- FCY=Device system frequency
- FSCK= SPI clock frequency

3.2.2 UART routine

In the output, the microcontroller is interfaced to the Processing unit through UART. The UART uses the standard Non-Return –to-Zero (NRZ) format with one start bit, 8 data bits, 1 mode bit and one stop bit. The mode bit is used to differentiate between command and reply. The command sequence from Processing Unit and the reply sequence from DAU (Data Acquisition Unit) in the RS-485 protocol are shown in Figure 4 and Figure 5 respectively.

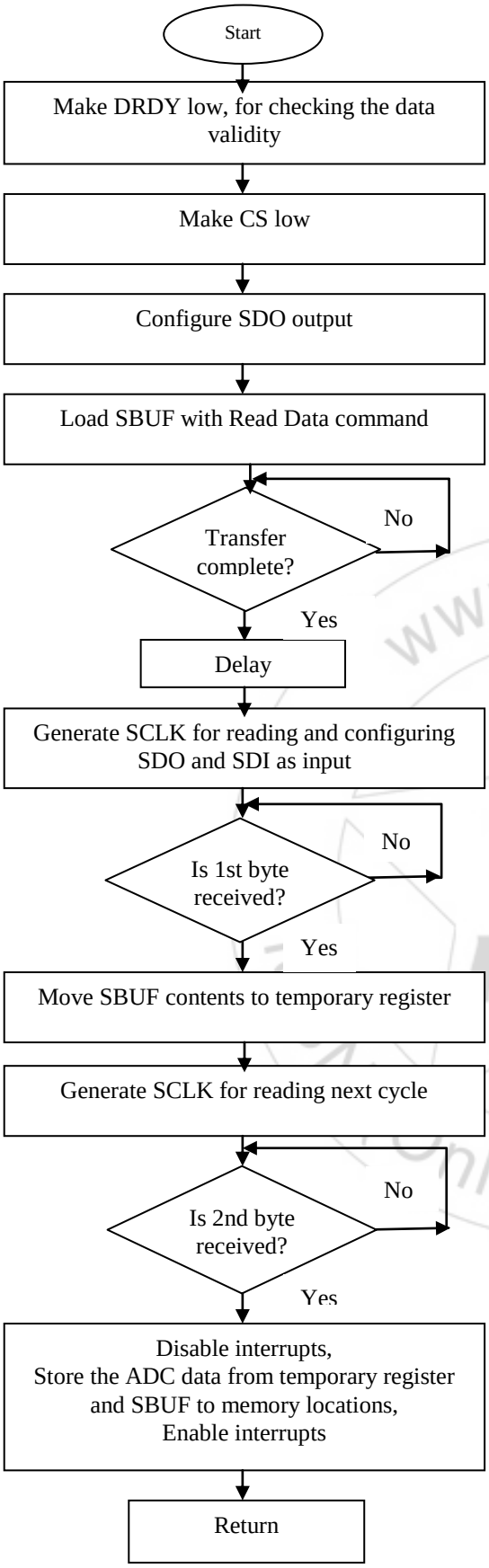

Figure 3: The flow diagram for SPI routine

The UART module consists of a dedicated 16-bit Baud Rate Generator. The UxBRG register controls the period of a free-running, 16-bit timer.

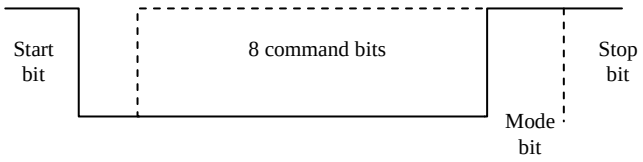

Figure 4: Command sequence from Processing Unit

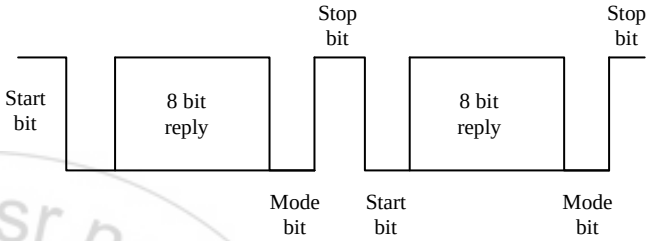

Figure 5: Reply sequence from DAU

UART Baud Rate calculation for BRGH = 1 is shown in equation 2.

$$Baudrate = \frac{FP}{4(UxBRG + 1)} \quad (2)$$

FP = (FOSC/2)

- FP = The instruction cycle clock frequency
- FOSC=Oscillator frequency

The maximum baud rate (BRGH = 1) possible is FP/4 (for UxBRG = 0) and the minimum baud rate possible is FP/ (4 * 65536).

3.3 Filtering Stage

A digital filter at the output of ADC using moving average concepts increases the efficiency of the system. The Effective number of bits (ENOB) in an ADC can be calculated using equation 3.Before filtering, 500 data samples from a channel with a Vref of 2.5 results in an ENOB of 14.05. A simple low pass filter produces an ADC with improved resolution and thus the system becomes more efficient [11]-[12].The ENOB values for different number data samples after filtering is shown in Table 3.

$$ENOB = Log2\left(\frac{Vref}{3 * S\tan dardDeviation}\right) \quad (3)$$

- ENOB=Effective Number of Bits

Table 3 The ENOB values after filtering

Number of Samples taken for average	Standard Deviation	ENOB
5	0.045357	14.16528
15	0.036069	14.49584
20	0.018575	15.45322

4. Results

In Data Acquisition mode, the ADCs channels are polled continuously and the available data is read and stored in the memory of microcontroller. This process continuous until it receives a command from Processing Unit. The command request is handled using interrupts and interrupt service routine handles the posting of reply to Processing Unit .The simulation results for SPI and UART routine in data acquisition mode are shown in Figure 6 and Figure 7 respectively.

The program is tested in the demo board of PIC24E series. The board provides a low-cost, modular development system for Microchip's enhanced 16-bit Digital Signal Controllers (DSCs) or High-Performance Microcontrollers (MCUs). It also consists of a crystal oscillators, Green power indicator LED, USB connectivity for on-board debugger communications, Three push button switches (SW1, SW2, SW3) for user-defined inputs, Three user-defined indicator LEDs (LED1, LED2, LED3), USB Type A connectivity for PIC24E USB host-based applications, Host mode power jumper and a Regulated +3.3V power supply for powering the starter kit via USB or an expansion board.

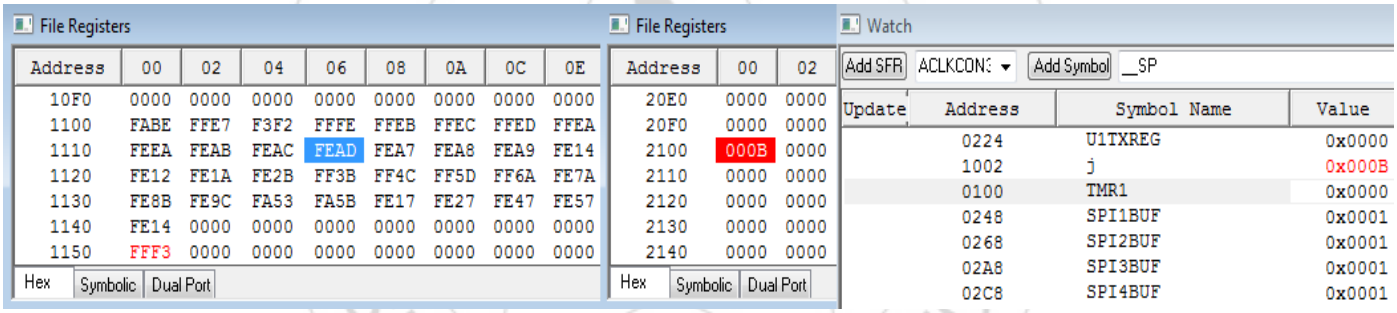

Figure 6: Polling process and reception of command by the microcontroller

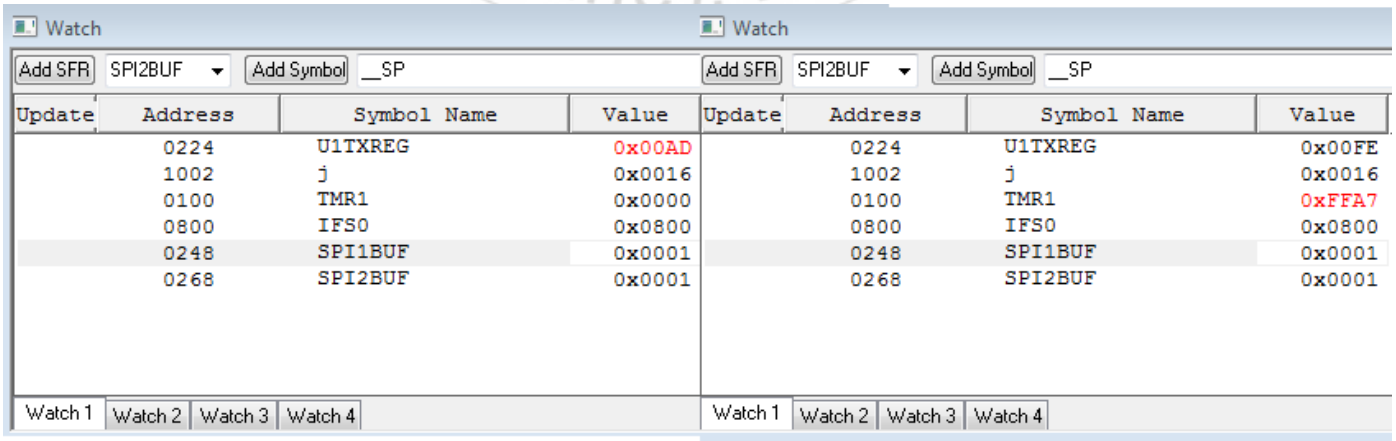

Figure 7: Transmission of required data requested by the Processing Unit

5. Conclusion and Future works

Data acquisition and telemetry are part of winning formula of many fields including industry and aerospace. The implementation of an efficient software programmable real time data acquisition system with reduced size and weight is discussed in this work. It results in an efficient system in terms of sigma-delta ADCs, that can offer higher input signal bandwidth and the digital filter placed at the output of ADCs, which produces improved resolution. The versatility of the system in terms of software reconfiguration, calibration and sensor interface extends its application.

Work is on track of improving the system performance by considering power reduction concepts. Introduction of a wireless protocol between different data acquisition module will also improve the performance [13].

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