DESIGN OF HIGH ACCURATE DATA ACQUISITION SYSTEM FOR REAL TIME MONITORING OF POWER GRID

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Abstract -- Now a days Automated Systems are widely adapted for most modern industries. Data acquisition is the major component of any automation system. The robustness of the automation system mainly depends on the accuracy and speed of the data acquired from Data Acquisition System(DAS). This paper mainly focusses on the design of high accurate multi-channel Data Acquisition System for real time automation applications. Data acquisition is used to acquire data from sensors and other sources under computer control and bring the data from different channels together to store and manipulate it. The sensors may include thermocouples, voltage and current sensors to make variety of measurements from different remote locations in the industries. The proposed method can sense all the 48 channels data in two seconds. The filters used in the application makes the acquired data to be more accurate with accuracy level of 30 PPM.

Keywords:

I. INTRODUCTION

It is often very useful to know the operating conditions of the electrical systems in the power grid at different situations. The parameters like voltage, current, temperature are usually measured to study the performance characteristics of the machine or system. It is usually complicated to have constant monitoring, recording and storing results of these parameters using the traditional measuring apparatus like meters. Hence a system is designed to have a constant monitoring and storing results of these parameters using sensor technology along with microcontroller. The sensors will sense the parameter under study. Since the output signals of sensors cannot be directly processed by the electronic system a signal conditioning circuit is used for each sensor to condition the signal. This is an analog signal and it is converted to digital signal by using analog to digital converter then they are given to the microcontroller and further to personal computer so as to achieve monitoring. This monitoring system is known Data Acquisition System (DAS).

The main aim is to design a Data Acquisition System the acquire the data with high accuracy and speed. This paper illustrates the technical approaches adopted to achieve the speed and accuracy in the system.

II. TECHNICAL APPROACH

The proposed DAS has mainly two features:

A. Accuracy and

B. Speed

To obtain high accurate data from the sensors, 24-bit ADC is used in the application. The ADC ADS1259 from Texas instruments provides this amount of resolution. This was found sufficient as the 24-bit ADC allows for a resolution of 1 part in 2^24 which makes the system more accurate. To further improve the accuracy level in the acquired data noise from the data obtained from ADC is removed with help of digital filters.

The next main feature of the DAS is speed. To improve the speed of the DAS, single ADC is employed for all 48 channels instead of maintaining one for each. This will reduce the amount of hardware and its settling time. So the speed of the system is improved. To further improve the speed of the system, firmware filters are employed instead of hardware filters. This will further reduce the hardware which will further improve the speed.

III. DATA ACQUISITION SYSTEM

The functional block diagram of proposed DAS is shown in Fig1. The major peripherals of the proposed DAS that need to controlled through firmware are as follows.

- Sensor Input Module (SIM)
- Multiplexer
- ADC
- Microcontroller
- Single Board Computer

Sensor Input Module

Sensor Input Module(SIM) is a hardware component that acts as a casing for different output sensors. The proposed DAS has four SIMs. Each SIM has the capability of holding twelve sensors. Therefore, all four SIMs hold a total number of 48 sensors. The SIM provides mechanical support to the sensors connected to it and also provides support for switching the channels.

Multiplexer

Multiplexer(MUX) acts as a switch to select one channel at time from available 48 channels. MUX switching was under the control of microcontroller. The micro controller was programmed to keep switching the different sensor channels. Truth table was developed for switching between different sensor channels.

ADC

An A/D converter does exactly what its name implies. It is connected to an analog input signal, it measures the analog input and then provides the measurement in digital form suitable for use by a computer. The A/D converter is the heart of any analog input DAQ system as it is the device that actually performs the measurement of the signal.

Microcontroller

Microcontroller is the brain of any computing system. It controls the functions of the all the peripherals connected to it. This application uses STM32F407IGT7 micro controller from ST microelectronics. Microcontroller collects the data from sensors through ADC and sends the data to Single Board Computer(SBC) after performing digital filtering actions on the data to remove the noise.

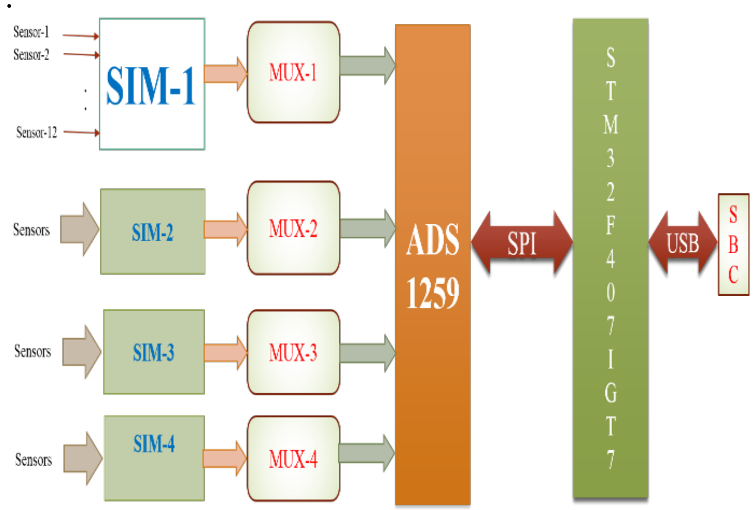

Fig.1 Functional block diagram of Data Acquisition

Single Board Computer

A single-board computer (SBC) is a small computer built on single chip that has the same features as functional computer such as microprocessor, memory, input/output etc., In this application, SBC is used to store the live data obtained from the sensors through microcontroller via USB communication protocol.

IV. DATA FLOW IN DAS

The data movement from the sensor to microcontroller output is described in flow chart. The flow starts from setting processer peripherals and initialize the channel data. Check the frequency of line whether it is 50 Hz or not if not change the settings. After finalizing the one channel switch the next channel followed by set the input and output gain of the Programmable Gain Amplifier (PGA). Give start command to ADC to convert the amplified analog signal to digital value to process and control the data in microcontroller.

The digital data is attained if the DRDY pin of the ADC is low otherwise the process waits for checking any errors and starts from initial step. using buffer, the digital data acquired from the ADC is stored after filling the buffer up to 10 samples reset the flag for the next count. After getting digital data from ADC fed it into microcontroller for the processing the data, like interpolate the data and decimation and increment the processor counter n times and rest the counter for the next count and clear the buffer and reset the full flag.

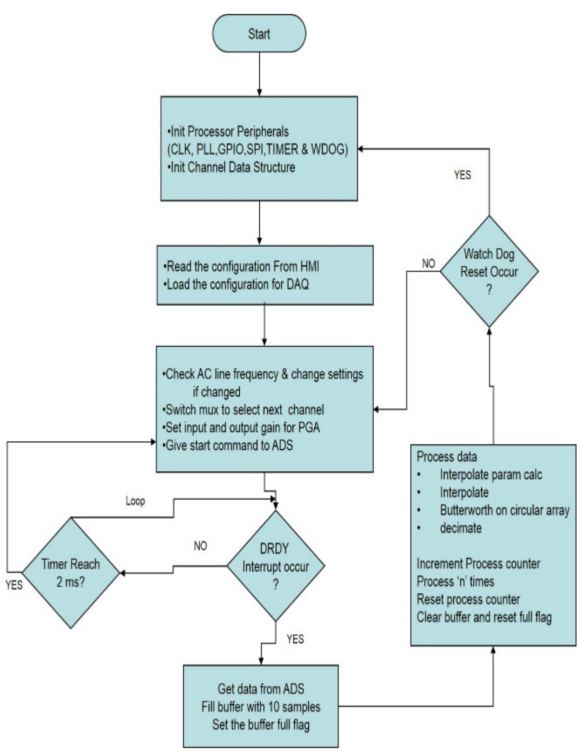

Fig.3 Data flow of DAS

This data flow is controlled and closely observes the watchdog from the various commands if there is no interlude it just start the loop from multiplexer otherwise its start again from initial condition.

V. OPERATION OF PROPOSED DAS

The micro controller was programmed to keep switching the different channels through multiplexing action. Truth table was developed for multiplexing action to switch one channel at a time from available 48 channels.

The flow chart for micro controller programming is shown in Fig3. The overall data acquisition process is as follows.

Initialization

When the system switched on the micro controller initializes various peripherals connected to it such as clocks, GPIOs, timers, watch dogs, serial communication engines etc.,

The channel selection data structure and interrupt vector address are loaded into the program memory. The microcontroller checks for AC line frequencies to which it is configured at present state and corresponding settings were initialized.

ADC is initialized through SPI communication protocol and correspond registers are initialized.

Channel selection

The sensor/channel was selected for obtaining data by loading corresponding value in the truth table onto the output ports. After the selection of channel, the sensor is ready to give input to the ADC.

ADC conversion process

When the sensor is ready to give output, the start command is given to ADS1259 from microcontroller. The ADC start conversion process. When the conversion process was over the ADC asserts data ready line (DRDY) which provides interrupt to the microcontroller telling data is ready to read. At each conversion process ADC provides ten samples of data at its output.

If the DRDY line is not asserted during channel scanning time which usually 20ms, the controller waits up to grace period which is usually 5ms for data. If still data is not available, the controller provides time out for that channel and switch to next channel.

Data Processing

The data obtained from ADC is not accurate and contains various frequency components in it. To obtain high accuracy in the accurate data, the noise frequency components as well power line frequency components has to be removed. For this, digital filters are designed and implemented in data acquisition firmware.

Digital low pass filter is implemented with cut-off frequency 5 Hz. It shows good attenuation response to the high frequency components. But this filter has poor attenuation response at 50Hz frequency. This project was majorly working at power line frequency of 50Hz, which is the major noise component to filter out from ADC output data.

The combined response of the digital low pass filter and notch filter is shown in Fig. 4. From the Fig. 4, it should be noted that the attenuation of power line frequency component is nearly -60dB, which is at acceptance level.

The transfer functions of the low pass filter and notch filter is shown in equation (1) & (2) respectively.

$$A = \frac{1}{0.001013s^2 + 0.04502s + 1} \quad \ldots (1)$$

$$A_{Notch} = \frac{s^2 - 1.6186 + 1}{s^2 - 1.616s + 0.998} \quad \ldots (2)$$

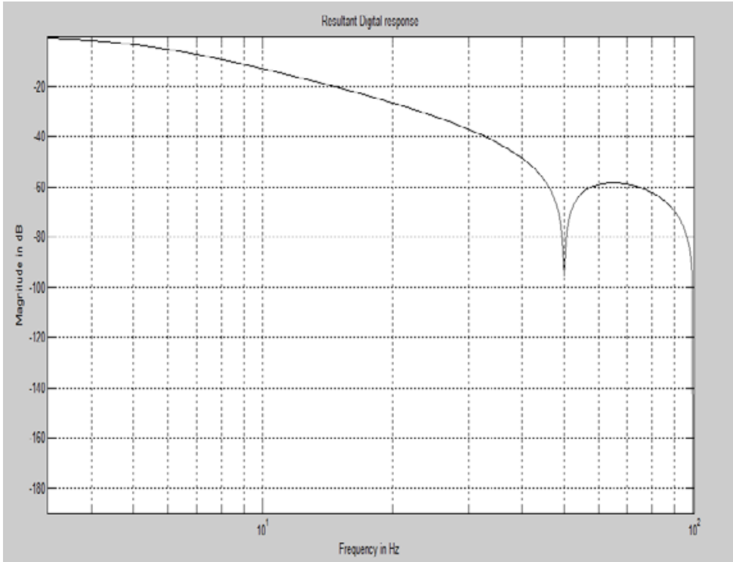

Fig.4 Digital low pass notch filter response

These two digital filters are implemented in firmware to increase the data rate by avoiding analog filters.

Data conversion

The ADC counts corresponding to the input to the sensor are passes through various filtering stages. The output from the digital filters is the filtered ADC counts corresponding to the actual input parameters. The actual parameters can be calculated from the ADC reference values. The service routine can be implemented in the firm ware to convert the ADC counts in the actual parameters.

Data storage

Once the data from ADC passed through various filtering stages, the noise in the data is removed, the filtered data which is in the form of ADC counts corresponding to the input parameters is converted into actual values. The final actual data is sent to the Single Board Computer to store and also the stored data is sent to the control center from remote location.

VI. APPLICATIONS

The proposed DAS has find its applications in the following areas.

1. In power system the DAS find its applications in the RTUs to send the real time data from remote locations to the control center

2. Due to real time monitoring, the proposed DAS can be used in the industrial automation to control the parameters automatically.
3. In biomedical applications, the DAS can be used to measure the ECG and EEG signals very accurately.
4. The proposed DAS has find its application in the power quality measurements.

In most cases, the data acquisition system provides the much needed real time data for the analysis of a particular fault. It can also provide the required data to optimize a control system in a given process industry.

VII. CASE STUDY

The prototype was developed based on the above principle to measure the data of voltage, current and temperature of the transformer.

The measured data from the transformer was sent to the remote location usually a control room to monitor and control. The transmitter and receiver sections of the prototype are shown in the Fig. 5 and Fig. 6 respectively.

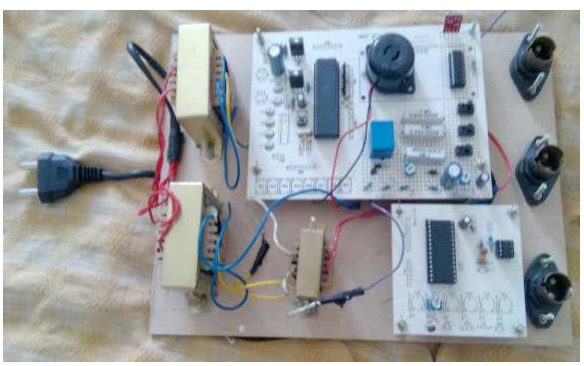

Fig 5: Hardware setup for transmitter section

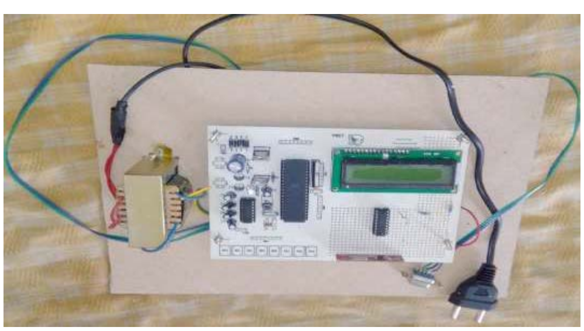

Fig 6: Hardware setup for receiver section

The measured data is send to the receiver section through RF wireless transmission. When the measured parameters exceed the pre-stored limits in the micro controller, an alarm signal is generated to make the operational alert. The limiting values are shown on the Table 1.

Table 1: Limiting values of the parameters of the transformer

Parameter	Limiting values
Voltage(v)	$220\text{ V} \leq v \leq 230\text{ V}$
Current(I)	$I < 100$ mA
Temperature(T)	$T < 50\ ^{o}C$

VIII. CONCLUSION

The multi-channel Data Acquisition System based on a STM32F407IGT7 microcontroller from ST Microelectronics is designed, developed and tested. The advantage of using the proposed DAS is that the Analogue to Digital Converter (ADC) with 24-bit resolution was used that makes the DAS to obtain high accurate data from measurement world. This allows for a measuring accuracy of one part in 2^24. The digital filters used in this DAS eliminates high frequency and power line frequency components in the measured data and most accurate data is sent to the Single Board Computer. The accuracy level of the measured data when tested was found to be 30 PPM.

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