IMPLEMENTATION OF LOW COST MULTI CHANNEL UNIVERSAL DATA ACQUISITION SYSTEM

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ABSTRACT

A multi channel data logging system is essential and useful in many Engineering applications especially where the environmental monitoring plays a significant role. Implementation of a low cost, universal data acquisition system based on analog multiplexer network is described in this paper. The system supports most of industrial analog and digital transducers where each universal input can be configured for any transducer in 2 wire, 3 wire or 4 wire mode. The analog front end of the system has been designed using low power CMOS analog multiplexer network, which acts as a universal interface to the transducers. The proposed system is ideal for battery operated low power data logging applications.

***Key words*:** Data Acquisition, Data Logging, Universal Interfaces, Multiplexers

1. INTRODUCTION

As in the process control and instrumentation engineering, the term Data Acquisition (DAQ) is often used and it becomes very important when dealing with dynamical systems. The characteristics of such a system are frequently analyzed and evaluated to make prediction of the system performance. Hence the acquisition and analysis of dynamical parameters plays a vital role and provides information to design an environmental model in many engineering applications [1].

Data acquisition, as the name implies, is a process of sampling or collecting data signals that measure real world physical conditions to analyze some phenomenon. As technology progressed, this process has been simplified, made more accurate, and moved to a PC based automated system where the data monitoring, recording and analyzing all take place in a single system. DAQ products serve as a focal point in a system tying together a wide variety of sub products such as transducers, human interfaces etc. Figure 1 shows the process of a typical DAQ system.

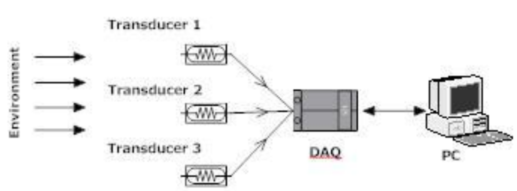

Figure 1: Typical Data Acquisition Process

Data Acquisition is used in a broad spectrum of applications. In product development, design engineers record performance parameters such as vibrations, radiations, battery level to evaluate the quality of the product. Civil engineers record strain, load on bridges over time to evaluate safety. Breweries log the conditions of their storage and brewing facilities to maintain quality [2]. Each application may have unique data type and hence requires a unique type of transducers.

The purpose of this paper is to provide a universal solution for data acquisition technology, concerning the general background of industrial transducers. Further it will describe the implementation of a low-cost, low power DAQ system in order to fulfill the universal purpose.

2. METHODOLOGY

2.1 Transducer Technology

Depends on the conversion process, they can be divided into two types.

- Active Transducers - voltage or current output
- Passive Transducers - measure of variation in passive components (Resistance, Capacitance or Inductance) [3].

Active transducers generate electrical signal directly in response to the environmental simulation. Examples of active transducers are, Thermocouples, Piezoelectric Accelerometers. Passive transducers produce a change in passive electrical quantities, and hence they require an additional electrical energy for excitation. Strain Gages, Resistive Temperature Device (RTD) and Thermistors are examples of passive transducers.

2.2 Universal Interface

Based on the operating principle and type of the central element of the transducers, they may have diferent interface types. Most of industrial transducers are available in 2 wire, 3 wire and 4 wire modes. In proposed system, the universal interface is realized using CMOS analog multiplexer network. This architecture enables the both excitation supply and sense signal of a transducer to switch to a relevant power source and to an amplifier stage respectively. Figure 2 shows the proposed multiplexer network.

of the amplifiers, *Ron* does not affect to the accuracy of measurement.

- User will be given an option to select preferred excitation supply for transducers. A known fixed current source can be used if the voltage excitation creates considerable voltage drops across *Ron* of the multiplexer switches.
- Transducer is switched to the excitation only during the time its measurement taken. That eliminates the self heating errors present in measurement
- When acquiring signals, only one transducer is switched at a time. That prevents making ground loops among transducers.

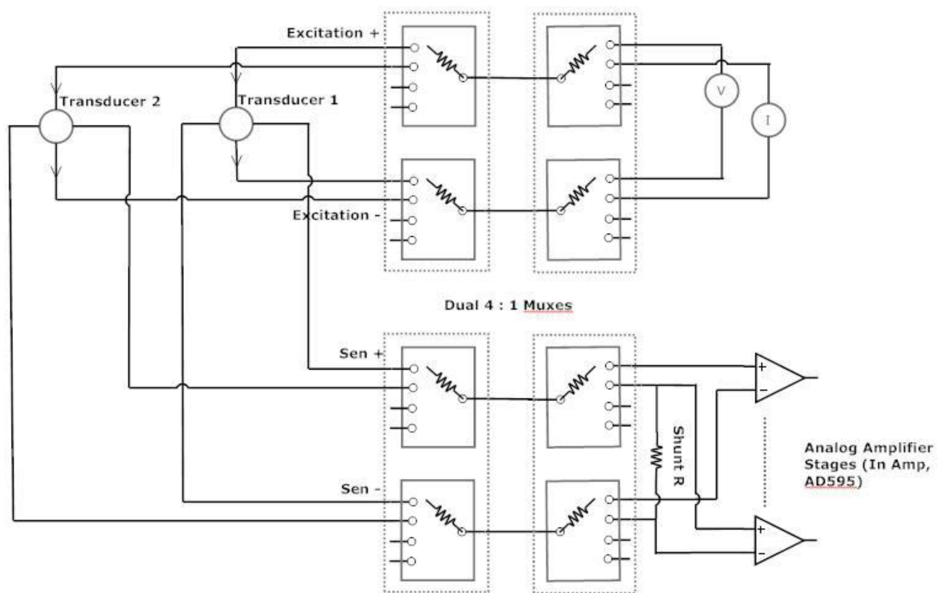

Figure 2: Universal Interface (4 Channel) based on Analog Multiplexer Network

Since CMOS devices have high noise immunity and low power profile, the design is preferred for low power application compared to relay based switching network. Transducer routing is done by writing appropriate logic to the control bus lines of the multiplexers. Besides that, the arrangement shows in Figure 2 has number of advantages to eliminate common measurement errors.

- The differential signaling scheme which used for interfacing signals and amplifiers reduce both environmental noise and multiplexer switching noise.
- Since the on resistance (*Ron*) of multiplexer switches is in series with high impedance input

2.3 Data Linearization and Manipulation

Some transducers have the advantage of a very high sensitivity to changes in physical phenomena, but the disadvantage of an aggressively nonlinear characteristic. This might introduce a non linear error to the measurement, which should be eliminated using a proper hardware design or software calibration. Thermistors have considerable non linearity where the change in the measurement is most rapid at low temperatures, giving great resolution for determining the corresponding temperature values there. At the other end of the range, resistance levels change relatively less with temperature and measurement resolution is relatively poor. Figure 3 [4] shows the typical response curve of a negative temperature coefficient thermistor .

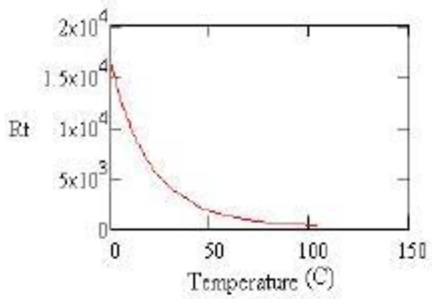

Figure 3: Thermistor Response Curve

Shape of the curve describes the nonlinear characteristics quite well. The correlation of the thermistor resistance and temperature can be written in as a third order polynomial equation, also called *Steinhart-Hart* equation eq. (01).

$$1/T = a + b\ln(Rt) + c\ln^3(Rt) \qquad (01)$$

Where *Rt* and *T* represent the thermistor resistance in ohms and temperature in Kelvin respectively. Constant a, b and c are thermistor coefficients provided by manufacturer. More over in RTD (Resistive Temperature Device) sensors, a gain error and an offset error can be noticed due to the impurities in platinum. For better accuracy, a higher order polynomial equation can be used eq. (02).

$$T = 1.008\times10^{-6}(R-100)^3 + 9.441\times10^{-4}(R-100)^2 + 2.56(R-100) \qquad (02)$$

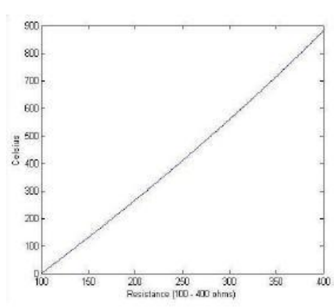

Figure 4: Linearization of RTD Data

Above curve emphasizes the linearization result of *Pt100* RTD sensor based on higher order polynomial function. In thermocouple mesurements, we need an additional hardware to maintain one junction (normally the cold junction) at a known reference temperature. Proposed device integrates a thermocouple interface IC, AD595 from Analog Device which supports k type thermocouples, provides low impedance, fixed voltage gradient with built in ice point compensation [5].

2.4 Signal Conditioning and Sub Peripherals

In proposed system, the multiplexer network is configured for four analog channels. Each analog channel consist of 4-wire interface, where *Ex+*, *Ex-*, *Sen+*, *Sen-* pins correspond to the positive/ negative terminals of the excitation supply, and the positive/negative differential signal outputs of the transducer respectively. If the transducer output is a 4-20 mA current loop, multiplexer will switch Sen+, Sen- paths to a shunt resistor. The final differential signal outputs will be fed into an instrumentation amplifier (*INA118 - 10 GΩ* input impedance).

An automatic Programmable Gain Amplifier (PGA) has been introduced to this system using an additional multiplexer, an op-amp and 4 precision resistors. The digital control bus line of the multiplexer is interfaced to the microprocessor digital outputs. In acquisition process, required gain is obtained automatically by switching proper gain resistors. The central unit of the system is based on an ARM Cortex M3 LPC1769 microprocessor which contributes analog to digital conversion, USB device operation and SSP communication interfaces for auxiliary peripherals. The processor is specially designed for low power high end applications.

The digital front end of the circuit has been treated with a special design. Each digital channel is isolated from the system using optical isolators. An inverting buffered Schmitt trigger IC, interfaced with digital channels provides a good noise rejection and sharp transitions.

2.5 Host Communication and GUI

The Universal Serial Bus (USB) has been proposed for the host communication. User interacts with the device through a GUI based host application in configuration and data loading stages. The host application was developed in C# language, where *Zedgraph* open source windows library enables user to plot and analyze the data with time stamping.

3. RESULT

The proposed system is able to perform data acquisition over a wide range of industrial transducers (Thermocouples, RTD, Thermistors, Load Cells, Pressure Gages, Analog Signals, 4 -

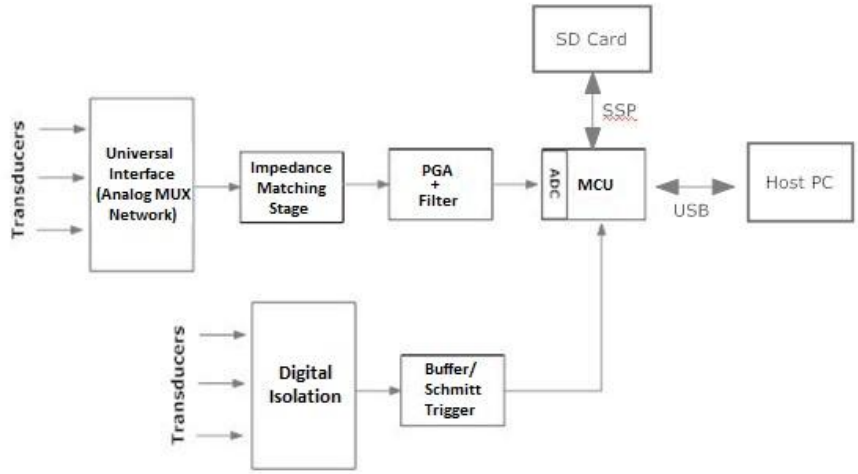

Figure 5: System Block Diagram

- 20mA Current Loops). Acquisition results can be generated in either graphical or tabulated form. Figure 6 shows the acquisition result of a thermistor (3.3k nominal resistance) in graphical form.

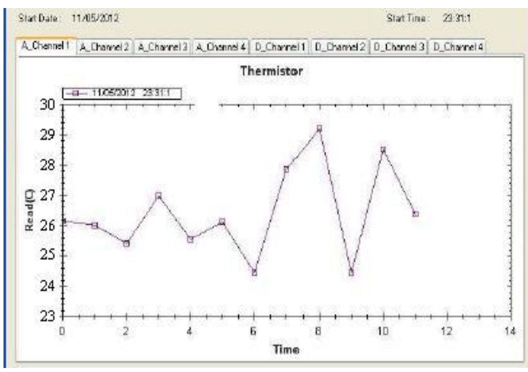

Figure 6: Thermistor Data Acquisition Result

Table 1 shows the acquisition result of different analog transducers connected to the universal interface. Standard K type thermocouple, Pt100 RTD sensor and 3.3k thermistor were attached to analog channels respectively.

Table 1: Test Result

Channel 1(˚C)	Channel 2(˚C)	Channel 3(˚C)
25.944	26.133	26.473
26.663	26.088	24.966
28.065	25.395	27.229
28.826	26.983	24.808

4. DISCUSSION AND CONCLUSION

The main objective of this paper is to introduce a universal interface for a standard DAQ system. Apart from that providing a low cost and low power solution is also concerned.

Following techniques have been used to reduce the additional cost of developing this system:

- Designing a low cost Programmable Gain Amplifier using a precision op-amp and an analog multiplexer.
- Using original USB stack of the Micro Processor reduce the cost for third party chips.
- Selecting low power components reduces the cost for high power batteries. (A low power processor, Analog Multiplexers over Relays)

5. REFERENCES

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[3] What Determines if a Transducer is Active or Passive, *http://digital.ni.com/public.nsf/allkb/084702CE98679BB886256CA3006752D7*

[4] Figure 1 - Typical Thermistor Curve *http://www.mstarlabs.com/sensors/thermistor-calibration.html*

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