# Network Based Data Acquisition and Logging System using PIC Microcontroller

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**Abstract**

This paper presents the design and implementation of a multi-channel data acquisition and logging system which can be used in a variety of applications. The designed data acquisition and logging system uses analog multiplexer, a bipolar analog to digital converter, a voltage reference and an SD card. The device is developed around PIC Microcontroller. The most important feature of the device which makes it different from other data acquisition devices is the presence of the Ethernet port. This feature enables it to work in networked environment. The performance of the device is tested and crosschecked. The present data acquisition and logging system is expected to be very useful to varieties of our own developmental projects, given its ability to locally store data and availability of general purpose digital I/O.

**Keywords:** PIC Microcontroller, Analog Multiplexer, Data Acquisition and Logging, Data Transmission, Network.

## 1. INTRODUCTION

Data acquisition system plays a vital role in measuring real world physical signals. These systems can be broadly classified into two categories, namely the stand alone data acquisition systems and the computer based data acquisition systems. Once signal is acquired by the device, many communication methods exist to transfer data to computer for further processing. Commonly used communication interfaces for data transfer are: serial communication (RS232 port), parallel port, USB port, Ethernet and wireless networks[1]. Serial ports are usually slow and parallel ports are becoming obsolete in modern day computers. Nowadays increasing number of devices support USB communication which is fast enough, but cannot work in networked environment and distance between device and computer is limited[2]. These constraints have led to the development of devices which work in networked environment like Ethernet and wireless data acquisition devices.

We present the design of a general purpose data acquisition device with a capability to locally store the data on SD card and also to transmit the acquired data to remote location over Ethernet. The device is developed around a high-end microcontroller PIC18F97J60 from Microchip, which acts as the main controlling and processing unit in the system[3]. An Analog to Digital converter (ADC) MAX1144AEAP from Maxim Corporation is used for data conversion[4]. It is a bipolar ADC and accepts signals up to 6V in both polarities and supports a maximum sampling rate up to 150KSPS. It is a single channel chip, meaning only one physical signal can be converted at a time. Since the conversion accuracy of the chip is dependent on the reference voltage supplied from outside, a voltage reference LM4040C20 from Texas instruments is used for providing 2.048V stable reference voltage[5]. Analog Multiplexer ADG406 from Analog devices is used, which can accept 16 analog inputs and can steer any one of them to the input of the ADC for conversion, depending upon the logic level present on the select lines of the chip[6]. Acquired data can either be stored locally or can be transmitted to a remote location for further processing. Storing device is a SD card. Data can be transmitted using either serial protocol or using Ethernet. A Real Time Clock (RTC) DS12887+ from Maxim Corporation is used for providing time information required for timestamp[7]. Unique feature of the device is the presence of the 16 general purpose digital I/O, which can be configured as demanded by the application. A programming port is provided on the device, which enables the user to upload customized software into the microcontroller using ICD3 programmer.

Paper is organized as follows: - Device hardware is described in section 2. Section 3 explains the software aspects. Device performance is presented in section 4. Concluding remarks are made in section 5. Finally section 6 presents the future plan.

## 2. DEVICE HARDWARE

Device is a combination of many individual components like microcontroller, ADC, Voltage Reference, Analog multiplexer, RTC, Serial Driver, SD card module and power supply module. All of these components are connected to microcontroller, and few are interconnected with each other as illustrated in the block diagram of the device in Figure 1. The completed device is shown in Figure 2. Some of the key components of the device are described in the following.

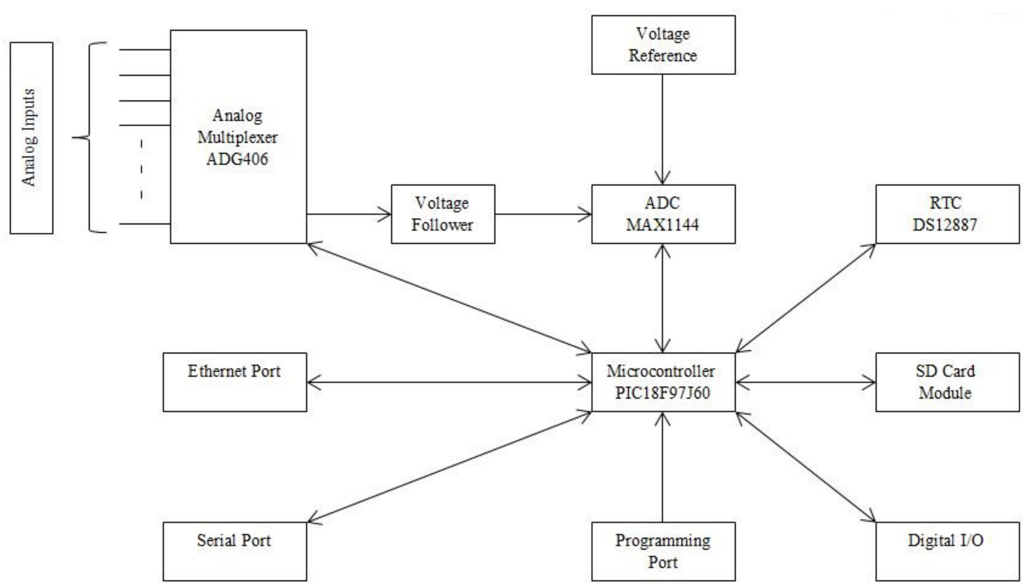


**FIGURE 1:** Functional Block Diagram of the Device.

### 2.1 Microcontroller

PIC18F97J60 microcontroller is the main component of the device which controls all other components and also processes the data coming from ADC. The main tasks handled by the microcontroller are:

- Generating control signals for analog multiplexer
- Operating ADC as required
- Providing serial and Ethernet connectivity to the device
- Storing data on SD card
- Acquiring time information from RTC
- Providing 16 general purpose digital I/O

70 general purpose I/O, two serial ports, two Master Synchronous Serial Port (MSSP), 40 MHz clock operation and small package are some of the features of the chip which make it most suitable for the application. Out of 70 general purpose I/O present on the microcontroller, many are used for controlling other components like analog multiplexer, RTC, ADC and serial port. Chip operates on 3.3 Volts, hence consumes very little power. The most important feature of the chip is the availability of the inbuilt Ethernet controller, which eliminates the need of any other external Ethernet controller and the associated complex programming.

Device works in two modes: - Working independently as a data logger and storing data on the SD card or it can work as data acquisition system along with a computer. When working as a data logger, device does not require any control computer. Once configured or the desired code is loaded in the microcontroller it works in the desired fashion. When device is to be used as a data acquisition system, the desired code can be loaded. In this mode of operation, devise receives commands from the remote or local control computer using either Serial or Ethernet port and sends back the data to the control computer.

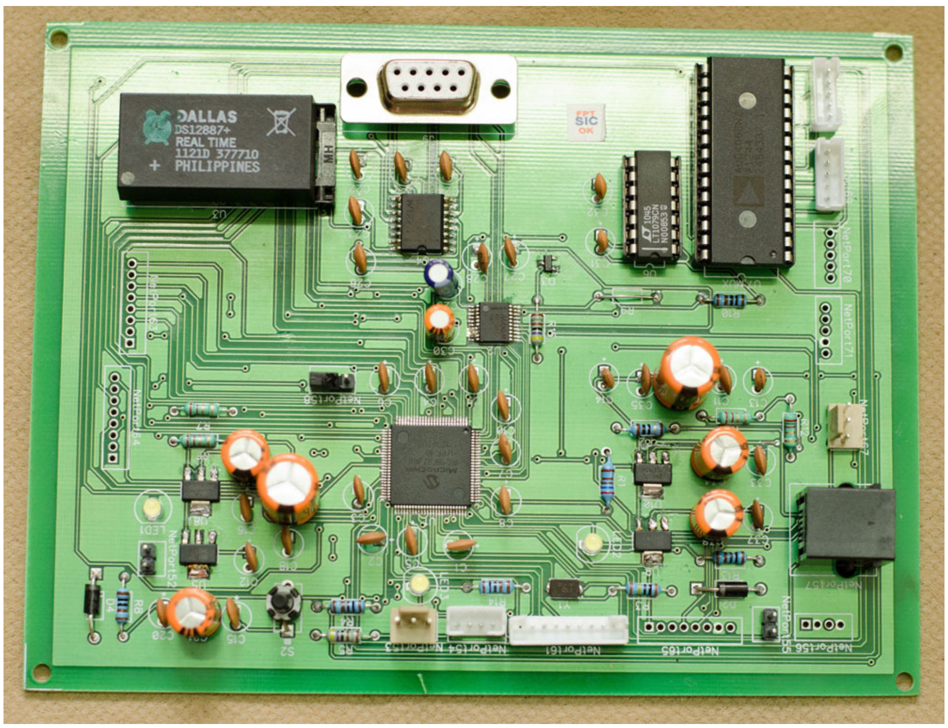


**FIGURE 2:** Laboratory Picture of the Data Acquisition and Logging Device.

### 2.2 ADC

The ADC MAX1144AEAP chip is used to convert analog signal to digital data. The resolution of the ADC is 14 bit and it can sample signal with 150K samples per second. The digital data is transmitted to the micro-controller via Serial Peripheral Interface (SPI). The SPI interface requires only four data lines which are chip select, data-in, data-out and clock signal. Hence reduces the number of lines required for communication. It is a bipolar ADC, means it converts both positive and negative signals. The chip comes in a 20 pin SSOP package, hence consumes very small space on the board. One more important feature of the chip is the internal calibration circuitry to correct linearity and offset errors. Whenever the operating temperature change by 10 degrees or the supply voltage changes by 100 mV, the chip is internally calibrated. Input to the ADC comes through a voltage follower circuit as shown in Figure 3. The input and output of the voltage follower circuit are same. This voltage follower circuit provides advantage of high input impedance and low output impedance. Which means it draws very small power from the signal source, thereby eliminating any loading effect. Operation amplifier used is LT1079CN from Linear Technology[8]. It is a precision Op-Amp with very small offset voltage and offset current.

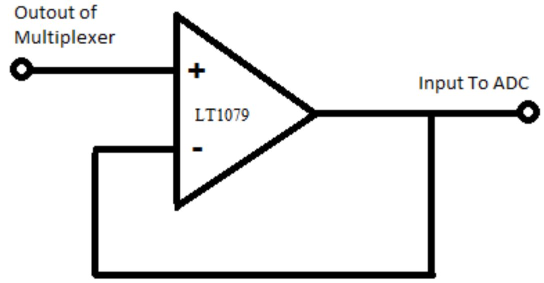


**FIGURE 3:** Voltage Follower Configuration.

The other interfacing circuitry required for the proper operation of the ADC have also been designed very carefully and values of the components are chosen based on recommendation given in the data sheet. The design is shown in Figure 4. This results in very accurate conversion of the analog signal, which is also evident in the result section of the paper.

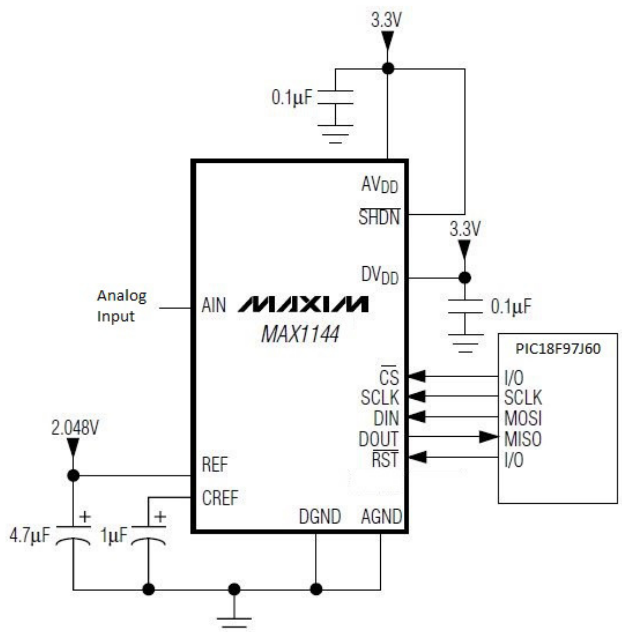


**FIGURE 4:** MAX1144 connection with Microcontroller as recommended in the Datasheet[4].

### 2.3 Voltage Reference

MAX1144AEAP ADC requires a precise and stable external voltage reference for reliable conversion of the analog signal. The required reference voltage is 2.048 Volts. A voltage reference IC LM4040C20 from Texas Instruments is used for fulfilling this requirement. The output voltage is 0.5% accurate and has very small noise content of 35 µV. The IC comes in 3-pin SOT-23 package and consumes very small space on board.

### 2.4 Analog Multiplexer

MAX1144AEAP can handle only one physical signal at any time, so some type of analog multiplexing was required, where one out of many signals can be selected and fed to the ADC using some interfacing circuitry. This task is handled by analog multiplexer ADG406 from Analog Devices.

ADG406 is a high performance analog multiplexer with 16 analog inputs and one output. Any of the input can be selected based on the digital logic present at the input of the selection lines and the enable input of the chip. ADG406 is able to handle both unipolar and bipolar signal. Switching time is very low, means signals are instantly available at the output. ADG406 too works under control of the microcontroller. Four selection lines (S0, S1, S2, and S3) and the enable control logic of the chip are connected to the microcontroller. Microcontroller chooses one out of the 16 analog signals present at the input of the multiplexer and feed this signal to the ADC for conversion. The 4-bit binary logic is applied to the selection lines of the multiplexer, means binary code 0 to 15 corresponds to the analog input 1 to 16.

### 2.5 RTC

Device can also store the data locally depending upon the application. A time-stamped data is more valuable for long term studies and archival purpose. RTC DS12887+ from Maxim Corporation is used for timekeeping. It is a totally self-contained unit with all the required circuitry, quartz crystal and battery (for maintaining time information in absence of power) placed inside the unit. Chip automatically switches to battery power in absence of the external power. This RTC counts seconds, minutes, hours, days, day of the week, date, month, and year with leap year compensation valid up to 2100. It can represent data in both BCD and Binary format. Time information is represented in 12 or 24 hour format. Chip also has the option for the daylight saving. Other important features of the chip are the availability of the programmable alarms and 114 bytes of general purpose RAM, which can also be used for storing data. All these configurations are accessible through four control registers. The time information flows from RTC to mircrocontroller through 8 bit wide multiplexed Address/Data bus. Other control signals are chip select, address strobe and read/write. All these signals are generated by microcontroller as and when required by the user program.

### 2.6 SD Card Module

SD card is used for locally storing the data. A separate SD card module is used; it is plugged to the device whenever required. The module consists of all the required circuitry like 3.3V regulator and a resistor network. This additional circuitry is required for proper interfacing of the card to the microcontroller. The module also consists of a SD card jack, where any standard SD card can be inserted.

### 2.7 Power Supply Module

Device accepts dual 9V from external power supply. There are many components on the device working at different voltages like 3.3V, 5V and dual 9V. Power supply module of the device consists of four voltage regulators. Two of them are 5V regulators and other two are 3.3V regulators. Output of these regulators is filtered using a RC filter, hence provides stable operating voltage to all components present on the device board.

## 3. SOFTWARE

The device utilizes both Embedded and High level software. The usage of either of the software depends on the mode of operation. If the device is working as data logger only embedded code is required to be running. On the other hand if the device is working as data acquisition system, both embedded software and High level software are necessary.

### 3.1 Embedded Software

This is the software which runs inside the microcontroller, and enables it to do different tasks like interfacing SD card, providing general purpose digital I/O, controlling ADC, controlling Analog multiplexer and handling tasks related to the communicating with the computer over RS232 or the Ethernet protocol. This software is written in Embedded C and was developed using MPLAB IDE from Microchip. MPLAB IDE converts the code written in C language to the equivalent Hex codes using C18 compiler provided by Microchip.

The microcontroller used in our device has got limited 128KB program memory. The availability of very limited program memory requires optimizing the code. This also makes it impossible to provide both Ethernet communication as well as data logging features in the same code. That is the reason why we have chosen two different modes of operation. One mode of operation is data logging mode where device acquire the data and stores it in SD card. The other mode is the data acquisition mode, where device acquire data and sends it to a computer for further processing. The flash memory of PIC18F97J60 can be written and erased for large number of times. The embedded codes for two different modes of operation can be uploaded to the device using ICD3 Programmer from Microchip anytime. Depending on the requirement, the embedded code is uploaded to the device using Microchips ICD3 programmer. Any other programmer from Microchip which supports In Circuit Serial programming (ICSP) can also be used[9].

### 3.2 High Level Software

The high level software runs inside the computer used for acquisition. This software is a terminal program developed under the Linux platform and has been developed using C/C++. The high level software first establishes communication with the device using either serial or TCP/IP protocols. Then after it facilitates the flow of commands and the data. The acquired data can be plotted on real time as well as stored in a file. The high level software also generate log of operation with the time stamp. In addition to this we are also looking at the possibilities of developing a LabVIEW driver for the device. This will not only provide a user friendly GUI to handle the device, but make job easier to analysis of data on real time.

## 4. DEVICE PERFORMANCE

Most important component of the device is the ADC, upon which the quality of the acquired data depends. The ADC MAX1144AEAP is one of the best ADC available with capability to handle signals of both polarities. Signal to the ADC comes through an intermediate voltage follower circuit, which provides high input impedance. This high input impedance draws the least amount of the power from the signal to be converted, thus enables the device to convert even the small signals with precision. The device is tested by applying a constant 4.5175 Volt signal to the input of the ADC with using one channel of the analog multiplexer and the intermediate voltage follower circuitry. The data samples were collected and transmitted to the PC. The data is analyzed for the precision as well as stability and related plots are shown in Figure 5 and Figure 6. The median value of the time series data is about 4.517287, whereas, the standard deviation with respect the median value is about 0.36mv. The temporal stability of the device is checked over variety of time scales and it found to be quite satisfactory. The transient events in the output (large spikes) are also found to be very few. The spectral analysis of the output shows that device does not add any ripples and power spectrum contains only white noise. The performance of our device was also compared with precision oscilloscopes as well as NI data acquisition card.

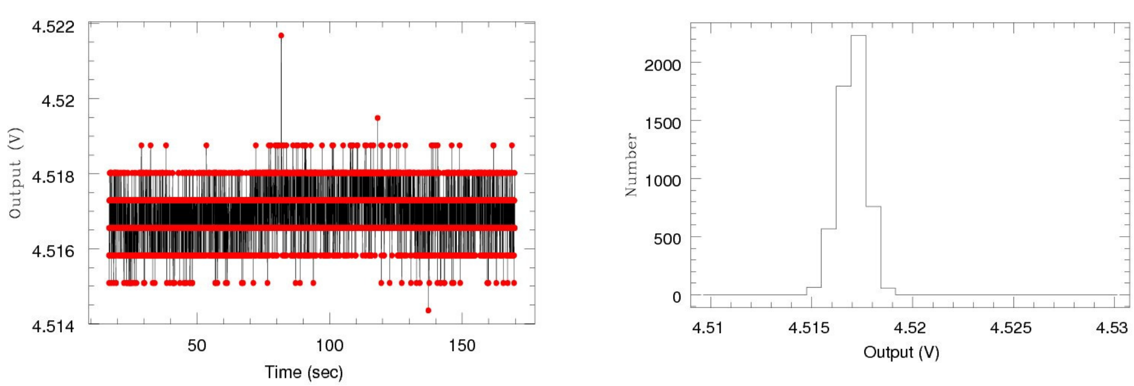


**FIGURE 5:** Test Results of ADC.

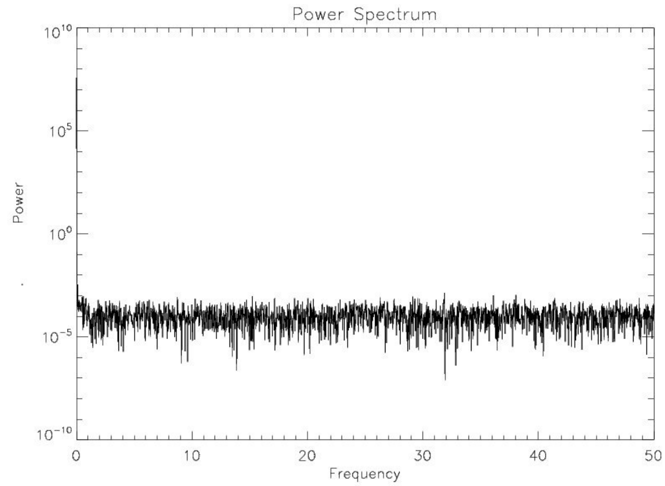


**FIGURE 6:** Power Spectrum of ADC.

## 5. CONCLUSION AND DISCUSSION

Although many data acquisition devices have been developed for various applications using microcontrollers, most of them had either serial or the USB interface[10][11]. These point to point communication protocols suffer from low speed of communication and require a host computer to be placed near to the device. The general purpose data acquisition device developed by us overcomes both of these limitations. Communication speed is fast enough because Ethernet protocol is used. We have also provided SD card functionality, so that the data can be stored locally without requiring any computer.

## 6. SCOPE OF FUTURE WORK

At present the device is used with the High Level Software which runs on Linux. We are also looking for the possibilities of developing the LabVIEW drivers for the device. This will not only provide the GUI to the software, but will also make the handling of device easier.
We intend to use this device for data acquisition for All Sky Scanning Cloud Monitor, which is currently under development at Indian Institute of Astrophysics.

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