IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-7, Issue-2, Feb 2019 E-ISSN: 2347-2693

ARM based Data Acquisition System for Physics Experiments

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DOI: https://doi.org/10.26438/ijcse/v7i2.706709 | Available online at: www.ijcseonline.org

Accepted: 10/Feb/2019, Published: 28/Feb/2019

Abstract—The technological evolution in VLSI design plays important role in the field of microelectronics. The microelectronic device such as microcontroller is widely used in the data acquisition system (DAS). The DAS for the physics laboratory application can be developed with microcontroller like Advanced RISC Machine (ARM) and supporting hardware. This paper comprises detail explanation about the data acquisition system using ARM 7 LPC -2148 and C – language programs. The system includes peripherals such as ADC, DAC, keypad, character LCD and external interrupt. The software programs for interfacing them with microcontroller are written and prescribed here for the first time learner. The physics experimental parameters like temperature, pressure can be acquired by the developed DAS.

Keywords— ARM, LPC2148, Microcontroller, Physics experiment, ADC, DAC.

I. INTRODUCTION

Data acquisition systems (DAS) are used by physicists in the laboratory for the measurement of physical parameters. Data acquisition system (DAS) provides connection between the real world of analog physical parameters and the artificial world of digital calculations. The devices which provide connection between analog and digital worlds are analog-to-digital (ADC) and digital-to analog (DAC) converters, which together are known as data converters. Besides data converters, DAS contains transducer and its signal conditioning circuit.

In the DAS; analog physical parameters resulting from the physics experiments such as position, acceleration, pressure, temperature are first converted into electric signal by means of transducer. The transducer output is a high impedance electric signal of the order of few microvolts. It is further processed by the signal conditioning unit. It includes the filter to filter out unnecessary frequency components or noise from the signal. It also includes the amplifier to raise the signal to the levels required for the digital signal processing.

In addition to the electronic part, DAS includes data analysis, data visualization, and data storage. Commercially available DAS devices range from relatively simple devices up to very sophisticated ones. The latter ones contain computer system, circuits for automatic offset and gain calibrations, *etc.* Such sophisticated DAS devices are very powerful and suitable for applications where functionality has precedence over price and used in research area and industrial applications. There are, however, also several applications where sophisticated systems are not necessary. In the physics laboratory, for example, less efficient, and low cost DAS devices are preferred. Nowadays, very simple and low cost DAS devices could be constructed using modern microcontrollers. A microcontroller is a small computer on a single integrated circuit containing a processing unit, memory, input/output ports and data converter circuits.

Several microcontroller-based data acquisition (DAS) systems have been presented in the literature. In the majority of the presented solutions the developed DAQ devices are not general purpose DAQs, but rather have been specially designed for specific DAQ applications, such as temperature or humidity measurements. In the authors present a microcontroller-based DAQ [1, 2, 3] that is applied to decentralized renewable energy plants [4] while in, for thermoelectric property measurements [4]. In the latter case the DAQ is based on a PIC18F4550 microcontroller which has inbuilt SAR type ADC with 10-bit resolution. In a data acquisition and control system for high-speed gamma-ray tomography [5] based on the USB and Ethernet communication protocols has been designed. This system is based on Microchip's PIC18F4550 and PIC18F4620 whilst the DAQ software is realized using LabVIEW [6]. In the authors present a microcontroller-based USB DAQ device for radiation detection and environmental monitoring purposes. The developed DAQ, which is based on an 8-bit AVR microcontroller, has 8 analogue input channels, 10-bit ADC and enables acquisition of analogue input with a maximum sampling rate of 50 kS/s. In the authors present a low-cost USB DAQ based on the PIC18C442 microcontroller, with integrated 10-bit ADC. 12-bit A/D and D/A resolutions [7]have been achieved using external A/D (TI ADS803) and D/A (TI DAC7545) converters. A USB data acquisition system [8] for humidity and temperature measurements is presented in. This DAQ device is based on PIC18F4550 and enables acquisition of 8-analogue inputs with 10-bit resolution. Humidity measurement is achieved using an HIH 4000 humidity sensor whilst for the temperature using an LM35 temperature sensor. An application program on the PC was developed using Visual Basic. The DAQ is connected to the PC using RS-485 serial interface, and enables sampling rates of up to 960 S/s. An application program on the PC was developed using Visual Basic. The sampling rate of the developed DAQ is 1 kS/s and is connected to a PC using the RS-232 serial bus, whilst an application program was developed using MATLAB. The DAQ is based on the PIC18F4550 microcontroller and two K-type thermocouples. Cold-junction compensation and digitization of a signal from a type-K thermocouple was achieved using a Maxim MAX6675 chip connected to the microcontroller via an SPI bus. The DAQ enables sampling rates of up to 4 S/s. The user interface was realized using LabVIEW. In this case the device is based on a PIC18F4550 microcontroller and an AD595AQ monolithic thermocouple amplifier that enables temperature measurements of K type thermocouples. The GUI was developed in Visual Basic. This DAQ is based on PIC12F675 and enables acquisition of four analogue inputs with 10-bit resolution. DAQ is connected to a PC using a serial RS-232 bus. An application program was developed using Visual Basic and MSComm components. Over recent times usage of the popular Arduino platform has been increasing in DAQ applications. In addition to the stated references, there are also some off-the-shelf USB DAQ devices available on the market. The key features of those devices that are comparable with the presented solution (USB interface, 12-bit ADC).

This paper presents a flexible, simple, microcontroller-based data acquisition device. The main components of the presented device are microcontroller with an integrated USB transceiver and 10-bit ADC and DAC. Organization of the research article is as follows: Section I contains the introduction to the research work. The remainder of the article is organized as follows: Section II contains the method of hardware design, Section III contains the software and its corresponding flow-chart, Section IV concludes the research work with its future scope.

II. METHODS

A DAS has been developed using ARM-7 LPC-2148 which is a 64 pin QFPA microcontroller having 10 channel ADC with 10 bit resolution. It also contains one 10 bit DAC. Fig. 1 shows the block diagram of the DAS, and Fig.2 shows its circuit diagram. It requires 5V and 3.3V regulated power supplies, LPC-2148, 2 line LCD, 16 switches keypad. The RxD (pin P0.1) of LPC-2148 is used to receive the serial data from the PC through the MAX 232 level convertor. It converts the TTL signal from the microcontroller into RS232 voltage level with the use of external capacitors. A 9 pin D type female connector is used to connect to the COM port of the PC. The PCB layout is made in ORCAD lite software.

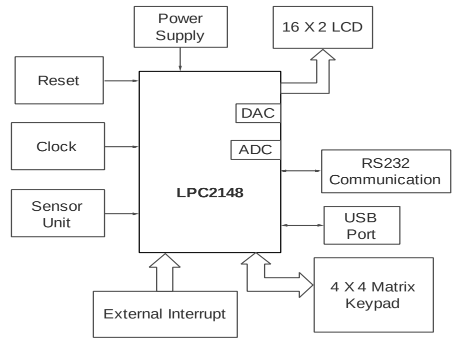

Figure 1. Block diagram of DAS

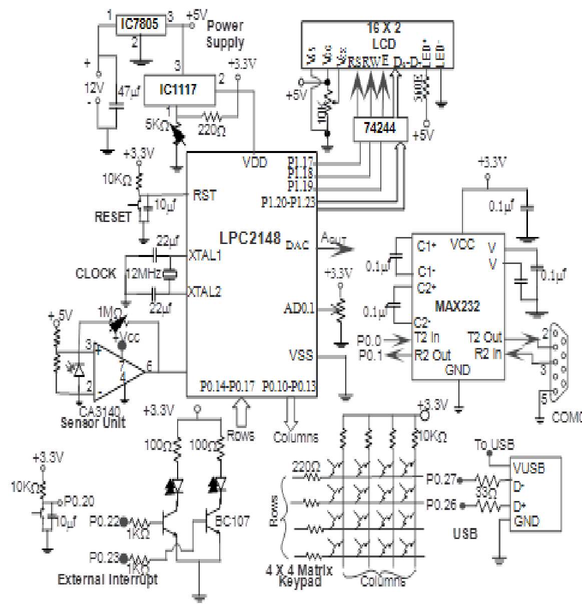

Fig.2. Circuit diagram

1. Sensor circuit

Photodiode is used to capture small light rays produced by some optics experiments. It converts light into electric current of the order of 10 to 100 ηA. The current is converted into voltage by trans-impedance amplifier. The fig. 2 shows circuit of LPC 2148. The amplified signal is then fed into the inbuilt ADC section. Digital output of the ADC is sent to the character LCD. The displayed parameters are the transmittance, optical density. The operational amplifier used is CA 3140 which has a very high CMRR (50dB) and voltage gain (100000). It is a low cost, low drift amplifier which requires only one feedback resistor to set gain of the amplifier.

2. Interrupt circuit

The interrupt at pin p0.20 is activated by the high-to-low voltage signal produced by the key switch. The occurrence of interrupt is indicated by the LEDs connected to pins p0.22 and p0.23. The NPN transistor BC107 is used as current driver and buffer.

3. ADC

The analog signal is converted into digital signal by using Analog to Digital converter. The conversion involves quantization, small error will encounter. An ADC performs the conversions periodically. Applications of ADC are many and also in Digital Signal processing. ADC is mainly implemented by RAMP, Dual Slope, Successive approximation, Delta-sigma method. The successive approximation ADC is more popular because it’s all parts can be integrated on silicon chip. Sampling can be done for varying in space, time, or any other dimensions. Functions that vary with time, i.e. continuous time can be sampled using sampling. Thus, the sampled function is s (nT), for integer values of n. The sampling frequency is defined as the no. of samples per sec. i.e. fs = 1/T.

Interpolation algorithm is used to reconstruct the continuous function. When the time interval between adjacent samples is a constant (T), the sequence of delta functions are known as Dirac comb. Sampled signals are not reconstructed and stored. Nyquist frequency of the sampler, s(t) frequency components must higher than fs/2 Hz. Without an anti-aliasing filter i.e. low pass filter, frequencies higher than the Nyquist frequency i.e. fs>=2fm will influence the samples in a way that is misinterpreted by the interpolation process. The guard band between the samples must be appropriate otherwise over sampling and under sampling done. There are different noises like jitter noise, quantization noise, thermal sensor noise, analog circuit noise, etc.

Four ADC pins are used for data acquisition; a Max-232 is used to convert the TTL serial logic to the correct RS232 format. An analog circuit is required to make sure the input voltage to the ARM7 based LPC2148 ADC falls between 0 to 5V, i.e. Bipolar. Two 741 op-amps, and a couple of diodes are used for protection as the ADC cannot handle voltages outside its range. A 5V voltage regulator is used to power supply i.e. 7 to 20 V DC to the circuit; there is a large DC input range of 7 to 20V.

III. SOFTWARE SECTION

For the proper functioning of the data acquisition system, a software program was developed in C-language and written to the microcontroller.

The LPC2148 microcontroller is supported by various commercially available IDEs for compiling and debugging of code. Keil is widely used IDE for LPC family of microcontroller. The Keil µvision software development platform has facility of editor, project manager and compiler facility. The hex file of source code generator by the Keil is downloaded into the downloader- LPC2000 flash ISP Utility. The algorithm of program is implemented in the flowchart as shown in fig.3 (a), 3(b) and 3(c). After the software and hardware designs have been completed, the system is tested for the given input physical parameters.

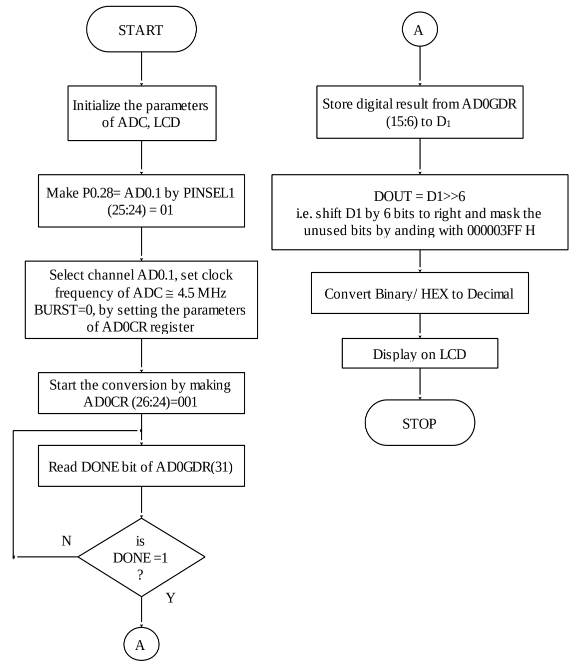

Figure 3 (a). Flow chart for main program

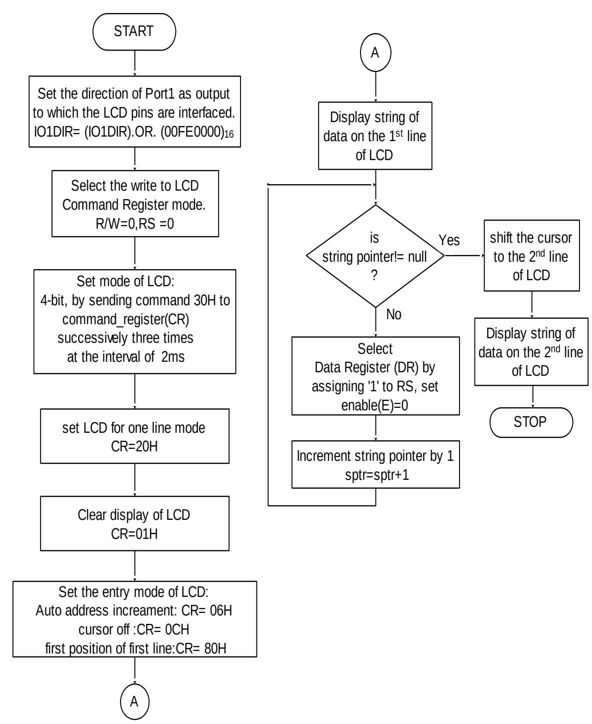

Figure 3 (b). Flow chart for LCD

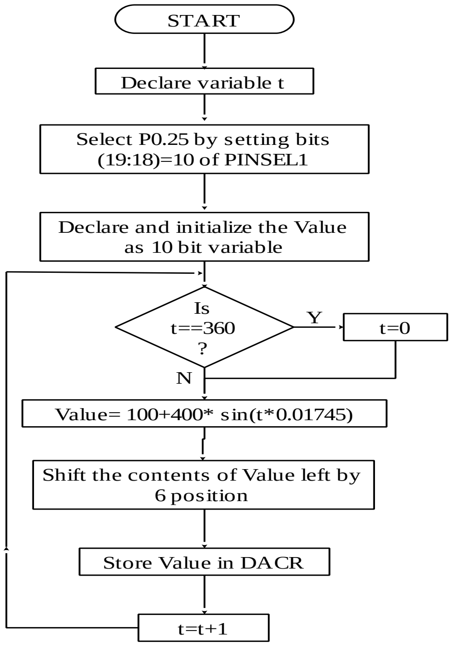

Figure 3(c). Flow chart for DAC

IV. CONCLUSION

In this paper, simple DAS and its applications are discussed. It has advantages of less number of components and good resolution. The DAS provides facility of ADC, DAC and interrupt for user interface keypad and LCD are provided. The detailed flow-charts and commented C-programs are easy to understand. They can be easily modified by the physicist as per the experimental requirement.

FUTURE SCOPE

The system can be modified according to the experimental procedure. The data logging facility can be included for the recording of the observations and to obtain results from the formulae.

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