Data Acquisition System

Vineet Patodkar[1], Rohit Kothawale[2], Sandhyarani Shirsat[3]
[1]Student, [2]Student, [3]Guide Department of Electronics and Telecommunication Engineering,
Sinhgad College of Engineering, Pune, Maharashtra, India

Corresponding E-mail: vineet.patodkar@gmail.com

ABSTRACT:
The collection of data which is in the form of analog signal is the main challenge faced by any design engineer. Mechanism of collection of data is the basic building block of any closed loop system. DAS is used in the most of the mechatronics applications, automation, automobile applications, biomedical high accuracy measurement and monitoring devices, etc. Physical quantity to be measured in such applications is in the form of analog signal. It is to be converted and stored in digital form so that it can be acted upon by a processing and controlling unit. DAS is made of three major components: transducer, signal conditioner and processor. DAS which is made of these components leads to several technical issues such as complex wiring, hardware and programming due to use of DAS in complex applications, human errors, noise interference, etc. This paper reviews general report on the basics of DAS based on the different types of sensors and electronic components used for the signal conditioning, storage and distribution of the data. It will also review a case study that describes the ways to improve the present day Data Acquisition System.

KEYWORDS
Acquisition, Arduino board interfacing, Bluetooth, Closed Loop System, Data Acquisition System, Digital Signal Processing, Microcontroller, Microprocessor, Sensors, Transducers, Zigbee.

INTRODUCTION

DAS is used in many applications. Mechatronics system uses various data acquisition techniques so that its output can be changed with change in input. Data is the basic requirement of any system. In any system data is acquired and processed to get the output. There are two types of systems. (A) Open Loop Systems: System without feedback. (B) Closed Loop Systems: System in which part of output is fed back to the input for correction called as feedback. Modern DAS is an example of closed loop system. Feedback is used to improve the performance of system.

Data Acquisition Systems are used in millions of applications such as in mechatronics systems it is used to collect data and/or to provide feedback. In biomedical applications it is important to detect the small changes in physical quantities such as blood pressure, blood sugar level etc. as well as the electrical quantities such as the voltage or electromagnetic field, etc. DAS is integrated part of the automation industry because it is important to record data in such applications time to time. In Automobile industry it is now the most important to provide the advanced features to attract consumers toward the products. For each such feature the data acquisition is the basic requirement. In traffic control different sensors are used to determine speed of car, amount of the traffic etc. In metrological surveys the wind speed, rainwater quantity, wind direction, temperature trends are recorded and used to predict the changes in such environmental factors in future. For designing a high security surveillance system it is important to use different sensors in such a way that their presence cannot be detected easily. This is possible only using the DAS more efficiently i.e by reducing hardware and wiring complexity to make the system undetectable, involving minimum human interaction to reduce human error and using digital transmission to increase nice immunity.

DAQ systems are hybrid electronic devices (analog and digital) with the main role of interfacing the digital signal processing systems to the environment [1][2].Data acquisition was traditionally carried out manually by noting down the readings of various instruments at specified times. Traditional instruments required extensive time and specific skills for adjusting the measuring range and for saving and documenting the results. Later, electronic recorders recorded the data acquired on paper plots. Computer-based data acquisition replaced paper records by digital data acquisition and storage. The automatic collection of data from sensors, instruments and devices in a factory, laboratory or in the field is called data acquisition. The use of computers in various aspects of data collection, control and analysis over the past few years has revolutionized modern-day research, development and manufacturing [3].

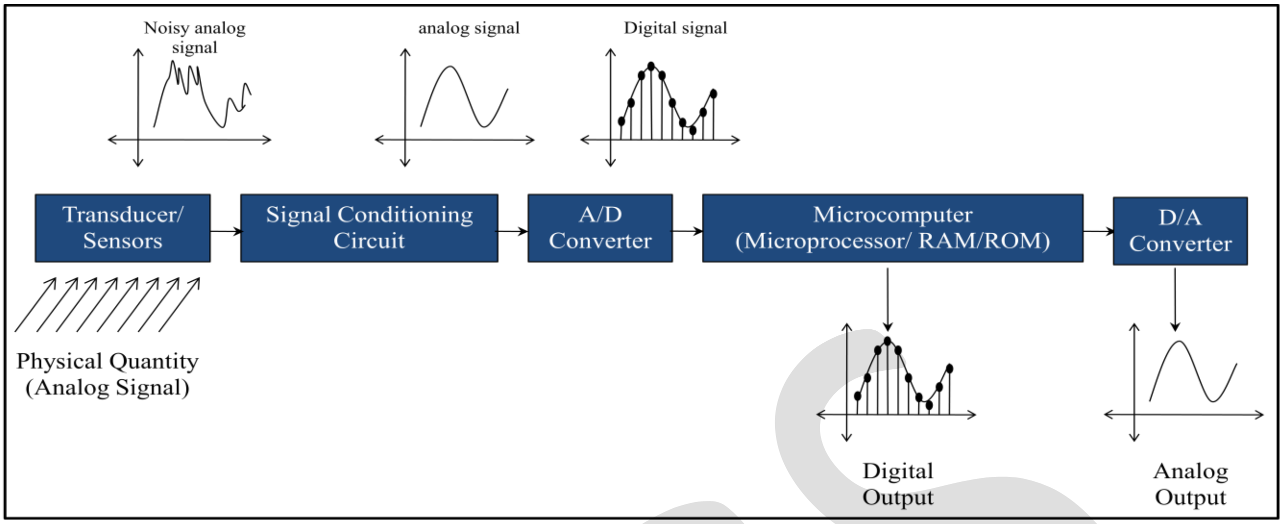

Figure 1: Basic Block Diagram of DAS

BLOCK DIAGRAM OF DAS/DAQ

DAS acquires analog input, removes noise from it, converts analog signal to a digital form, processes it so as to take a necessary action and coverts it to analog form which is easily understandable to a human being. Data is processed by electronic component and hence it becomes compulsory to convert the input into the digital form (language of ones and zeroes) as it is the only language understood by electronics components. Digital Signal processing is performed by either old techniques such as programmable logic controllers or by the advanced versions of processors and microcontrollers.

DAS uses many electronic components which are discussed in this paper. Sensors are nothing but the transducers which convert physical quantities into the equivalent electrical quantities such as voltage, current. Data Acquisition system is differentiated in many types with respect to the sensors or transducers used in the system. For example, in "temperature DAS", LM35 sensor is used to detect and maintain the temperature inside the room. Or in "greenhouse data acquisition system", humidity & temperature sensors are used together to control green house gas in the polyhouses. ADCs are used to convert analog signals to digital whereas DACs convert digital signals to analog. Low pass filters are used for removal of noise from analog signals. Digital signals are easy to work with and they can be processed by using several devices such as microprocessors, microcontrollers, RAM/ROMs, PLCs, etc. Significance of each of these components is described briefly in this paper.

SENSORS

Different sensors are used in DAS. They are selected according different parameters such as the type of physical quantities to be measured and processed in application, output voltage or current of sensor, range of operation, accuracy, precision, resolution and sensitivity of sensor, etc. here are few examples of selecting sensors according to different parameters: In airplane systems it is important to collect, store and transmit flight-test data in digital form as fast as possible, so fast digital sensors are selected in such systems [4]. In telemedical data acquisition system based on a mobile device, sensor which allows the communication with other the sensors by forming a Wireless Personal Area Network (WPAN) for measurement, chronological sorting and continuous transmission of data to a communication server via WLAN or mobile radio standard, like GPRS and UMTS is selected [5].

Parameter	AD/TEMP/001–EN	DT034	DT038	DT088	DT108
Response time	< 2.2 seconds	< 3.7 seconds	< 1.5 seconds	< 120 seconds	< 120 sec
Temperature range	up to 400 °C	0 / + 400 °C	0 / + 400 °C	- 50 / + 200 °C	0 / + 400 °C
Sensing element	One 4-wire Pt 200 element	One 4-wire Pt 100 element	One 4-wire Pt 100 element	One 4-wire Pt 100 element	One 4-wire Pt 100 element
Installation area	directly on the primary circuit	directly on the primary circuit	directly on the primary circuit	ventilation ducts or explosive atmospheres	Thermowell or surface temperature measurement

TABLE 1: Different parameters to select Temperature sensor in the nuclear power plants

The Solar Radiation and Environmental Monitoring measurement system uses the SolData silicon-cell pyranometer as the solar radiation sensor [6]. Similarly if someone wants to observe change in temperature in greenhouse for temperature control, then according to range of operation, accuracy, precision, resolution and sensitivity, LM35 sensor can be selected as it is perfect for the domestic [7]. Temperature measurement in the primary circuit of a nuclear reactors presents some significant challenges and hence AD/TEMP/001–EN, DT034, DT038, DT088, DT108, the highly accurate, fast and wide range sensors are used for the measurement [8][9].

SIGNAL CONDITIONING CIRCUIT

In sensor-based measurement systems, the distant transmission of analog signals may severely degrade accuracy, while information integrity is more easily maintained for digital data. Therefore, the physical location of the analog-to-digital converter (ADC) stage becomes important, particularly in distributed sensor systems [10]. The analog signal from a transducer must be conditioned by a signal conditioning circuit to meet the input requirements of an ADC input. Circuits such as operational amplifiers, bridges and comparators are used for analog signal conditioning. Signal conditioning involves the following steps: (i) Signal amplification, (ii) Isolation, (iii) Multiplexing, (iv) Noise filtering, (v) Transducer excitation, (vi) Use of simultaneous sample and hold and (vii) Anti-aliasing filtering [3]. Generally sensors produce very small voltage at the output side and hence there amplitude is boosted using amplifiers to meet the input requirement of the device further connected. OpAmps can be used as buffers to electrically isolate sensors and transducers from other electronic systems. This is done so that the noise or signal in the other systems does not affect the transducer responses. Low pass filters are used to restrict the bandwidth of signal to particular value to increase the noise immunity of the DAS. Sample and hold circuit is used to convert analog signal into discrete time signal. Aliasing is the appearance of phantom

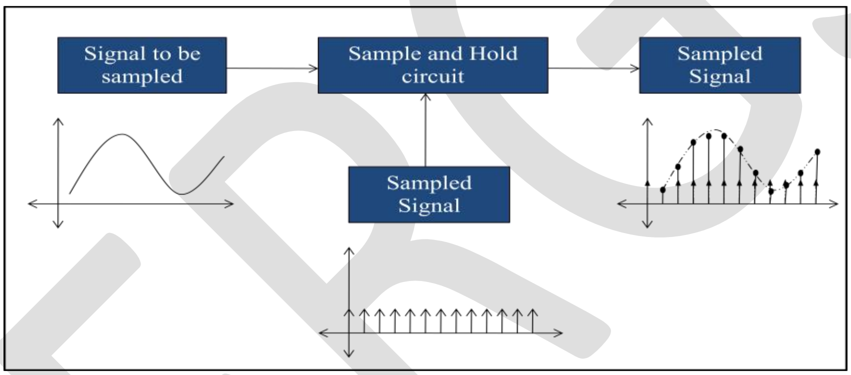

Figure 2: Sample and Hold circuit

frequencies when a signal is not sampled at a high enough rates [11]. As the lower frequency components are masked due to aliasing, there is loss of information and hence anti-aliasing filter is used to minimize the aliasing affect.

A/D and D/A CONVERTER

Sensors detect change in physical quantities and then convert them to the electrical quantities such as change in voltage or current. Voltage as well as current changes instantaneously with respect to time hence they are analog signals and so are all the environmental physical quantities according to common knowledge. This means Sensors convert one analog signal into the other. Any device such as computer, microprocessor or microcontroller responsible for processing of data, works on the digital signal. Digital signal is the discrete time signal with finite number of amplitude levels. Signal in terms of ones and zeroes is an example of digital signal. Hence analog signal is converted to digital signal using an electronic device called as analog-to-digital converter. Flash type ADCs, successive approximation ADCs, dual slope ADCs are some types of analog-to-digital converters [12].

Similarly human cannot understand the digital signal in terms of ones and zeroes. Man deals with the decimal numbering system. Hence the digital signal produced by the processing element is either given to some interface that interprets the digital signal and displays it in easily understandable form such as 8 segment display or digital waveform etc. or to DAC i.e. digital-to-analog converter that converts digital signal to an analog form. Pulse Width Modulator (PWM), R-2R ladder DAC, weighted resistor DAC are some types on digital-to-analog converters [12].

MICROCOMPUTER

It is the most important part of any DAS. Microcomputer (µComputer) is the device that performs mathematical operations on the data collected by the sensors. A microcomputer is generalized term for a microprocessor (µProcessors) or a microcontroller (µControllers) used in any system. This is the programmable device. µComputer acquires data from sensors processes it and gives processed output. There are different types of µControllers as well as µProcessors and they are to be selected according to the applications.

Until recent times all the DASs were very complex due to heavy wiring used in the circuitry, but now µComputers are used to interface the Bluetooth modules, ZigBee device or Wi-Fi modules to it. This reduces the circuitry to very high extent and device can be remotely controlled from the long distance. ZigBee device is built to support sensor networking-based applications which utilize radio frequency. They are designed for simple and lightweight wireless networks. ZigBee's transmission ranges are up to 100 m indoor and 1.5 km outdoor (line-of-sight) [13]. ZigBee is two-way wireless communication standard with low cost and low power consumption, developed by the ZigBee Alliance. ZigBee network based on IEEE 802.15.4 standard offers unique advantages for wireless applications. One of the application areas of ZigBee is focuses short range wireless data transfer at low data rates [14]. The Bluetooth wireless technology can link digital devices within a range of 10 m (expandable to 100 m, by increasing the transmitted power) at the speed of 1 Mbps [15][16][17].

Programming a µComputer is a tedious task for any individual with no fundamental knowledge of coding. Hence to make such individuals handling µComputer easy, a few open source platforms were built by some organizations. Appearance and development of various Single Board Computers (SBCs) like Arduino [18][19], BeagleBone [20], RaspberryPi [21], RIoTboard [22], PandaBoard [23] and others together with mobile phones, created enormous potential for building various devices capable of interaction with environment, data processing and network communication.

SBC	SOC	Clock frequency	RAM size
Arduino	AT328P	16 MHz	2KB
BeagleBone	TI Sitara AM335x	720 MHz	256 MB
RaspberryPi	BroadcomBCM2835	700 MHz	256 MB
RIoTboard	Freescale i.MX6 Solo	1 GHz	1 GB
PandaBoard	TI OMAP4460	1.2 GHz	1 GB

TABLE 2: Comparison between some parameters of different SBCs

CASE STUDY

Traffic control is one of the biggest problems faced by developing and densely populated areas. In Intelligent Traffic Control Using Sensors [24], there are many disadvantages. In this case study we will identify those and we will try to generate an alternative traffic control system to overcome these disadvantages. In sensor based traffic control systems sensors such as induction loop, microwave radars and cameras with expensive cards are used to detect the presence of vehicle at the traffic control signals. In induction loop based control system (CS) the change in induction due to heavy steel object above the induction coil is used to detect vehicle. In microwave radar based system microwaves are used instead of change in induction for the detection. In video based CS the additional specialized camera with expensive card is required to detect the vehicles. In all the above systems additional hardware is required to detect the presence of vehicles at the traffic control signal. Moreover, this hardware is required at each and every signal present in densely populated area which makes it difficult for maintenance if and when required and also makes the whole system expensive.

To overcome these disadvantages the design engineers can use the image processing technique along with IOT based system to reduce the expenses. This might also improve the performance of the system such as reducing complexity of hardware, increasing range of application, reducing human involvement and therefore increasing the accuracy at the same time. In such system normal CCTV camera can be used to detect the vehicle whereas the image processing technique will be used to decide the amount of traffic in terms of high, medium, low terms. This same data, from all the cameras all over the city, can be sent to the centralized server using the concept of IOT. There, this data can be processed altogether; using various algorithms to set the signal timer for each signal of the city and the waiting time at the signal can be changed accordingly.

ACKNOWLEDGMENT

I would like to thank my colleague ROHIT KOTHAWALE for his help in completion of this paper. I would also like to thank PROF. SHIRSAT S. A., my guide and to DR. M. B. MALI, professor & head from electronics and telecommunication engineering, Sinhgad College Of Engineering, Vadgaon for their support and help. Last but not least many thanks go to "ANONYMOUS REVIEWERS" for their valuable insights.

CONCLUSION

Data Acquisition System is made of three major blocks, sensors/ transducers, signal conditioner and microcomputer. DAS is basic component of any closed loop system. Selections of sensors depend upon the application, output voltage or current delivered, range of operation, accuracy, precision, resolution and sensitivity, etc. The analog signal from a transducer must be conditioned by a signal conditioning circuit to meet the input requirements of an ADC input. In this process mainly the signal is amplified, filtered and sampled. Microcomputer is the device that performs mathematical operations on the data collected by the sensors and takes necessary action. For individual with no fundamental knowledge of coding, programming microcomputer is difficult task and hence few organizations have built open source platforms having very easy programming language. It is also important to note that the performance of DAS can be improved by selecting the suitable sensors, signal conditioners and microcontrollers to the great extent.

REFERENCES:

[1] Maksym Antonyuk, Mykhaylo Lobur, Volodymyr Antonyuk, *"Design Digital Data Acquisition and Processing Systems for Embedded System*", *International Conference on Perspective Technologies and Methods in MEMS Design*.doi:10.1109/memstech.2007.4283423, 2007

[2] M. V. Micea, "Signal Acquisition and Conditioning Systems: Laboratory Workshops", "Sisteme de achizitie numerica a datelor: Indrumator de laborator"), Comanda 270/2000, Centrul de multiplicare al Universitatii POLITEHNICA Timisoara, 2000.

[3] Chidambaram M., "*Basics of Data Acquisition and Control",* Handbook of Networked and Embedded Control System, Page numbers*: 227–257*, doi: 10.1007/0-8176-4404-0_10, 2015.

[4] S. Cogan and W. K. Hodder, *"A High-Speed, Airborne Digital Data Acquisition System",* IRE Transactions on Space Electronics and Telemetry (Volume: SET-5), **DOI:** 10.1109/IRET-SET.1959.5008673, 1959.

[5] Neubert S, Arndt D, Holzmuller-Laue S, and Stoll R, "*Telemedical data acquisition system for use in preventive medicine", 2nd Conference on Human System Interactions.*doi:10.1109/hsi.2009.5090968, 2009.

[6] Raphael Mukaro and Xavier Francis Carelse, "*A Microcontroller-Based Data Acquisition System for Solar Radiation and Environmental Monitoring"*, IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 48, NO. 6, DECEMBER 1999.

[7] ABB Limited Process Automation Salterbeck Trading Estate Workington, Cumbria, "*Application Description: AD/TEMP/001–EN Temperature measurement Nuclear power reactors"*, https://library.e.abb.com/public/f04f51bb433ef38cc1257936002de2c3/AD_TEMP_001-EN.pdf

[8] Texas Instruments, LM35 Precision Centigrade Temperature Sensors, SNIS159H –AUGUST 1999–REVISED DECEMBER, http://www.ti.com/lit/ds/symlink/lm35.pdf, 2017

[9] https://camatsystem.com/wp-content/uploads/2014/07/Temperaturgivare-f%C3%B6r-k%C3%A4rnkraft.pdf

[10] Ferrari V, Ghidini C, Marioli D and Taroni A, "*Oscillator-based signal conditioning with improved linearity for resistive sensors",* IEEE Transactions on Instrumentation and Measurement, 47(1), 293–298.doi:10.1109/19.728837, 1998.

[11] Bogdan M, "*Sampling rate and aliasing on a virtual laboratory",* Journal of Electrical and Electronics Engineering, Vol.2, Nr.2, page number: 121-124, 2009

[12] https://en.wikipedia.org/wiki/Main_Page

[13] Farihah Shariff, Nasrudin Abd Rahim, Hew Wooi Ping, *"Zigbee-based data acquisition system for online monitoring of grid-connected photovoltaic system"*, Expert Systems with Applications, 42(3), 1730–1742.doi:10.1016/j.eswa.2014.10.007, 2015.

[14] Chavan S and Shirsat S, "*Performance Comparison of Network Topologies in ZigBee Based WPAN*", International Journal of Scientific & Engineering Research, Volume 4, Issue 10, ISSN 2229-5518, page No. 488-491, October-2013

[15] The official Bluetooth website from Bluetooth SIG www.Bluetooth.com, Bluetooth Specification Version1.1., March 21, 2001

[16] Bluetooth Committee, Specifications of the Bluetooth System (Core), V1.0B, December 1999

[17] Sriskanthan N, Tan F, & Karande A, "*Bluetooth based home automation system",* Microprocessors and Microsystems, 26(6), 281–289.doi:10.1016/s0141-9331(02)00039-x, 2002.

[18] http://arduino.cc

[19] http://arduino.org

[20] http://beagleboard.org/BLACK

[21] https://www.raspberrypi.org/

[22] http://riotboard.org/

[23] http://pandaboard.org/

[24] http://www.automatesystems.co.uk/how-traffic-light-sensors-work/