ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 4, April 2017

Portable Swiss Knife Data Acquisition System for Remote Applications

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ABSTRACT: Data acquisition systems need data to be collected from various resources and in different forms. Also, it is required to store, process and reproduce the data for outside world in desired format. Micro-controller architecture of proposed system, as name indicates ("swiss knife"), will have capability of collecting data from various subsystems and different buses (SPI, CAN, USB, ...etc). I/O pins of the micro-controller will be multiplexed with different tasks. Micro-controller will work in different modes for executing various tasks. Mode of the micro-controller will be selected by four mode select pins. Thus it is possible to change mode of micro-controller by external switches.

KEYWORDS: SPI (Serial Peripheral Interface), USB (Universal Serial Bus), I2C (Inter Integrated Circuit), CAN (Control Area network), UART (Universal Asynchronous Receiver Transmitter), DAQ (Data Acquisition)

I. INTRODUCTION

DAQ (Data Acquisition) is simply the process of bringing a real-world signal, such as a voltage, current, temperature into the computer, for processing, analysis, storage or other data manipulation. A real-world signal represents the physical phenomena you are trying to measure. These real world signals are converted into digital form and stored in the memory by DAQ systems. Digital data is easy to handle. Automation is possible with digital data.

Swiss knife micro-controller based DAQ system optimizes performance, data handling capacity and cost of embedded system.

Rapid advances in hardware and software technologies have resulted in easy data handling and efficient DAQ systems. Adoption of embedded systems in various fields for precise measurement and complex control applications generates need of DAQ systems.

An embedded system based measurement or control application requires conversion of real world analog signal into digital form. Analog data is generally acquired and transformed into the digital form for the purpose of processing, storage, transmission and display. A Swiss knife micro-controller based DAQ system performs conversion of analog signal to digital signal and vice versa (signal conditioning).

It can be further interfaced to other systems to implement the functions of a measurement, control and instrumentation, digital signal processing, medical instrumentation, audio/video recording and processing applications, ... etc. Simply collecting the data from various types of sensors/buses, digitizing and storing it in databases along with time stamp and other key information is a big job of data acquisition systems.

A main aim of Swiss knife micro-controller is to build a portable DAQ system which will be useful at the field or remote places. Especially, where data format (interface) is not known prior. It should acquire all types of data, store and reproduce in desired format to main system/user. As it is having on chip memory, it can keep on collecting data periodically and store it together in memory. For large data, it is having external NAND flash memory interface.

II. RELATED WORK

Micro-controller are available from various manufacturing semiconductor firms for generic embedded applications. This micro-controller integrates variety of interfaces for application in various embedded systems.In this project [1] author have used the electromagnetic sensor to acquire the data of a magnetic disk angular velocity using

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8051 micro-controller. In DAQ system [2] Liquid Crystal Display (LCD) and EEPROM are used on major basis for the display and storage purpose. I2C bus protocol is used while interfacing 8051 with EEPROM. This system consists of two modules as one "Data Monitoring" and other "Data Storage". In [3] the different hardware aspects of data acquisition systems are described. 16-bit micro-controller MAXQ612/MAXQ622 based data acquisition system is proposed along with amplifier, ADC and DAC. In [4] PIC micro-controller based Data Acquisition System prototype is realized by interfacing micro-controller with Input switches and output LEDs. The prototype board is interfaced to PC with serial UART port and GUI on PC indicates the status of the data acquired. In [5] authors have described practical considerations for bio-potential measurements (rate of amplification, filter band-pass frequency, overall bandwidth and Analogue-to-Digital conversion rate) in designing Data Acquisition System.The overview of the electrical characteristics of different bio-potential measurements and general data acquisition architecture for portable bio-potential measurement equipment is given by the authors. In thesis [6] author has explored development of low-cost small-sized DAQ system based on PCI24 micro-controller and a high speed USB based interface to PC is proposed. In [7] an extensible vehicle performance monitoring system is developed based on micro-controller PIC16F877A and "Xilinx Spartan3A FPGA Data Acquisition Unit". In [8] low cost real time data logging system is proposed for slowly varying signals PIC12F675 micro-controller. All these DAQ systems are proposed based on micro-controller available in the industry. In my work, a new micro-controller architecture class is proposed considering advances in the integrated circuit fabrication technology and increased demand of data acquisition for various researches and development at many places. In turn, making embedded systems/devices smart and intelligent. In this research work, we looked for, system adaptability, portability for commonly used existing interfaces. Also, 32 bit processor core included here, is capable of handling high data rates, processing of data, data logging and storage. Purpose is to give a good, handy and portable but powerful tool for data acquisition.

III. MICRO-CONTROLLER

A micro-controller (sometimes abbreviated µC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of Ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Micro-controllers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. Micro-controllers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, micro-controllers make it economical to digitally control even more devices and processes. Mixed signal micro-controllers are common, integrating analog components needed to control non-digital electronic systems.

Architecture of the micro-controller has been topic of innovation, leading evolution of application specific architectures. Today micro-controllers are deployed for various types data storage for monitoring purpose. The sensors for temperature, pressure, altitude, acceleration, etc are available with I2C or SPI interface. The GPS receivers have UART/CAN interfaces to send positional data. So new architecture for micro-controller - 'Swiss knife' is proposed for interfacing all types of sensors and recording all types of data received from sensor and other interfaces.

IV. NEED OF SWISS KNIFE DATA ACQUISITION SYSTEM

Many places we need various functions to be done by same system just like normal swiss knife. With micro-controller, data acquisition system can shrink into a portable device. With movable systems, naturally, a requirement pops up of collecting data from various scenarios. Every place, nature of data and data handling sub system may change in architecture. This Swiss Knife micro-controller will fit in this type of situation quickly. Various sensors are available for creating situational awareness in ubiquitous and pervasive applications.

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V. ARCHITECTURE

A micro-controller with 32 bit microprocessor core and peripherals for all type of connectivity is envisaged here. A parallel Nand-Flash controller in micro-controller provides fast data storage capability. It is proposed to have peripheral interfaces for USB (multiple host ports and one device port), SPI (one master port and one slave port), I2C (one master port and one device port) and multiple UART serial ports. Also micro-controller will have 16 bit GPIO, 12 channel ADC to acquire analog input data, on chip SRAM, RTC, 2 Timers, 12 channel DAC, 16 channel DMA controller for managing memory access for the peripherals and 16 hardware interrupts. A boot Flash of size 16KB is sufficient for streaming the data from interfaces to external Flash Memory. To keep the low pin count, peripheral related input output pins will be multiplexed. Since this swiss-knife micro-controller is having device/slave ports, it can form a grid of same or similar micro-controllers. They can share the work load of each other. And this way, they can form any size of data acquisition system. For data storage, time stamping will be done with inbuilt RTC and timers.

Fig1: Swiss Knife Micro-Controller

A reason of proposing this micro-controller architecture is to have maximum integration of microprocessor and its peripheral devices/sub systems on silicon with minimum pin count suitable for data acquisition systems. Maximum integration on silicon gives world class facilities of data acquisition and low pin count will give easy handling and less complex system design. Micro-controller should become a small ace or “Chhota Magic”! Having these many interfaces recorded data can be offloaded for post processing and analysis onto computers/embedded control applications.

Fig. 2: Swiss Knife micro-controller based Data Acquisition System

Figure 2 shows Swiss knife based micro-controller system block diagram. As shown it includes all types of interfaces to collect digital data and store in flash memory. Figure 3 shows internal architecture where all IP cores are included along with processor core.

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Vol. 5, Issue 4, April 2017

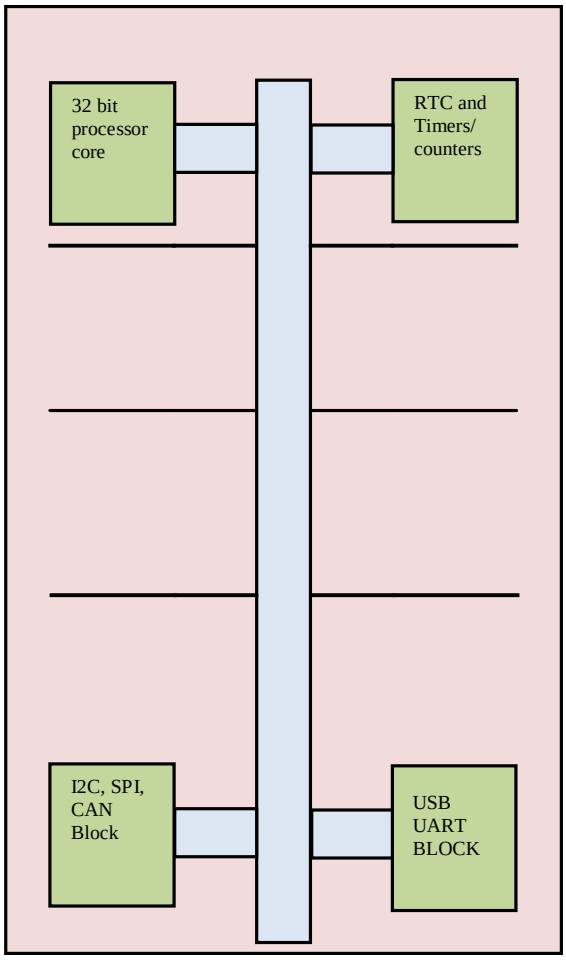

Fig. 3: Internal Block Diagram

Figure 4 shows image of Swiss-knife DAQ system. Small box is the proposed DAQ system, interfaced with data visualizer using USB. Small DAQ system can be carried to field and later data can be analyzed on visualizer at the office conveniently.

Fig 4: Portable DAQ system with visualizer

Figure 5 is envisaged image of Swiss-knife DAQ system. As it is seen, system will fit in small board 30 mm by 15 mm. Interface connectors only are size deciding factors for the system.

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Fig 5: Envisaged micro-controller board

VI. MODES OF MICROCONTROLLER

As it is specified in the architecture micro-controller will have less pin count with multiplexed functioning, we need to select these functions through some mean. This will be done through modes of micro-controller. A special four hardware pins will be provided to select particular mode of a micro-controller. Following table gives the options for 16 GPIO pins which will be multiplexed.

Mode select pins	Functioning on 16 GPIO pins
0000	16 GPIO pins (simple I/O mode)
0001	16 Analog pins (ADC input mode)
0010	16 Analog pins (DAC output mode)
0011	simple I/O and SPI
0100	USB mode
0101	I2C and SPI mode
0110	H/W Interrupt mode
0111	USART mode
1000	Simple I/O 8 pins and Analog 8 pins mode
1001	8 pin input analog and 8 pin output analog mode
1010	LCD and keyboard interface mode
1011	USB and SPI mode
1100	USB and UART mode
1110	USB and I2C mode
1111	I2C and UART mode

Table 1: Modes of micro-controller

Apart from these multiplexed pins and select pins, additional pins for parallel interface to external Nand-Flash memory, pins for reset, clock and power supply will add to the total pin count of micro-controller.

VII. SIMULATION AND RESULTS

A 44 pin lead-less chip carrier (LCC) or Ball Grid Array(BGA) package less than 5mm X 5mm is sufficient for integrating these peripherals. This architecture can be implemented in available fabrication technology at 40/55 nm node supporting Embedded Flash. The micro-controller core, memory cells and peripheral IP cores are available from

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ISSN (Print): 2320-9798

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multiple commercial sources. (Synopsys, ARM, ARASAN, Cadence, etc) as well as from academic institutes. For this research work, we collected information from opencores.org and data sheets of IP cores available on www.dcd.pl. Expected die size will be 10 to 15 sq mm depending upon amount of flash memory and SRAM integrated at 55 nano meter technology. Following table gives gate complexity of each IP core integrated in micro-controller

Sr. No	IP Name	Gate Count
1.	UART	6600
2.	SPI	1200
3.	CAN	9900
4.	I2C	2200
5.	Memory Controller	14000
6.	Timer	1000
7.	DMA Controller	8000
8.	Cortex M0	12000
9.	Cortex M3	33000
10.	ADC & DAC block	Equivalent to 10000

Table 2: IP cores and Gate counts

With above IP cores data acquisition rates achieved are given in following table.

Sr. No.	Interface	Data Acquisition Rate in bps
1.	UART	115000
2.	I2C	400000
3.	CAN	1000000
4.	SPI	5000000
5.	USB	480000000

Table 3: Data Acquisition rates achieved with interfaces

PSEUDO CODE

```
//swiss knife microcontroller module in verilog
//I2C, SPI, USB, CAN, UART and other IP cores are referred from opencores.org
Module SwissKnifeMicon ( Reset,Clock, ModeSel, FlashData, FlashCle, FlashAle,FlassRe, FLashWe, FlashWp,
FlashRB, ModeSel,GPIO);
Input [3:0] ModeSel ;
Input Clock, Reset ;
Inout [7:0] FlashData ;
Inout [15:0] GPIO ;
..
..
// IP Core instances
 Uart U1 (UartClock, Reset, UartSelect, UartDataOut, UartDataIn, UWr,URd, TxD, RxD,Cts, Rts)
 I2C U2 (I2CClock, Reset, I2CDataout, I2CDataIn,IWr,IRd,SCl, SDA)
 ...
 ...
// mode selection logic
```

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```
If (ModeSel == 4'b0000) GPIO   = GPIOport  ;
Elseif (ModeSel == 4'b0001) GPIO  = ADCOut;
elseif(ModeSel == 4'b0010) GPIO  = DAC;
Elseif (ModeSel == 4'b0011) GPIO = {GPIOPort,SPIPort};
…
...
elseif (ModeSel == 4'b1111) GPI ={I2Cport,Uartport};
```

VIII. INTENDED APPLICATIONS

Automatic parameters recording in industries, medical instruments, personal health monitoring and data logging, home automation systems, intrusion detection and security systems, vehicles and automobiles, smart city data recording, electronic agricultural applications, seismic data, weather recording, maintaining all types of logs are the application areas where the proposed architecture is suitable. A very small board based on the proposed micro-controller could be as small as 30mm X 15 mm having provision to connect specific interface cards for data logging applications.

IX. CONCLUSIONS AND FUTURE WORK

A proposed micro-controller architecture offers advantage of capability to store the data acquired from different interfaces at the same time ensuring small form factor, low power and portability. The future work is planned to estimate the silicon area required for realizing the micro-controller at leading fabrication technologies available and work out the architecture variants for additional interfaces suitable for specific applications. Capability of 'Instant data visualization at the field' also can be added. For today's smart wireless and digital world, addition of wireless interfaces (Blue Tooth, Wi-Fi and Zigbee) to the system will make it suitable for Internet Of Things (IOT) applications.

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ISSN(Online): 2320-9801
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International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 4, April 2017

BIOGRAPHY

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