REMOTE DATA ACQUISITION SYSTEM USING ARM9 AND GNU/LINUX

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LIST OF ABBREVIATIONS

3G	Third Generation of Mobile Telecommunications Technology
ADC	Analog to Digital Converter
AJAX	Asynchronous JavaScript and XML
AM	Analysis Module
API	Application Programming Interface
APN	Access Point Name
ARC	Attached Resource Computer
ARM	Advanced RISC Machine
AT	Attention Telephone / Attention Terminal
CLI	Command-Line Interface
CPU	Central Processing Unit
DAC	Digital to Analog Converter
DHCP	Dynamic Host Configuration Protocol
DIO	Data Input Output
DMA	Direct Memory Access
DNS	Domain Name Server/Service
DSL	Digital Subscriber Line
EDGE	Enhanced Data rates for GSM Evolution
FSF	Free Software Foundation
FTP	File Transfer Protocol
GPIO	General-purpose input/output
GPL	General Public License
GPRS	General packet radio service
GSM	Global System for Mobile
GUI	Graphical User Interface
HDMI	High-Definition Multimedia Interface
HSDPA	High-Speed Downlink Packet Access
HSUPA	High-Speed Uplink Packet Access

HTML	Hyper Text Markup Language
IM	Initialize Module
IPC	Inter Process Communication
ISA	Industry Standard Architecture
ISO	International Standards Organization
LAMP	Linux Apache MySql PHP
LAN	Local Area Network
LCD	Liquid-Crystal Display
LED	Light-Emitting Diode
LKM	Loadable Kernel Module
LLC	Logical Link Control
MAC	Media Access Control
MM	Monitoring Module
NM	Notification Module
OS	Operating System
OSI	Open Systems Interconnection
PC	Personal Computer
PCI	Peripheral Component Interconnect
PHP	Personal Home Page
POSIX	Portable Operating System Interface
PPP	Point-to-Point Protocol
PPPd	Point-to-Point Protocol Daemon
RISC	Reduced Instruction Set Computer
RDAS	Remote Data Acquisition System using ARM9 and GNU/Linux
RAM	Random Access Memory
RoHS	Restriction of Hazardous Substances
SBC	Single Board Computer
SD	Secure Digital
SMS	Short Message Service

SMTP	Simple Mail Transfer Protocol
SoC	System On Chip
SQL	Structured Query Language
SSH	Secure Shell
TCP	Transmission Control Protocol
TS	Technologic Systems
TS-Linux	Technologic Systems Linux
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
VPN	Virtual Private Network
WvDial	Weave-Dial

Jauh Sistem Pemerolehan data menggunakan ARM9 dan GNU/Linux

ABSTRAK

Terkini, Pelbagai Sistem Perolehan Data (DAS) boleh didapati di pasaran. yang operasi asas semua DAS adalah sama; terdapat perbezaan dari segi perkakasan rekabentuk, kadar pensampelan, resolusi, penyokong saluran perolehan data, kos, saiz, ciri-ciri mesra pengguna, dan lain-lain. Projek penyelidikan ini memberi tumpuan kepada reka bentuk dan pembangunan sistem perolehan data terbenam mencadangkan yang ciri-ciri yang menarik seperti, sokongan saluran boleubah (8-64), dua jenis pemberitahuan melalui Penhantaran Mesej Pendek (SMS) serum dan serat elektronik (EMAIL) dihantar kepada pengguna apabila menerima sebarang nilai saluran yang tidak dijangka, laman sesawang (WEB) pemantauan dan menguruskan untuk bekerja di kawasan kawalan. Seterusnya, dipanggil sistem kawalan pemerolehan data menggunakan ARM9 dan GNU/Linux (RDAS). Dalam kajian ini, fasa pembangunan terdiri daripada Papan Komputer Tunggal (SBC, TS-7800) sebagai pemprosesan unit, GNU/Linux berasas Terbenam Debian 7 Sistem Operasi (OS) sebagai platform pembangunan aplikasi dan modul kernel yang disesuaikan untuk menyokong perkakasan baru seperti modem 3G untuk menghantar pemberitahuan ke kawasan jauh. TS-7800 SBC digunakan juga sebagai pangkalan data dan pelayan WEB yang mengandungi data yang dikumpul dan boleh mengakses pangkalan data ini melalui rangkaian oleh pelayar WEB. Modul permohonan RDAS dipisahkan ke dalam Modul Permulaan (IM), yang memulakan semua peringkat keperluan modul kernel dan pengguna; Analisis Modul (AM), menganalisis data input melalui saluran ADC sama ada data kesilapan atau data sebenar dan menyimpan di pangkalan data terbenam; pemberitahuan data ralat Modul Pemberitahuan (NM) adalah memberitahu pengguna melalui SMS dan EMAIL; dan Pemantauan Modul (MM) adalah aplikasi berasaskan WEB yang mana pengguna mampu untuk meneroka status semasa dan sejarah data melalui mana-mana pelayar WEB.

Remote Data acquisition System using ARM9 and GNU/Linux

ABSTRACT

Now a days, various Data Acquisition System (DAS) is available in the market. The basic operation of all DASs are same; the differences found in terms of hardware architectures, sampling rate, resolution, data acquisition channel supports, costs, size, user friendly features, etc. This research project focuses on design and development of a proposed Embedded Data Acquisition System which interesting features are, variable channel support (8 to 64), two notification types by Short Message Service (SMS) and email send to user when receive any channel unexpected value, web monitoring system as well as manage to work in remote area; so, called Remote Data acquisition System using ARM9 and GNU/Linux (RDAS). In this research, the development phase consists of a Single Board Computer (SBC, TS-7800) as a processing unit, GNU/Linux based Embedded Debian 7 Operating System (OS) as a application development platform and customized kernel module to support new hardware like 3G modem to send notification to the remote area also using the TS-7800 SBC as database and web server which contain the data collected and can access this database through network by web browser. RDAS application module is separated into Initial Module (IM), which initiate all kernel and user level necessary modules; Analysis Module (AM), analyze the input data through the ADC channels either error data or actual data and save into embedded database; error data inform the Notification Module (NM) to notify user by SMS and email; and the Monitoring Module (MM) is a web based application by which user able to explore real and historic data status through any web browser.

CHAPTER 1

INTRODUCTION

1.1 Overview

Data acquisition is very important role in many fields such as measuring devices, processes control, engineering applications, life science research, industrial maintenance, E-government, weather station (DATAQ Instruments, 2014; National Instruments, 2104). The data collected can be used to to monitor system efficiency and ensure system reliability. This research focus to design, development and implementation of data acquisition system to get the analog data from physical parameters in a real world through variable number of channels work in parallel and save it as artificial world of digital data in embedded system. An embedded system is a specific computer system which is built into a certain system or device. Using a computer system rather than other control methods offers many benefits such small size, low cost, light weight, portable, high efficiency and low power consumption. These basic features can be used to improve the device or overall system in various ways such as reduced cost, increased dependability, improved performance, more functions and features (Dean et al., 2012).

1.2 Problem statement

All available traditional data acquisition systems in market and produced papers are: Fixed number of channels depend on ADC board used, without system notification when any channel received unexpected, almost not support or used flixable FOSS to modify application according to user need, with simple or without database to save collected data and not contain LAMP web services to monitor data from remote area.

1.3 Objectives

- To design and development of a data acquisition system supporting variable ADC channels for remote applications.

- To analyze data and send notification through SMS and Email when any channel receives unexpected data.
- To monitor current and historic data from the developed data acquisition system through any web browser.

1.4 Research Scope

This research aim to design and development an data acquisition system (DAS), with focusing on build system contains analysis data, send notification to the user by using USB modem and support variable input channels number. In this DAS used SBC connected to network to monitoring data through web browser, specially when the system placed in a remote area. The data collect from many sensors depending on analog to digital convertor (ADC) channels and save these data in database. The sensors types divided according to function of use. There are many terms and parameters used to define the performance of ADC's such as resolution, sample rate, number of channels and Quantization level. This project use embedded Linux based TS-7800 single board computer (SBC). This SBC consist ARM9 processor and many I/O interfaces to build complete system with all peripheral devices needed. Linux seems to be important in the embedded field because it's free, reliable, flexible to modify and can be upgraded to the latest version.

1.5 Thesis Outline

This work is organized as follows:

- Chapter 2 introduces the existing work and concept related to remote DAS monitoring system. It contains study of the DAS tools, embedded system and operating system.
- Chapter 3 describes the hardware components, software configuration, integration of the peripheral devices, importance of the services setup and methodology.
- Chapter 4 covers the software development, it includes creating 4 software modules, each module responsible on special manage part or more in system.

- Chapter 5 display all the system results in the form of screen shots such as kernel compiled result, connected to network by USB modem and shows the data collected through network by web browser in client side.

- Chapter 6 covers the conclusion and recommendation, it concludes the thesis by summarizing the important ideas for the contributions and future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

High growth of technology makes the use of The Data Acquisition system (DAS) easier and user friendly. Nowadays, researchers are more focusing on upgrading features and reducing complexity by optimizing the sampling process for particular Analog to Digital Converter (ADC) in DAS. In early stage of DAS, people use magnetic tape, paper charts and rolls as storage device. Current technology creates a wide field for the digital data storage technique (HDD, SD, Micro SD, Compact Flash) by which DAS data can be easily stored in continuous pattern, extremely accurate, error-free and reliable even though the processing speed and ADC sampling rates are different (MC Corporation, 2012). ADCs are designed either as an independent device dongle or embed with embedded computers. ADC dongle can be used as a plug and play device or need to install software to access. Some companies provide ADC peripheral card and need to integrate through PC104 or USB (Feynman, 2007). The focus point of this research is to use an embedded computer platform as a processing unit as well as ADC (either on-board or peripheral card) as a data acquisition unit to build a DAS portable and lower power consumption for using in remote area (Bakiri et al., 2012).

2.2 Data Acquisition System (DAS)

DAS, which is an important branch of embedded applications, is an integrated application of technology, based on sensors, signal measurement and data processing. Figure 2.1 shows the basic DAS components.

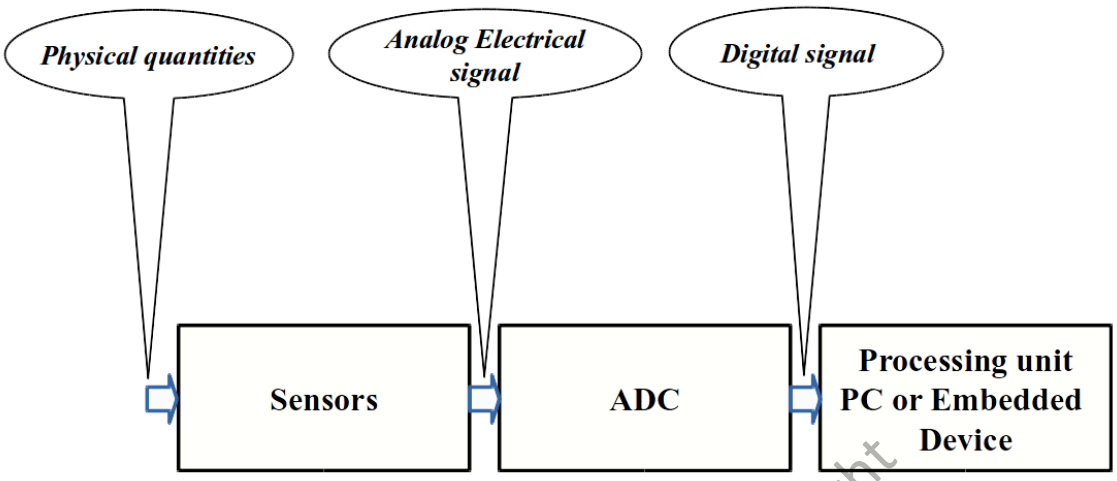

Figure 2.1: Basic DAS components

DAS is use to collect and measure physical or electrical quantities such as sound, pressure, light, voltage, current, or temperature. With a processing unit such as desktop computer system or an embedded system. The internal acquisition process is to collect analog data from a particular environment using sensors to be stored in digital form on a storage device (Scholar, 2011). A DAS, built around the flexibility of the PC and power, may contain of a wide variety of miscellaneous hardware building blocks of several equipment manufacturers. The system integrator task bring these individual components together into a full working system (John Park, 2003).

2.2.1 Sensors

There are many important variables to watch in the work environments such as temperature, humidity, lighting, voltage, length, current, smoke, pressure. To discover these variables, the physical quantities which transferred to electrical quantities by using specialized equipment. These equipments or devices called (Sensors) have many forms and types. The sensor can be divided into two main types Active sensors and Passive sensors. The Active sensors require an external source of power that provides the majority of the output power of the signal. The Passive sensors require the output power which mostly and entirely provided by the measured signal without an excitation voltage(ARC, 2012).

2.2.2 Analog to Digital Converter (ADC)

All signals found and present in the nature, are continuous and not quantized. All these signals also varied with time. Natural signals such a sound, temperature, light, are converted by a sensor or transducer to a proportional analog electrical signal. Thus, it is requisite to perform a conversion process of the analog electrical signal to a digital representation. Fundamentally, Digital signal processing systems require that signals are quantized at discrete time samples and represented as a series of words consisting of 1ŝ and 0ŝ. Typically, voltage to a binary number (Madisetti et al., 1999). This process of conversion from one format to another is called Analog to digital convertion (ADC). Where using digital circuits and digital signals offer greater advantages as compared to analog efficient transmitting and circuits in processing speed. In the conversion process there are many properties that are taken into consideration like Bandwidth, Power dissipation, Conversion Time, Sampling rate and Errors. The number of bits that represents the digital number determines the ADC Accuracy and resolution. Most ADCs, as illustrated in figure 2.2 are composed of two distinct circuit blocks performing the sampling in time and in magnitude(Halupka, 2002).

Figure 2.2: Block diagram of a typical ADC

2.2.3 Processing Unit

In DAS there is a processing unit designed to process the drawn digital streaming data. The processing unit that use in the DAS can be divided into two main types (Desktop PC and Embedded device). The PC is a general-purpose computer with standard ports, such as USB and PCI that limiting the interface devices number with this port. The embedded device designed to perform specific task by using embedded computer or microcontroller. The embedded computer is a small computer on a single board contain the microprocessor, memory and other components.

2.3 Embedded System

A system is a way of organizing, working or doing one or many tasks according to the program, set of rules or a fixed plan. Also the system arrangement in which all its units hardware and software gathering and work together according to the plan. Thus, the embedded system refer to specific computer programs that collect the functions of specially designed hardwares and softwares in one device that perform a certain tasks unlike a general-purpose personal computer. The embedded systems or computers exist everywhere such as automobiles, robotic, digital cameras, airplanes, home appliances, microwave ovens, card readers, military vehicles and equipments, medical devices, mobile communication system.

The embedded system characterized by many important properties make them more prevalent to use than other systems supported by a wide array of processors and processor architectures. They usually small size, low cost, light weight and portable, efficiency, power consumption, real-time, constraints and others (Berger, 2002).

One model of embedded system technology that uses in a recent year is a single board computer (SBC). The SBC able to perform tasks like computer as it has a processor, RAM, storage unit, I/O ports and OS. There are various SBC provider companies and selling customized depend on the application development needed for example Technologic Systems (TS)(Technologic Systems Inc, 2009), Raspberry A and B(Raspberry Pi Foundation, 2014), Beagle Bone Black(BeagleBoard.org, 2014), Parallels, Odroid-X2(Hardkernel Co., 2013), Hackberry(QuickEmbed Technology Co., 2014), UDOO(SECO USA Inc., 2014), APC Rock(APC-1, 2014), Cubie board(Cubieboard, 2014), Mars board, A13-OlinuXino(Olimex Ltd., 2014). Table 2.1 show the specifications for this SBCs. Each board is different from the other in the design, hardware and OS. TS offers a number of embedded devices with a wide variety of products, includes boot-loaders and firmware to high-level applications and operating systems.

Table 2.1: Specifications of various SBCs types

SBCs\Specs	CPU	RAM	OS	I/O ports	Storage Unit
Raspberry Pi	700 MHz ARM	512MB	GNU/Linux	USB, Ethernet , GPIO, UART, HDMI	SD Card
BeagleBone	720 MHz ARM	256MB	GNU/Linux and Android	USB, Ethernet	Micro SD Card
Parallella	800 MHz ARM	1024MB	Ubuntu	USB, Ethernet, HDMI	Micro SD Card
ODROID-X2	1.7GHz ARM	2048MB	ArchLinux	USB, Ethernet	SD Card
Hackberry	1 GHz ARM	512MB	GNU/Linux and Android	USB, Ethernet, HDMI	4GB flash, SD card
UDOO	1GHz ARM	1GB	GNU/Linux and Android	USB, Ethernet, HDMI	Micro SD Card
APC Rock	800MHz ARM	512MB	GNU/Linux	USB, ,Ethernet, HDMI, COM, GPIO	4GB flash Micro SD Card
Cubieboard	1 GHz ARM	1GB	Linux, Windows and Mac	USB, Ethernet HDMI, GPIO, UART	4GB flash SD Card, SATA
Marsboard	1.6 GHz ARM	1GB	GNU/Linux and Android	USB, Ethernet, HDMI	Micro SD Card
A13-OLinuXino	1 GHz ARM	512 MB	GNU/Linux and Android	USB, Ethernet, HDMI, GPIO, UART	SD card, SATA
TS-7800	500MHz ARM	128MB	GNU/Linux Debian	USB, Ethernet, DIO, LCD, PC104 GPIO, COM, RS232, RS485, JTAG, ADC	512 MB NAND flash, SD card, Micro SD Card, SATA

2.3.1 Hardware

The computer hardware systems consisting of many physical components work together with software (operating system, programs, and applications) to give general-purpose computer. The embedded system focus on run with limited computer hardware resources (little memory, CPU or microcontroller, NAND flash or SD card, small or non-existent screen or keyboard) this features make the embedded hardware device more desirable to perform specific task.

The most important feature of the DAS is reliability and accuracy, that can be achieved with use of reliable hardware instruments. SBC can work in harsh environments because

all the components of the SBC proven to the one Board directly by solder. This operation minimizing the number of connectors and sockets used are mostly prone to a mechanical failure. This SBC is different in hardware design, depending on the task that is performed, such as: CPU, Memory I/O Ports and OS. The essential difference is in the ARM processor architecture that gives important parameters to the SBC is power consumption. The SBCs are produced mainly using the processors architectures as following:

1. x86 a set of processor families began with the 32-bit Intel 80386 to last Intel Core i7, the most widespread processor architecture that supported by almost operating systems

2. Advanced RISC Machine (ARM) dominant and diffuse architecture on the embedded market and mobile for its low power demands, high performance and simplicity that supported by a many embedded operating systems like Windows CE, Linux and Android (Steve, 2000).

3. Performance Optimization With Enhanced RISC - Performance Computing (PowerPC) this architecture used for a long time by Apple which supported by almost operating systems that designed for this architecture specially.

The ARM processor has many features compared with X86 when used in embedded system. This includes RISC, low power, high performance and price. Table 2.2 looks at the characteristics of Technologic Systems ARM-based SBCs products (Technologic Systems Inc, 2009).

Table 2.2: Various Technologic System SBCs product characteristics based on ARM9

Product	TS-7200	TS-7250	TS-7260	TS-7300	TS-7350	TS-7370	TS-7400	TS-7800
CPU	200 MHz ARM9	200 MHz ARM9	200 MHz ARM9	200 MHz ARM9	200 MHz ARM9	200 MHz ARM9	200 MHz ARM9	500MHz ARM9
Category	SBC	SBC	SBC	SBC	SBC	SBC	SoM	SBC
PC/104 Connector	✓	✓	✓	64 pin only	64 pin only	64 pin only		✓
on-board FPGA				✓	✓	✓		✓
RAM	32 MB	32 MB	32 MB	32 MB	32 MB	64 MB	32 MB	128 MB
opt. RAM	64 MB	64 MB 128 MB	64 MB 128 MB	64 MB 128 MB	64 MB 128 MB	128 MB	64 MB 128 MB	
Flash	8 MB	32 MB	32 MB				32 MB	512 MB
std. A/D		✓	✓		✓	✓	✓	✓
Ethernet ports	10/100	10/100	10/100	2 10/100	1 10/100	2 10/100	10/100	1 Gigabit
2 USB ports	Full-Speed	Full-Speed	Full-Speed	Full-Speed	Full-Speed	Full-Speed	Full-Speed	High-Speed
SD Card socket			1 full	2 full	1 full	1 full	1 full	1 full 1 micro
Digital I/O	20	20	30	55	3	3	20	110
RS-485	opt. full/half	opt. full/half	opt. full/half	opt. full/half	opt. full/half	opt. full/half		2 opt. full/half
COM Ports	2	2	3 or 5	10	10	10	3 TTL	10
RS-232 Console	✓	✓	✓	✓	✓	✓		✓
LCD Interface	✓	✓	✓	✓	✓	✓		✓
Keypad Interface	✓	✓	✓	✓				✓
SATA Ports								2
Default Kernel	2.4	2.4	2.4	2.4	2.6	2.6	2.4	2.6
TS-Linux	✓	✓	✓				✓	
Debian Linux	opt.CF	opt.USB	opt.SD	✓	✓	✓	opt.SD	✓
Linux Fast Bootup			avail.	1.69s	under 1.5s	under 1.5s	1.1s	under 2s
Linux-based Bootloader	opt.	opt.	opt.	✓	✓	✓	✓	✓
RoHS Compliance	✓	✓	✓	✓	✓	✓	✓	✓

2.3.2 Development Software Platform

High-level programming languages usually use for writting software that are more efficient and easier for people to use. Operating system is a combination of software that manages hardware resources of the computer and at the same time provides common services for the computer programs. Embedded computer systems must be supported by operating systems designed to be used in limited computer hardware resources. There are wide variety of embedded systems, duo to a lot of the functionality requirements of embedded OSs. Because of the many technical benefits and economic, there are robust growth in the adoption of GNU/Linux OS for embedded devices. This direction has