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Ethernet Enabled Digital I/O Control in Embedded Systems

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ABSTRACT

This paper presents very simple and economical way to provide Ethernet connectivity to microcontroller based embedded systems. This system uses ATmega328p microcontroller to store the main application source code, web pages and TCP/IP stack which is a vital element of the system software. An Ethernet controller chip, ENC 28J60 is used to handle the Ethernet communications and is interfaced with the host microcontroller using SPI pins. There are several I/O pins available at the microcontroller which are used to interface with sensors and relays for monitoring and controlling operations. Nowadays, Internet has spread worldwide and most of the internet connections use Ethernet as media for data transfer. In industries or in home appliances, most of the time we need to monitor and control different parameters using microcontrollers. Once we enable Ethernet interface to such systems, we can communicate with them remotely over the internet.

INTRODUCTION

Now a days we are using many Networked embedded systems for monitoring and control the home or industrial devices. With the scalable networking solution the server enables Web access to distributed measurement/control systems and provides optimization for educational laboratories, instrumentation, Industrial and home automation. In this paper , we present the principles and to design a system for Internet-based data-acquisition system and control by using Advanced RISC Machine i.e ARM processor and in-build web server application with. The main core of the system is an embedded hardware running on a NUT OS, a industrial grade RTOS for hard time applications. The proposed system eliminates the need for server software and maintenance. The proposed system minimizes the operational costs while operating with a large amount of data. Web access functionality is embedded in a device to enable low cost widely accessible and enhanced user interface functions for the device. A web server in the device provides access to the user interface functions for the device through a device web page. A web server can be embedded into any appliance and connected to the Internet so the appliance can be monitored and controlled from remote places through the browser in a desktop.

SYSTEM ARCHITECTURE DESCRIPTION

This section gives information regarding various components related to the system various options options available for using them.Some of the important components and protocols are listed below

Potential Transformers

PTs or VTs are the most common devices used. These devices are conventional transformers with two or three windings (one primary with one or two secondary). They have an iron core and magnetically couple the primary and secondary. The high side winding is constructed with more copper turns than the secondary (i.es), and any voltage impressed on the primary winding is reflected on the secondary windings in direct proportion to the turns ratio or PT ratio.

Current Transformer

A current transformer (CT) is a type of instrument transformer designed to provide a current in its secondary winding proportional to the alternating current flowing in its primary. They are commonly used in metering and protective relaying in the electrical power industry where they facilitate the safe measurement of large currents, often in the presence of high voltages. The current transformer safely isolates measurement and control circuitry from the high voltages typically present on the circuit being measured.

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Power Supply

A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones and rarely to others.

Microcontroller

Microcontroller is a heart of this project. ARM 7 is suitable microcontroller for this proposed embedded system. LPC2148 is ARM 7 controller used in this project. The main feature of LPC2148are as follows,

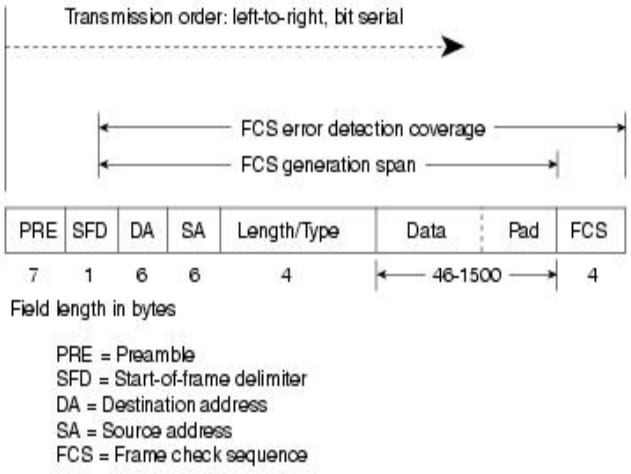
LPC2148 microcontroller board based on a 16-bit/32-bit ARM7TDMI-S CPU [5] with real-time emulation and embedded trace support, that combine microcontrollers with embedded high-speed flash memory ranging from 32 kB to 512 kB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30% with minimal performance penalty. The meaning of LPC is Low Power Low Cost microcontroller. This is 32 bit microcontroller manufactured by Philips semiconductors (NXP).Due to their tiny size and low power consumption, LPC2148 is ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. The LPC2148 contains one SSP. The SSP controller is capable of operation on a SPI, 4-wire SSI, or Micro wire bus. It can interact with multiple masters and slaves on the bus. However, only a single master and a single slave can communicate on the bus during a given data transfer. The SSP supports full duplex transfers, with data frames of 4 bits to 16 bits of data flowing from the master to the slave and from the slave to the master. Often only one of these data flows carries meaningful data. Features of LPC2148 Microcontroller are

- 16bit/32bit ARM7TDMI-S microcontroller in a tiny LQFP64 package.
- 40kB of on-chip static RAM and 512kB of on chip flash memory.
- In System programming/In application programming via on chip boot loader software.
- USB 2.0 full speed compliant device controller with 2kB of endpoint RAMS.
- In addition, the LPC2148 provides 8kB of on chip RAM accessible to USB by DMA.
- Two 10-bit ADCs provide a total of 14 analog inputs, with conversion times as low as 2.44 ms per channel.
- Single 10-bit DAC provides variable analog output.
- Two 32-bit timers/external event counters (with four capture and four compare channels each), PWM unit (six outputs) and watchdog.
- Low power Real-Time Clock (RTC) with independent power and 32 kHz clock input.
- Multiple serial interfaces including two UARTs (16C550), two Fast I2C-bus (400 kbit/s), SPI and SSP with buffering and variable data length capabilities.
- Up to 45 of 5 V tolerant fast general purpose I/O pins in a tiny LQFP64 package.
- Up to 21 external interrupt pins available.
- 60 MHz maximum CPU clock available from programmable on-chip PLL with settling time of 100 ms.
- On-chip integrated oscillator operates with an external crystal from 1 MHz to 25 MHz and Power saving modes includes idle and Power-down.
- Individual enable/disable of peripheral functions as well as peripheral clock scaling for additional power optimization.
- Processor wake-up from Power-down mode via external interrupt or BOD.

ETHERNET

Ethernet is a large and diverse family of frame-based computer networking technologies for local area networks (**LANs**). The name comes from the physical concept of the ether. It defines a number of wiring and signaling standards for the physical layer, through means of network access at the Media Access Control (MAC)/Data Link Layer, and a common addressing format. On top of the physical layer Ethernet stations communicate to each other by sending each other data packets, small blocks of

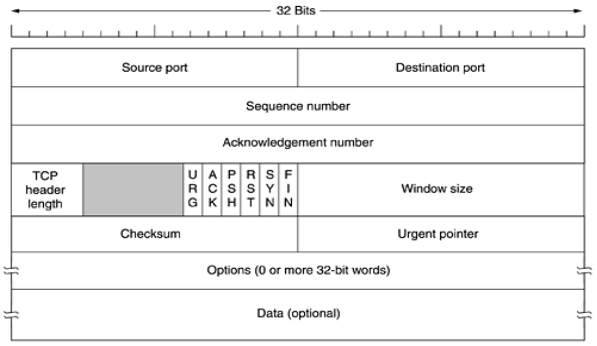
data that are individually sent and delivered. Ethernet is standardized as IEEE 802.3. The combination of the twisted pair versions of Ethernet for connecting end systems to the network, along with the fiber optic versions for site backbones, is the most widespread wired LAN technology. It has been in use from around 1980 to the present, largely replacing competing LAN standards such as token ring.



Basic Ethernet Frame Format

Transmission Control Protocol

TCP (Transmission Control Protocol) was specifically designed to provide a reliable end-to-end byte stream over an unreliable internetwork. An internetwork differs from a single network because different parts may have wildly different topologies, bandwidths, delays, packet sizes, and other parameters. Each machine supporting TCP has a TCP transport entity, either a library procedure, a user process, or part of the kernel. In all cases, it manages TCP streams and interfaces to the IP layer. A TCP entity accepts user data streams from local processes, breaks them up into pieces not exceeding 64 KB (in practice, often 1460 data bytes in order to fit in a single Ethernet frame with the IP and TCP headers), and sends each piece as a separate IP datagram. When datagram's containing TCP data arrive at a machine, they are given to the TCP entity, which reconstructs the original byte streams.



TCP Frame Format

Internet Protocol (IP)

Communication in the Internet works as follows. The transport layer takes data streams and breaks them up into datagram's. In theory, datagram's can be up to 64 Kbytes each, but in practice they are usually not more than 1500 bytes (so they fit in one Ethernet frame). Each datagram is transmitted through the Internet, possibly being fragmented into smaller units as it goes. When all the pieces finally get to the destination machine, they are reassembled by the network layer into the original datagram. This datagram is then handed to the transport layer, which inserts it into the receiving process' input stream. In practice, it is often much more than six.

The IP Protocol

An appropriate place to start our study of the network layer in the Internet is the format of the IP datagram's themselves. An IP datagram consists of a header part and a text part. The header has a 20-

byte fixed part and a variable length optional part. It is transmitted in big-endian order: from left to right, with the high-order bit of the Version field going firstOn little endian machines, software conversion is required on both transmission and reception.

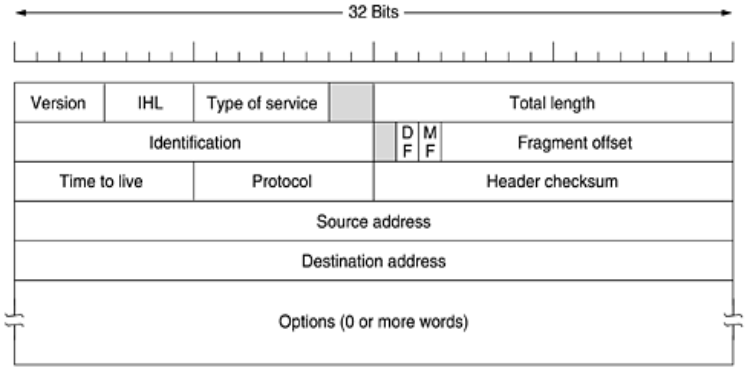


Fig2.4. *the IPv4 (Internet Protocol) header*

Hypertext Transfer Protocol

The transfer protocol used throughout the World Wide Web is HTTP (Hypertext Transfer Protocol). The HTTP is an application level protocol. It is a generic, stateless, object oriented protocol that can be used for many tasks, such as name servers and distributed object management systems, through extension of its request methods (commands). It uses a client-server relationship and is based on a stream-oriented transport layer, such as TCP. Today, the most important use is transferring HTML documents with multimedia contents between Internet servers and clients (WWW). It works with the principle of request and response. The simplest case is that a client establishes a connection to a server and requests a content referred by a Uniform Resource Identifier (URL) that specifies the path and name of the resource.

ENC28J60 Ethernet Controller

The ENC28J60 is a stand-alone Ethernet controller with an industry standard Serial Peripheral Interface (SPI). It is designed to serve as an Ethernet network interface for any controller equipped with SPI. The ENC28J60 meets all of the IEEE 802.3 specifications. It incorporates a number of packet filtering schemes to limit incoming packets. It also provides an internal DMA module for fast data throughput and hardware assisted checksum calculation, which is used in various network protocols.

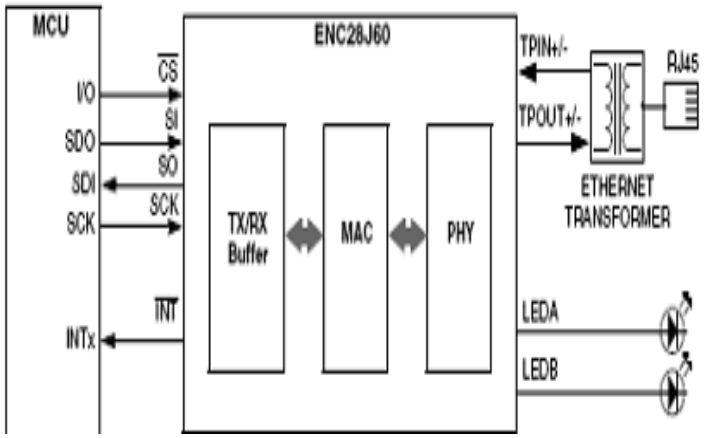


Fig3.7.3. *Interfacing of ENC28J60*

SOFTWARE DEVELOPMENT

In an Ethernet network, the interface to the network is an Ethernet controller chip and its driver. The Ethernet driver contains program code that manages communications between the controller chip and a higher level in the network protocol stack [I]. For internet communication over Ethernet, a Transmission Control Protocol/Internet Protocol (TCP/IP) software stack is necessary. This stack resides on the Host MCU. Microchip's TCP-IP stack, need to be configured according to the host microcontroller used in the system. Microchip provides a driver for the ENC28J60 and a TCP/IP

stack including an HTTP web server. Web pages need to be stored in external or internal EEPROM. These pages can be accessed using internet browser by accessing the IP address assigned to the system. Figure 5 shows user interface in an internet browser. The system IP address and server IP address can be configured by making changes in the program.

IDE for Microcontroller's Program Development

Keil uVision4 is the Integrated Development Environment (IDE) for developing and debugging embedded Keil uVision4 applications [3], [8]. Keil uVision4 IDE gives a seamless and easy-to-use environment to write, build, and debug C/C++ and assembly code. Flash Magic is a PC tool for programming flash based microcontrollers from NXP using a serial or Ethernet protocol while in the target hardware. The following are the steps to dump program into Microcontroller.

CONCLUSION

Embedded web servers are an integral part of an embedded network. Embedded Servers in our project can be used to change the status of the various Gadgets connected to the kit by means of Internet. The Embedded web server design includes a complete web server with TCP/IP support and Ethernet interface. It provides the software for automatic configuration of the web server in the network. The Embedded web server reference design includes complete source code written in C-language. A comprehensive model of the Embedded Web Server has been designed using ARM. We can reduce the power consumption by making use of a different kind of Microcontroller called the AVR, which makes use of only 3.3V Power Supply. Our design is a quick start to embedded web servers.

Future Scope

By the addition of wireless circuitry to the sensor module, this embedded web server's capabilities like range *can* be enhanced. In the case of home security system, e-mail alerts can be sent even to a mobile phone or to the local police station on occurrence of break-in into the house. Set point violations in the case of a process control environment to the concerned plant engineer and abnormalities in the body parameters of a patient in ICU will alert the doctor wherever he is. Intelligent homes will be connected to the Internet and require a higher end microcontroller to communicate with the other network devices. The Embedded web server can simplify the design process for embedded web server applications. It also can be made to include support for sending mail or an SMS regarding the status of the device connected to the kit and change the status of the device by decoding the message sent to it.

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