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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 ARM 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 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.

1. 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.

The aim of the project is to control the devices or equipment's from the remote place through a web page. Here all the devices, which are to be controlled, are connected to the relays (acts as switches) on the web server circuit board. The web-server circuit is connected to LAN or Internet. The client or a person on the PC is also connected to same LAN or Internet. By typing the IP-address of LAN on the web browser, the user gets a web page on screen; this page contains all the information about the status of the devices. The user can also control the devices interfaced to the web server by pressing a button provided in the web page.

2. BACKGROUND SURVEY:

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 vital element of the system software. An Ethernet controller chip, ENC28J60 is used to handle the Ethernet communication and is interfaced with 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. For many years, embedded systems and Ethernet networks existed in separate worlds. Ethernet was available only to desktop computers and other large computers. Embedded systems that needed to exchange information with other computers were limited to interfaces with low speed, limited range, or lack of standard application protocols. But developments in technology and the marketplace now make it possible for embedded systems to communicate in local Ethernet networks as well as on the Internet. Network communications can make an embedded system more powerful and easier to monitor and control. Ethernet solves the problem of remote communication with the embedded application. Challenges like application monitoring, control, diagnostics and data logging can all be accomplished from a remote, centralized location. With the ability to access the application remotely, corporations can eliminate the need to send a service person to the application and thus save labor time and money. There are compelling reasons behind considering Ethernet for remote communication. Ethernet is the most widely deployed network in offices and industrial buildings.

3. SYSTEM ARCHITECTURE DESCRIPTION :

The overall block diagram of proposed system An Integrated Health Management System for Automobiles is illustrated in fig 2.1. This block diagram consists of three types of sensors, current and voltage transformers, RPM counter, Microcontroller block, CAN, GLCD modules. The three types of sensors include temperature sensor, level sensor and fire sensor. The inputs from the sensors are given to the ADC pins of LPC2148. Here the signals are converted into digital signals through analog to digital converter. These signals are sent to the serial communication block (SPI) where the input data is sent bit by bit manner. The serial communication block is connected to CAN controller module. The output signals of CAN controller are given to CAN transceiver module where the signal are converted into CANL and CANH i.e data can be placed on CAN bus. These bus signals can be read by LPC2148 of Receiver. The receiver part is having GLCD for display purpose, Fan for temperaturecontrol purpose and toy car for fire.

The sensor readings are collected and displays on the GLCD. Whenever the values of sensor exceed the threshold limit, corresponding action can be takes place and message is displayed on to the screen.

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.

Relay:

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches. Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link.

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

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• 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.

• 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.

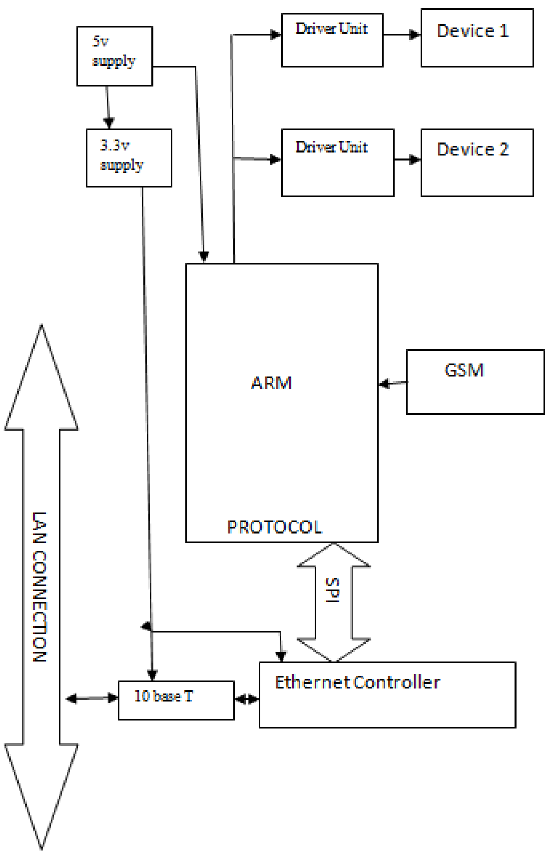
• Processor wake-up from Power-down mode via external interrupt or BOD.

• CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V tolerant I/O.

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.

MCP2551:

The MCP2551 is a high-speed CAN, fault-tolerant device that serves as the interface between a CAN protocol controller and the physical bus. The MCP2551provides differential transmit and receive capability for the CAN protocol controller and is fully compatible with the ISO-11898 standard, including 24V requirements. It will operate at speeds of up to 1 Mb/s. Typically, each node in a CAN system must have a device to convert the digital signals generated by a CAN controller to signals suitable for transmission over the bus cabling (differential output). It also provides a buffer between the CAN controller and the high-voltage spikes that can be generated on the CAN bus by outside sources (EMI, ESD, etc.).



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4. MODULE DESCRIPTION:

A) ETHERNET:

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, FDDI, and ARCNET. In recent years, Wi-Fi, the wireless LAN standardized by IEEE 802.11, is prevalent in home and small office networks.

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.

a. Ethernet Network Elements :

Ethernet LANs consist of network nodes and interconnecting media. The network nodes fall into two major classes:

• Data terminal equipment (DTE)—Devices that are either the source or the destination of data frames. DTEs are typically devices such as PCs, workstations, file servers, or print servers that, as a group, are all often referred to as end stations.

• Data communication equipment (DCE)—Intermediate network devices that receive and forward frames across the network. DCEs may be either standalone devices such as repeaters, network switches, and routers, or communications interface units such as interface cards and modems.

b. The Ethernet MAC Sub layer :

The MAC sub layer has two primary responsibilities:

• Data encapsulation, including frame assembly before transmission, and frame parsing/error detection during and after reception

• Media access control, including initiation of frame transmission and recovery from transmission failure .

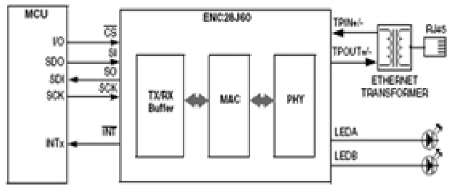

Fig: Interfacing of ENC28J60

c. The Ethernet Physical Layers :

Because Ethernet devices implement only the bottom two layers of the OSI protocol stack, they are typically implemented as network interface cards (NICs) that plug into the host device's motherboard. The different NICs are identified by a three-part product name that is based on the physical layer attributes.

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B) TRANSMISSION CONTROL PROTOCOL (TCP):

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. TCP was designed to dynamically adapt to properties of the internetwork and to be robust in the face of many kinds of failures. 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

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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. For simplicity, we will sometimes use just ''TCP'' to mean the TCP transport entity (a piece of software) or the TCP protocol .

a. The TCP Service Model:

TCP service is obtained by both the sender and receiver creating end points, called sockets. Each socket has a socket number (address) consisting of the IP address of the host and a 16-bit number local to that host, called a port. A port is the TCP name for a TSAP. For TCP service to be obtained, a connection must be explicitly established between a socket on the sending machine and a socket on the receiving machine. A socket may be used for multiple connections at the same time. In other words, two or more connections may terminate at the same socket. Connections are identified by the socket identifiers at both ends, that is, (socket1, socket2). No virtual circuit numbers or other identifiers are used. Port numbers below 1024 are called well-known ports and are reserved for standard services. For example, any process wishing to establish a connection to a host to transfer a file using FTP can connect to the destination host's port 21 to contact its FTP daemon. A list of few ports is shown .

Port	Protocol	Use
21	FTP	File transfer
23	Telnet	Remote login
25	SMTP	E-mail
69	TFTP	Trivial file transfer protocol
79	Finger	Lookup information about a user
80	HTTP	World Wide Web
110	POP-3	Remote e-mail access
119	NNTP	USENET news

Table: A few assigned ports.

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b. The TCP Protocol:

In this section we will give a general overview of the TCP protocol. In the next one we will go over the protocol header, field by field.

A key feature of TCP, and one which dominates the protocol design, is that every byte on a TCP connection has its own 32-bit sequence number. When the Internet began, the lines between routers were mostly 56-kbps leased lines, so a host blasting away at full speed took over 1 week to cycle through the sequence numbers. At modern network speeds, the sequence numbers can be consumed at an alarming rate, as we will see later. Separate 32-bit sequence numbers are used for acknowledgements and for the window mechanism,

The sending and receiving TCP entities exchange data in the form of segments. A TCP segment consists of a fixed 20-byte header (plus an optional part) followed by zero or more data bytes. The TCP software decides how big segments should be. It can accumulate data from several writes into one segment or can split data from one write over multiple segments. Two limits restrict the segment size. First, each segment, including the TCP header, must fit in the 65,515-byte IP payload. Second, each network has a maximum transfer unit, or MTU, and each segment must fit in the MTU. In practice, the MTU is generally 1500 bytes (the Ethernet payload size) and thus defines the upper bound on segment size.Segments can arrive out of order, so bytes 3072–4095 can arrive but cannot be acknowledged because bytes 2048–-3071 have not turned up yet. Segments can also be delayed so long in transit that the sender times out and retransmits them. The retransmissions may include different byte ranges than the original transmission, requiring a careful administration to keep track of which bytes have been correctly received so far. However, since each byte in the stream has its own unique offset, it can be done.

C) 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.

As can be seen from Fig. 4.15, a packet originating at host 1 has to traverse six networks to get to host 2. In practice, it is often much more than six.

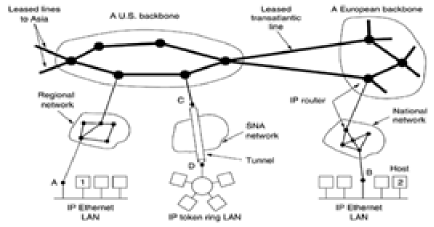
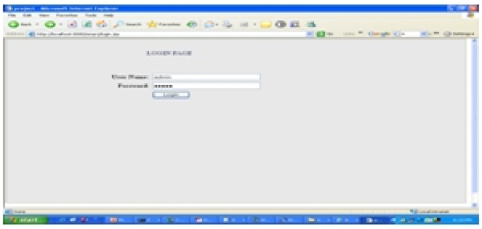


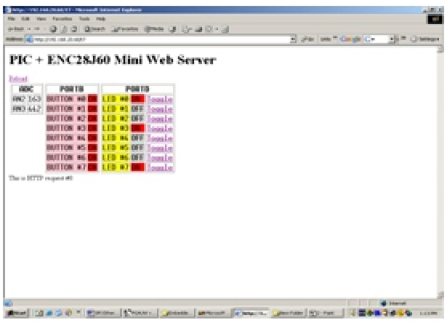
Fig : The Internet is an interconnected collection of many networks.

D)HYPERTEXT TRANSFER PROTOCOL (HTTP):

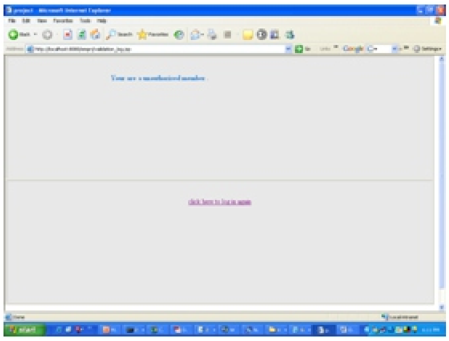
The transfer protocol used throughout the World Wide Web is HTTP (Hypertext Transfer Protocol). The HTTP is an application level protocol. It is a generic, stateless, object oriented protocol that can be used for many tasks, such as name servers and distributed object management systems, through extension 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.

Screen Shots When username and password are correct





When either Username or Password are wrong



Conclusion and Future Scope:

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 PIC. 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.

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.

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