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Arduino Compatible World Wide Web Controlled Embedded System

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Abstract - Embedded computing systems have become a pervasive part of our daily life. These are used for tasks ranging from providing entertainment to assisting the functioning of key human organs. An embedded system with the connectivity with the World Wide Web (internet) enables them to react with the system anywhere & anytime. The ARM Cortex M3 microcontroller provides single chip interface for processor and Ethernet controller to reduce the system size and power consumption. The Cortex M3 processor with in-built Ethernet controller can be used in cost-sensitive and miniaturized size embedded systems. Further, integration of the system using Arduino compatible will reduce time-to-market and use of off-the-shelf modules.

Key words: **Arduino, Cortex M3 processor, Embedded system, Ethernet controller, World Wide Web.**

I. INTRODUCTION

Embedded systems permeate our society. Current estimates indicate that over 90 percent of worldwide computers are embedded systems [1]. Embedded computing systems have become a pervasive part of daily life, used for tasks ranging from providing entertainment to assisting the functioning of key human organs [2]. Embedded system is a special-purpose computer system which is designed to perform a small number of dedicated functions for a specific application [3], [4]. Embedded systems show up in all kinds of applications from medical instruments, office equipments and traffic signals to room temperature controls and industrial machines [5]-[8]. Embedded systems consist of sensors to capture various input signals from the environment and process these inputs using some processors and also actuate or control output devices interfaced with these systems [9], [10]. The computing function is performed with the intelligence provided in the system so that it performs as per the requirements. An embedded system with the connectivity with the internet (World Wide Web) enables them to react with the system anywhere & anytime [11], [12]. These web controlled embedded systems will be really improving our daily need in every aspect of life, i.e., personal, medical, industrial or natural requirements. The wide varieties of microcontrollers available are suitable for most of the embedded system developments. The microcontrollers available are 8-bit to 64-bit. The 32-bit data handling capacity of ARM microcontrollers provide complex data processing faster [13], [14]. The higher operating frequency along with the pipelined architecture makes it to execute Millions of instructions per second (MIPS). The larger memory capacity makes it possible to develop complex systems. The Stellaris family of microcontrollers Cortex-M3 brings high-performance 32-bit computing to cost-sensitive embedded microcontroller applications. These microcontrollers deliver 32-bit performance at a cost equivalent to legacy 8- and 16-bit devices, all in a package with a small footprint. The Stellaris family offers efficient performance and extensive integration, favorably positioning the device into cost-conscious applications requiring significant control-processing and connectivity capabilities [15], [16]. World Wide Web controlled embedded systems can be developed as conventional way of system integration on a Printed Circuit Board (PCB) or a new way of system integration with Arduino compatible interface. The Arduino compatible interface has advantage that it provides a common standard in the system sizing and stacked one over other. It also gives flexibility to the embedded system developers to use external Arduino shields which are available in markets [17], [18]. This makes development of embedded system easier and time-to-market; the key challenge to develop embedded systems.

II. SYSTEM CONFIGURATION

The ARM processor based web-controlled embedded system consist of ARM processor, an Ethernet controller, RJ45 jack, sensors / transducers etc. The web controlled embedded system using Cortex M3 microcontroller LM3S8962 development will be easier as compared to ARM processor based embedded system because the Cortex M3 microcontroller LM3S8962 has in-built Ethernet controller along with various peripherals. The on-chip Ethernet controller can be directly connected to the RJ45 jack and is connected to the world through internet. The on-chip Ethernet controller reduces the system size, power consumption and cost of the embedded system. The schematic diagram of Cortex M3 microcontroller LM3S8962 based web controlled embedded system is shown in fig 1 below: The web controlled embedded system designing requires various components interfacing as shown above. Each of the components is connected to the cortex M3 microcontroller LM3S8962. The data acquisition module depends on the application for which the system is

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designed. With the change of application, various data acquisition modules are used. The analog inputs are connected to the ADC channels. To control output devices, they have to be connected to the input/output ports or through the relays.

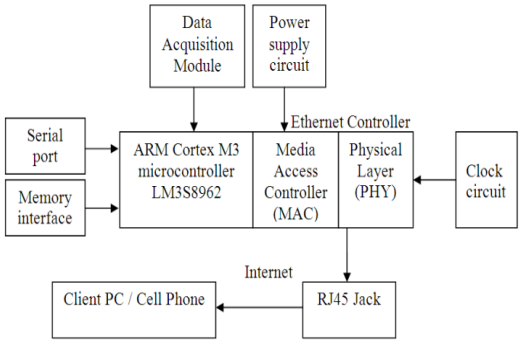

Fig 1: Schematic Diagram

In Cortex M3 microcontroller, the Ethernet controller is in-built. To initialize the access of internet, HTML is used to develop web pages for application layer. The µIP TCP/IP stack is used, which is open source, connects to the Stellar is Ware Application Programming Interface (API) and Ethernet. The Ethernet Application Programming Interface (API) provides the set of functions required to implement an interrupt-driven Ethernet driver for this Ethernet controller. The functions are provided to configure and control the MAC, to access the register set on the PHY, to transmit and receive Ethernet packets, and to configure and control the interrupts that are available. This driver is contained in Peripheral Driver Library. The files driverlib/ethernet.c, with driverlib/ethernet.h containing the API definitions is used by applications. The data flow for µIP TCP/IP stack is shown in fig 2 below.

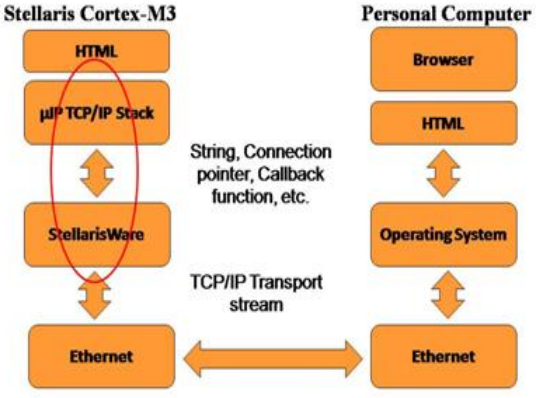

Fig 2: µIP TCP/IP stack flow

The µIP TCP/IP Stack flow shows the data processing by Stellaris Cortex M3 microcontroller and the command send through the internet from Personal Computer (PC). A user can send a control signal through the browser on PC. The browser accesses the web pages written in HTML language. Further the operating system of PC connected to the Ethernet controller sends data packets on internet. On the receiving end of web-controlled embedded system, the Ethernet controller receives the packets, decodes and processes the data to the StellarisWare. The µIP TCP/IP stack executes the various functions to process the data using the microcontroller. Depending on the commands received will perform read/write operations on various input/output devices connected on data acquisition modules.

III. ETHERNET DRIVER LIBRARY

To initialize the Ethernet functions in Cortex M3 microcontroller, following functions are used:

- Initialization
  - EthernetInitExpClk ()
  - EthernetPHYWrite (), EthernetPHYRead ()
  - EthernetConfigSet ()
  - EthernetMACAddrSet ()
  - EthernetEnable (), EthernetDisable ()
  - EthernetIntRegister ()
  - EthernetIntEnable ()
- Physical Layer (PHY)
  - EthernetPHYPowerOff (), EthernetPHYPowerOn ()
  - EthernetPHYRead (), EthernetPHYWrite ()
- Interrupt handler
  - EthernetIntStatus ()
  - EthernetIntClear ()
- Receive
  - EthernetPacketAvail ()
  - EthernetPacketGet ()
  - EthernetPacketGetNonblocking ()
- Transmit
  - EthernetPacketPutNonBlocking ()
  - EthernetPacketPut ()
  - EthernetPacketPutNonBlocking ()
  - EthernetSpaceAvail ()

IV. PROGRAMMING OF ETHERNET

The web-controlled embedded system uses the HTTP protocol to transmit Web pages from the embedded system to the web browser and to transmit the data back to the embedded system attached to the appliance. The embedded system requires a network interface, such as Ethernet, a TCP/IP protocol stack, embedded web controlled software and static and dynamic web pages that form the user interface for that specific device. When implementing the TCP/IP stack for microcontrollers, some features can be omitted depending on the specific application requirements. In order to serve wide range of application requirements while keeping the size compact, an embedded system should implement five basic protocols of the TCP/IP protocol suite: TCP, UDP, IP, ICMP and ARP. Moreover, application level protocols

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DHCP, DNS and HTTP should also be implemented. Users can interact with appliances by submitting data on the web pages. The data submitted on web page is processed by a CGI script and the results are returned back to the user as an HTML page. Appliances can be monitored and controlled by the command given on web pages directly. A device plugged into the network can receive its IP address and subnet mask either by dynamic host configuration protocol (DHCP) or Auto IP. If there is a DHCP server in the network, device is configured automatically by DHCP. On the other hand in Auto IP mechanism, the device randomly chooses an IP address from a reserved range and then sends out a request with address resolution protocol (ARP) to detect whether the IP address is used by another device. UPnP does not specify any security mechanism for access and control of UPnP devices. Security has to be provided by the applications or services. Security standards on lower networking layers such as SSL may be used to gain security.

V. POWER MANAGEMENT

The Cortex M3 microcontroller uses multiple power supply in the circuit. The external interfaces to various peripheral devices are TTL compatible (+5V tolerant). The Cortex M3 microcontroller is operating at Low-drop-out (LDO) 3.3V supply. The power saving modes, sleep mode and idle mode, operates at 2.7V and 1.8V/0.9V. Thus, using multiple power supply in the system, total power consumption of the Cortex M3 microcontroller based web-controlled embedded system is reduced to minimum level. The web-controlled embedded systems are normally in idle condition where minimum power is consumed by the system. The system will wake-up only when a request sent by a user from the web pages received. This awakening of the system is interrupt driven. Depending on the request send through the web pages, the Ethernet controller decodes and processes to initiate desired read/write operation in the embedded system. As per the status of the embedded system, an Ethernet packet is transmitted to the web pages and updates them.

VI. SYSTEM INTEGRATION

The World Wide Web controlled embedded system development requires to integrate each of the system components on a PCB. Assembling each component for specific application will be useful only if the system is designed for fix purpose. As the embedded system is continuously evolving, this method of integration is quite exhaustive as flexibility is common characteristics of an embedded system. Thus using a new method of integration of embedded system will enhance the flexibility in the development. The Arduino interface introduced in the embedded system will make us flexible to design different applications. The Arduino interface will have standard sizing of the system integrated on the board. Any further modification of modules will just add a new board compatible to the Arduino interface is stacked one over another board. The Arduino interface also enables to use of the off-the-shelf modules available in the market. The integration of the Arduino based interface is flexible to design multiple applications by using a standard microcontroller based circuit board and additional modules as Arduino interface. The application of embedded systems varies and easily can be designed by changing some of the data acquisition module and control systems. Thus enabling an Arduino interface in the embedded system will provide flexibility and also time-to-market.

VII. CONCLUSIONS

The Cortex M3 microcontroller having Ethernet controller on-chip makes it optimized solution for the web controlled embedded systems. Due to on-chip Ethernet controller, it reduces the system size, power consumption and less memory for programming (coding), as most of the Ethernet functions are hardware controlled. The multiple layers of Ethernet controller are reduced using Stellar is Ware API and initialized using Stellaris driver library functions. The multiple power supply used in the Cortex M3 based web-controlled embedded systems; the lowest power consumption is achieved in the system designing. It helps in long life uses of the embedded system as well as in-built Ethernet controller makes it wide usability in portable systems. The Arduino compatible interface will enhance the systems modification and will be used for multiple applications. The available off-the-shelf modules can be used in the embedded system development due to Arduino interface is stacking of boards one on another. Thus Arduino interface will make flexible system development and time-to-market.

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