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Research of DSP-based Embedded Systems Connected to the Internet

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Abstract

DSP as the core of the system with Ethernet interface hardware circuit and software design method is introduced. Introduce the working principle of the network controller RTL8019AS and the DSP hardware circuit design in detail. Achieve a simplified TCP/IP protocol stack software programming for the reception and transmission of packets in DSP. The system can transmit data to Ethernet according to the network processing protocol.

Keyword：DSP, Ethernet, TCP/IP protocol

1. Introduction

Embedded system permeates all aspects of the control field with high-speed development of information technology and network technology. People set an even higher demand on acquiring information quickly, economically and conveniently. At the same time, intelligent application of household appliances had become one of life styles which people were after. In application, how to monitor and operate household appliances by Internet had been a hot in information household appliances industry. At present, embedded network techniques whose core was embedded microprocessor and embedded operating system had applied in some field. The combination of embedded systems and Internet network will become a new direction in the field of control and become the main way to achieve remote control. Study shows that 95% of liaison equipments were not the traditional computers but the embedded system with the function of Internet by the end of 2011.

DSP chip as a special kind of embedded microprocessor system has embedded coprocessor and parallel data channels for fast data processing. Introduction of DSP technology in the embedded network devices, can make embedded Ethernet to become faster, cheaper, and easier to expand functionality. Combining with DSP technology and computer network technology, integrating network technology into the embedded systems with core of DSP, benefiting all kinds of equipment sharing network of huge information resources, the embedded device has incomparable superiority in the price and real time. DSP technology is more widely used in the network products development [2].

In this paper, a digital signal processor (DSP) and the Ethernet controller build intelligent access Ethernet, complete the Ethernet communication interface design, and embedded TCP / IP protocol in hardware platform.

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2. System Hardware Design

The design chooses DSP chip TMS32LF2407 as core processor. TMS320F2407 is a low-price, high-performance 16-bit fixed-point DSP chip. It is a superset of the TI TMS320LF240x series chip, the clock frequency reaches 30MHz (TMS320LF2407A to 40 MHz).

On-chip resources include: 2.5K RAM, 32K Flash, BOOT ROM, 16-channel, 10-bit A / D converter, 2 event handlers (including 16 16-bit PWM module, 4 16-bit general-purpose timers, 6 captureunits, etc.), external memory interface, watchdog module, SCI / SPI interface, CAN controller, PLL circuit, 40 general-purpose I / 0 ports, 5 external interrupt port [3].

Ethernet controller chip choose the RTL8019AS produced by Realtek. It main features are as follows: Adaptation in Ehtenret and IEEE802.3; support 8-bit or 16-bit data bus, compatible with NE2000 standard; built-SARM, for the send and receive buffer, reducing the speed of the host processor requirements; the full duplex transceiver can both achieve 10Mbps, avoid channel content conflict may be caused due to the CSMA/CD protocol.

The internal RAM of RTL8019AS is a dual port 16K bytes of RAM,two sets of bus link to the RAM. One network controller to read/write network card RAM which also called local DMA, another set of DSP read/write RAM on the card, also known as remote DMA. Local DAM complete data exchange between controller and cable, remote DMA is responsible for data transfer between the DSP and RAM, The main processor can receive and send data by operating remote DMA only. When it wants to send online data, the main processor send a data frame to buffer zone of RTL8019AS via remote DMA first, then transfer command. After MAC comparison, CRC check, FlFO stored the data to receive buffer. When a frame full, it notify the host processor by interrupt or register marks [4].

The whole system is divided into two parts of data processing and network control.

The data processing part of the DSP processor chip TMS320LF2407 is mainly responsible for the network card chip RTL8019AS to receive or transmit data for analysis, processing and storage. In the process of receiving or sending data, the DMA controller is triggered when the MCBSP buffer data is full。Then data transmission begins, complete work coordination between MCBSP and DMA. Show as Figure 1.

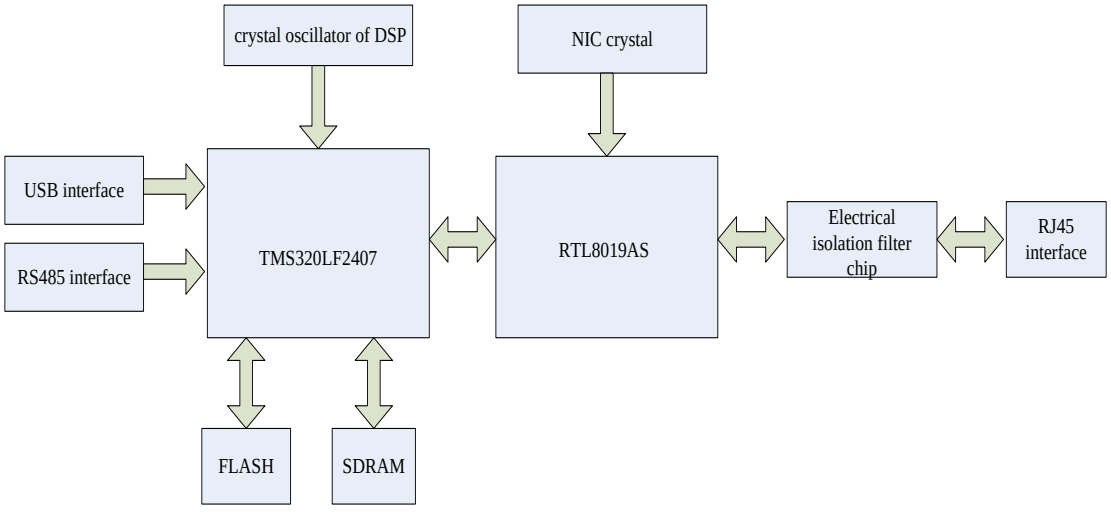

Figure 1. Block diagram of system hardware

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The network interface chip RTL8019AS of the network controlled part responsible for the reception and transmission of network data stream. In order to obtain a steady stream of data, prevent interference, electrical isolation filter chip is required between the chip card and external internet cable.

3. Various Scheme of Embedded System Link Internet

3.1 8 bit MCU + TCP/IP protocol chip

Because of running speed and memory space constraints, it's very difficult to implement TCP/IP protocol in 8-bit microcontrollers directly. In order to achieve communication with the Internet, the schemes suggest the 8-bit MCU with chips solidified the TCP / IP protocol application, applications can be directly connected to Internet, the hardware circuit is also relatively simple.

The advantage of this approach is that the 8 bit single chip microcomputer system is connected with the Internet directly. You can remote access microcontroller system use PC by Internet; also can send information to a remote PC or other terminal by use the SCM system through Internet. But system design is very difficult, software design work is also very large, design engineer should familiar with TCP / IP and other protocols and associated interfaces. In addition, as each embedded device needs an IP address, the current crisis of IP address depletion deepened.

3.2 8 MCU + light protocol + gateway

It is very difficult to implement TCP/IP protocol in 8 MCU, but it is relatively easy to implement a simple protocol RS232, RS485, *etc*... So we can use these protocols connect with a PC support by TCP / IP protocol or a high-performance MCU to achieve the final connection to the Internet. First, through the lightweight bus contact with multiple embedded equipment, forming a light network, and then the light network and gateway of this embedded system connection. Gateway uses PC or high-performance MCU, which runs on TCP / IP protocol and running HTTP service program, become a server remote user can access. So by adding only a gateway to solve the problem of embedded devices to access the Internet. Gateway can manage multiple embedded devices simultaneously, thereby enhancing the embedded network structure, intelligence, browse information resources normalization.

This approach can solve the problem low-speed microcontroller based embedded systems connected to the Internet. But the disadvantage is that the embedded computer must have a PC or high performance of the scheme as a gateway. Between the gateway and the embedded system, communication will be affected by the distance and the speed; each embedded system can not be directly connected to the Internet, low flexibility.

3.3 16/32 MCU + RTOS + TCP / IP protocol

The scheme has run real-time multitask operating system in high-speed 16/32 8-bit microcontroller, with real-time multitask operating system as the software platform, the implementation of TCP/IP protocol in real-time multitask operating system directly, so as to realize the embedded Internet. At present, many kinds of real-time multitask operating system in this regard, common Psos, Nucleus, Linux, Clinux, Win CE, *etc*... These operating systems come with a complete TCP/IP protocol stack, so there is nothing in the realization of technical difficulties [5]. Show as Figure 2.

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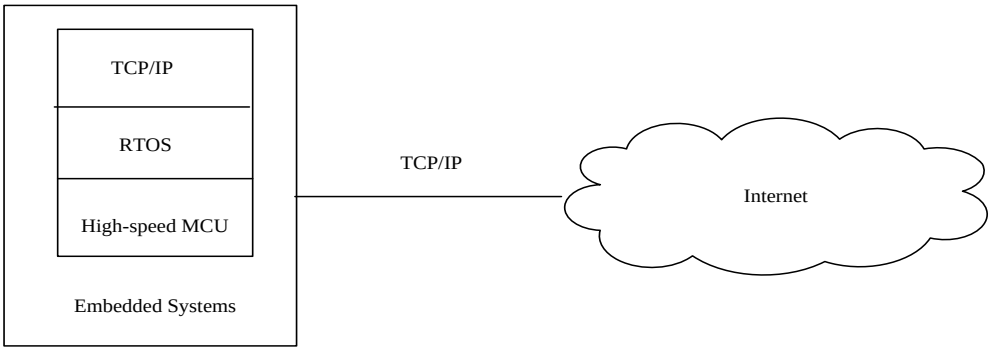

Figure 2. Scheme of 16/32 MCU + RTOS + TCP/IP protocol

The advantage of this scheme is to allow the various embedded systems connected to the Internet directly, have great flexibility, does not require a PC as a gateway. Disadvantage is that the TCP / IP protocol runs on real-time multi-tasking operating systems, the real-time multi-tasking operating system to run requires a large amount of processor resources and storage space, the hardware configuration also have minimum requirements. Most operating system can run the TCP / IP protocol stack has the basic requirements :at lest 16-bit processors, the processing speed is not too low, the storage space larger than 100K byte.For many low-rate, low profile 8-bit processor is difficult to achieve.

In the domestic and international research of embedded Internet, the manufacturer such as MOXA, CMX, Motorola, Nec all have the corresponding products.

3.4 8-bit MCU+ fieldbus protocol + 32-bit MCU

Distributed Control System (DCS) will gradually be replaced by fieldbus, so a lot of 8-bit MCU-based devices connected through CAN, LonWorks and other fieldbus. As the control center, by the high performance MCU, thus can realize the TCP/IP protocol in the MCU 32 high performance, access to the Internet, you can achieve the low-end MCU access Internet through the field bus. Show as Figure 3.

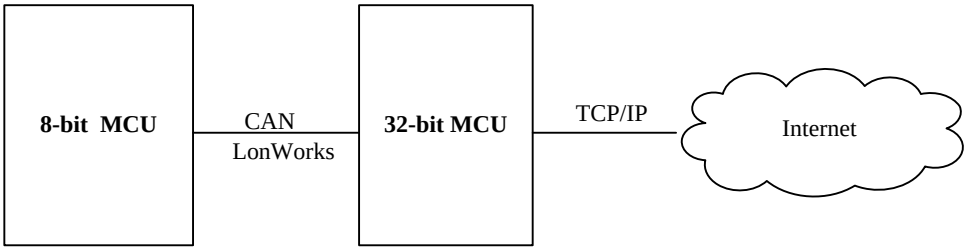

Figure 3. Scheme of 8 MCU + fieldbus + 32 MCU

The field bus can be connected to the Internet through a 32 bit MCU, almost need no extra work on the terminal equipment of distributed control system in this scheme [6].

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4. System Software Design

Embedded systems are dedicated systems designed to accomplish a specific function. Due to limited resources of embedded system with the DSP processor as core, the network protocol should cut based on the embedded application requirements to improve the real-time. This can ensure both DSP access Ethernet and meet the requirements of embedded system application. So embedded TCP / IP is a selection of four layers of the TCP/IP protocol family, including link layer, network layer, transport layer and application layer [7].

4.1 Implementation of TCP/IP protocol stack

TCP/IP protocol stack, including the network interface module, ARP module, IP module and UDP module, is realized by calling interface function of each layer. The network interface module includes RTL8019AS driver, buffer management and interface scheduling, provide interface functions for upper software.

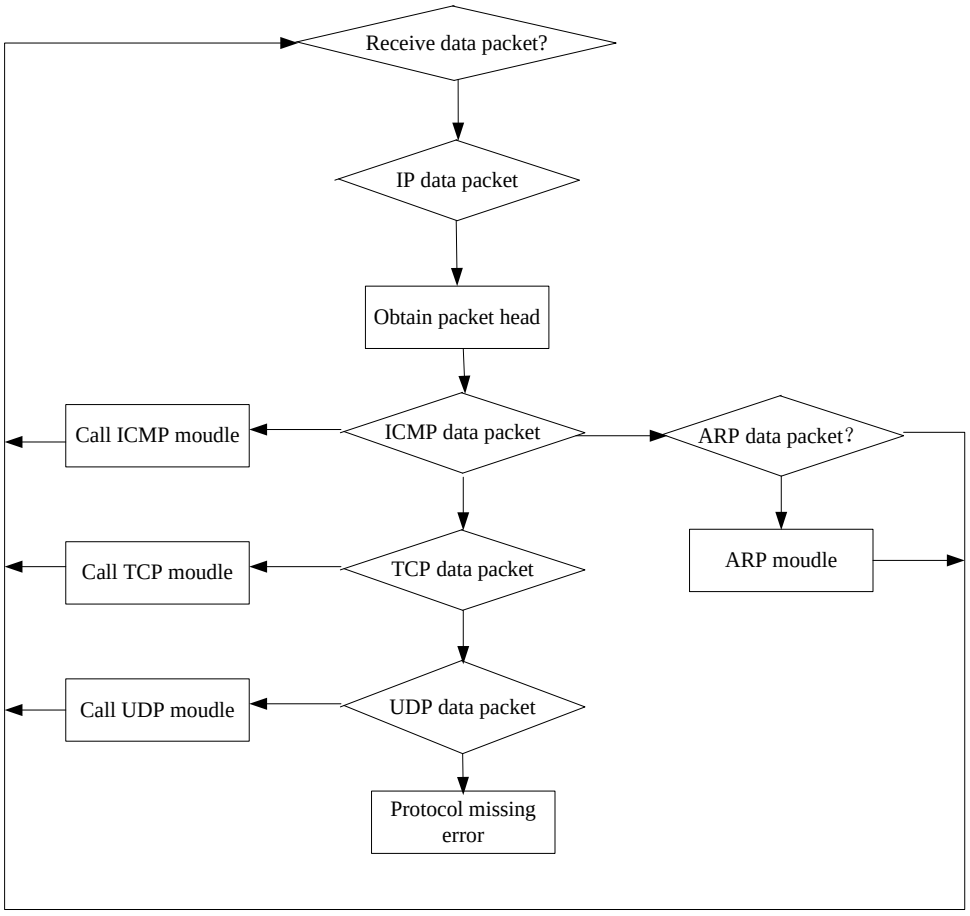

Figure 4. Flowchart of TCP/IP Protocol processing

The ARP module implements the mapping of the upper-layer protocols and the underlying hardware address. ARP module processes ARP data from the network [8]. Update and maintain the ARP cache, and provide the hardware address binding for data to be sent. The IP module receives input datagram from the network, at the same time also receives the output

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data from an upper layer protocol. UDP module provides unreliable data transfer function. It doesn't require buffer of the send data. Add the first UDP to data received by the application layer and send out directly. Compared to the TCP protocols, UDP has higher efficiency. The UDP protocol also doesn't affect transmission rate.

Input and output data flow process procedure of TCP/IP protocol show as Figure 4.

The incoming data packet is processed by the lower layer protocol firstly in input process procedure of protocol. Then passed to the corresponding upper-layer protocols respectively，according to the data of the different types [9]. After received datagram, the network interface layer determine whether the destination address is the same as the header of the Ethernet address. If consistent, then process.

Outputs datagram of ARP module is transmitted to the network interface module directly in protocols output process flow. There are to output of ARP: ARP response and ARP request [10]. On the other hand, UDP module add it's own header in the application data will be sent to the IP module. Then add IP header by IP module, transmit to network interface module to encapsulate Ethernet data, and output the data by the network interface layer.

4.2 Receive program design

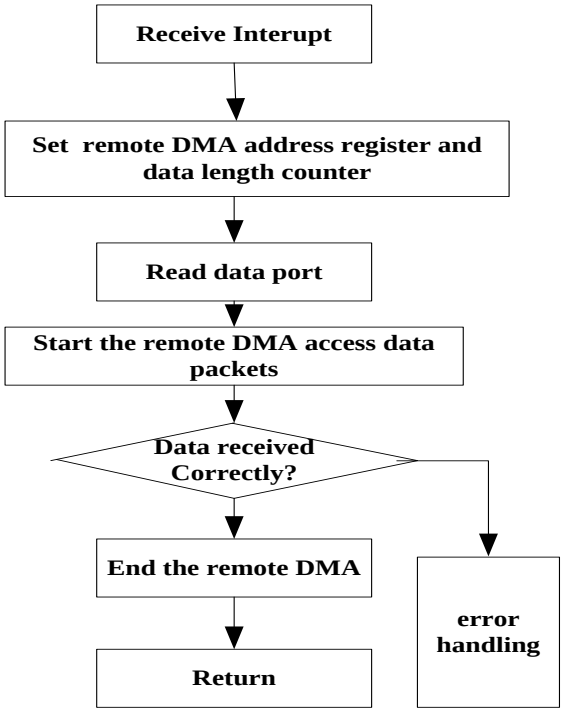

Figure 5. Data receiving process

The 8019AS receives data by interrupt mode. In order to improve the processing efficiency of the interrupt routine, when the data arrives in the network, network control chip RTL8019AS verifies CRC automatically, after receiving the first complete frame of Ethernet data packets. If the CRC error will discard the data and not send an interrupt request to the DSP. If the card correctly receives one data frame, the reception counter plus 1, and sends an interrupt request to DSP. After response card interrupt application, the DSP enter the interrupt service program begin to receive data. Data receiving process show as Figure 5.

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When the main program detected the NIC reception counter is greater than 0, it call data receiving program to read one data frame to the host from internal cache of network card. The frame receiving process consists of two steps: for the first step, store the frame to receive buffer by local DMA; for the second step, read the data from receive buffer to memory cache.

4.3 Data sending program design

NIC sends data need to wait the network card send state idle. In order to improve the efficiency of the implementation of the program, use the strategy of each cycle in the main loop of the program can send at most one data packet [6]. Data transmission process consists of three steps: encapsulation of the data packet; transmit data packets into network card send buffer through the remote DMA; transmit data into a FIFO by local DMA of network card, then send the data to transmission line by network card. Data transmission flow chart show in Figure 6.

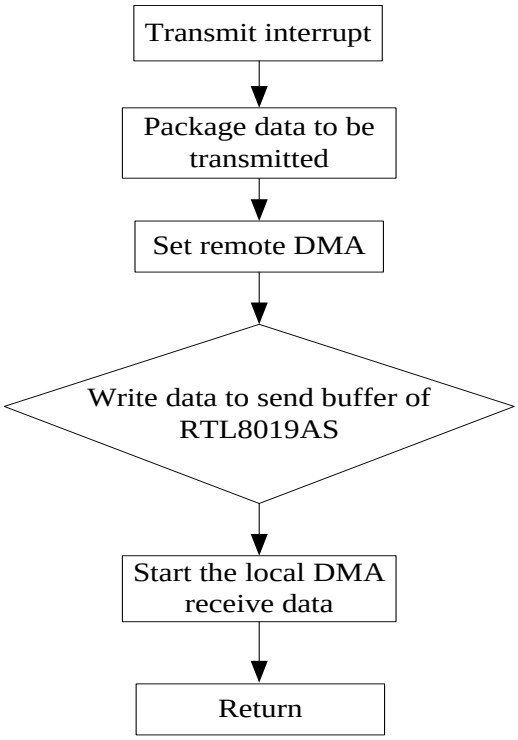

Figure 6. Data transmission flow chart

5. Conclusions

This design takes TMS32LF2407 as the core control component. The RTL8019AS card is well connected with the microprocessor. Data processed by this system can be sent directly to the Ethernet. The system not only take advantage of the powerful function of the network data transmission, but also combined with the flexibility of embedded systems. Due to powerful computational capabilities and network communication capabilities, the system can be applied in a variety of applications. Embedded Ethernet can be used not only in industrial field to realize the scene node surf the Internet automatically, but also can be used in Ethernet interface of information appliances, has broad market prospects.

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