DESIGN OF SINGLE-PHASE POWER METER BASED ON ETHERNET

Huimei Yuan [1,*], Yan Wang [1]

[1] *College of Information Engineering, Capital Normal University, Beijing, 100089, China*
[*] *Corresponding author, Address: College of Information Engineering, Capital Normal University, No. 56 Northern Road of Xisanhuan, Haidian District, Beijing, P. R. China, 100048. Tel: +86-10-68902762-230, Fax: +86-10-68416830, Email: yuanhmxxxy@263.net*

Abstract: According to the related technology about power meter, single-phase power meter based on Ethernet is designed and researched. Single-chip processor MC9S12NE64 is used as system's CPU and in charge of the system control and information processing. Power measurement chip CS5460A is applied to calculate electrical parameters. EMAC and EPHY modules which are MC9S12NE64's inter parts are adopted to accomplish Ethernet communication, and how to design Ethernet protocol and data processing are illuminated in detail. The system has realized real-time settlement of electric charge and other network-controlled functions such as power stoppage and supply. It overcomes current problems about electric charge's disagreement due to offline running of power meter. The power meter is mainly used in the environment where Internet network has been realized, and it is unnecessary to establish wired communication network in addition. Resources of network sharing can be achieved and cost can be saved greatly.   Keywords: Ethernet; single-phase power meter; single-chip processor; communication protocols, power measurement.

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1. INTRODUCTION

Current domestic market of the power meter is entering a stable period of development, but power meter still hold a large market capacity because of

resident's increased demand, power girds' reconstruction and external demand for export. At the same time, the functions of the power meter have became long life, high-precision, and multi-functional compared with the ordinary functions of original power meter (CHEN Chi-pei et al., 2002).

Traditional power meters usually use infrared and 485 serial transmission as their communication methods when it transcribes. Distance of the infrared communication is not more than 20 meters, but for 485 serial communications, it is required to lay cable separately. These traditional communication methods are time-consuming, laborious and unreliable (ZHU Xiao-hong et al., 2007; WANG Yue-zhi et al., 2007;SHA Zhan-you et al.2006).

With the wide use of the internet, technology of the computer and network develop rapidly, and all these impel the related technology become mature. The Ethernet technology is widely used in various computer networks in order to join the different network equipments with each other. The equipment-control technology based on Ethernet develops more rapidly, and it has a deep impact on instrument industry. So, there appears a strong tendency of the network instruments.

In recent years, the related research about the network power meter has been done by many (LI Wei-dong et al., 2000; ZHOU Yao-yi et al., 1999), and how to realize it has been discussed in these papers. However, these researches are basically concentrated on the possibility of achieving it with laboratory network communication technology. Some researches such as cost constraints, anti-jamming capability and the choice of the whole system scheme are not done deeply, and the practical significance is not enough.

With the requirements of communications network, there exist too many problems to deal it with 8-bit microcontrollers which are the mainstream MCU products (DU Qiong et al., 2005). Now, ARM32-bit microprocessor is very common on the market, it's network function is so strong that it can meet requirements of network-based instruments. But as a commercial chip, ARM32-bit microprocessor takes too many market factors into account, so it integrated many on-chip and out-chip equipments(GUO Shu-jun et al., 2004), some of them are unnecessary, and it is unreasonable for consumers to pay for these additional costs .On the other side, for Ethernet network communications, ARM32-bit microprocessor need external related devices such as Ethernet Token ring physical layer protocol/ Media Access Control (PHY/ MAC) Control Chip, network electromagnetism transformer, RJ45 and so on. The further cost is unacceptable for users.

According to the problems above, the single-phase power meter based on Ethernet is designed and researched in this paper, so that the power meter's network can de realized. The power meter is faced to the environment where the internet connection has been achieved, so that establishing the wired communication again can be avoided, resources of network sharing can be achieved, and cost can be saved greatly too.

2. DESIGN OF HARDWARE EQUIPMENTS

Block diagram of single-phase power meter based on 16 bits single chip MC9S12NE64(freescale semiconductor,2004) has been put forward in this paper. If methods of wires connecting in the hardware and the corresponding program modules in the system are adjusted, the block diagram can be applied to the design of three-phase power meter too.

The block diagram of single-phase power meter's hardware system based on Ethernet is showed in Fig.1
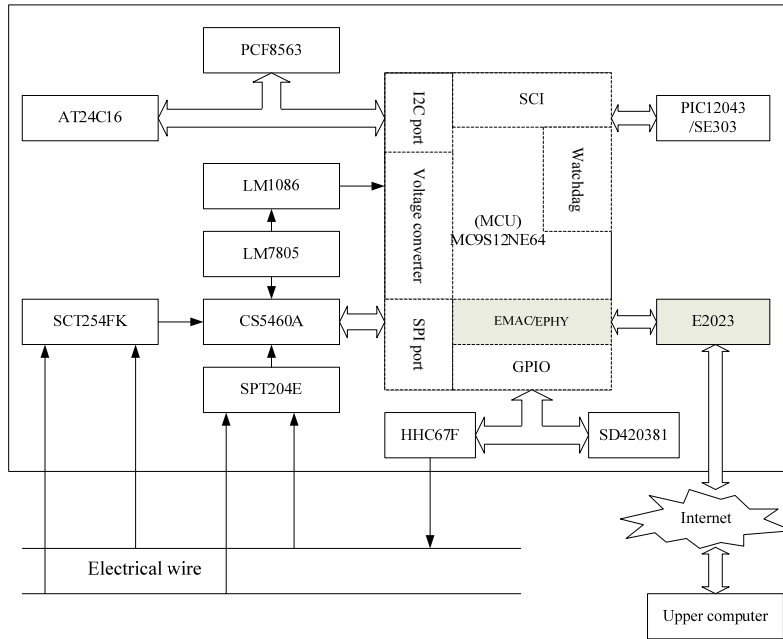

Fig.1: block diagram of hardware

In our system, single-chip processor MC9S12NE64 is used as the system's CPU and in charge of the system's control and information's process.

LM7805 is used to stable 5V DC voltage produced by transformer and supply power to CS5460A. LM7805's output is connected to the input of LM1086, whose function is transforming 5V DC voltage to 3.3V DC voltage to provide MC9S12NE64 with working voltage.

Voltage from electrical wire is transformed to small current signal and small voltage signal through current transducer SCT254FK and voltage transducer SPT204E, then power measurement chip CS5460A(HUAN Ling et al. 2002; GUO Song-lin et al. 2002; LIAN Xiao-qin et al.2005; ZHU Yun et al.2004; WANG Yi-jun et al.2001) takes charge of calculating all kinds of

parameters such as the effective values of voltage and current, values of active power, reactive power and apparent power, values of active energy, reactive energy and apparent energy with these signals. MC9S12NE64 can read all parameters calculated by CS5460A through Serial Peripheral Interface (SPI) and process them with software. These parameters are stored in EEPROM chip AT24C16 by I2C bus and exported to the LED or LCD module by general pin input and output（GPIO）in order to shown, and whether energy power is send by relay HHC67F is determined by operating conditions. In our design, the special power meter nixietube-SD420381 which is made by Wuxi Ark Technology Electronic Co., Ltd. is used as LED module. Real time chip PCF8563 is used to provide reference time to system by IIC bus pin SCL and SDA. The system mainly communicates with the upper computer through Ethernet. When these communicate method do not work, workers should take advantage of infrared communication to read meter and check it in order to recover the communication. In our design, infrared communication module is composed of infrared transmitting tube SE303 and infrared receiving tube PIC12043.

MC9S12NE64 contains internal module of Ethernet Media Access Controller (MAC)and Ethernet Physical Layer (EPHY)(LI Wei-dong et al., 2000), so its Ethernet interfaces to the outside just need electromagnetic isolation transformer(in our design E202 is selected), RJ45,resistance and capacitance. The internal EPHY module can also be replaced by exterior PHY chip, but doing that not only adds cost of the system, increases area of PCB but also influences the system's stability. The hardware diagram of communication circuit which uses internal EMAC and EPHY module is shown in Fig.2.

In Fig.2, PHY_RXP and PHY_RXN are positive and negative pins in MC9S12NE64 for Ethernet communications to transmit differential signals, while PHY_TXP and PHY_TXN are positive and negative pins to receive differential signals. The internal electromagnetic isolation transformer have 8 signal wires followed as J1….J8, in which J1 and J2 are the positive and negative pins separately to transmit differential signal, J3 and J6 are the positive and negative pins separately to receive differential signal, and other four signal wires are unused.

In Ethernet communications, data transmitted by MC9S12NE64 are transformed into differential level signal and then delivered by PHY_TXP and PHY_TXN, and they are sent into internet by J1 and J2 after passing internal electromagnetic isolation transformer of RJ45. When received, the data on internet enter J3 and J6 of RJ45 as the differential signal data, and they are sent to PHY_RXP and PHY_RXP of MC9S12NE64 after passing through electromagnetic isolation transformer, at last they are received by EPHY of MC9S12NE64.
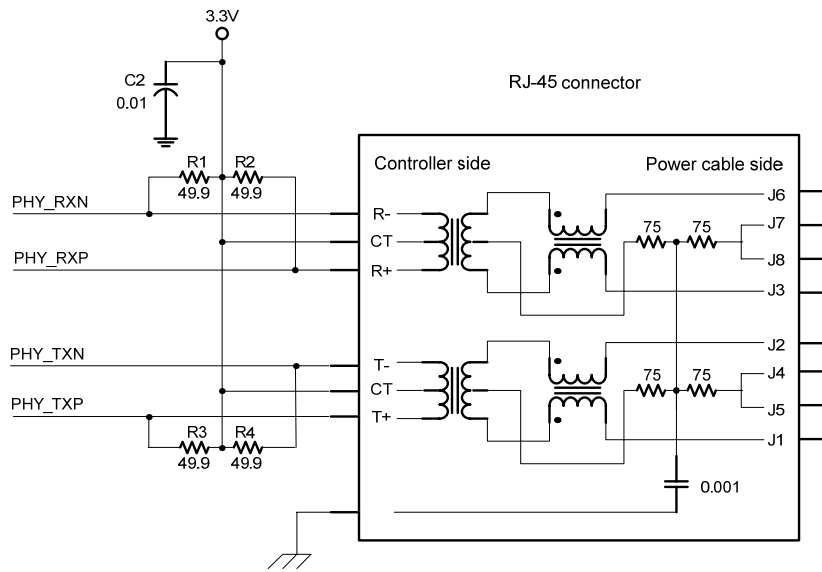
Fig.2: Circuit diagram of Ethernet communication

3. DESIGN OF ETHERNET PROTOCOL

On the basis of realization of hardware equipment, the functions of Ethernet communications should be as: responding to the ping request of upper computer on internet, so as to inform upper computer that network connection is normal; accomplishing the communication with upper computer, including timing proof requisition of upper computer, request of transmitting electro-parameter data and requisition of current failure.

According to system requirements, Ethernet communications only need to accomplish parts of transmission control protocol/internet protocol (TCP/IP)l stack, such as Address Resolution Protocol(ARP),IP, Internet Control Message Protocol (ICMP)and User Datagram Protocol (UDP).It is enough to finish the system. TCP is not selected because it is more complicated than UDP and its realization occupies too many resources. By contrast, UDP is simpler and requires fewer resources. Although reliability of the data transmitted by UCP is uncertain, it can be vouched by upper software. At the same time, considering functions of the whole system and limitation of hardware resources, project of transplant Embedded Operating System is not adopted too.

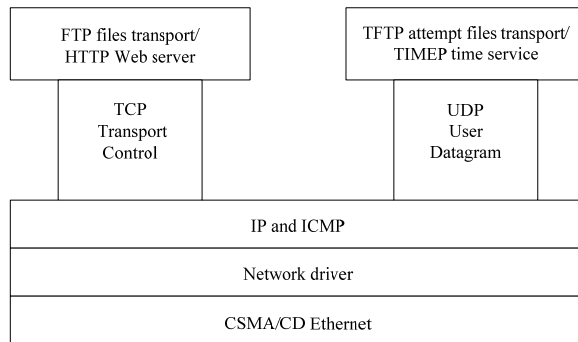Structure of TCP/IP protocol stack in our design is shown in Fig.3.

FTP files transport/ HTTP Web server		TFTP attempt files transport/ TIMEP time service	
TCP Transport Control		UDP User Datagram	
IP and ICMP			
Network driver			
CSMA/CD Ethernet			

Fig.3: structure of TCP/IP protocol stack

When system begins, it must complete initialization of Ethernet communication, which is the most necessary work of communication. These works include initial configurations such as address of EMAC、EPHY module, size of receiving and transmitting buffer, data type of communication, and enable of interrupt mode. After initialization, the system comes into the state of waiting for receiving information.

When system receives request for receiving interruption, the program judges and handles the data transmitted by Ethernet. If received data are true, the system will begin to analyze them.

If received data is ARP frame, the system will judge whether the other side is searching for it. If the answer is right, ARP response sign will be established and interruption will be quitted, otherwise, this frame will be discarded and interruption will be quitted. If received data is IP frame, the system will continue to judge if it is ICMP datagram or UDP datagram.

The system only needs the simplest Ping function to test condition of the network. If received data is ICMP datagram, the system will judge if it is Ping requisition or not. If the answer is right, Ping response sign will be established. Otherwise, if the checkout is incorrect, this frame will be discarded, error sign will be established and interruption will be quitted.

If received data is UDP datagram, the system will check it. If checkout is wrong, error sign will be established and interruption will be quitted. If checkout is right, data will be read into EMS memory, corresponding signs will be set up for the master program to deal with, and then the system will be quitted.

Transmitted data of Ethernet communications in the system are carried out in master program. When corresponding signs are read by master program, the data will be dealt with according to them. If the sign is ARP responses sign, the corresponding data frames will be sent out by EMAC and EPHY; If the sign is Ping responses sign, a response frame will be sent out; If the sign is UDP datagram and it's function is to inform the system adjusting time, register settings of the timepiece chip PCF8563 are amended according to

the time received; If the sign is UDP datagram and it's function is to inform the system sending electrical parameters of local user to upper computer of network, the system will transmit power consumption of this month and last month, peak value voltage and current.

The transmitted data need to be packaged in the format of all kinds of protocol frames. If needed, some padding bytes and Cyclic Redundancy Check (CRC) should be added.

4. DESIGN OF DATA PROCESSING MODULE

After the power meter terminal receives interruption of Ethernet communications, it will finish request of upper computer by inquiring all signs in master program, so that it could accomplish these functions such as response、timing, tariff readjust, transmission of electrical parameters (power consumption, peak value of voltage and current and so on) and power-off while communication network is connective.

Master program read the sign named EtherFlag which is produced by Ethernet communications circularly. If the sign is zero, it means that Ethernet request of upper computer have not been received, and then master program will jump over other signs produced by Ethernet communications. If the sign is '1', it means that request have been received, and then master program will judge whether it is Ping request whose sign named PingFlag, ARP request whose sign named ArpFlag, system timing request whose sign named TimeFlag, electrical parameters transmission request whose sign named ElecFlag or power on/off request whose sign named RelayFlag/Relay1Flag. If one of them is set to 1, it means that upper computer has produced request, and then master program will call corresponding functions to meet the request and clear the sign at the same time. The respondent data will be packaged into corresponding format of data frames and sent out by Ethernet, and then EtherFlag sign will be cleared to zero in order to prepare for accepting the next Ethernet communications request of upper computer.

After this Ethernet communications is achieved, master program will continue to check the other signs or to complete display function of the system.

The system also set up the infrared communication to avoid communication broken and guarantee normal communication. If the power meter unable to connect with Ethernet, worker could go to local to gather data and recover Ethernet communications network in time.

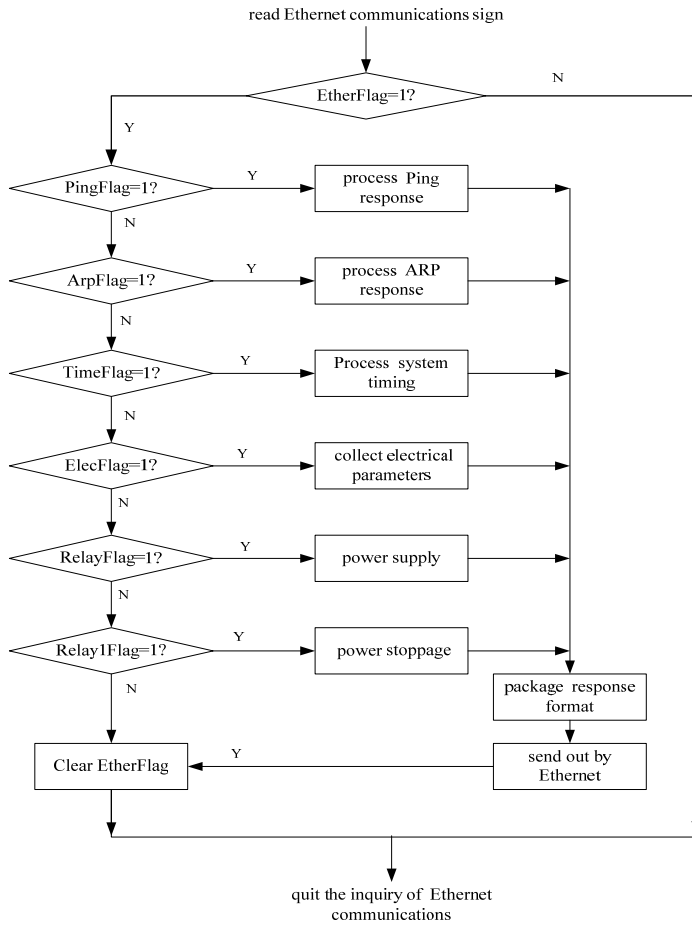Fig.4 shows data processing of Ethernet communication in the master program.

Fig.4: flow of data processing

5. CONCLUSIONS

The single-phase power meter based on Ethernet is a digital power meter with Ethernet interface and communication protocols. A network power meter based on 16 bits single-chip is designed in this paper, and how to design the hardware configuration, Ethernet protocol and data processing module of the meter have been illustrated in detail. The system has realized real-time settlement of electric charge and other network-controlled functions such as power stoppage and supply. It overcomes current problems about electric charge's disagreement due to offline running of power meter. The power meter is mainly used in the environment where Internet network

has been realized, and it is unnecessary to establish wired communication network in addition.

If this kind of power meter is used in power grid, resources of network sharing can be achieved and cost can be saved greatly, so the system has good practical value.

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