A LOW-COST HOME AUTOMATION SYSTEM BASED ON POWER-LINE COMMUNICATION LINKS

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Abstract: This paper presents a practical, cost-effective intelligent home system based on power line communication (PLC).PLC has become a viable local area network (LAN) solution for in-home networks. PLC has been a very important interdisciplinary topic for power, communications, industrial, and automation engineers and researchers since the 1980s Because of the implementation of PLC technology; no rewiring is required, thus making the installation of such system simple, low-cost and efficient, which is favorable for the popularization of intelligent home. Power line Communication for home appliances using Network Protocol is a prototype that enables to implement an electrical device switch control through the domestic power line. Smart Home is simply, high technology home with developed control and self control facilities, shortly, it's a living house

IndexTerms - **Power line communication, Amplitude-shift keying, Home Automation system, Microcontroller, Power Line Modem**

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I.INTRODUCTION

Nowadays, there is an increasing demand for power monitoring and control through home networks for electric home appliances. The most widespread methods today are RS-232 hardware, IP-based device and radio frequency (RF) or Bluetooth technologies. However, the implementation of the named home power management requires new wiring for both networked electric home appliances and home networks. For this reason, new methods have been intensively investigated, one of them being the use of power lines.

The idea to use power lines to data transfer is relatively old. The first tests were made 20 years ago, but the principles were described as early as the first half of the 20th century. The data transfer via power lines can be used in computer areas, building automation or industrial automation. The mentioned technology brings a lot of advantages. The main advantage of this technology is the use of installed power cable for data transfer, so there is no need to install data cable. On the other hand, the system for data transfer is very sensitive to a signal noise. Power line communication refers to the technology that transmits data, video and audio information on common power line, which supports both low-speed and high-speed transmission. Power line communication, which was applied to intermediate and low voltage communication initially, has unique advantages on network installation as it can transmit AC power and information simultaneously.

As a medium of transmission, there is an inevitable drawback for power line because of the electromagnetic noise and the variable loads, which can significantly affect the quality of transmission. On the power line channel, there are different kinds of noise, such as narrowband noise, pulse noise, background noise, etc. Within wide range of frequencies, the power of noise differs, that low frequency noise has high power and high frequency noise has low power.

As the frequency increases, the power of noise decreases exponentially. Moreover, there are multi-direction effect and time-variation on power line channel, which would cause obstruction and interference, and lead to asynchrony of carrier transmission. Because of the severe selectivity of frequency and long-term fading of signals, it is important to restrain noise and adopt suitable modulation and demodulation Technique for high-quality transmission in power line communication.

Power line Communication for home appliances is a prototype that enables to implement an electrical device switch control through the domestic power line. The main controller is a programmable microcontroller integrated to the PLC.Graphical user interface (GUI) using Microsoft Visual Basic 6.0 software is used as a switch to control electrical devices connected to power line. The devices are composed of the microcontrollers and their mutual communication via power line is provided by TDA5051AT modem. Network protocol is designed for communication with power line.

II. THE STRUCTURE OF INTELLIGENT HOME

The system consists of a master unit connected to PC and at least a slave unit (fig.1) [1]. At each unit there is an integrated modem. User can choose the unit and the function what he/she wants to do by the Visual Basic GUI. User's desire is sent to the master unit over RS-232. The microcontroller at the master unit sends control packets to the line by the help of the modem. Modems at slave units, that observe the line continuously, determine whether the packet belongs to them or not by microcontrollers. Owner of the packet receives the packet and does the function user wants.
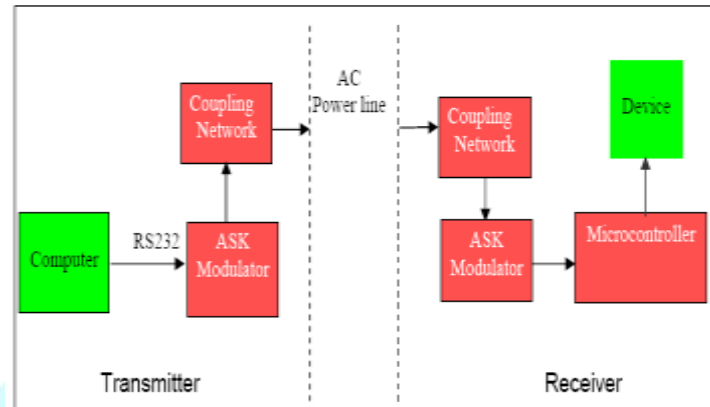

Figure 1. Block diagram of home automation system via power line

III. CONTROL CIRCUITS

In the system, master and slave units consist of microcontroller and modem in basic.

A. MICROCONTROLLER

Digital control signal is send by computer to the power line modem at the transmission end. Then at the receiving end power line modem will demodulate the analog signal to the same digital signal that has been send by computer. At the receiving end, controller will be connected to receiving modem. Controller will retrieve digital data from the receiving modem and process this data accordingly depend on the digital data. This data may be instruction for the controller to turn on or off devices that connected to it. This is the function of controller in power line communication system.

To reduce the cost of the system, AT89C51 microcontroller made by ATMEL will be used in this system. This application doesn't require more advance controller because there is no data logging applications in this system; only devices are control in two state conditions whether on state or off state.

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4 Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM) [4]. The device is manufactured using Atmel's high density nonvolatile memory technology and is compatible with the industry standard MCS-51TM instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly flexible and cost effective solution to many embedded control applications.

B. POWER LINE COMMUNICATION MODEM

A modem is a device that modulates an analog carrier signal to encode digital information, and also demodulates such a carrier signal to decode the transmitted information. The goal is to produce a signal that can be transmitted easily and decoded to reproduce the original signal digital data. Power line modem operates in the same manner as mention above. At the transmission end, power line modem modulates the digital signal from data signal through RS-232 interface onto the carrier signal in the power line. At the receiving end, the modem recovers the data from the power line carrier signal by demodulation and sends the data to controller or data terminal.

TDA5051A is a 16 pin integrated modem produced by PHILIPS. It is designed to control electrical appliances in the house by supplying data transmission on the electrical line [3]. It can sends and receives data so it works in full duplex mode. Modem uses ASK (Amplitude Shift Keying) modulation technique. TDA5051A has 8 bit analog to digital converter, band pass filter, 6 bit digital to analog converter, digital demodulator, automatic gain control (AGC) at signal input and over load protection at signal output(fig.2). It has minimum 600 baud and maximum 1200 baud data transmission rate [3].

Fig.2 TDA5051A Functional Circuit Diagram

Generally, the applications of TDA5051A are for home appliance control, energy, heating control and also for ASK data transmission using home power network. It is an ASK modulator and demodulator which responsible of full digital carrier generation and shaping. Its digital demodulation delivers baseband data. The high clock rate of 6-bit Digital to analog converter rejects aliasing components and it has narrow digital filtering. These ensure low bit error rate. It has fully integrated output power stage with overload protection. This chip can operate at any lower oscillator frequency. The specification of this chip follows the industry standard and standard for signaling on low-voltage electrical installations in the frequency range 3 kHz to 148.5 kHz.

Low cost application circuit of TDA5051A is shown in Fig. 3[3]. TDA5051A operates in three modes; transmission, reception and power-down (sleep) mode. In transmission mode, the carrier signal is generated by scanning the ROM memory under the control of the on-chip oscillator of the modem. The frequency of the carrier signal is equal to 1/64 of crystal's frequency. Therefore, to produce 120 KHz signal in X10 protocol we need 7.680 MHz crystal.

Produced carrier signal is converted to analog signal by digital to analog converter, amplified and then sent to the line by TXOUT pin. In reception mode, the analog signal received by RXIN pin, is amplified, converted to digital by analog to digital converter, unwanted signals are filtered by digital band-pass filter , passed through demodulator and finally signal is at DATAOUT pin. In sleep mode, controlled with PD pin, power consumption is minimum when pin PD is high. In this mode, all functions are disabled, except clock generation

Fig.3 Low cost application circuit of TDA5051A

T 630 mA fuse and 250 V (AC) Metal Oxide Varistor (MOV) are used to protect all the components during power surge. Coupling network consists of one 47 nF/X2 250 V (AC) capacitor, one 47 nF (63 V) capacitor and two 47 µH inductor. SA5.0A zener diode is used to protect voltage sensitive components from high voltage and high energy transients.

IV. NETWORK PROTOCOL DESIGN

By taking into considerations the nature of PLC, a network protocol is designed. This network protocol is specially designed for home automation system. The details of this network protocol will be discussed in the following sections.

A. Simplex multinode communication

The network protocol adapts simplex multinode communication. In this home automation system, master-slave relation and star network topology are used. Therefore, one-way communication can be implemented. The main controlling unit will be the one, transmitting the packets, while the client units will only receive the packets. The main controller needs no response from client units.

In multinode communication, network protocol supports more than one node in the network. It is not a one-to-one master-slave relation. There can be more than one slave in this case.

B. Frame format

A packet contains six bytes of data. The frame format is shown in Figure 4. The first byte is the start byte which will indicate the start of the sent data. Client units will start to receive data after it senses start byte. Next four Bytes are address fields (Microcontroller address, Device address).Last byte is stop byte which will indicate the end of the sent data.

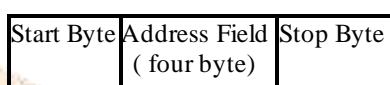| Start Byte	Address Field (four byte)	Stop Byte

Fig.4 Frame Format

Address field is of four bytes, out of which two bytes are used for microcontroller addressing and remaining two bytes for device addressing.

V. METHODOLOGY

The system operates in the following sequences:
1. Computer sends command to PLC modem using
Serial communication when button on GUI is pressed.
2. PLC modem modulate the data and send through mains power line using ASK modulation.
3. Then, at the receiving end, PLC modem receive the data and demodulate it back from ASK signal to serial signal.
4. Microcontroller receives the signal and turn on or off devices depends on the signal received.
This system can be implemented in two major part, namely software and hardware implementations.

A. Software implementation

In software implementation, it is mainly the Programming of AT89C51 microcontroller. The microcontroller, as the 'brain' of the system, is responsible of processing network protocol, which consists of transmitting packets and receiving packets. Besides, the microcontroller will also do the job of receiving users' inputs and executing commands.

B. Hardware implementation

Hardware implementation involves the circuit design of home automation system prototype. There are two types of circuits in this system. One is for the main controlling unit while the other is for client units. The amplitude shift keying (ASK) modulation is carried out using Philips TDA5051A ASK modem .The main controlling unit and client units have the same schematic for ASK modem.

V. CONCLUSION

Home automation or Smart House is developing Technology. Power Line Communication (PLC) aims at exploiting the power supply line to send/receive information without using separate dedicated wires. Power line technology offers an inexpensive and easy to install communication access technology which will cover a very large area of network

Using microcontrollers in control units for data processing and TDA5051A integrated modem for data transmission on the line, make control units low cost, smart, and small sized simple structured.Because of user control on master side, the system is easily settable and controllable. The main problem encountered on data transmission over the line is noise. Modem uses coupler circuit on sides connected to line, and all these properties help to decrease the effects of noise and to increase the trust of the data on receiver side.

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