

## MICROCONTROLLER BASED HOME AUTOMATION

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### ABSTRACT

The Smart Home Technology, which makes home, business and family trio closer, is one of useful and new technologies of our century. Today, lots of big firms over the world continue R&D and production activities on smart home appliances that are basic parts of the smart home. Smart Home is simply, high technology home with developed control and self control facilities, shortly, it's a living house. Smart Home communicates us continuously and performs duties according to commands taken from us.

In this study, a home automation model implementation which is user controlled and actable according to environment conditions is realized as an application of Smart Home.

### 1. INTRODUCTION

As an answer to the increasing effect of the information technology, people's expectations in their life fields are developing. People want their houses to make their lives easier, answer their necessities, and offer more safety, more comfortable and more economical life. The adaptation of control systems used in industry field to life field created home technology concept. The system which is designed form of the home technology according to personal necessities and wishes is called Home Automation. So, Smart Home ideal means a house which is in contact with us continuously with developed control units is reached.

The most common used standards in Smart Home design are; CEBus, LonWorks and X10 [1]. X10 standard uses PLC (Power line carrier) technology. It sends control messages on the line when the voltage level of the power is zero. X10 doesn't need extra cabling, because it uses existing electrical line system in the house [2].

In this study, X10 standard, which is more flexible more understandable and more common, among others, is chosen as basis. Besides, it is preferred to reach the aim of this study reducing cabling for control process to minimum.

In the control circuits which are backbones of this study integrated modems are used that send and receive X10 codes on the line. These modems supply communication on the line. The system consists of master and slave control units. Master unit is connected to the PC. User can control appliances connected to slave units by using a GUI created with Visual Basic Program.

### 2.1 SYSTEM'S GENERAL STRUCTURE

The system consists of a master unit connected to PC and at least a slave unit. 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 in X10 standard 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.

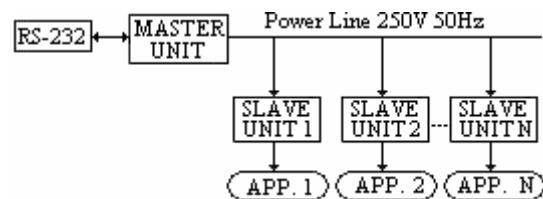


Fig.1. System's General Structure

In X10 protocol, there are 16 house codes and 16 unit codes. With combinations of these codes 256 units can be controlled. Slave units are set to desired house and unit code by switches.

A small system risk is present when communicating on power lines. Control signals can pass to neighbor's electrical system. But data signals are weakened by the distance and the electric meter to a level under threshold of the modem. A simple solution is to use different house codes in neighboring houses. Another solution is to use blocking coupler or signal attenuator [3]. And this risk can be removed by using security code in the software.

## 2.2 CONTROL CIRCUITS

In the system, master and slave units consist of microcontroller and modem in basic. Other components on units are auxiliary components.

### 2.2.1 MICROCONTROLLER

Microcontroller is the embedded chip form of RAM and I/O that are basic parts of a computer. Today, microcontroller is used in cameras, automobiles, TV's, cellular phones, toys, radios and many similar areas. Microcontroller is preferred because of speed, small size, reduced instruction set, serial port control over 2 pins, interrupt control, internal timer, and re-programmable flash memory properties. PIC's (Peripheral Interface Controller) are the most popular and common used microcontrollers produced by Microchip firm. PIC has easy understandable and small sized instruction set because it's produced with RISC (Reduced Instruction Set Computer) architecture.

In this study, the idea of realizing an application with low-cost and low-power consumption in small sizes by the help of all properties given above is the reason of why we have chosen PIC.

Microcontrollers preferred for master and slave units are PIC16F877 and PIC16F628 in the order. The difference is caused from properties needed as I/O pin number, RAM

capacity, internal timer number etc. for construction of circuits. PIC used to detect zero-crossings and 120 KHz X10 carrier signal on the line in this study.

PIC16F877 that is used in the master unit can communicate on COM port of PC by using only 2 pins RD and WR. Signal levels received from COM port are; +3V~+25V for logic 0 and -3V~-25V for logic 1 [4]. Typical voltages used are  $\pm 10V$  and  $\pm 12V$  and these values are not suitable for PIC which uses TTL inputs. MAX232 is the most used RS232 driver for connection of PIC to the COM port. It converts serial port signal at level  $\pm 12V$  to TTL (+5V, 0V) level and TTL signal level to  $\pm 12V$  level. In Fig. 2. Pin diagram of PIC 16F628 and in Fig. 3. the connection of PIC16F877 to COM port via MAX232 are shown.

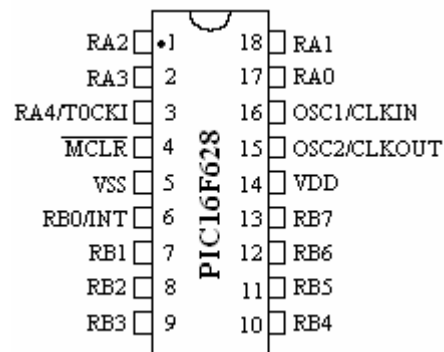


Fig. 2. Pin Diagram of PIC16F628

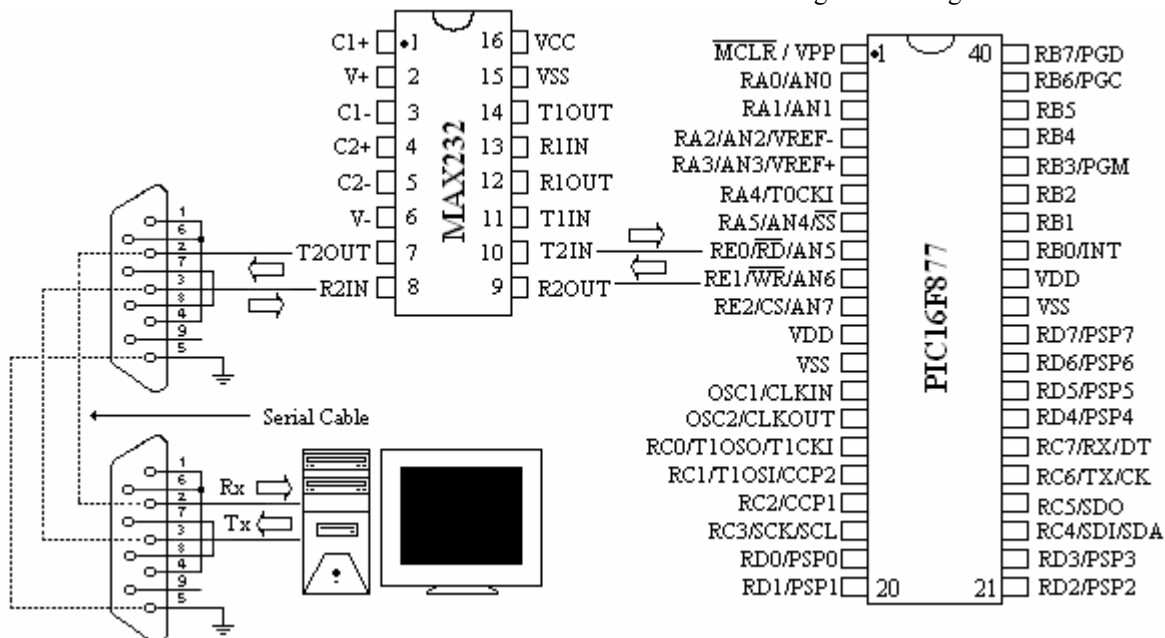


Fig. 3. Connection of PIC to COM port via MAX232

### 2.2.2 MODEM

PLC (Power Line Carrier) technology is based on the principle of controlling each unit connected to an electrical socket by using the existing power line in the house. Electrical line is an analog environment and a translator unit is needed to make data communication on it. This unit must be a modem which modulates the digital data to analog at sender side and demodulate it to digital at receiver side. In this study, an integrated modem is used to supply communication between microcontrollers in the master unit and slave units.

In the market, there are some kinds of integrated modems that can be used in home automation project; ST7537 (ST Microelectronics), LM1893 (National Semiconductor) and TDA5051A (Philips). Modulation techniques used by these modems are different. ST7537 and LM1893 use FSK (Frequency Shift Keying) technique and data communication is more protected from the effect of the noise on the line than ASK (Amplitude Shift Keying) technique [5]. TDA5051A uses ASK.

In this study, TDA5051A integrated modem is chosen, because it is small, it uses less external components, it has low price and it can be found easily.

#### 2.2.2.1 TDA5051A

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. It can send and receive data so it works in full duplex mode. Modem uses ASK (Amplitude Shift Keying) modulation technique. Binary data modulation with ASK technique is shown below.

$$a(t) = \begin{cases} A \cos(2\pi ft) & \text{Binary 1} \\ 0 & \text{Binary 0} \end{cases}$$

In this modulation technique, the amplitude of the modulation signal is "0" for binary 0, and it is equal to the amplitude of the carrier signal for binary 1.

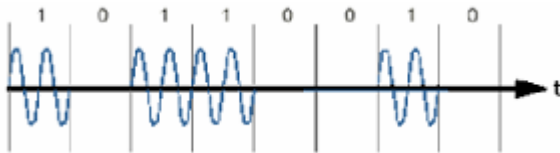


Fig. 4. Amplitude Shift Keying

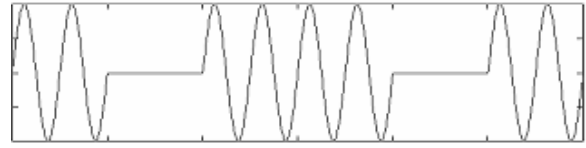


Fig. 5. ASK signal of data '101101'

ASK is also called as on-off keying because of this property.

In X10 protocol, control message consists of totally 13 bits and a 1 bit data is sent to the line when 220V 50 Hz residential voltage is zero. If the data is binary 1, a 120 KHz 1 ms burst is put on the sinusoidal wave of the line. If the data is binary 0 no signal is put on the line. This data transmission property of X10 protocol is fit data transmission property of TDA5051A that uses ASK modulation technique. In this study, this is another reason of why this modem is chosen.

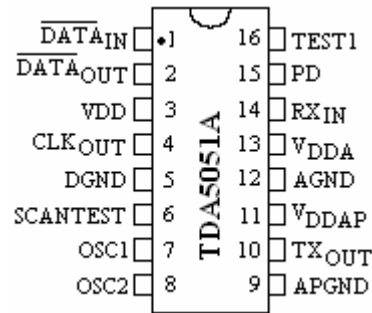


Fig. 6. Pin Diagram of TDA5051A

TDA5051A has 8 bit analog/digital converter, band pass filter, 6 bit digital/analog converter, digital demodulator, automatic gain control (AGC) at signal input and over load protection at signal output. It has minimum 600 baud and maximum 1200 baud data transmission rate [6].

TDA5051A communicates with microcontroller by DATA\_IN and DATA\_OUT pins. TX\_OUT and RX\_IN are analog input/output used for communication on the line. At CLK\_OUT clock output a frequency value equal to 1/2 of the crystal, which is connected to OSC1 and OSC2 pins of the modem, is present and it is used by the microcontroller. PD (power-down) pin is controlled by microcontroller and it is used to reduce the power consumption of the modem. At this condition, modem passes to sleep mode and all functions are stopped but clock output continues. AGND is analog, DGND is digital and APGND is power amplifier's ground. VDDA is analog, VDD is digital and VDDAP is power amplifier's voltage source. TDA5051A works with 5V supply.

TEST1 and SCANTEST is only used for production test of the modem [6].

Low cost application circuit of TDA5051A is shown in Fig. 7. A transformer for isolation can be used for high cost application circuit.

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 by digital/analog converter, amplified and sent to the line by TXOUT pin. In reception mode, the analog signal received by RX<sub>IN</sub> pin, is amplified, converted to digital by analog/digital converter, unwanted signals are filtered by digital band-pass filter, passed through demodulator and finally signal is at DATA<sub>OUT</sub> pin. In sleep mode controlled with PD pin, power consumption is supplied. In this mode, all functions are disabled, except clock generation[6].

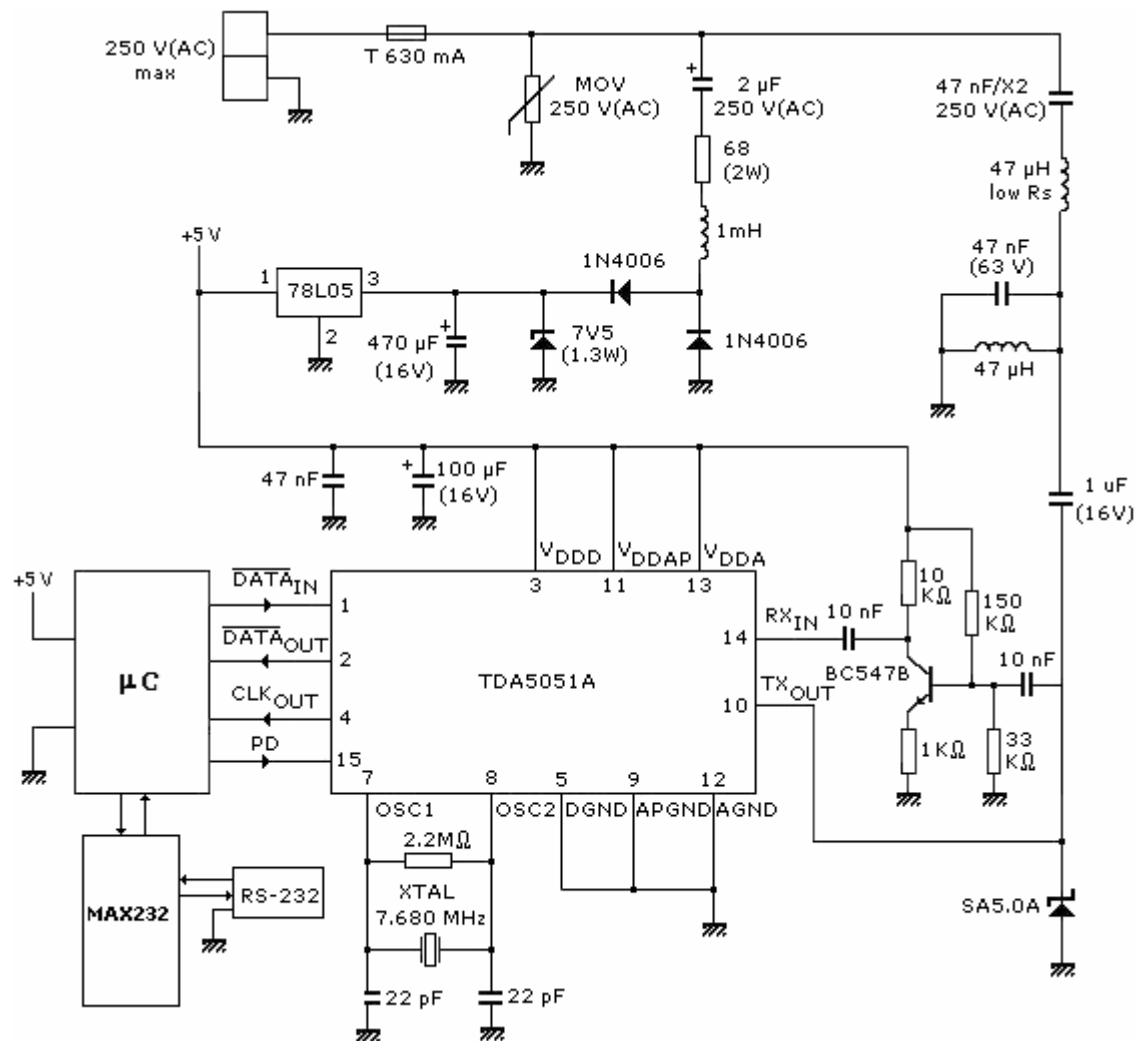


Fig. 7. Low cost application circuit of TDA5051A

### 2.3 X10 PROTOCOL

Control units in the home automation system must use same language to communicate each other. This condition is obtained by using same protocol in the system.

X10 protocol uses Power Line Carrier technology. A 120Khz 1ms burst is generated when 220V 50Hz line voltage is zero (50Hz sinusoidal wave becomes zero 100 times per second). This bursts used for coding in binary form. Two bursts are needed for transmission of each bit. A basic X10 message consists of 13 bits. First 4 bits of the message is start code, following 4 bits are house code, following 4 bits are unit (or function) code and the last bit is function/operation code. The last bit shows preceding 4 bits are unit code or function code. If f/o is 0 the preceding code is unit code, and if it is 1 the preceding code is function code. Unit code in the beginning of the message is received by all units in the system, but only the unit has right unit code receives rest of the message [7].

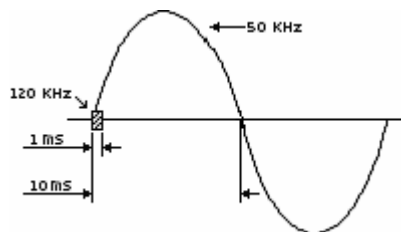


Fig. 8. X10 Signal

Start code for X10 protocol is "1110". X10 codes are shown in Fig. 9. [2].

	HOUSE CODES				KEY CODES					
	H1	H2	H4	H8	D1	D2	D4	D8	D16	
A	0	1	1	0	1	0	1	1	0	Unit Codes
B	1	1	1	0	2	1	1	1	0	
C	0	0	1	0	3	0	0	1	0	
D	1	0	1	0	4	1	0	1	0	
E	0	0	0	1	5	0	0	0	1	
F	1	0	0	1	6	1	0	0	1	
G	0	1	0	1	7	0	1	0	1	
H	1	1	0	1	8	1	1	0	1	
I	0	1	1	1	9	0	1	1	1	
J	1	1	1	1	10	1	1	1	1	
K	0	0	1	1	11	0	0	1	1	
L	1	0	1	1	12	1	0	1	1	
M	0	0	0	0	13	0	0	0	0	
N	1	0	0	0	14	1	0	0	0	
O	0	1	0	0	15	0	1	0	0	
P	1	1	0	0	16	1	1	0	0	
All Units Off					0	0	0	0	1	Function Codes
All Lights On					0	0	0	1	1	
On					0	0	1	0	1	
Off					0	0	1	1	1	
Dim					0	1	0	0	1	
Bright					0	1	0	1	1	
All Lights Off					0	1	1	0	1	
Extended Code					0	1	1	1	1	
Hail Request					1	0	0	0	1	
Hail Acknowledge					1	0	0	1	1	
Pre-Set Dim					1	0	1	X	1	
Extended Data (analog)					1	1	0	0	1	
Status-on					1	1	0	1	1	
Status-off					1	1	1	0	1	
Status Request					1	1	1	1	1	

Fig. 9. X10 Codes

Two zero-crossings are used for transmission of each bit. Because, in X10 each bit is sent as complementary bit pairs. "0" is equal to '0-1' and "1" is equal to '1-0' complementary bit pairs. For instance, House Code A(0110) is sent as "01101001". If data is binary 1 than 120 KHz 1 ms burst is put on sinusoidal wave of the line. If data is binary 0, no signal is put on the line, do nothing. 5 bits of Key Code becomes 10 bits in complementary format. The last two bits are "01" for Unit Code and "10" for Function Code. Start Code is "1110" and complementary format isn't used for it and transmission period is two sinus cycles. Other transmission periods are; four cycles for house code, and five cycles for key code.

X10 message is sent as blocks. A block consists of a start code, a house code and a key code (unit code or function code). The first block formed of start-house-unit codes is sent twice and a pause is started for three sinus cycle. Second block, formed of start-house-function codes, is sent twice and again a pause for three sinus cycle [8].

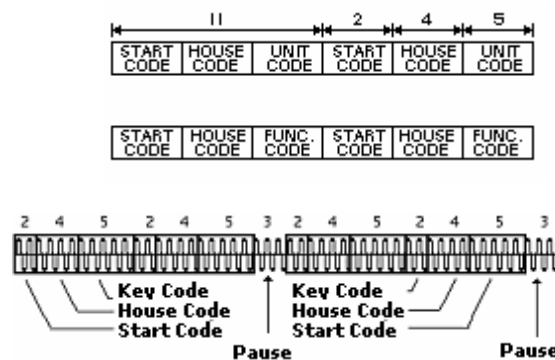


Fig. 10. X10 Message Format

As shown in Fig. 10. , standard X10 message is formed of 50 sinus cycle. Because of the frequency of the line voltage is 50 Hz (50 AC sinus cycle per second), X10 message is sent in 1 second duration. Three cycles (six zero-crossings) pause duration is not used for Dim and Bright functions. The transmission duration for these functions is 44 sinus cycles.

Electrical power is assumed to distribute in single phase for knowledge given up to this point. Actually, in places where the electrical power is distributed in 3 phases, X10 protocol sends data on all phases when the voltage is zero for each of them.

### 3. USER CONTROL

In this study, a GUI (Graphical User Interface) is constituted for user control by using Visual Basic program. In the system suitable house and unit codes are set for units by switches on them. The user can choose the unit and the function by GUI on PC. It is necessary to enter house and unit codes set for all units connected to the system. Besides, entering house and unit addresses to a database is necessary for truth of the controlling process. For instance, house code for slave unit connected to lampshade in the living room is set to A, and unit code is set to 2. When user opens GUI on PC and selects "A 2 ON", this data is sent to master unit by RS-232 and then it is sent to the line over the modem. Finally, target A2 unit, receives X10 message by modem and does the function. So the lampshade is opened. Fig. 10 shows VB GUI.



Fig. 10. Visual Basic GUI

### 4. SOFTWARE

Software consists of three parts;

- 1 - Visual Basic GUI Software
- 2 - Master Unit Software
- 3 - Slave Unit Software

Used components for Visual Basic 6.0 program are; Microsoft ADO Control 6.0(OLEDB), Comm Control 6.0 and Tabbed Dialog Control 6.0. Block diagram of VB program is given in Fig. 11.

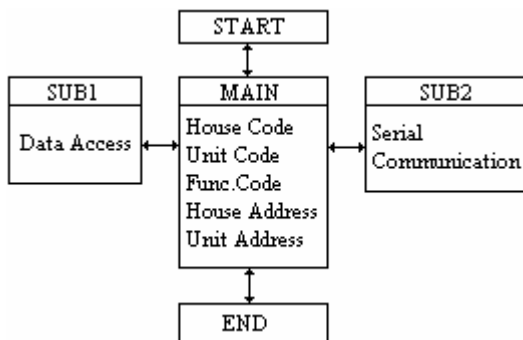


Fig. 11. Block Diagram of Visual Basic GUI

Flow charts for units are given below can give the idea of how units work with X10 communication protocol. Fig. 12. and Fig. 13. show flow charts of the master unit and the slave unit in the order.

In X10 format Start code is 4 bits (1110). House Code, Unit Code, and Function Code are 8 bits with complementary pairs. X10 command is sent as X10 blocks. Each block is sent twice. And there is 3 cycles (6 zero-crossings) delay between each block. First and second block are 22 bits. X10 command consists of 88 bits (22x4) for data and 6 bits for delay. Therefore, it is 94 bits long and sent with 94 zero-crossings.

In programs, data in X10 blocks is sent bit by bit and sending or receiving "one bit" data ensured at zero-crossings of falling edge and rising edge. For instance, to read 8 bits house code microcontroller checks if zero-crossing is present on the line firstly. Then it toggles the edge flag for detecting reverse edge. If 120 KHz signal is present, data is accepted as 1 and if not it is accepted as 0. Second bit is received at the following zero-crossing and remaining six bits are received with same procedure.

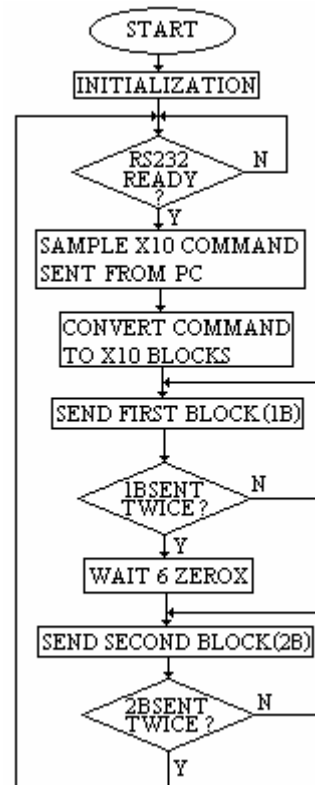


Fig. 12. Master Unit Software Flow Chart

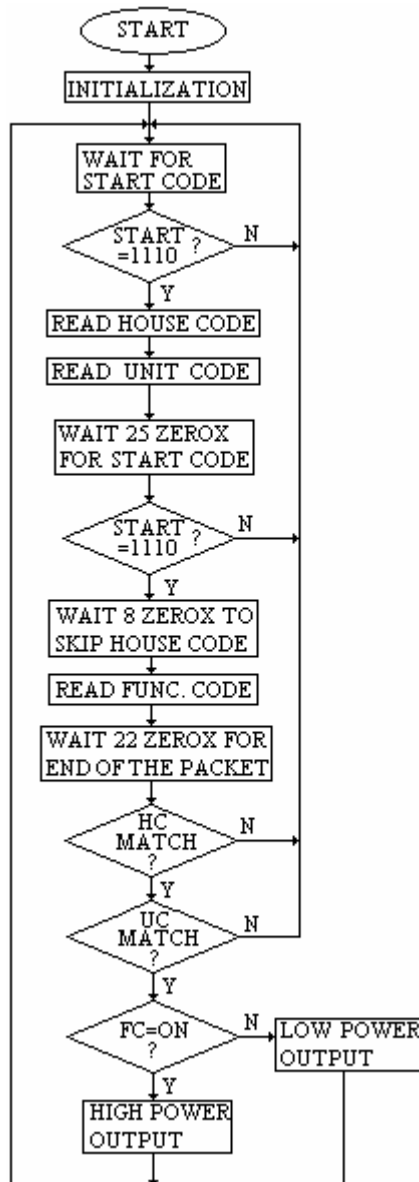


Fig. 13. Slave Unit Software Flow Chart

Abbreviations are used for House Code (HC), Unit Code (UC), Function Code (FC) and Zero-crossing (ZEROX).

## 5. DATA TRANSMISSION PROBLEMS ON THE POWERLINE

On the electrical line medium, the data transmission is effected by line noise and attenuation badly.

Most effective noise types on the power line are; background noise, impulse noise, narrowband noise and harmonic noise [9]. Background noise is the existent noise of the line. Distribution transformers or local lighting systems cause this type of noise. Switching phenomenon causes impulse noise. Capacitor banks being switched in

and out for power-factor correction create impulse noise [10]. Impulse noise is classified as instantaneous and continuous. When units as lamp and TV are opened, they cause 1V pulse lasting 1ms or more. But units as dimmer and thermostat cause 20 V impulse series lasting over tens of microseconds. Nonlinear loads (regulator, UPS, DC motors etc.) pull current from the line that is not the form of sinusoidal wave. This current called as harmonic and causes voltage drop and voltage corruptions.

Besides, the attenuation and impedance variations effect data transmission on the line.

A coupler circuit must be used to protect the transmission from these bad factors on the line. Basic technique is to put on the data signal on 220V 50Hz line signal, and to filter the signal for receiving data signal at the receiver side. The duty of the coupler circuit is to filter unwanted signals on the line and to put the signal on the line. For coupler circuit of TDA5051A integrated modem a LC circuit is used as shown in Fig. 7 and also an isolation transformer can be used for this process.

## 6. CONCLUSION

Home automation or Smart House is developing technology. In this study, X10 based home automation application, which uses home's existing electrical line without extra cabling, is done. So, cable pollution and cable cost is removed. Usage easiness and easy understandable of X10 protocol is support the project. 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. User control and manual setting of control unit codes becomes the system easy settable and controllable.

The main problem encountered on data transmission over the line is noise. X10 protocol chosen for this study sends control message twice, 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.

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