International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 4 Issue: 5
ISSN: 2321-8169
226 – 228

X-10 Based Power Line Carrier Communication

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Abstract—X-10 based Power Line Carrier Communication (PLCC) is a unidirectional communication which was primarily used for home automation system. In this communication, a digital signal is transmitted through household electrical wiring using X-10 protocol. This paper describes how X-10 protocol modulates 120 kHz carrier signal to convert it into digital signal for transmission over power line to perform various operations. The existing domestic electrical wiring is used to send the digital signal thereby reducing the need of extra wiring for communication purposes. This paper also describes the methodology of X-10, how it works and various applications of power line communication.

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I. INTRODUCTION

Power Line Communication basically means any technology that enables data transfer through power lines. PLC systems can be used to transfer data inside buildings using power lines discounting the cost of insulating communication cables. X-10 based Power Line Communication is used in a master-slave configuration. The transmitter circuit which is connected to the mains power supply (230V) acts as a master circuit which sends the digital information on power lines and is received by the receiver circuit which acts as a slave circuit. Power Line Communication using X-10 protocol is the cheapest means of communication as it uses same (230V) mains electrical wiring.

II. HARDWARE DESCRIPTION

The hardware functionality of X-10 circuitry can be divided into three functional blocks:

1. Zero-crossing Detector

In X-10, information is timed with the zero-crossings of the AC power. A zero-crossing detector is easily created by using the external interrupt on the RB0 pin and just one external component, a resistor, to limit the current into the PIC micro MCU.

In the United States, Vrms = 117 VAC, and the peak line voltage is 165V. If we select a resistor of 5 MΩ, Ipeak = 165V/5 MΩ = 33 μA, which is well within the current capacity of a PIC micro MCU I/O pin.

Input protection diodes (designed into the PIC micro MCU I/O pins) clamp any voltage higher than VDD or lower than VSS. Therefore, when the AC voltage is in the negative half of its cycle, the RB0 pin will be clamped to VSS - 0.6V. This will be interpreted as a logic zero. When the AC voltage rises above the input threshold, the logical value will become a ‘1’.

In this application, RB0 is configured for external interrupts, and the input buffer is a Schmitt trigger. This makes the input threshold 0.8 VDD = 4V on a rising edge and 0.2 VDD = 1V on a falling edge. Using the following equation, it is possible to calculate when the pin state will change relative to the zero-crossing:

V = Vpk*sin(2*π*f*t), where Vpk = 165Vand f = 60 Hz

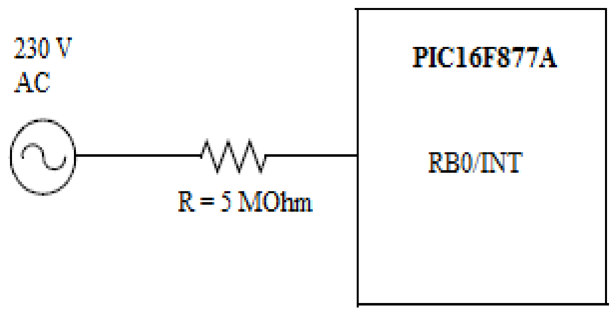

Fig :- Zero crossing detector with PIC16F877A

2. 120 kHz Carrier Detector

To receive X-10 signals, it is necessary to detect the presence of the 120 kHz signal on the AC power line. This is accomplished with a decoupling capacitor, a high-pass filter, a tuned amplifier, and an envelope detector. The components of the carrier detector are illustrated in Figure 4.

Because the impedance of a capacitor is: Zc = 1/(2*π*f*C), a 0.1 μF capacitor presents a low impedance (13Ω) to the 120 kHz carrier frequency, but a high impedance (26.5 kΩ) to the 60 Hz power line frequency. This high-pass filter allows the 120 kHz signal to be safely coupled to the 60 Hz power line, and it doubles as the coupling stage of the 120 kHz carrier generator.

Since the 120 kHz carrier frequency is much higher than the 50 Hz power line frequency, it is straightforward to design an RC filter that will pass the 120 kHz signal and completely attenuate the 50 Hz. A high-pass filter forms the first stage of the High-Pass Filter and Tuned Amplifier Block. For a simple high-pass filter, the -3 db breakpoint is:

f3 db = 1/(2*π*R*C). For C = 150 pF and R = 33 kΩ,
f3 db = 1/(2*π*150 pF *33 kΩ) = 32 kHz.

This f3 db point assures that the 50 Hz signal is completely attenuated, while the 120 kHz signal is passed through to the amplifier stages. Next, the 120 kHz signal is amplified using a series of inverters configured as high gain amplifiers. The first two stages are tuned amplifiers with peak response at 120 kHz. The next two stages provide additional amplification. The amplified 120 kHz signal is passed through an envelope detector, formed with a diode, capacitor, and resistor. The envelope detector output is buffered through an inverter and presented to an input pin (RC3) of the PIC16F877A.

Upon each zero-crossing interrupt, RC3 is simply checked within the 1 ms transmission envelope to see whether or not the carrier is present. The presence or absence of the carrier represents the stream of ‘1’s and ‘0’s that form the X-10 messages.

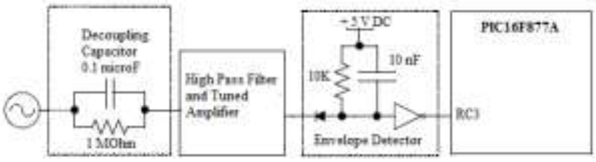

Fig :- 120 kHz carrier detector

3. 120 kHz Carrier Generator

X-10 uses 120 kHz modulation to transmit information over 50 Hz power lines. It is possible to generate the 120 kHz carrier with an external oscillator circuit. A single I/O pin would be used to enable or disable the oscillator circuit output. However, an external oscillator circuit can be avoided by using one of the PIC micro MCU’s CCP modules.

The CCP1 module is used in PWM mode to produce a 120 kHz square-wave with a duty cycle of 50%. Because X-10 specifies the carrier frequency at 120 kHz (+/- 2 kHz), the system oscillator is chosen to be 7.680 MHz, in order for the CCP to generate precisely 120 kHz. Calculations for setting the PWM period and duty cycle are shown in the code listing comments for the function InitPWM.

After initialization, CCP1 is continuously enabled, and the TRISC bit for the pin is used to gate the PWM output. When the TRISC bit is set, the pin is an input and the 120 kHz signal is not presented to the pin. When the TRISC bit is clear, the pin becomes an output and the 120 kHz signal is coupled to the AC power line through a transistor amplifier and capacitor.

Since the impedance of a capacitor is $Zc = 1/(2*\pi*f*C)$, a 0.1 μF capacitor presents a low impedance to the 120 kHz carrier frequency, but a high impedance to the 50 Hz power line frequency. This high-pass filter allows the 120 kHz signal to be safely coupled to the 50 Hz power line, and it doubles as the first stage of the 120 kHz carrier detector.

To be compatible with other X-10 receivers, the maximum delay from the zero-crossing to the beginning of the X-10 envelope should be about 300 μs. Since the zero-crossing detector has a maximum delay of approximately 64 μs, the firmware must take less than 236 μs after detection of the zero-crossing to begin transmission of the 120 kHz envelope.

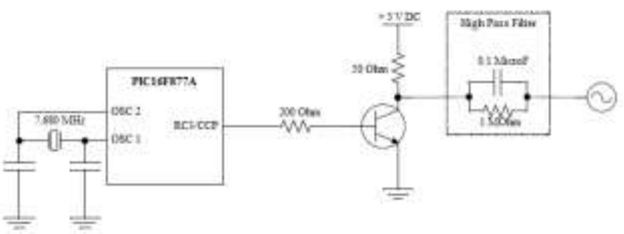

Fig :- 120 kHz Carrier Generator

III. X-10 PROTOCOL

X10 is a protocol for communication among electronic devices used for home automation (domotics). It primarily uses power line wiring for signaling and control, where the signals involve brief radio frequency bursts representing digital information. A wireless radio based protocol transport is also defined.

X10 was developed in 1975 by Pico Electronics of Glenrothes, Scotland, in order to allow remote control of home devices and appliances. It was the first general purpose domotic network technology and remains the most widely available.

X-10 transmissions are synchronized with the zero-crossings on the AC power line. By monitoring for the zero-crossings, X-10 devices know when to transmit or receive X-10 information. A binary ‘1’ is represented by a 1 ms long burst of 120 kHz, near the zero-crossing point of the AC. A binary zero is represented by the lack of the 120 kHz burst.

A complete X-10 message is composed of a start code (1110), followed by a house code, followed by a key code. The key code may be either a unit address or a function code, depending on whether the message is an address or a command.

When transmitting the codes two zero-crossings are used to transmit each bit as complementary bit pairs (i.e., a zero is represented by 0-1, and a one is represented by 1-0). For example, in order to send the house code A, the four-bit code is 0110, and the code transmitted as complimentary bit pairs is 01101001. Since house and key codes are sent using the complimentary format, the start code is the only place where the pattern 1110 will appear in an X-10 data stream.

The key code, which is 5-bits long, takes 10 bits to represent in the complimentary format. Because the last bit of the key code is always zero for a unit address and one for a function code, the last bit of the key code can be treated as a suffix that denotes whether the key code is a unit address or function code.

A complete block of data consists of the start code, house code, key code and suffix. Each data block is sent twice, with 3 power line cycles, or six zero-crossings, between each pair of data blocks.

For example, to turn on an X-10 module assigned to house code A, unit 2, the following data stream would be sent on the power line, one bit per zero-crossing.

IV. ADVANTAGES OF USING POWER LINE COMMUNICATION BASED SYSTEM

The biggest advantage of PLC based system is that it reduces re-wiring as it uses existing electrical wiring for communication. PLC based systems are portable i.e. they can be removed from one home and can be installed into another home without much trouble. Less wiring reduces the cost and hence PLC based systems seems to be more affordable.

V. LIMITATIONS

The power lines are not designed for communication and hence some problems can occur when transmitting the data over power lines. In low voltage domestic supply, a single transformer at the distribution pole supplies power to a number of homes. Hence high frequency signals from one house may pass to another causing interference. Hence, high frequency signals from landlines may also interfere with the transmitting signals and create an unwanted distortion that disturbs the operation of the system.

VI. CONCLUSION

This paper has described a simple PLCC system. The system can achieve required demands such as stability, reliability and accuracy. With the speed of the system satisfactory at the domestic level certain improvements in the future can make the PLCC based home automation system more reliable and it may be a preferable choice over wireless or other home networking technologies due to its ease of installation, availability of AC outlets, low cost, reliability and security.

VII. REFERENCES

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