AUTOMATIC TELEPHONE CALL INDICATION DEVICE USING POWERLINE

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Abstract

This paper describes the design of an automatic telephone call indication device with power line as the channel for communication. The communication scheme used is Amplitude Shift Keying. The design of a typical power-line coupling filter is also discussed. The basic device topology consists of a transmitter, which includes DTMF decoding, recorded voice playback, a microcontroller, and a coupling filter stage. The microcontroller produces control signals for the device as well acts as an ASK modulator. The coupling filter consists of a series resonant LC tank circuit with component values calculated taking account of the reflected impedances from the powerline. The receiver section, also consisting the same filters contains stages for amplification and demodulation of the carrier. The ASK demodulator circuit, which is basically a low pass filter, provides input signal to a comparator. The comparator output, given to the microcontroller is the transmitted data, and the controller activates appropriate audio-visual indication circuits to alert the called person. The features of our design include the cheaper receiver sections, and robust coupling circuits.

Introduction

In our college hostel, there is no one to attend the telephone call and even if someone attends, it proves to be a tedious task to inform the called person. We have seen the same problem in other hostels and similar establishments. When we were trying to find a solution to this problem, we came across the idea of power line carrier communication, a widely researched technology. What we present here is a solution for the above-mentioned problem using power line

Technologies that could solve our problem :

1. Phone line networking : We can provide telephones, which has got high-performance, in each room. But it is definitely uneconomical.

2. Radio frequency communications links : Although they allow for flawless device control and are very flexible, radio frequency communications links are currently too expensive to be viable for the average user.

3. Traditional wiring schemes : Traditional wiring schemes (coaxial cable, unshielded, twisted pair) are of high performance. They are a very practical way of implementing a home network in a new home under construction. Yet traditional wiring schemes are not suitable for retro-fitting a home network to an existing building. Major building work is required to install traditional network wiring in an existing building, the alternative being unsightly cable strung around walls.

4. Power line carrier communications : Using the power lines as the communications channel, PLCC techniques have the potential to economically install an automation network into any building, new or old, and connect any room in that building that has a power point.

PLCC techniques have traditionally been used either by electrical utilities for control and monitoring of their distribution networks, or for simple home automation systems. With rapid growth in home networks, PLCC methods are a flexible way to implement low cost, reliable and widely accessible networks in the domestic environment.

Due to above mentioned reasons, we decided to use power-line as our medium for communication.

Domestic Power Line Carrier Systems Currently In Use [9]**:**

PLC communications is a well-known and reasonably common method of communication in domestic households. These methods are fairly simple in design, employed mostly for home-automation purposes. There are a number of systems commercially available for such home automation purposes. The most popular PLC communication systems are:

CEBus, or Consumer Electronics Bus[5] : CEBus is based on the concept of Local Area Networks (LAN's), for the home. CEBus gives protocol standards for RF, twisted pair, PLC and a number of other home networking methods. The CEBus PLC standard specifies that a binary digit is represented by how long a frequency burst is applied to the channel. For example, a binary '1' is represented by a 100 microsecond burst, whilst a binary '0' is represented by a 200 microsecond burst. Consequently, the CEBus transmission rate varies with how many '0' characters, and how many '1' characters are transmitted. CEBus is a commercially owned protocol, and thus attracts registration fees.

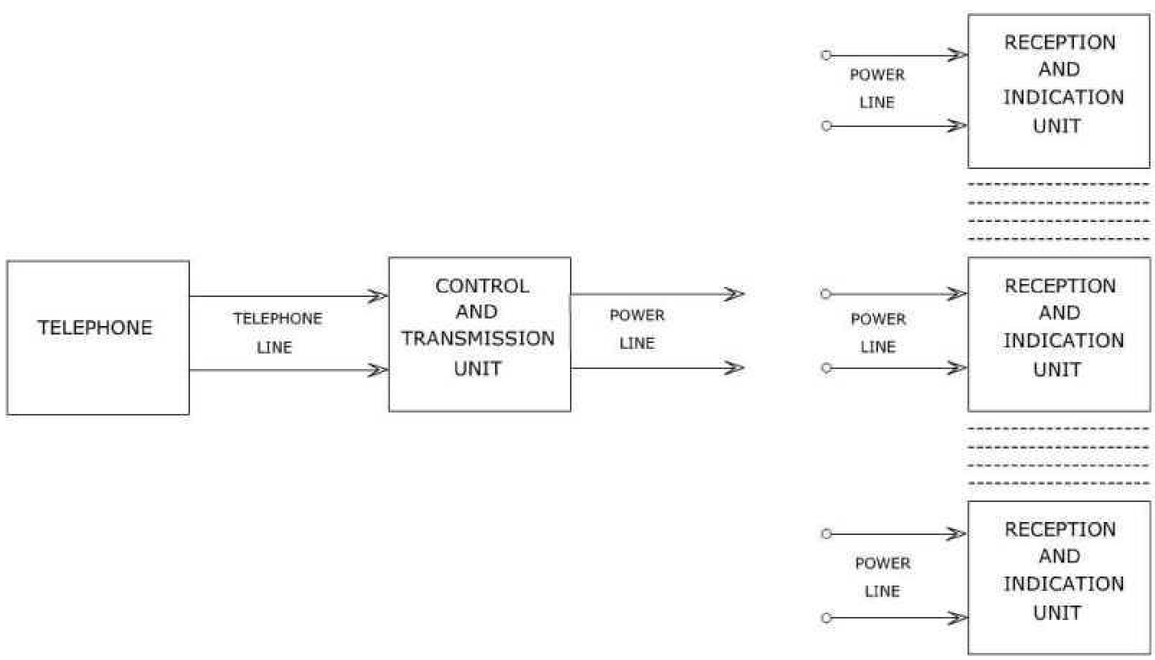
X-10[5] : In terms of sheer popularity, X-10 is the de-facto world standard for home automation. X-10 is a simple home-automation standard that includes addressing mechanisms to individually identify appliances. X-10 Uses zero crossing point of the mains carrier for synchronization, the presence of a 120 kHz signal burst at the zero crossing indicates the transmission of a binary one, whilst the absence of the 120 kHz signal indicates a binary zero. It also specifies a scheme to prevent device clash.

Our Protocol

For our particular application or in case of any low data rate transmission, we don't feel it necessary to use the above standards. We are defining a serial communication protocol, whose data can be modulated using Amplitude Shift Keying (ASK)[7] with a carrier of 110KHz. The reason for this is partially due to the required cheapness of the receiver section, and also due to the relative performance of ASK even without error correction at our data rate of 10 bits per second. Our carrier frequency is also within the 148.5KHz recommended by CENELEC[9]. Other modulation schemes like FSK, in terms of noise immunity and reliability in high phase delay channels and PSK in lower phase delay channels can also be used. But since our application is not all that critical, and economy is a factor as far as receiver sections are concerned, we prefer ASK.

System Overview

Our device consists of two parts TRANSMITTER and RECEIVER. Each room has got a receiver and is connected to the transmitter through power line. Transmitted signals reach all the receivers.



. **Figure: 1 The main block diagram**

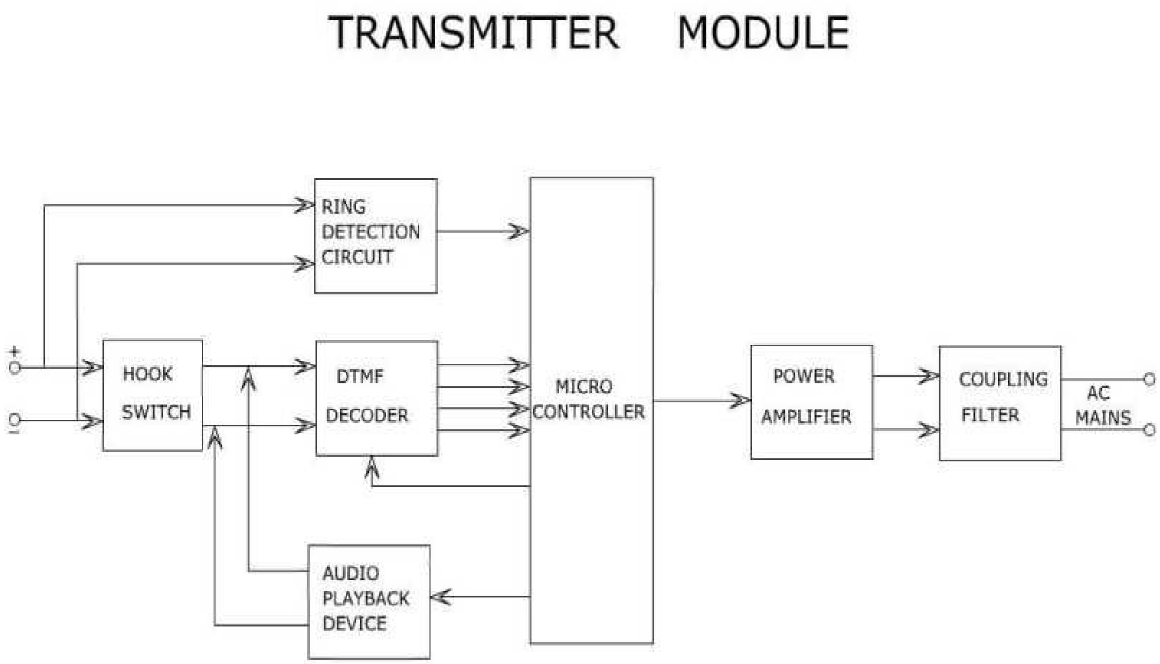


Figure 2

When phone rings, our device counts the number of rings. After a preprogrammed count the call is connected. Then the device enters the voice response mode. In this mode a recorded message play back device is connected to the telephone line. The message asks the caller to "Enter the room number and student number in the tone mode". The information provided by the caller is decoded and is converted into a format compatible for transmission through power line. Appropriate error correction codes are provided with the data. This data is coupled to the power line using a custom made filter.

The operation can be divided into the following modes

1. Voice response mode

This mode begins with a person making the call. When the phone is on hook, there is a dc voltage of 48V. While ringing there will be a 25 Hz signal across the line. We use this signal as an interrupt for our microcontroller AT89C51[2], with appropriate isolation using an opto coupler. After a fixed interval the line is again checked for the signal. ,if it is still there we connect a low value resistor to emulate off hooking. After this the audio out of audio playback IC-ISD 1400[3], which has a recorded message is connected to the telephone line. With the completion of the message the DTMF decoder IC MT8870[1] is enabled and ISD1400 is disabled.

The MT8870 receives the dual tone multi frequency signals produced when the caller presses the keys. MT8870 converts it to corresponding BCD .The four output pins of this chip is connected to the microcontroller. The microcontroller reads the data from these pins whenever the output latch of 8870 is updated,which is indicated by a high on the "delayed steering "pin of 8870.

The microcontroller also takes care of error conditions such as the caller going on hook, without entering the codes. The call is cancelled if the delay between successive numbers pressed is more than 15 seconds. There can also provision for correction of the entered data.

2.Modulation stage

The microcontroller AT89C51 also serves the purpose of a modulator. The BCD code of the room number and student number is converted into an eight bit binary number. The first 7 bits represents the room number and the last bit represents the student number (assuming only two students are there in a room). This eight bit data along with a start bit and stop bit is sent to all the receivers. The modulation scheme used by us is On Off Keying – ASK with zero amplitude for logic '0'.For a logic '1' in our data stream, we produce a 110kHz square wave, and no signal at logic '0'. In our basic testing, we used a data rate of 10 bits per second, with start and stop bits taking the same time as each data bit (100ms). This OOK data stream is then coupled to a preamplifier formed by the high frequency OPAmp, LM357[4].

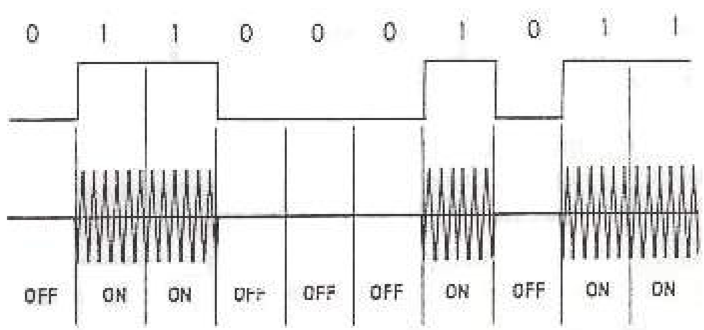


Figure 3: **On OFF Keying**

3.Amplification and coupling stage

LM357 is pin compatible with the LM 741 and has a higher slew rate. The chip is configured in non-inverting configuration, with a closed loop gain of 5. Since the output is fed to a basic complementary symmetry class B power amplifier, we chose to connect the feedback resistor of pre amplifier as in the circuit, so that the whole circuit acts as a combination of precision rectifier and class B power amplifier, resulting in a complementary symmetry class AB configuration. The power amplifier is chosen to be class AB, instead of the commonly used class C, due to their inherent low output impedance, which enabled us to match load impedance of the power line to a great extent.

The coupling filter on transmitter side utilizes a series resonant LC tank circuit, which we found advantageous in our application due to the following reasons.
a: Maximum voltage is developed across reactive elements at series resonance.
b: In case the capacitor becomes open, in the parallel resonant circuit, the power amplifier will have only the inductor as load and thus can lead to damage of load inductance and amplifier transistors. This does not occur in the series resonant circuit.
c: Moreover, in parallel resonant circuit, there is a chance for the dc voltage to pass through L1, decreasing Q of the circuit.

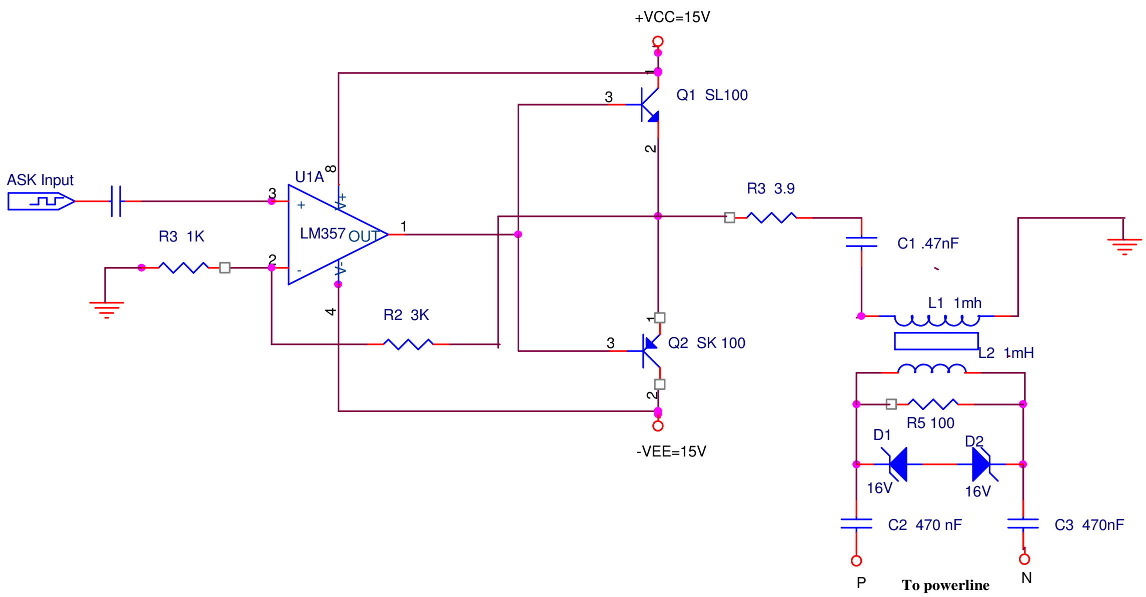


Figure 4: **Amplification and coupling filter section.**

The inductors used for coupling, and hence isolation, were wound over a plastic former on toroidal ferrite cores (T37) with a high inductance of 1mH to improve the Q factor. The number of turns N on the toroidal core for a particular inductance is calculated using the empirical relation[8],

N = 10 * SQRT (L / L10) ;Where N is the required number of turns , L is the required inductance and L10 is the inductance for 10 turns on the core.

A turns ratio of 1:1 is used so that the power line side impedance is transferred exactly as they are. This is because turns ratio K = N2/N1 = 1 implies impedance on primary side due to secondary impedance Z_{LS} becomes $Z_{LP} = Z_{LS} / K^2 = Z_{LS}$ itself [5] .

The effective capacitance of the series LC circuit can be calculated using the usual equation for resonance frequency Fo as

$$Fo = 1 / (2 * \prod * SQRT (L eff * Ceff))$$

Here, Leff is the equivalent inductance of primary and secondary combined, analyzed using basic transformer theory. The impedance of power line was simulated at the secondary of coupling transformer by connecting a 15ohm resistor. The coupling capacitors at output offer higher impedance to low frequencies and negligible impedance to our working frequencies. The combined effect of these coupling capacitors and our chosen line impedance at operating frequencies prompted us to change the value of resonance capacitance Cr to a value obtained from the equation,

$$Ceff = Cr * Cc' / (Cr + Cc'); \text{ where } Cc' = Cc1 * Cc2 / (Cc1 + Cc2).$$

A 100ohm resistor R5 was put in parallel to L2 to prevent the drastic change in filter frequency response when the line is open. Diodes are added for spike protection, preventing excessive voltages from reaching the front-end of the receiver module.

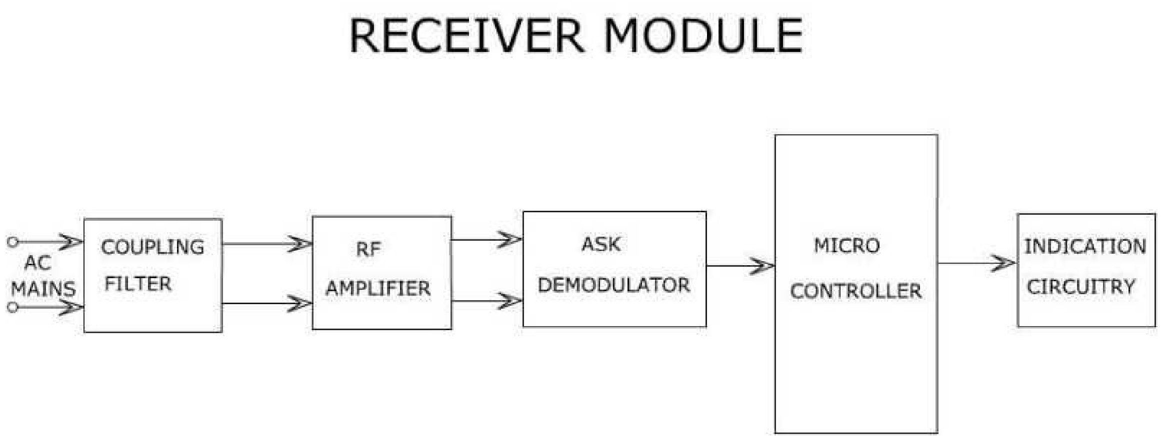


Figure 5

Each receiver has got an address and the received signal is decoded and data is compared with the stored address. When a match is found, appropriate audio- visual indication is given.

Coupling stage

Here we are using the same filter that we used in the transmitter part. The filter only allows the 110 KHz to pass through it and the 50Hz signal is blocked. Only the secondary of coupling transformer is tuned to pass the desired 110KHz signal using C_T. Here also reflection of capacitance from the primary side occurs and the tuning capacitor value in the secondary side is decided taking this into consideration.

The amplitude of the signal reaching the secondary at the receiver side varies with drastically with distance. The tabular column shown below has more details.

Distance test results with 25 V pk sine wave* at 110Khz

Position	Received signal amplitude (V)
On the next desk	20V
On the other room	16V
On the other side of the building	13V
The other side of next floor	4V

* This is the signal amplitude measured at the primary of transmitting transformer.

Figure 6

After the filter we have provided an RF amplifier. It amplifies the signal to the desired voltage levels so that it can be fed to the ASK demodulator circuit.

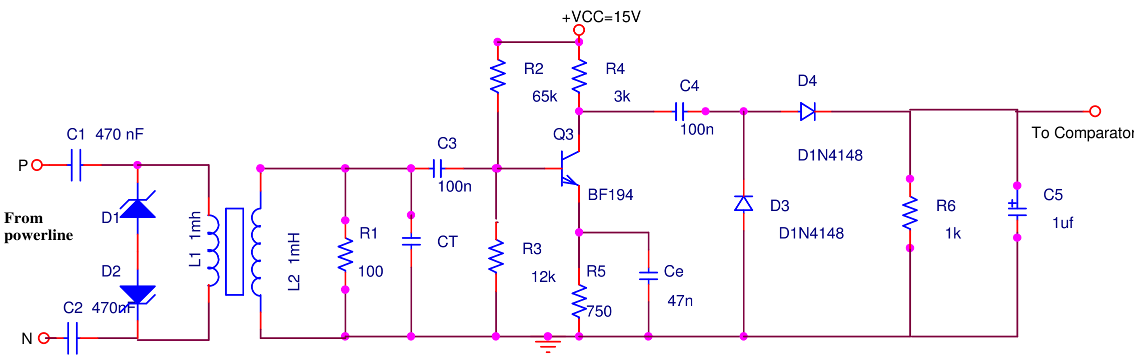


Figure 7: Receiver side coupling filter and demodulation circuitry

Demodulation stage

We designed a peak holding circuit which serves the purpose of ASK demodulation. The output of the RF amplifier is positively clamped. The capacitor in the peak holding circuit gets charged in these positive half cycles giving an averaged output. When there is no carrier signal the capacitor gets discharged through a resistor connected in parallel. The

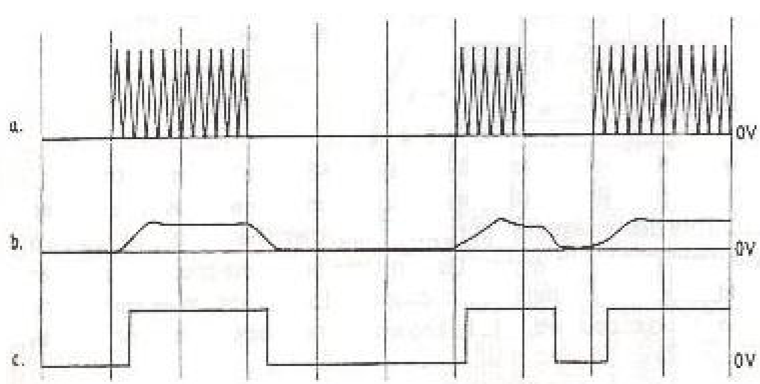


Figure 8: Demodulation of an OOK signal

Value of resistor is decided considering baud rate of transmission. This output is connected across the non-inverting terminal of LM 311 and a reference voltage is provided in the inverting terminal. This reference voltage is the maximum allowed error amplitude for the signal. In our case the reference voltage level was 5V. The output of LM 311 is made compatible with the voltage levels of the microcontroller.

The output from LM 311 is fed to the microcontroller, AT89C51.The first received data is interpreted as the start bit by the microcontroller ,it is taken as an interrupt and the following 8 bits are stored. The first 7 bits of this stream is the address of a particular room. The last bit represents the student. The address of each room is stored in the microcontroller and the microcontroller compares the received data with the stored address in it and if a match is found then an audio-visual indication is given.

Conclusion

We have succeeded in establishing a low baud rate communication network through power line. This paper also provides guidance to the design of coupling filters, which can be used in other PLCC projects. We are in the process of completing the microcontroller programs to integrate our blocks. We also plan to add battery back up to the circuit as well as some protection to lightning noise in the future.

Our present experiments show that, power lines and their associated networks are not designed for communications use. They are a hostile environment that makes accurate propagation of communication signals difficult . Noise levels are often excessive, and cable attenuation at the frequencies of interest is often very large. Important channel parameters such as impedance and attenuation are time varying in unpredictable ways.

. Nevertheless, the medium can extensively used for low baud rate narrow bandwidth applications like ours, including home automation and low speed networking, with economy. During the course of our research on power line, we came across various Digital Power line Carrier communication schemes like Spread Spectrum frequency hopping, and Differential Code Shift Keying. A judicious application of these communication schemes can result in broad band internet, transmission of streaming videos and similar applications.

Acknowledgments

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