Ministry of higher Education and Scientific Research

University M'hamed Bouguerra Boumerdes

Faculty of Engineering

Department of Electrical Engineering and Electronics

Report

Presented in Partial Fulfilment of the requirements of the

MAGISTER DEGREE

In Electronics Systems Engineering

Title

Design and Implementation of an Energy Saving System Using Power Line and Home Automation

By

Mohamed Zoubir SAIDI

In front of the Examiner board

Pr. L. REFOUFI	Prof. at Univ. of Boumerdes	Supervisor
Pr. DJ. BENAZZOUZ	Prof. at Univ. of Boumerdes	President
Dr. H. BENTARZI	Maitre de conference at the Univ. of Boumerdes	Examiner
Dr. D. OUAHDI	Maitre de conference at the Univ. of Boumerdes	Examiner
Dr. C. LARBES	Maitre de conference at ENP	Examiner

ملخص

مع التزايد السريع لاستعمال الأجهزة المنزلية، و السعي الدائم نحو مزيد من الرفاهية نتيجة تطور أجهزة جديدة و كذلك مع الحرص أن يكون الفرد يجاري نمط الاستهلاك العالمي، أصبحت قضية الاستهلاك الطاقوي مسألة في غاية الأهمية و التطويق من حدتها ضروريا، و بلادنا ليست بمعزل عن هذا الإشكال. الإضاءة في المباني الإدارية أو المنازل تشكل أحد أهم المسائل في سياق استهلاك طاقوي متزايد و هو ما حفزنا لهذا العمل من أجل انجاز نظام مؤتمت و موثوق فيه للاقتصاد في الطاقة. يدور البحث حول تصميم نظام اقتصادي و فاعل باستعمال عتاد و أدوات و برمجيات مناسبة مع وسط اتصالي في المتناول. يبحث هذا العمل في قابلية تطبيق نظام الشبكة الكهربائية كوسط اتصالي مع شبكة التوزيع المنزلية بمعنى التحكم في الأجهزة المنزلية المختلفة و نبائط الإضاءة بواسطة الشبكة الكهربائية المنزلية. البحث نظري و عملي في آن واحد حيث يقدم وصفا مفصلا لجوانب تقنية الاتصالات بالحاملة عبر خط الطاقة (PLC)، قابلية تطبيقها و كذا النبائط المستعملة. يقوم الاتصال على تكنولوجية حاملة بطيف موزع (SSC). هذه التكنولوجية أثبتت نجاعتها و حققت مستوى أداء و فاعلية عاليين في البيئة الصعبة الموجودة في الشبكة الكهربائية. مشروع الاتصال بالطيف الموزع قد أنجز بنجاح و تم اختباره.

Résumé

Avec l'accroissement rapide du nombre d'appareils domestiques, la recherche non satisfaite pour un confort toujours poussé et entraîné par le développement de nouveaux appareils et équipements et l'aptitude d'être à jour avec les modes de comportement contemporains, la consommation d'énergie devient un sujet de prime considération et sa réduction nécessaire. L'éclairage dans les bâtiments administratifs et dans les foyers est l'un des objets majeurs dans la consommation toujours croissante de l'énergie et constitue l'objet de ce projet. Afin d'accomplir un projet fiable et adéquat pour économiser l'énergie, un système économique et efficace employant une circuiterie et des outils de programmation avec un média de communication abordable est recherché. Une partie du travail dans ce projet est l'investigation quant à l'applicabilité du réseau électrique comme média de communication en réseau domestique : i.e. le control des différents appareils domestiques et les éléments d'éclairage à travers le réseau de distribution électrique. Cette investigation est théorique et pratique, avec un rapport détaillé sur les aspects de la communication à travers les lignes de courant électrique (PLC), son applicabilité, sa faisabilité et des circuits utilisés. Le type de communication est basé sur la technologie de modulation de porteuse à étalement de spectre (SSC). Cette technologie a été prouvée faisable et a accompli une grande performance et une grande efficacité dans l'environnement hostile présent dans le réseau électrique. Le mode de modulation de porteuse à étalement de spectre a été réalisé et testé avec succès.

Abstract

With the rapid growth of home devices, the unsatisfied query for comfort always boosted by new developed apparatus and appliances, and the eagerness to be in pace with worldwide behaviour; energy consumption is becoming a prime concern and its curb necessary. Lighting in office building or home is one of the major subjects in an ever increasing energy consumption context and constitutes the motivation of this project. To achieve a reliable and automated scheme for energy saving, an economical and efficient system employing adequate hardware and software tools along with affordable communication media is looked after in this present work. This work investigates the applicability of power line, as a communication media, to home networking: i.e. the control of various home devices or light fixtures through the domestic power network. The investigation is both theoretical and practical, with a detailed description of the aspects of power line carrier communication (PLC), its application feasibility, and power line carrier devices. The type of communication is based on the Spread Spectrum Carrier technology (SSC). This technology has proved to be robust and achieved great performance and efficiency in the hostile environment present inside the power network. The Spread Spectrum Communication scheme has been successfully implemented and tested.

Acknowledgments

The success of this project can be attributed to the help of a number of people. Firstly, I would like to thank my project supervisor, Pr. Larbi REFFOUFI, for his support and technical advice during the course of the project. I am very grateful to Pr D. BENAZZOUZ, Dr D. OUAHDI, Dr C. LARBES, and Dr H. BENTARZI for their great effort in evaluating my project and accepting to be part of the jury. I also thank Dr. H. BOURDOUCEN for his early help. Warm thanks go to my family and friends who have provided support during the challenges, and understanding of my many hours spent at work.

Dedication

I dedicate this work to my wife, my two sons, my mother and father, my wife's family who all of them have given me uncountable support and courage until the completion of this work, and my fellow colleagues of long years.

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CHAPTER 1

Introduction:

1.1 Motivation

The rapid growth of offices, office equipments, and computer based tools in the business activities has led to the multiplication of spaces for men and machines. With the unsastified querry for comfort for the employees in matter of lighting, heating, air conditionning and security always boosted by new developed apparitus and appliances , and the eagerness to be in pace with worldwide modern behavior; there is an ongoing awareness for energy conservation. Energy comsumption is becoming the prime consern on top of any matter. Lighting, HVAC, and security in office buildings and as well as in residential buildings or home are major subjects in ever increasing energy comsumption.

1.2 Project Aims

The project report describes the theoretical and practical aspects of powerline communication , spread spectrum carrier techniques, and control techniques applied in home network control system as well as in the offices. Tthus, the goals are summarized as follows:

- To gain a detailed knowledge of the challenges faced by power line communication techniques and carrier techniques.
- To investigate the applicability of recent communications methods towards improving the proposed communication system.
- To research, simulate, design and build a working controling system to achieve energy saving.

Contributions to this project are:

- Literature research examining aspects on power line communication , spread spectrum carrier techniques, and control under Home Automation system.

Technical journals, internet resources, and standards specifications were searched for information applicable to achieve the project aims.

- Topics covered include history of power line communication, first designed home system control, evolution and development of related electronic components and elaborated communication tools. Regulations and standards are widely described in order to enable the applicability of home control system in saving purposes.
- Applying the conclusions of theory research in the design of the practical part that is the physical layer (the lower level layer) and the development of the procedures to implement the control schemes that make up the higher layer (the software part) applied to controling energy consumption requirements. Also, another important aspect can be described, that is the capability for the energy supplier to develop the remote monitoring of energy consumption for billing purposes and helping custommers to optimize their power networks .
- The novel application of ongoing developing Home Automation, appropriately applied, for an efficient "engineering solution" for managing energy consumption.
- The design and construction of testing circuits to implement the hardware part to realize the complete connected chain made of from the various circuit elements: the testing or simulating circuit, the carrier generator circuit, the symbols generator cicuits, the amplifying circuit, the filters, and the power line coupling circuits.

1.3 Outline of report

This report can be divided into two sections. The first section describes the theoretical aspect of power line media communication, the carrier technique using spread spectrum, and the control system used. History of home control system is presented, as well as the recent applications of Home Automation. Challenges faced by powerline communications due to its hostile environment are studied. Regulatory and standard specifications are covered. The carrier and modulation techniques are chosen in order to lessen the effects of the noisy power line media. All the described methods of modulation, carrier, and communication are chosen and implemented under the obligation to obeying the adopted specifications and regulations.

The second section of the report covers the design, implementing and testing of a working control system.

The appendices of this report give technical information related to the practical elements of this project. Appendix A includes the different specifications and tables for applying procedures and configuration.

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1.4 Uses of powerline

Power line communication, in the past has been used by a restricted number of professionals for a very limited number of applications because of weak techniques for reducing noise, which is very dominant in AC lines. The main users of powerline communication were the electricity companies that use its powerline distribution network to monitor measurement equipment's, to communicate between them, and to remote control certain power devices [1].

The speed of communication in powerline was too low; perhaps satisfactory for those days needs, due to the available electronic components and to not well developed digital techniques. For the consumer side, the use of powerline was restricted to the basic audio intercommunication. But with the start of digital and computer communication, many tries have been continuously made by electronic industries and universities to use the powerline as a medium for data communication [2].

The first breakthrough came until the late seventies with the outcome of the X.10 system. The X.10 system consists of sending a 120 kHz signal at every zero crossing on a 50 (60) Hz AC line. The baud rate is of 60 bps. Hence the X.10 communication system is of relatively low speed and has low noise immunity and poor communication effectiveness. So, a more effective technology has been developed to replace the X.10 system, which is however still in use in low speed communication applications [3].

1.5 Selecting Modulation Technique and Carrier for Communication

Several types of powerline communication technology that use FSK modulation and Spread Spectrum Carrier along with forward error correction are used nowadays. These recent technologies, thanks to the development of low cost and powerful digital circuits, meet the every day growing demand for faster and reliable electronic equipment's for a large span of needs in industrial communication, commercial and home automation[4].

And one of the important feature in powerline communication system is the energy management. In order to conciliate the desire of using more and more intelligent equipments and the awareness of keeping the electricity costs at reasonable levels, efforts are being made to manufacture goods that integrate these new capabilities and features[5].

Previously, the interest in office and home automation was justified by the use of the relatively advantageous noise-free medium such as twisted pair , coaxial cable or optical fiber but they impede their development for they were expensive , difficult to expand, and difficult to develop. They may be, nonetheless, practicle for new offices and home under construction [1].

All of these applications rely on higher communication technology provided a highly reliable link on a noisy media over a wide range of conditions. In addition the system must be realized for a relatively low cost of development and deployment .

Today, the new Spread Spectrum Carrier technology developed by Intellon, based on a swept frequency chirp, for power line and radio frequency , is being implemented on low cost integrated circuits enabling the development of systems with low hardware costs as well as low development costs, and increasing speed of transmission to 100-150 times faster than the X-10 system [3].

Therefore, the Spread Spectrum Communication has become practical and economical these last ten years. In this work, the Spread Spectrum Carrier technology is chosen for it allows the achievement of effectiveness and reliability of communication through AC lines. The designed system may be implemented very profitably to help in energy management for both customers and utility companies. Powerline communication has a great number of applications in the field of building automation.

Historically, spread spectrum communication systems have been used for secure communication and/or for overcoming narrow-band impairements in the communication medium. Early spread spectrum receivers, very often, needed an initial period of time for the synchronization with the carrier, so they have not been appropriate for CSMA (carrier sense multiple access) networks [5].

The use of Spread Spectrum Carrier , adopted here, on the contrary is very suitable for CSMA for the used method is to generate a series of short swept “chirps” that act as carrier.

The Spread Spectrum Carrier technology on the powerline communication has increased capacity and function to office and home products, electronic control devices, sensors, and appliances. The Spread Spectrum Carrier technology is used to interconnect electronic devices through AC power line under an intelligent network standard in order to control, monitor, and optimize the use of modern equipments and appliances. Today's new technologies are using the advantageous media (Powerline, Radio Frequency, Infra Red) to counter the costs and limitations drawbacks of the other media(ie:twisted pairs,telephone lines,coaxial and optical fibers) [1].

Spread Spectrum Carrier technology has been adopted by Electronic Industries Association (EIA) as the physical layer specifications for the Consumer Electronic Bus (CEBus) home automation standards. The use of powerline, enabled the development of reliable and low cost wireless distributed control network for commercial and residential applications because AC powerline is present everywhere in buildings or home [2][3][4].

Since this technology has low cost and robust performance, it is used in a myriad of distributed control and monitoring application, not related to office or home automation. Some examples of these applications are: utility Distribution Authorization/Demand-Side Management (DA/DSM), coin operated machine networking, remote point of sale transaction processing and control, transportation system control and monitoring, traffic control and monitoring [1].

The goal of this work is to investigate an energy saving system through the use of modern tools. It must be emphasized and implemented despite of the growing tendancy of energy consumption.

In commercial and business use, the ever-growing number of office equipments such as computers, printers, photocopiers, faxes, and Heating Ventillation and Air Conditioning (HVAC) along with the lighting also make the managers seek ways to reduce energy consumption . With the growth of the number of home devices for domestically needs such as of necessity as the HVAC, lighting, security, and computer and that of leisure as TV's , VCR's, and computer games; energy management has become an important matter to take in account for efficient use and saving on the electricity bill. So, a system is to be applied in order to achieve this goal in lieu of man control. The human sets the rules, and the devices control and monitor every thing for him according to his wishes. In commercial buildings or at home, lighting and HVAC are of the most energy consuming elements; so they will be thoroughly described and tentatively implemented [6].

1.6 Home Automation

An efficient energy savingsystem requires the use of a modern automated technique. This technique call for reliable ways to control electronic equipments . Such a technique relies on new communication systems fully integrated and automated .

A novel technique, the Home Automation, allows more reliable communication systems to handle low cost and powerful devices that control various office and home electronic devices. The Home Automation is nowadays rapidly developing as a consequence for fulfilling and joining the saving quest and the desire of enjoying the ever large span of electronic goods [3].

Communication media for controlling devices can be chosen from several already existent and recent ones such as: RF, coaxial, twisted pair, powerline, Infrared, and optical fiber. In various applications, more than one of these media are used, complying with efficient criteria relying on the nature of the electronic devices and the desired comfort to meet the consumer preferences. One can, with the help of IR remote control, gives commands to monitor outside temperature or turns on lights from the screen of the TV set and through the powerline.

For energy saving purposes, especially for devices of important energy consumption such as lighting and HVAC in the office or at home; the use of powerline media already existing anywhere is highly recommended . Communication chanal for control purposes between electronic equipment is implemented with no additional cable network [6].

Manufacturers are producing electronic equipments for offices and home that incorporate the new capabilities for energy management and comfort. These sophisticated electronic devices, to be fully controlled, must bear on them high level components that operate under Home Automation technique. To allow different manufacturers to produce various electronic devices that work under common techniques, standards have been adopted. Such standards are the CEBus adopted by the EIA association , the Cenelec EN 50065-1 by the the European Home System Automation (EHSA), the EHS 1.3 (issued by the EHSA), Convergence 0.3 (issued by the EHS 1.3 for low baud rates), the ENEL DH028/29, the Echelon LONWorks (for peer-to-peer communication under the LonTalk protocol), the IEEE 1394 (Firewire), and the Intelogis Plug-In (that uses client/server toplogy) [1] [7].

These standards cover all the aspect of Home Automation ; electrical specifications, physical layers, higher level layers, data link layers, and application layers [8]. The Home Automation is still on development. Some of the trends are for using this technique for fast data communication such as computer-to-computer communication in the form of network that is easy to use ; devices plug and play on the mains powerline [2][9][4].

More ever; the energy suppliers companies, through the powerline, are able to offer services to help their customers to better manage their energy consumption and to monitor the utility meters remotely through the use of power lines[10].

1.7 Needs for Power Line Utilization in Energy Saving

In Algeria, the national electrical power company is aware of this technology, that is the use of powerline network for its proper services and its customers , and some works have been conducted to acquire experiences in this matter. In Annaba , some local area networks using powerline have been installed and tested for experimental studies. Hence , in this order, the burden on the national telecommunication company especially the internet services will be alleviated [11] . Morever, the use of powerline is becoming very attracting to the internet companies thanks to the fast development of highly inegrated circuits with ininmaginable performances and unlimited tasks that can be executed; limits on speeds and rates are time after time pushed away. The best and not the least argument in favor is still the already available physical media everywhere. The immediate suggestion is to help and emphasise researches in this field. The energy saving in the business offices and at home is also the other important reason, and this adds another interest to be considered in developping research on the use of powerlines.

Many research reports and papers have been published on Home Automation , the powerline communication, security, noise, modulation methods, and on reducing error bits concerns[2]. Investigations are being done on what type of modulation method, which type of counter noise techniques, and which type of mathematical processing of coding of bit streams to realize efficient communication schemes. Coded Modified Frequency Shift Keying (M.FSK) for power line communication is a study on how to improve communication on powerline by designing a coding scheme that combines M.FSK of constant envelope modulation with a permutation code of length M where every code has M different symbols decoding [12].

Bit error handling is, in another work, designed with ARQ algorithms (Automatic Repeat Quest for error control on data link) for performance enhancement on networks with variable-quality links such as the powerline [13][14].

Another way to reduce errors is to transmit data only at certain time where the likelihood of errors is at the most minimum. It has been observed that most of the noise is cyclostationary and synchronous with the 50(60)Hz mains frequency. The largest error pattern is in the last quarter of the cycle where the largest noise pattern exists. Therefore, only certain portion which is approximatively 10% of the cycle can be used [6].

As far as this project goal concerns the energy saving; the modulating method that is proposed is the Spread Spectrum Carrier that, with respect to speed, can withstand the noisy and hostile nature of the powerline . Detection of errors is implemented by the CEBus error detection schemes.

CHAPTER 2

Power line communication:

2.1 Introduction

The use of Power Line Communication (PLC) as a communication medium is now feasible, thanks to developments in communication technlologies[2].

There are several obstacles to PLC. The transmitters are output voltage limited and bandwidth limited. There are different types of noise involved in PLC : (a) narrow band noise generated by TV sets or computer terminals is permanent during a long period of time and (b) impulse noise. These impulses are of 0.1 to 1 second apart and have a duration of typically less than 100 μs for data communication on existing power conductors [15].

The advantage of using power line for communication stems from the fact that the mains power network is easily reconfigured and can be accessed through any wall socket without additional wiring costs. Unfortunately, the AC power conductors present a hostile transmission media for data signal : due to the high noise levels, low impedance, and severe attenuation; all of witch change with time [6].

To face the effects of noise, researchers have used Frequency Shift Keying (FSK), Spread Spectrum Carrier (SSC) and forward error correction (FEC)[2].

The proliferation of personal computers in the business places has led to the need of interconnecting them for the purposes of resources sharing: such as shared software, data, and peripherals (printers). Computers may be interconnected using local area network (LAN) and usually this requires special installation that results in high costs and a long waiting period . In this context, the power line can be used as a communication medium at competitive cost when compared to special installation [6].

This work proposes the use of the existing electrical power distribution system as a communication medium. The topology of the distribution lines is universal in coverage. Lines are easily accessed through any wall socket. This allows the equipments to be portable and the network to be easily reconfigured.

However, the power distribution has not been intended or designed for data transmission and represents a hostile environment for digital communication. Attenuation varies from point to point as well as with time and frequency. Noise in the form of 50 Hz (60Hz) systematically interferes and random noise creates problems during transmission. Impedance variation is a function of both frequency and time. Thus, it is difficult to obtain the required power transfer from the transmitter to the line. Attenuation and impedance variations are further complicated by effects similar to multipath propagation arising from stub lines [2][6].

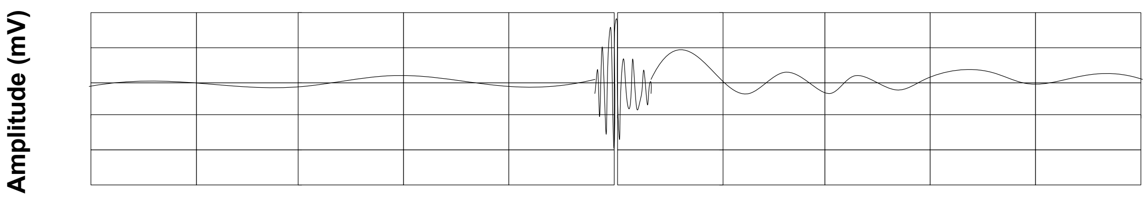
2.2 Disturbances and Noise

With the advent of the latest communication technologies, and the arrival of new high-speed devices, PLC is evolving to reach the mainstream of communication research .The problems to be overcame are due to the hostile environment of the power lines, are noise levels that are often severe [2].

2.2.1 Disturbances:

The causes of noise on electrical power line are : corona discharge , lightning, power factor, and circuit breaker operations. In low voltage domestic network, much of this noise is filtered by medium/ low voltage distribution transformers. The interferences, then, are essentially caused by household devices and office equipment. Figure 2.1 gives an illustration of two sources of noise:

a)



b)

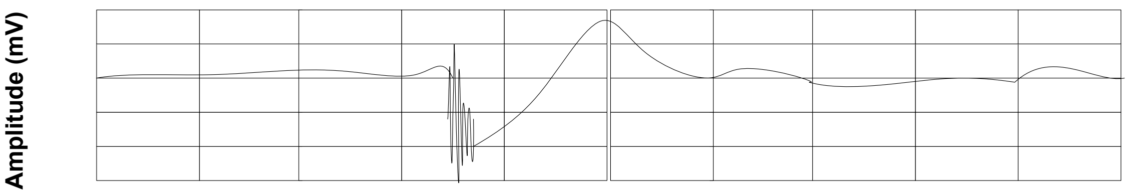


Figure 2.1 One sample of impulsive noise generated by a) an electrical drill b) a light dimmer [2].

Classification of noise and disturbances on the electrical power network .

Different types of disturbances on the the electrical power network can classified as follows: [15]

1) Waveshape disturbances
    a) Over voltages, persistent (> 2 seconds) or intermittent (< 2s)
    b) Under voltages, both persistent or intermittent
    c) Outages
    d) Frequency variations
    e) harmonic disturbances
2) Superimposed disturbances
    a) Persistent oscillations, coherent or random
    b) Transient disturbances, impulse and damped oscillations

Waveshape disturbances have little effect on PLC systems. Transceivers are designed in such a way that they can overcome over voltage and under voltage effects. Line outage results in non-viable transmission.

Harmonic is a a major source of disturbances at low frequencies. PLC systems relying on the mains carrier (50 Hz) for synchronization are subject to the harmonic disturbances. In latest systems, synchronization relying on the mains is strongly avoided .

Superimposed disturbances at home and office building are caused by various appliances and equipments.

Also, noise can be categorized as follows: [13][15]

A. Noise having line component synchronization with power system frequency
B. Noise with smooth spectrum
C. Single event impulse noise
D. Non synchronous noise
    A) Noise having line component synchronous with the power system frequency. This type of noise, called Type A noise, is caused by triacs or SCR's inside the light dimmers or photocopiers. Its spectrum is a series of harmonics of the mains fequency (50 Hz) . Due to the fact that Type A noise is regular in its nature, it can be avoided by using modulation modes that avoid or have nuls at these

frequencies. Also, the use of filtering reduces greatly this noise.Class A noise pulses are expected at equal intervals; using time division multiplexing schemes and error correction allow minimized noise effects .

B) Noise with a smooth spectrum called class B type noise is generally caused by universal motors contained in motor powered appliances: blenders, vaccum cleaners, copiers etc… It can be modeled as limited white noise. The appliances that generate class B type noise are of intermitent and short time use. PLC systems that do not have to function in real time can avoid this noise by operating at a time when the noise is absent. Real time systems, on the contrary, must be able to counter this noise by appropriate methods.

C) Single event impulse noise, called class C type noise, is mainly due to switching phenomena, lightning, and contacts closings. This type of noise is distributed over the whole frequency band, but for a short time. It can be overcome by error correcting codes .

D) Non synchronous noise known as D type noise with periodic components occuring at frequencies other than harmonics has as major source the scanning and synchronization signals generated in TV sets and computer monitors. To minimize this kind of interferences, data transmission at the frequency and associated harmonics of these synchronization signals is simply avoided.

In developing PLC communication systems, appropriate error correcting codes should be employed to reduce A, B, and C noise effects. Frequency hopping greatly helps system immunity to the above mentioned noise types. In table 2.1, are listed various relevant types of noise with amplitude and duration [16].

Table 2.1 noise source types[16]:

Electric Apparatus	Amplitude (mV)		Duration (µs)	
	Average Value	Standard Deviation	Average Value	Standard Value
(Single pulse)				
Electric Oven	329.2	431.2	1015.8	505.2
Iron	369.3	3585.8	760.2	347.9
(Periodic pulses)				
Television Monitor	197.2	311.3	722.4	34.3
Light Dimmer	670.8	1199.3	140	7.5
(Continuous pulses)				
Vaccum Cleaner	1457.5	2155.5	Always	---
Dryer	87.9	119.7	105.3	56

2.2.2 Powerline Channel Impedance and attenuation.

The characteristic model impedance for a power cable is :

$$Z = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \qquad (2.1)$$

At the PLC frequencies, tens of kHz to 500 kHz, this impedance can be approximated

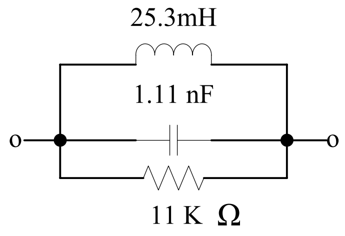
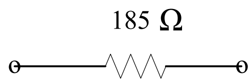
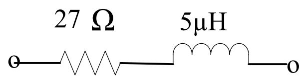
to $$Z = \sqrt{\frac{L}{C}} \qquad (2.2)$$

Where the parameters (per length) are:R for the resistance , G for the conductance, L for the inductance, and C for capacitance.

In PLC , there are number of loads , that are appliances with different impedances connected at different lines and at different of time. Consequently, the line impedance is much of a random time varying variable that is difficult to be predicted [17].

Following table 2.2 shows some impedance models of current electrical appliances:[16]

Table 2.2 – Impedance models for common electric apparatus [16].

Apparatus	Impedance model
Refrigerator	
Incondesant lamp	
Food warmer	

The overall impedance resulting from parallel connection of all the loads existing on the power line network will be dominated by the load having the smallest impedance [16].

Shaap [18] quoted figures of 0.1- 2 Ω for low voltage network. Doster [18], 2-150 Ω. Malack and Egstron [17] attribute a figure of 0- 0.8 Ω. It has been noticed that impedance is very low , and hence leads to obvious difficulties in the design of coupling network for PLC communication.

Power line channel models whose parameters vary with time are difficult to determine. No accurate model can be designed in a straightforward manner. Two models are generally accepted as good representations of PLC channels.Dostert [18] proposes the model type that is shown in Figure. 2.2

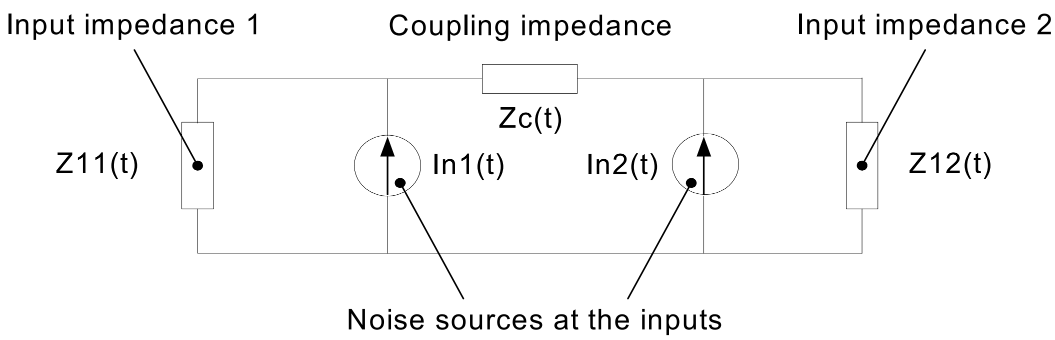


Figure 2.2 Dosert's Power Line Channel Model [18]

Onunga et al[19] propose the model of Figure. 2.3

The filter response H(f,t) represents the change in electrical loads, and B the fading level of the noise relative to the signal.

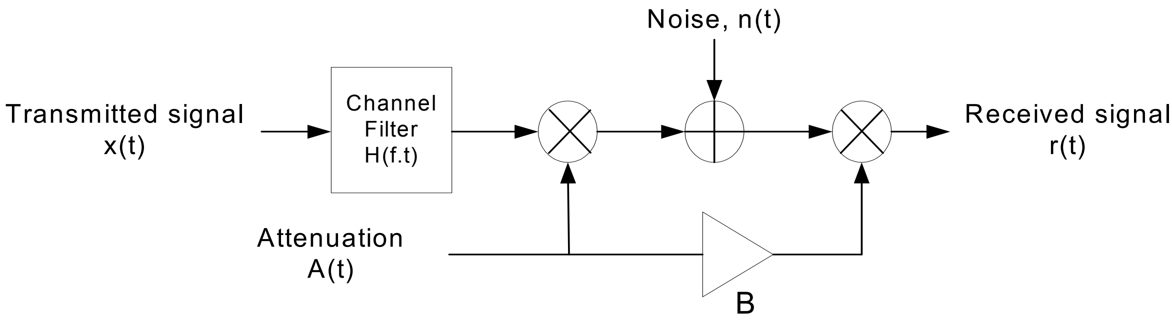


Figure 2.3 Onunga's Channel Model [19]

In the past, attempts have been made to transmit data at low bit rate over the lines using technologies such as FSK, SSC, FEC, and other types of error control; coding have also been applied to control interferences [13][20].

There have been commercial products designed for use on the power distribution lines. Ex: Signalies NE5050.plm which uses either FSK or ASK (Amplitude Shift Keying), the Echelon PLC.10 and the Intellon SSC P485 PL which use SSC. These systems have transmitted with bit rates between 1kb/s to 10kb/s [5].

2.3 Regulations on PLC

The increasing use of power line as a communication medium has led to the need of establishing regulations.

2.3.1 Available bandwidth

The available bandwidth for PLC is not limited by physical constraints, but rather by regulations set up by the authorities. The regulations may differ from one country to another. The standards used in the communications obey to regulations and recommandations. They list the limitations on the bandwidth in order to prevent interferences and other contentions [21].

2.3.2 Regulatory Standards for PLC

Various standards provide regulations in the form of operating specifications when using PLC systems. These standards result in from several considerations under maximum multiple-user efficiency and ways to avoid interference from external sources. The most rigorous standards of PLC are provided by CENELEC and the E.E.C's electrical standardization organizations.

The CENELEC's EN 5006 " Low voltage mains signaling" sets the regulations of main parameters such as frequency range, signal power, and so on. The operating frequency band is 3-148.5 kHz, so choosen to avoid interferences with ripple control at the lower boundary and interferences with long wave (LW) and medium wave (MW) radio broadcasting at the upper boundary.

On the other hand, CENELEC divides this band into several categories:

The A band, from 3-95 kHz, is allocated for electrical utilities like meter reading and customer load control.

The B,C, and D bands ranging from 95 to 148.5 kHz, are left for end-user applications. In each of these bands, a different protocol provides its own regulations. The B band, from 95 to 125 kHz, is especially used in applicatios not allowing simultaneous transmission from two separate systems; for there is no access protocol for establishing two ways communication. In this band, baby monitoring and intercoms are adequate uses.The C band, from 125 to 140 kHz, needs an access protocol to establish communications between transmitting devices; but, only one transmitter can operate at a time under specified access protocol frequencies. Main application in this band includes intra-building computer communication.

The D band, from 140 to 148.5 kHz,as in band A, requires no access protocol; therefore,messages colisions may highly occur.

2.4 Relation of Specification to the CEBus Model

PLC deals with the part that interconnect more than one device in a network that is the home or the office building mains power network. The way they communicate among them depends on the standards which set the rules and give the recommandations to allow different devices manufactured by different companies to recognize each other. The CEBus model, which is the standard for the EIA, is chosen to be the one to be used and its specifications applied to the PLC. Figure 2.4 illustrates the entire relation to the CEBus.

Specifications described in this work, are relevant only to the powerline, other specifications exist for other CEBus media such as the twisted pair, the coaxial, th RF, and the IR media [1].

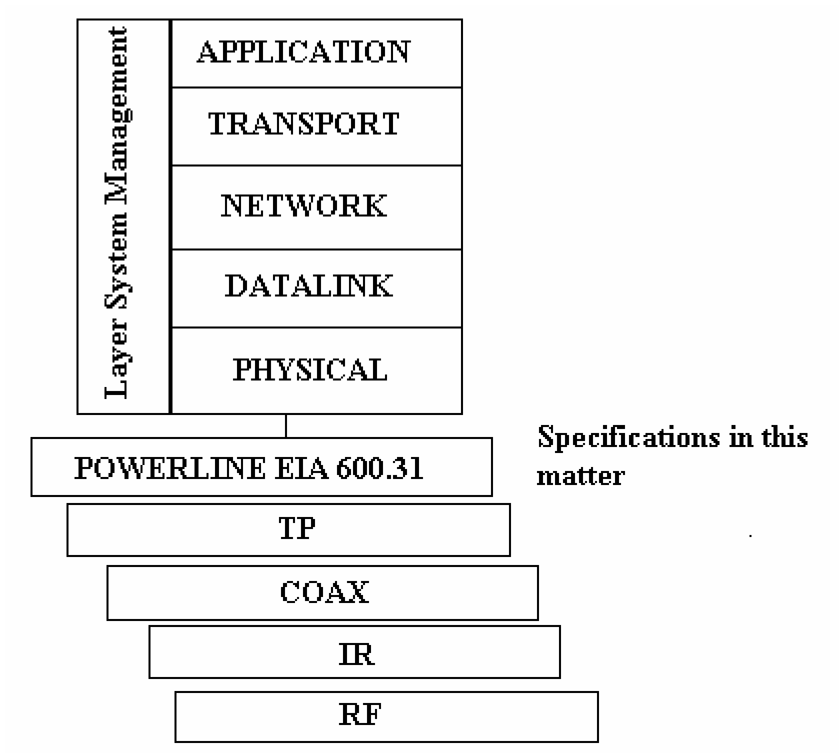


Figure 2.4 CEBus Relation chart.

2.5 Powerline Topology

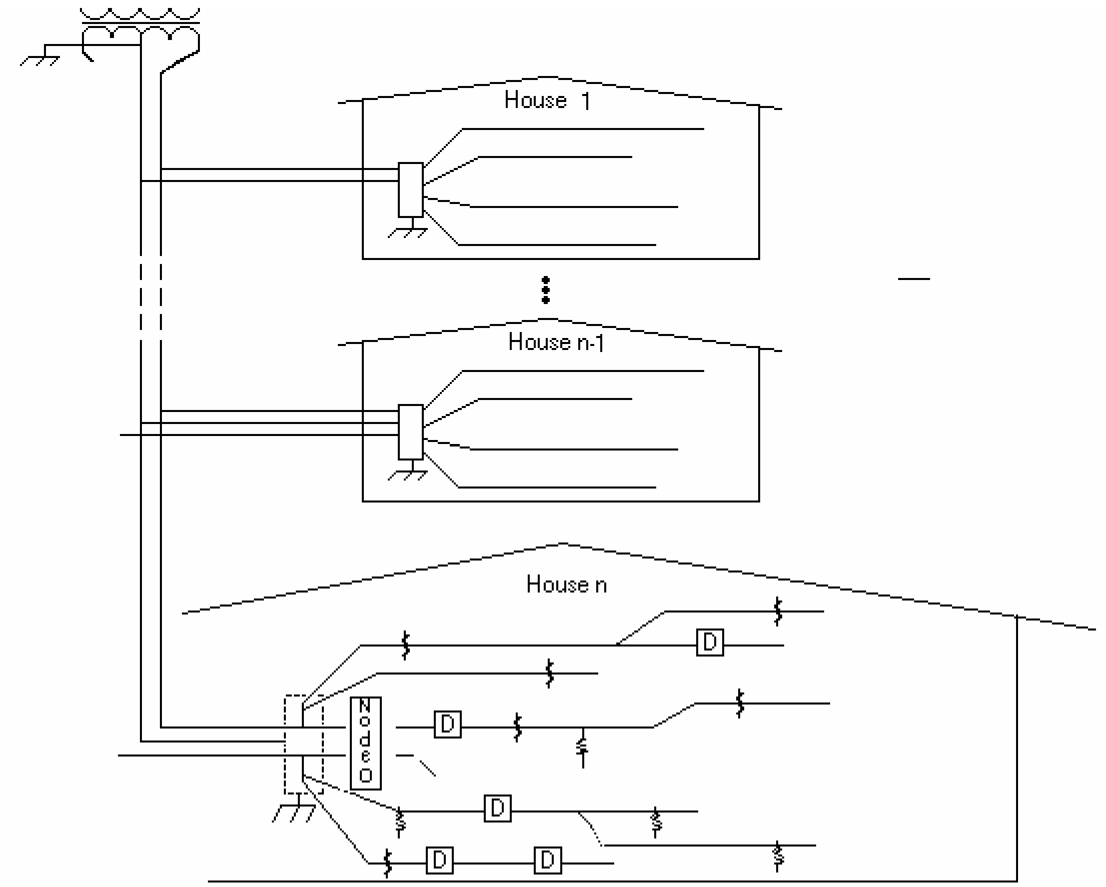
Here is described the physical topology of the powerline network, regarding the possible configurations of powerline wiring, the powerline devices connection, and the connection of other non-CEBus load devices to the network.

2.5.1 Powerline Network Description and Components.

A powerline network consists of the wiring from the distribution transformer throughout all buildings and homes connected to that wiring system. A powerline consists of wiring from the service entrance throughout buildings and houses. Node 0 devices (routers, data bridges) may exist if other media (telephone lines, RF, coaxial cables, IR, Optical Fibers, etc..) exists in the buildings and houses.

The powerline network contains a great number of resistive and reactive loads randomly connected and disconnected. This network is isolated by a distribution transformer appearing as a high impedance to the used signaling frequencies.

Figure 2.5 represents a typical PL network to show the most encountered topology . Any PL device in any building or house may communicate(and interfere) with any PL device in any other house in the network. In this manner, sources of network noise and load are not isolated to a home on the network [21].



D = CEBus PL Device ⌇ = PL Load

Figure 2.5 Typical PL Network Topology [21].

2.5.2 General Representation of the PL Network

Figure 2.6 shows a more general electrical representation of the PL network which shows that electrically, the home is merely a logical concept , and PL devices are either a pair of 120V, or 240V from the distribution transformer. Node 0 shown in Figure 2.5 and 2.6 includes any routing device to enable control channel signal transfer to and from other CEBus media present at the home. Node 0 could optionally integrate any data channel coupling device for coupling data channel signals to other media. No router or data bridge is required , if no other media is used in the home.

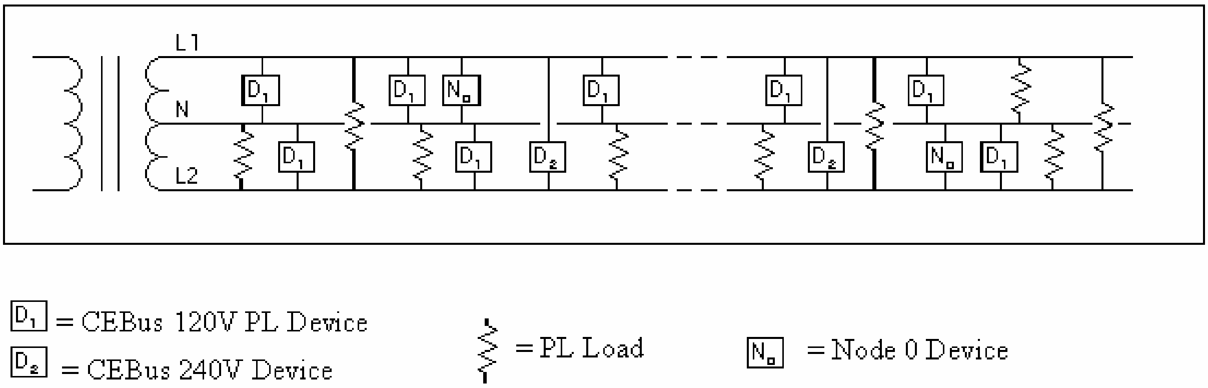


Figure 2.6 General PL Network Topology [21]

2.6. Power Line Medium Specifications

PL medium must have specific properties, both mechanical and electrical, that must be considered in order to support information transfer within the CEBus PL network.The specifications deal with the medium sublayer of the physical layer as shown in figure 2.4.

2.6.1 Frequency Allocation

CEbus standard divides frequency resources on a medium into CEBus and non-CEBus related application [21].

2.7 Conclusion

The power line was never intended for communications purposes. There are many inherent factors that make its use very challenging. Strong interference, varying attenuation and impedance are the main challenges that may limit PLC devices to simple automated use. But, with the advances achieved by modern communications, such as spread-spectrum methods, theses challenges can be overcome. Nonetheless, limitations on the use of PLC are not of physical nature but of regulatory standards imposed by governing authorities especially in regard of bandwidth availability. In face of these challenges, many existing techniques can make communication over the power line feasible and reliable.

One of the most powerfull technique is the Spread Spectrum Carrier (SSC) which is described in the next chapter.

CHAPTER 3

Spread Spectrum Carrier Technology:

3.1 Introduction.

Spread spectrum techniques, applied nowadays are producing results in communications, navigation, and test systems that are not possible with standard signal formats. A spread spectrum system, as a definition, is a system in which the transmitted signal is spread over a wide frequency, much wider, than the minimum bandwidth necessary to transmit the information.

Three general types of techniques exist:

a) "Direct sequence " modulation system where a carrier is modulated by a digital code sequence whose bit rate is much higher than the information signal bandwidth.

b) Carrier frequency shifting in discrete incrementations based on a pattern dictated by a code sequence. These are called "Frequency hoppers".

c) Pulsed FM or chirp modulation in which a carrier is swept over a wide band during a given pulse interval [5] [13] [21].

The Spread Spectrum Carrier signal which can be classified as pulsed FM or chirp modulation uses a swept frequency pulse, called a chirp; that is a very short sequence pattern that spreads the signaling energy over a wide frequency range [20].

In the case of EIA's CEBus standard, the signal is spread over a frequency range of 100 kHz to 400 kHz with an effective bit rate of 10 kHz. Other systems; especially in Europe, the frequency range of a chirp is between 20 kHz and 80 kHz. At first instance, the frequency sweeping of the pulse or chirp could be from 100 kHz to 400 kHz . Intellon has implemented a sweeping pattern that begins and ends at 200 kHz with a middle transition from 400kHz to 100 kHz. The reasons behind this are for simplifying the filtering requirements in order to limit harmonic energy generated by the signal; and for allowing a smooth transition between data bits [22]. The resulting signal is shown in

Figure 3.1

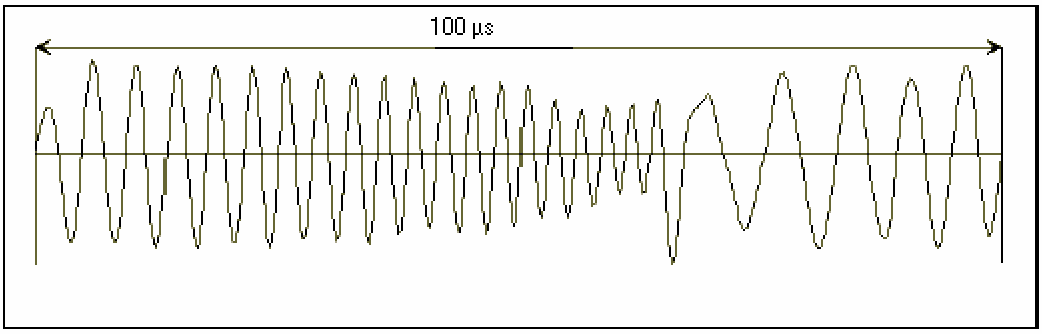


Figure 3.1 Spread Spectrum Carrier Chirp

In Figure 3.1, the chirp is shown to occur over a 100 µs time period which is the unit time. This is for a 100 kHz to 400 kHz sweeping yielding a 10kb/s communication bit rate. The signal amplitude varies noticeably with the frequency change; this is because of the change in powerline impedance with frequency [4] .

The processing gain (ie: the advantage gained over conventional narrow band techniques provided by the Spread Spectrum signal is equal to the spread bandwidth divided by the data bandwidth). This ratio is 30:1 which corresponds to a processing gain of 14.8 dB. The frequency spectrum is shown in Figure 3.2 [1].

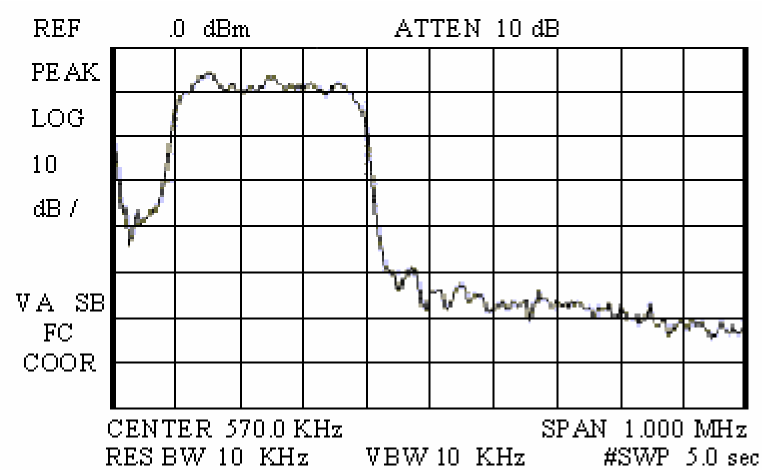


Figure 3.2. Frequency Spectrum of a PL "Chirp" [1]

The Spread Spectrum technology allows the implementation of very low cost yet reliable spread spectrum transceiver IC's The sweeping frequency signal can be generated by the implementation of a simple lookup table stored in a ROM (see the ROM chirp lookup table as table A-2 in appendix A-2). This way, a very simple correlation method can be employed to decode the received chirp.

3.2 Signal Encoding.

In the EIA CEBus standards, the type of signal encoding for powerline control is NRZ (Non Return to Zero), and of pulse width encoding by the use of four distinguished symbols: “1”, “0”, “EOF”, “EOP”.

These symbols are encoded as series of chirps coupled to the powerline. The carrier is a sinusoidal waveform that is swept linearly from 203 kHz to 400 kHz in 19 cycles, then to 100 kHz in one cycle, and back to 203 kHz in 5 cycles during a 100µs time period.

This unit of time equals the shortest symbol time, that is the symbol “1”, and is called the unit symbol time (UST). For longer symbol times, the chirp repeats for a multiple of the unit symbol time. The follwing table 3.1 gives the symbols in terms of UST:

Table 3.1: encoding symbols

SYMBOL	PREAMBLE		NON PREAMBLE (Packet Body)	
	UNIT SYMBOL TIME	TIMING	UNIT SYMBOL TIME	TIMING
“1”	**1**	**114 µs**	**1**	**100 µs**
“0”	**2**	**228 µs**	**2**	**200 µs**
END OF FRAME “EOF”	**8**	**800 µs**	**3**	**300 µs**
END OF PACKET “ EOP”	**N/A**	**N/A**	**4**	**400 µs**

The basic principle of encoding these symbols is the use of two different states on the powerline medium in two cases .

3.2.1 Preamble encoding.

In order to start a transmission from one node to other nodes , there must be a way to provide a signaling pattern to be detected by the receiving nodes. This pattern is the preamble that is encoded differently from the message packet that conveys the information to be transmitted. During the preamble part, there is a superior state that represents the presence of the frequency swept carrier, and the inferior state that represents the absence of the carrier. During the preamble part, the type of modulation is Amplitue Shift Keying (ASK) Figure 3.3 :

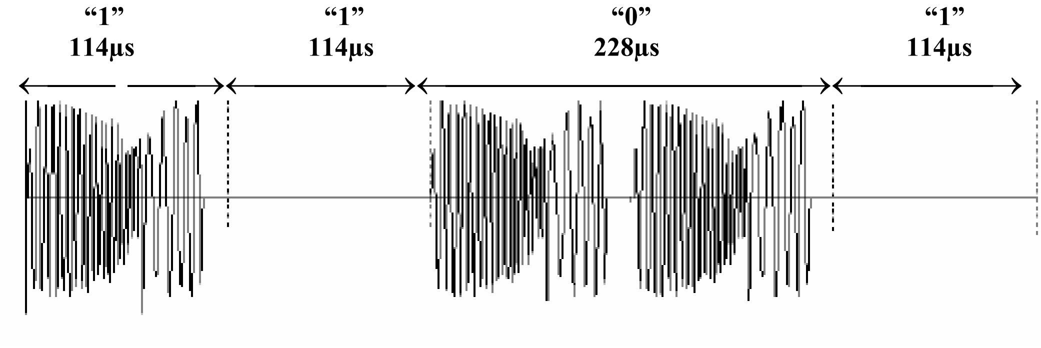


Figure 3.3 Amplitude Shift Keying (ASK) Data Pattern

A quiet time of 14 µs of length is added to the chirp in the superior state, and in the same manner the inferior state is extended by the same quiet time. During the absences of the chirp ; that is in the inferior states, and during the 14 µs quiet times in the superior states a continuous detection scheme is enabled in order to check the availability or the occupancy of the channel. Inferior state or superior state are not respectively and exclusively related to symbol "1" or "0", but they alternate at each data symbol occurrence. For example two successive "1" take an inferior and a superior state. On the other hand the symbol "0" can take a superior state having two UST , (ie: two consecutive chirps , since a "0" equals twice the unit symbol time), or an inferior state during two UST (ie: two consecutive absences of chirp).

3.2.2 Packet encoding.

The encoding for the message packet is different from preamble encoding. The two different states are the superiorØ1 and superiorØ2 states that encode the different symbols. The two states are distinguished by just reversing the phase of the carrier at the beginning of every new data symbol occurence. For example two consecutive "1" woulld be two chirps of equal length but with 180° phase shift with respect to each other. A "0" symbol will consist of two consecutive chirps of same length and same phase.At the occurrence of another "0", there would be two consecutive chirps having a 180° phase shift with respect to the two previous ones.The superiorØ1 is stated as phase1, and superiorØ2 is stated as phase2 in the incomming paragraphs.This type of modulation is Phase Reversal Keying (PRK) as shown in Figure 3.4.

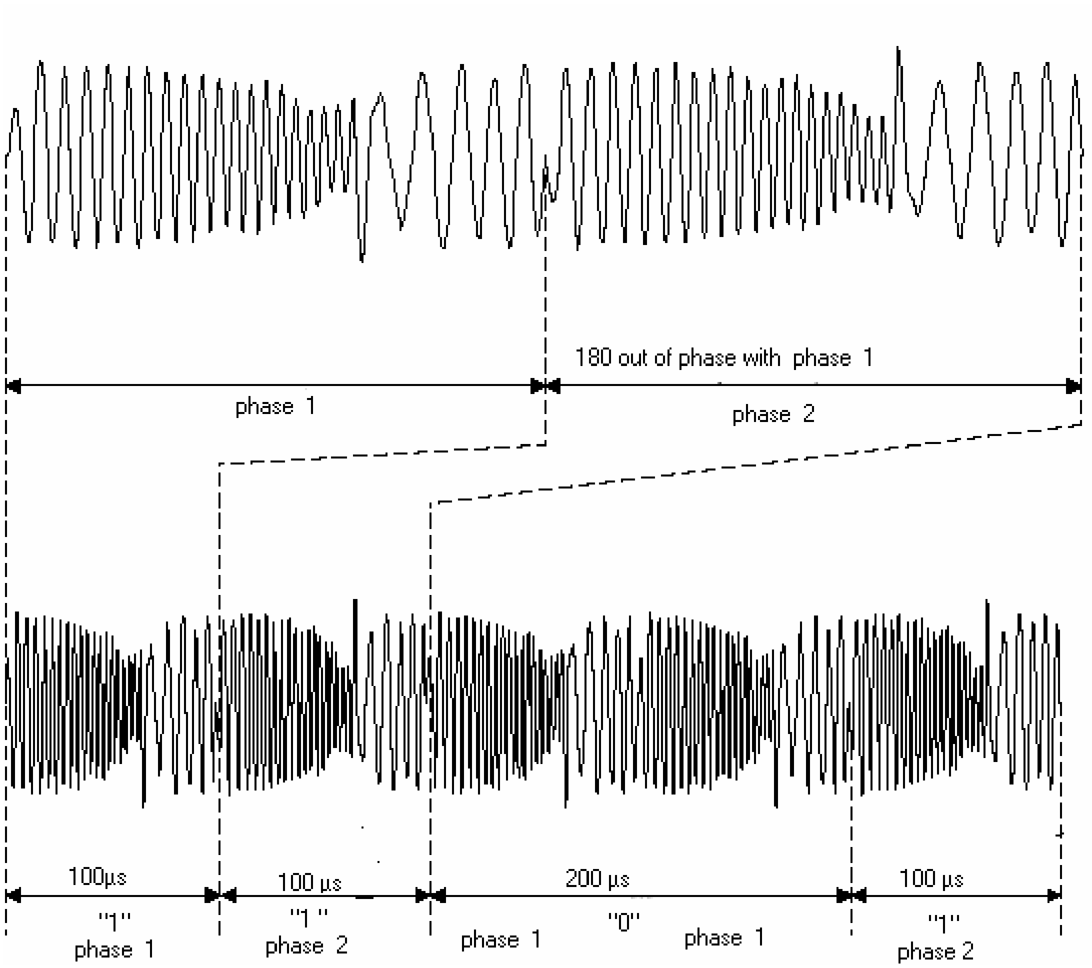


Figure 3.4 Phase Reversal Keying (PRK) Data Pattern

3.2.3 Preamble and Packet data Pattern.

The two modulation schemes used for symbol transmission are distinguishable for the preamble part used for synchronization, and the packet body part that convey the main configuration and controlling messages.

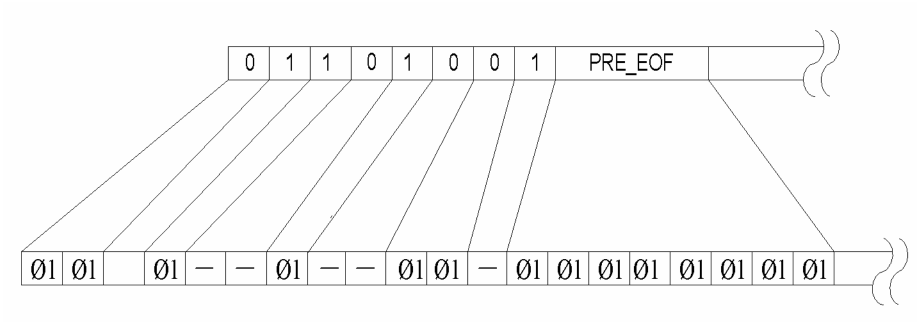
3.2.3.1 Preamble data Pattern.

The first part uses the ASK type modulation, and it consists of a pseudo-random pattern of eight “1” or “0” symbols followed by a preamble_EOF symbol. Whenever the preamble is encoded, the first symbol, whether it is a “1” or a “0”, must be encoded as a Superior state. After the preamble data, follows the Preamble_EOF, which consists of eight Superior states (i.e.: 8 consecutives chirps of 100 µs with no additive quiet time in between as in the preamble data) to terminate the preamble part.

Example:

Preamble symbols to be transmitted.

"0" "1" "1" "0" "1" "0" "0" "1" + Preamble_EOF



Ø1: Superior state

__ : Inferior state

PRE_EOF: Preamble End of Frame

Transmission begins with a "0" symbol in the Superior state

3.2.3.2 Packet Body Data Pattern.

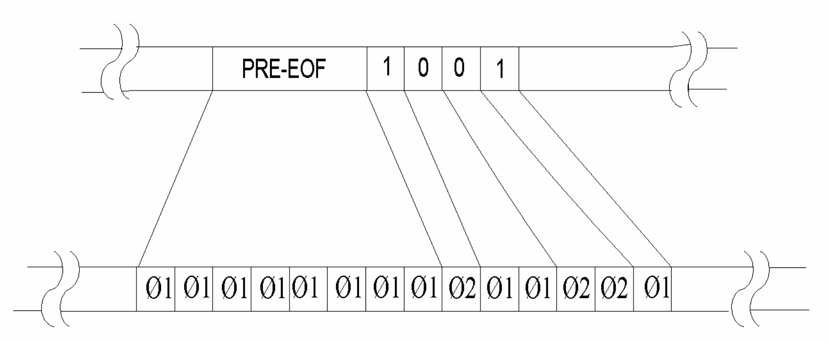
The second part, that is the body of the data packet uses the Phase Reversal Keying (PRK) type of modulation, and it consists of two phases of the Superior states; phase 1 which is the SuperiorØ1 and phase 2 which is the SuperiorØ2 . These phases are 180° out of phase with one another. This modulation technique is more efficient than the ASK technique, because it enables the physical layer to correlate and track each UST, contrarly to the ASK where the correlation and tracking is applied only on the superior state or during the presence of the chirps [5].

At the end of the transmission of the Preamble_EOF, the following symbols of the packet body transmitted using PRK must obey a certain rule.The SuperiorØ1 state will have to be in phase with the Preamble_EOF. The first symbol following the Preamble_EOF must be encoded with the opposite state of the Preamble_EOF. The data packet will end with an EOP symbol as:

"1111" or "0000".

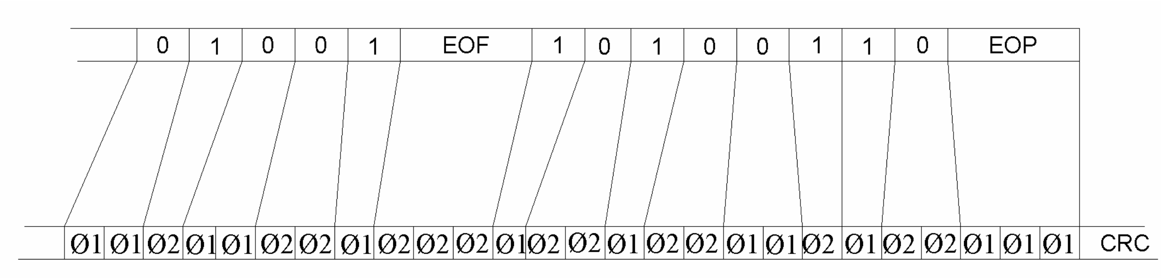
<u>Example-Packet Data Pattern</u>

a) beginning of packet



PRE-EOF:Preamble end of Frame

b) <u>End of Packet</u>



EOF : End of Frame — Ø1: SuperiorØ1 (phase 1)

EOP : End of Packet — Ø2: SuperiorØ2 (phase 2)

CRC : Cyclical Redundancy Check — ØX : SuperiorØ1 or SuperiorØ2

ØX	ØX	ØX	ØX	ØX	ØX

Cyclic Redundancy Check. Cyclic redundancy checking uses a division operation on the transmitted sequence, appending the remainder of the division operation to the message transmitted. At the receiver, this same operation occurs. If the result of the division is other than zero, an error has occurred. CRC error checking methods have very high detection percentages (more than 90%), but are very demanding in terms of computation time.

3.2.3.3 CRC Generation and Reception.

At th end of each transmitted packet, a 16-bit Cyclical Redundancy Check is added to improve the reliability of the communication. The physical layer is in charge of the generation and the detection of all CRC's. Upon detection of the Preamble_EOF, the CRC is computed and prepared for inclusion in the packet. Once the EOP symbol is detected and transmitted, the CRC is appended to the packet and transmitted following the EOP. Upon reception, the Preamble_EOF is used to determine the SuperiorØ1 state of the incomming packet. If the SuperiorØ1 state is detected as a "0", the complement of the incoming data is used to check the CRC received at the end of packet. This allows the physical layer to correctly decode the CRC when the transmitting node is connected to the opposite phase of the powerline from the receiving node [5].

3.3 Signal Characteristics.

3.3.1 Device AC Input Impedance.

The combined AC input impedance of the receiver and transmitter measured at the device network terminals must be equal to or greater than the minimum value verses frequeny, that is shown on table 3.3. These requirements are to be applied whenever the PL devices are coupled to the powerline except in the Superior state. The impedance is to be measured using a sinewave signal [21].

Table3.3. Input impedance [21].

Device input impedance vs. frequency 20-5000 KHz	Measurement amplitude
> 300 Ω	12 Vpp

3.3.2 Transmitter Characteristics

The device while in the transmission duties shall have a differential driver capable of driving the specified carrier waveform on the PL network. The following sections detail the transmitter requirements for generating the Superior (either phase) and Inferior states on the PL network.

3.3.2.1 Superior Output States

At the reception of M_STATE.request(SuperiorØ1), the transmitter will generate the SuperiorØ1 state. Upon reception of M_STATE.request(SuperiorØ2), the transmitter will generate the SuperiorØ2 state. The Superior state carriers are defined by the waveform shape and amplitude requirements as depicted in sec.3.3.2.2

3.3.2.2 Waveform Generation

The AC output voltage generated during either Superior state shall be a swept frequency series of sine waves, as shown in Figure 3.5, impressed upon the instantaneous AC power line voltage. The only difference between SuperiorØ1 and SuperiorØ2 is that one is the exact opposite phase of the other.

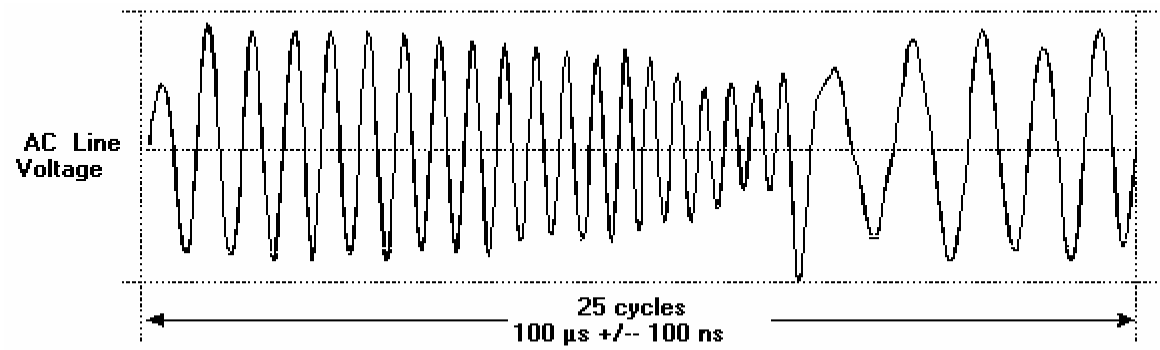


Figure 3.5 Frequency Swept Carrier Waveform

The carrier will begin at the 0° point at 203 kHz and linearly sweep to a frequency of 400 kHz in 66µ sec (19 full cycles), then linearly sweep to 100 kHz in 4µ sec (1 full cycle), and then linearly sweep to 203 kHz in 33µ sec (5 full cycles).Therefore, the obtained waveform is of 100µ sec (± 100nsec) ending at the 0° point after 25 cycles. The carrier can begin with either a positive or negative going phase. The shape and relative amplitude of the waveform over time, approximated in Fig-3.5 is a complex function designed to reduce out-of-band radiated interference from the carrier.

The specification for the waveform shape is given in (Table A-2 of Appendix A-2) that describes the relative amplitude of the waveform over 360 evenly spaced intervals (over the 100µ s frequency sweep period). The values shown in this table for each point are relative to a maximum of ± 0.5 about a 0.0 reference level. The values for the waveform of the opposite phase will be identical except for having the opposite sign [21].

3.3.2.3 Amplitude

The amplitude of the carrier output voltage during either Superior state, into the test load shown in Figure 3.6 at the PL connector of the device, shall be between the minimum and maximum output levels given in table 3.4. The output voltage is measured between adjacent waveform peaks developing the highest differential amplitude. These output levels will be met over the load range represented by the switched load conditions of the test circuit.

Table 3.4- Amplitude Output voltage [21].

Output Voltage Minimum	Output Voltage Maximum	Load Range
5 Vpp	14 Vpp	39Ω -8. 2KΩ

To obtain proper reception and minimum out of band interference, the envelope shape of the transmitted swept carrier (relative amplitude of each cycle of the output with respect to the maximum output amplitude) will match the envelope shape of the waveform of Table A2 of appndix A2 to within ± 10% measured while driving the test circuit of Figure 3.6 [21] in the closed switch position.

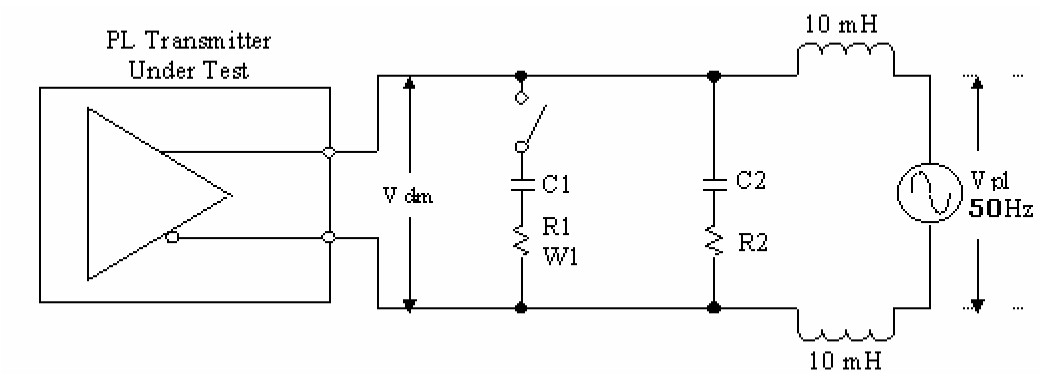


Figure 3.6 Carrier Output Voltage Test Circuit [21].

Switch closed: Minimum network impedance

Switch open: Maximum network impedance

C1	R1	C2	R2	V_{PL}
1.3µF	39Ω	3.6nF	8.2KΩ	240 VAC

3.3.2.4 SuperiorØ1 to SuperiorØ2 Transition

At the occurrence of output transition from the end of one Superior state to the start of another Superior state of the opposite phase, the waveform amplitude ±2 intervals about the transition point may take any value necessary to implement the phase reversal (less than the maximum waveform amplitude allowed during this interval) provided the out-of-band signal level requirements of Section 3.3.2.6 are met.

3.3.2.5 Inferior Output State

Upon reception of the M_STATE.request (Inferior) in the case of preamble transmission, the transmitter will enter the Inferior state. The transmitter also will automatically enter the Inferior state after the completion of the transmission of the SuperiorØ1 or SuperiorØ2 state waveform if the reception of an additional M_STATE.request (SuperiorØ1|SuperiorØ2) has not occurred before completion of the waveform. Figure 3.7 shows the relationship between the lower layers and their corresponding input/output elements.

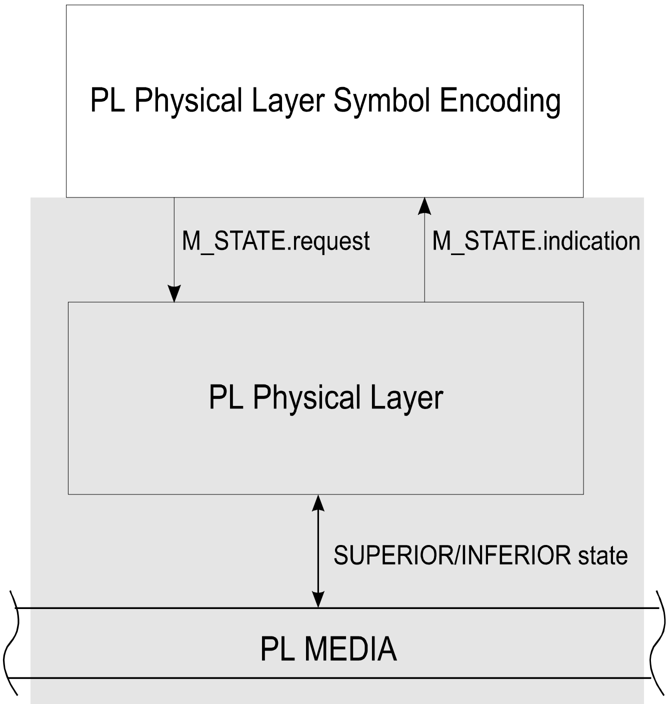


Figure 3.7 Powerline Lower Layers Relationship [22]

While in the Inferior state, the level of the AC output voltage at any frequency shall be less than 0.1mV p-p. This output level will be met over the load range appropriate for the operating voltage of the device while connected to the test circuit of Figure 3.6 [22].

3.3.2.6 In-Band and Out-of-Band Signal Levels

The maximum conducted carrier signal level within the band from 100 KHz to 400 KHz will be 14.0V pp.

The maximum out-of-band conducted signal level generated by the frequency swept carrier measured in any 9 KHz band will be 1) less than 5mV RMS from 20 KHz to 80 KHz, 2) less than 500µ V RMS from 2.5 MHz to 5.0 MHz, and 3) less than 1mV RMS elsewhere within the band from 450 KHz to 30 MHz.[22]

3.3.3 Receiver Characteristics

The Powerline receiver shall be able to detect the two valid swept frequency carrier unit symbol state waveforms of SuperiorØ1 and SuperiorØ2. Detection is said to occur by correlating the received waveform with an internal model of the waveform and generating an indication to the Power Line Symbol Encoder (PLSE) layer when successful correlation has occurred after the completion of the state (of 100µ s). The difference between the received SuperiorØ1 and SuperiorØ2 state is 180° out of phase (with respect to the correlation function) of the carrier.The SuperiorØ1 sweep is to match the SuperiorØ1 carrier emlpoyed in the message preamble.

3.3.3.1 Superior States Recognition

The receiver indicates the detection of a unit symbol time of SuperiorØ1 state through the M_STATE_indication(SuperiorØ1) service primitive, when the receiver detects a positive correlation match with the incoming swept frequency carrier.

In the same manner the receiver indicates the detection of a unit symbol time of SuperiorØ2 state through the M_STATE_indication(SuperiorØ2) service primitive, when the receiver detects a negative correlation match with the incoming swept frequency carrier (the phase of the detected carrier is opposite of the phase of the SuperiorØ1 carrier).

Unit Superior state symbol recognition (of either phase) will occur when the received swept frequency carrier signal level is ≥ 10mV and <14V p-p in the band from 100 KHz to 400 KHz with respect to the instantaneous AC power line voltage at the receiving device terminals. The transmitted swept carrier waveform meets the relative amplitude and waveform timing requirements given in Section 3.3.2.2

3.3.3.2 Inferior State Recognition

In the case of Inferior state occuring only during the preamble part of the messages, it does not exist any requirement for the receiver to detect or report the Inferior state. No receiver correlation happens and no state recognition is signaled to the PLSE layer.[22]

3.4 Conclusion

In designing any communication system a number of choices exist as to what types of modulation methods, channels, media, and so on. After comprehensive litterature investigation, it was found that spread spectrum communication is the most suitable scheme in an environement of quasi unpredictable phase shift. The coupling network used to couple a signal onto the power line will represent a trade off between desired impedance and frequency response. As a result of testing a certain number of coupler topologies, a two-secondary coupler design has been chosen that optimizes that trade off..

CHAPTER 4

Home Automation:

4.1 Introduction

In today's man life, many devices are used for various needs. The devices are of several types; some for business equipements, some for lighting, ones for air conditioning, some for security, and some for entertainments. Most of these devices can be optimallly controlled to satisfy the needs for a better energy management and the quest for enjoying maximum comfort from smarter equipments and appliances.

A term that becomes self suggestible, to the extent that to define the automation of all home devices, is Home Automation. It describes the process of controlling devices using different standards, different methods, and different media. Standards are X10, CEBus, Lonwork, and Firewire. Media can be PL, RF, IR, TP, CX, and Optical Fiber.

In the present work, the chosen standard is CEBus (Consumer Electronics Bus) of the EIA (Electronic Industry Association), and the chosen media is Power line. This choice is based on the fact that the CEBus is well spread, of proven reliability, of medium complexity, and adopted by several companies. Power line; as a communication media, is inexpensive, and already available everywhere at home. All devices are plugged on the mains, then they are identified and taken in charge by control schemes. Such techniques come under another term that is Home Plug and Play (HomePnP) applied in Home Automation.

4.2 Home Automation Principles and HomePnP

Today, the control of the many appliances is accomplished by the operation of stand-alone subsystems that can be environmental control, security, and lighting. In general, interoperation between these subsystems are installed by different manufacturers or by different agents. A global home control system in such case can only be complex since individual system is installed separately and at different times. Furthermore, every individual installer has little knowledge of the entire home system design and is not trained for the integration of the whole system. He may have detailed knowledge of his own subsystem, and can seldom be cross-trained to deal with other subsystems in an integrated frame work . Exception to this, are the wealthy customers whose highly customized home control system is entirely installed and programmed by professionals [9].

HomePnP (or Home Plug and Play) introduces features that are integrated into a single home control system. HomePnP subsystems are harmonized with the activities of the homeowner and other subsystems within the home [23]. This can be illustrated in the following figure :

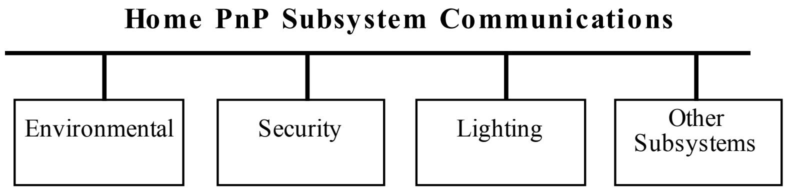


Figure 4.1 interoperation Using HomePnP Subsystem Communications

Common capability , with the HomePnP subsystems , is made available on the major subsystem and standardized status information is shared by all subsystems. For example, a security subsystem is able to notify all the listening subsystems that it is in an "armed " state. In response, a lighting subsystem is enabled to switch to a live-in-look mode, and a windows control subsystem will not allow opening a window without expressed homeowner intervention.

Interoperation among subsystems permits a basic level of integration. Consequently , the homeowner gains benefits in the form of convenience, and savings [23]. Home customization can be regarded under two distinguishable sides. On one hand for highly customized homes , extensive rules are to be used for higher quality systems and subsystems behavior. These rules are set depending on individual homeowner lifestyle and require the help of intelligent installation tools and procedures; and of a general-purpose computer.

In the other hand, the HomePnP concept allows for customization only those owners of advanced home automation who desire more customization and integration to bear the costs of custom rules. Morever, customization under HomePnP enables low-cost entry products for a wide market . This can be illustrated in Figure 4.2

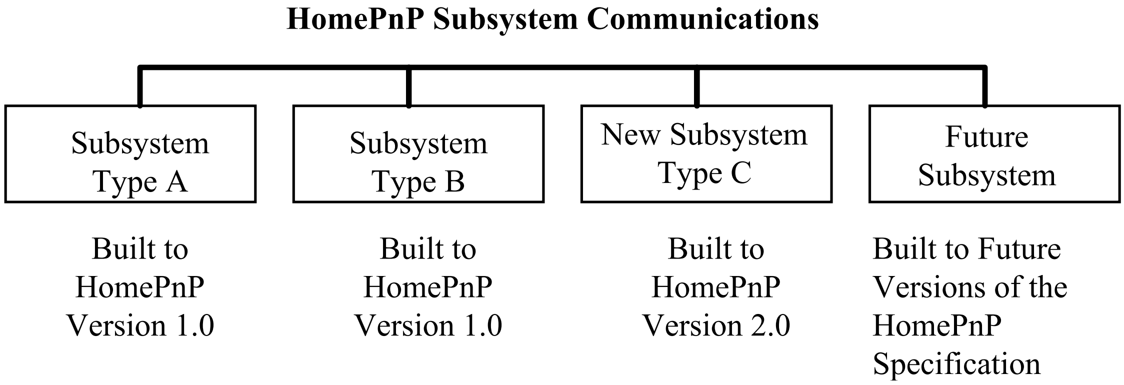


Figure 4.2 Adding On to an HomePnP system

Subsystems used for stand-alone and harmonized interaction should be controllable from a central system. Hence , the market and the homeowner may begin with the system essential for normal operation and then add features, customization and integration as shown in figure 4.3.

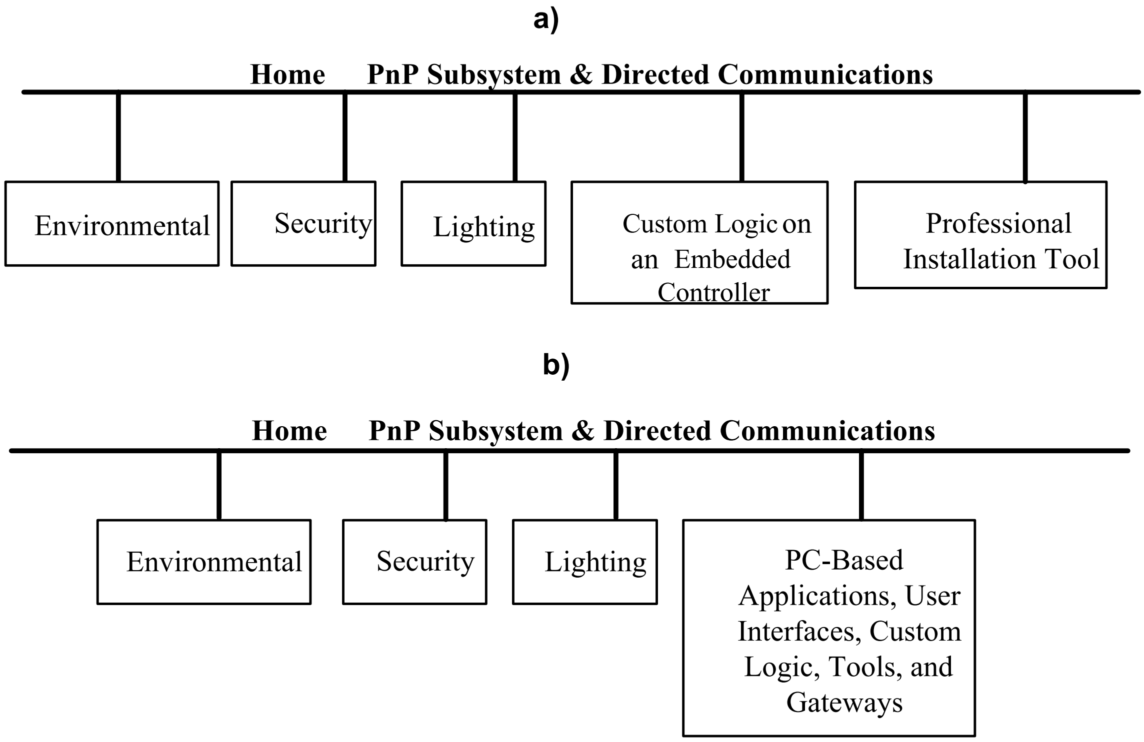


Figure 4.3. Configuration for Highly Customized Homes

The figure 4.3.a represents a customized system having an embeded controller and a portable installation tool. This can be one possible approach which can be used for the professionally installed market segment. The figure 4.3.b shows one other possible configuration in which a PC is part of the home control system. The PC provides application programs to control many types of subsystems in software, and acts as a user interface for both system and subsystem, and to function as a gateway across different home networks [23].

Necessary mechanisms must accompany the contexts and the objects for both loosely and tightely coupled or centrally controlled home control systems.

4.3 CAL and Application layer Used in Home Automation

Home devices communicate over a variety of home networks. Physical media for home networks include twisted pairs, IEEE 1394, coaxial cables, power lines, and wireless RF and Infrared.

The HomePnP techniques set the rules to enable a home control device to query or control another home device using any HomePnP network available in the home. HomePnP is developped in order to provide application level communications and interoperation among subsystems regardless of the lower level protocols [23].Home Automation protocols, classified as of the Open System Intercommunication (OSI) communication models, define physical, data links, and network components and as well as an appication level protocol.

Physical and data link protocols are specific to physical home networks. CEBus defines its own physical and data link protocols for power lines, twisted pairs, coaxiable cables and other networks. Network prtocol operates on top of any physical and data link protocols which are refered as low-level or transport-level protocols. These protocols describe how data is transfered between two devices. Application-level protocols describe Home Automation control commands and responses than can be exchanged between devices [23].

HomePnP refers to an application protocol able to run on top of different low-level protocols. It is designed to establish an industry standard within the application level by defining the control messages that are exchanged between controllers and devices.

As a starting point, HomePnP uses the Common Application Language (CAL) and application layer of the EIA 600 (Electronic Industries Association) standard. CAL is a language sufficiently complete and flexible enough to support a wide variety of devices. It has also been adopted by many companies with the advantage of being an open specification. CAL is the language by which network-compliant devices communicate. It is a robust language that it is not dedicated to a particular function within the Application Layer. Instead, it provides a language for controlling devices and allocating ressources [23].

4.3.1 Application Layer Interfaces

Figure 4.4 describes the overall diagram of the composing elements of an application process used in Home Automation and HomePnP networks[23].

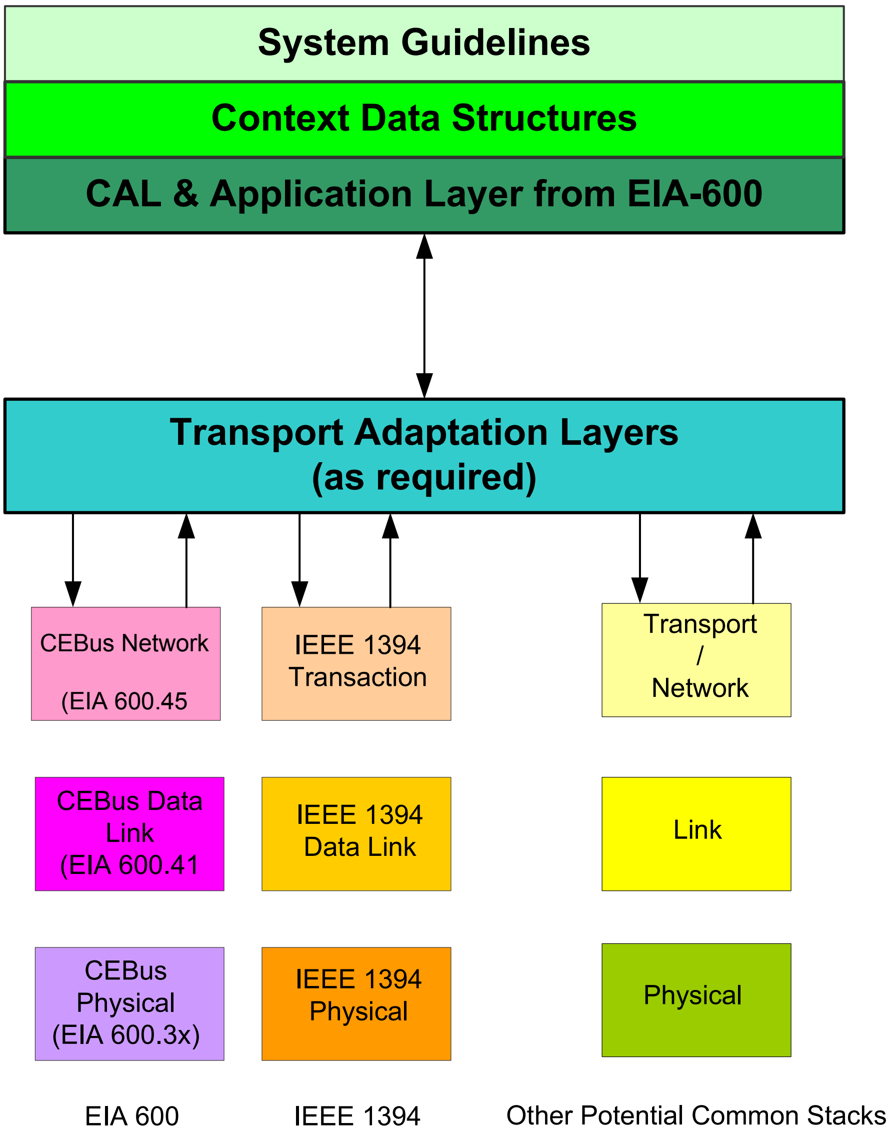


Figure 4.4 Application Diagram Supporting HomePnp on Multiple Stacks.

Figure 4.5 describes the overall block diagram of the composing elements of an application process from the EIA-600. The next sections explain the role or function of each element [23].

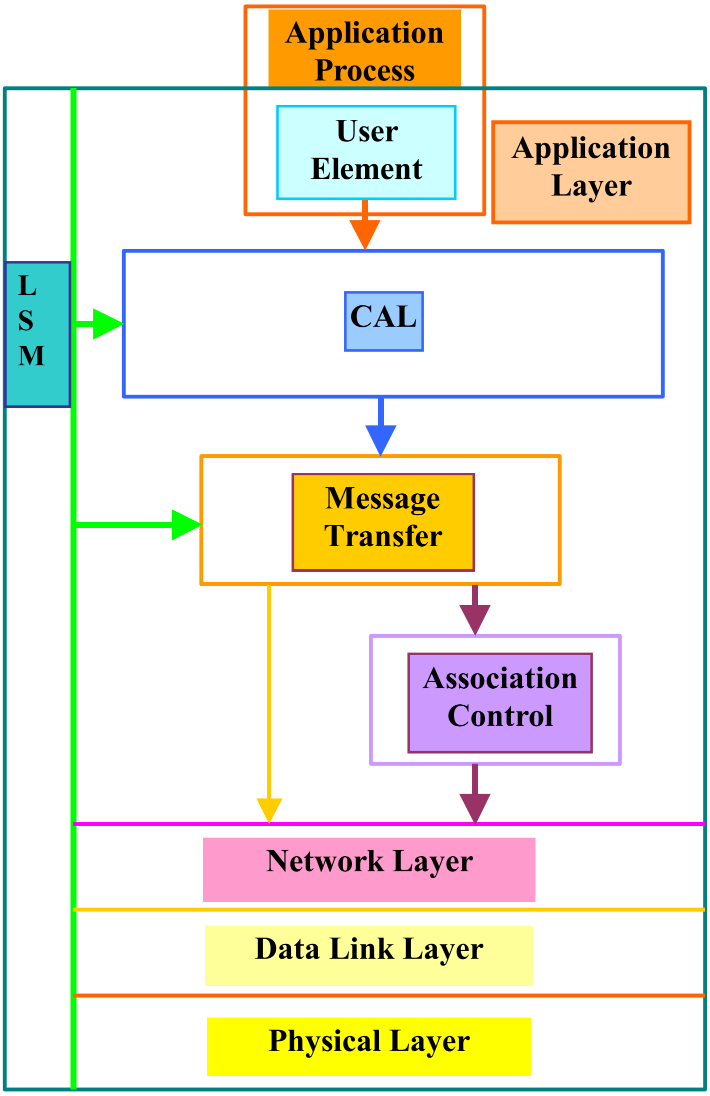


Figure 4.5 Application Layers Interfaces.

4.3.1.1 Aplication process

An application process is defined as the device domain that performs the information processing. It can be a person, a processor, or a combination of the two. The link to the

Application Layer is done by the User Element (UE) , which is a part of the Application Process.

The role of the User Element is to call on the services of the CAL Element, when the desired functions of the Application Process are to be executed. Among the many tasks performed by the Application Process, are the ones that must be done with the aim of minimizing traffic in order to reach the highest overall performance for all nodes [23].

4.3.1.2 Layer System Management

The Layer System Management is the administrator of the functions that perform tasks across different layers or devices as a whole. The nature of functions can range from the ones that are of local importance such as addressing to the ones of system-wide importance such as routing information.

4.3.1.3 CAL

The Common Application Language or CAL is the language used for communication by the devices that are connected to the Network and comply with it. The CAL is a robust language that allows the control of devices and the allocation of resources.

4.3.1.3.1 Resource Allocation

Resource Allocation is a function contained in the CAL Element. It is the other name for the functions of requesting, using, and releasing network resources. The resources include Device Address, group addresses, and data channels. The generation of a Resource Allocation can be illustrated by the description of the following sequence. Upon the request from the Application Process to the services of the CAL Element to obtain a resource, the Resource Allocation function generates the Application Service Data Unit (ASDU) by using the CAL system that request, assign, or release network resources. The CAL in turn calls the services of the Message Transfer Element to deliver the ASDU to the destination.

4.3.1.4 Message Transfer Element

The Message Transfer Element is the communication element in the Application Layer. It handles all the ASDU's that are generated either internally or as a result of an Application Process. The MTE assembles the Application Layer Protocol Data Unit (APDU) and passes them directly or via the Associated Control Element to the Network Layer.

4.3.1.5 The Association Control

This element comes into play when two Application Processes are associated. Figure 4.6 describe the association control. The task is passed to CAL in the CON_DATA request service primitives. At the level of the CAL, the primitives named above cause the Device A to generate the proper CAL command and request that the MTE delivers the data in the form of an MT-Invoke service primitive. The peer to peer communication between Device A and Device B MTE's is shown as MT service, which represents both MTE's, the lower layers, and the network interconnection.

At Device B, the arrival of the command becomes an MT_Invoke_indicate service primitive. Then the CAL parses the command and passes the task to the UE in the CON_DATA_indicate service primitive.

Now, at this stage, the task is completed and an indication of the task completion must be returned. A CON_DATA response is returned to the CAL element. At its turn, CAL syntax is used to formulate a result that is returned via the MT_Result_request service primitive. The result arrives as an MT_Result_indicate. And last, the task is confirmed by the CON_DATA confirm service primitive.

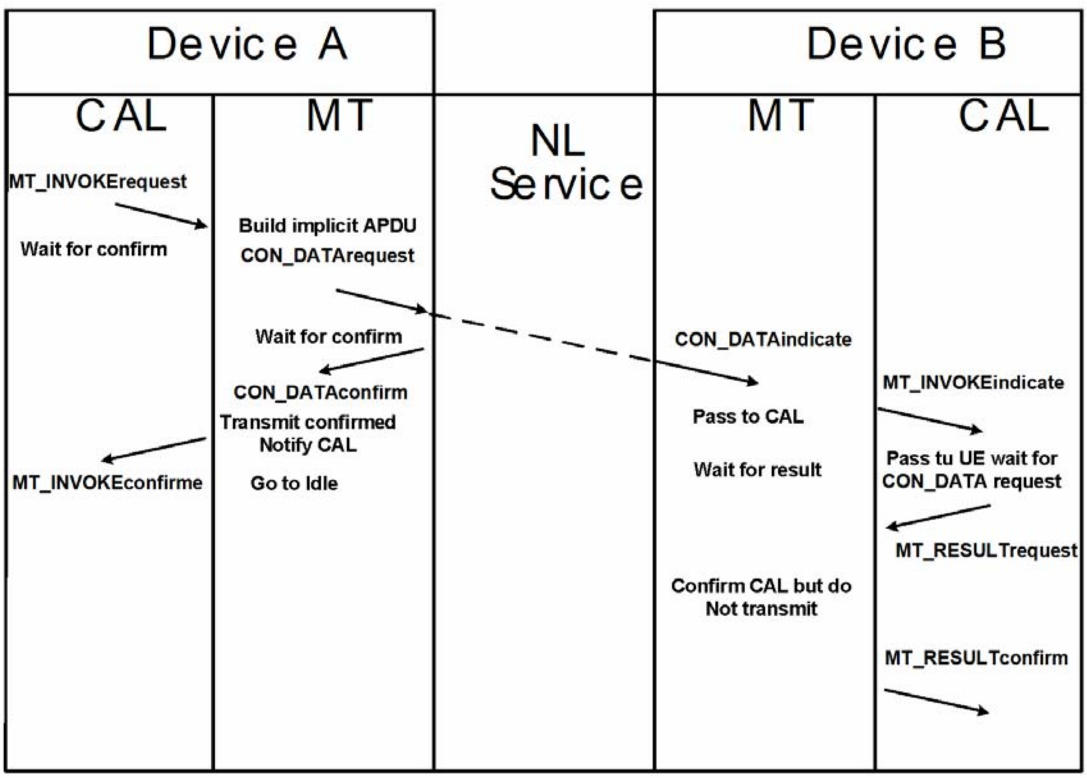


Figure 4.6 Association control description.

4.4 HomePnP Architecture for Interoperability

Five different layers of constructs may be depicted. The most basic layer begins with the Basic CAL building blocks that are documented in EIA-600 [9]. They include the concepts of addressable devices, contexts, context numbers, set of objects that contain instance variables, a reporting mechanism, and a set of transport-level services. In the second layer, to the HomePnP are added building blocks of a subsystem, status and listener objects, sensors, alarms, and a subsystem for developing and sharing house mode information. The third level concerns the mechanisms for creating interoperability between HomePnp devices and subsystems. Mechanisms contain default binding, loose coupling, dynamic context numbers, status information, and state vectors. In the fourth layer, is described the use of tightly coupled objects for intra-subsystems. The final layer adds other elements essential for interoperation. This is illustrated in table 4.1 [23].

Table 4.1. HomePnp Constructs [23]

Constructs Used By HomePnP	Elements
Building blocks provided by CAL	Devices, contexts, context numbers, objects, instance variables, CAL reporting, HomePnP broadcast and directed messaging
Building blocks used by HomePnP	Subsystems, status & listener objects, sensors, alarms, house mode.
Interoperability constructs for subsystem to subsystem (Intersubsystem) communications	Loose coupling, dynamic context numbers, broadcast of status information, state vectors, automatic binding and manual binding
Interoperability constructs for tightly coupled (Intrasubsystem) communications	Tight coupling, installation tools
Other requirements essential for interoperation	Start-up, configuration, resource management, heartbeat messages, authentication and encryption and transport requirements

4.4.1 Basic Building Blocks Used in HomePnP

Various levels of products may be constructed using the CAL Building of context, objects, and instance variables. These may be sensors or actuators, single-function devices or multi-function devices.

The CAL standard gives a standard set of object definitions that are:

Object: a CAL term used to define a single control function within a context. For example, an Audio context contains a gain object.

Context: a group of one or more CAL objects representing a common device function. Several contexts may be present in a single device.

Device: a mechanism that exposes state and control variables through a home network using the CAL protocol. Devices may be stand-alone hardware devices or may be implemented in software programs installed in a PC. A device contains a set of CAL contexts that receive messages to the same transport layer address. This address may be a unique system or unit address, one of many group addresses, or a broadcast address.

4.4.2 HomePnp Building Blocks

The first elementary HomePnp building block is the subsystem construct. A subsystem is a device that manages a major set of functions within a Home Automation system. Subsystems may include: security system, lighting system, environmental system, and entertainment system. A subsystem contains a set of CAL contexts that are responsible for a part of a control region. Also, it typically consists of controllers and other hidden or exposed functions. A subsystem may reside in a single device or may be spread over many devices. A device may include all or parts of multiple subsystems. This is illustrated in figures: 4.7, 4.8, and 4.9

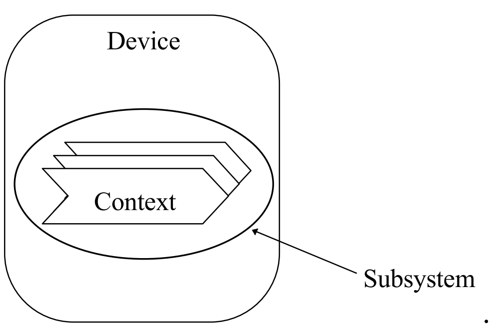


Figure 4.7 One HomePnP Subsystem per CAL Device

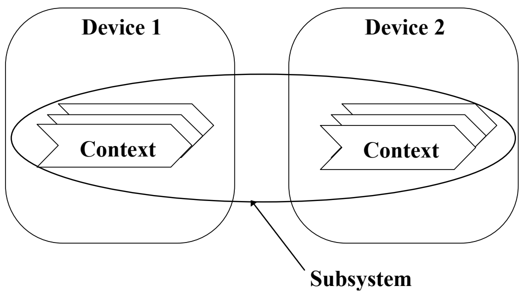


figure 4.8 One Subsystem May Span Several Devices

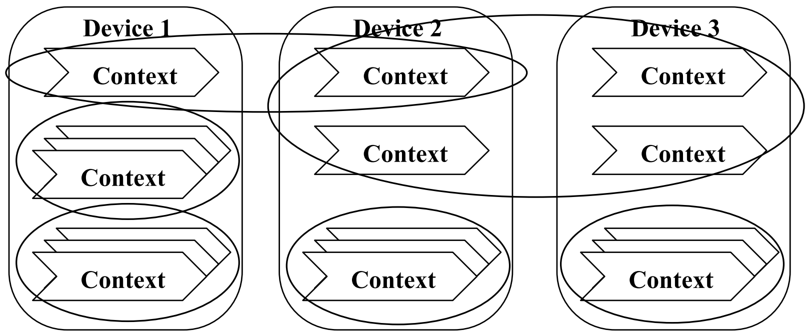


Figure 4.9 Illustration of Six Subsystems Contained in Three Devices

The reason for implementing subsystems is to achieve lower cost products. The subsystem concept permits multiple functions to be aggregated in a single network connection. An example could be an outdoor temperature sensor directly wired to an environmental controller that shares this temperature with other HomePnP subsystems by providing a context containing an object model of the sensor. Subsystems, also, contain status and state information for its control region that may be shared with other subsystems. For example, a security subsystem may share its arm/disarm state with a lighting subsystem so that the lighting subsystem could provide exit lighting and a lived-in-look function.

4.4.3 Standard Modeling Construct

HomePnp specifies sets of CAL constructs in which subsystems can publish their status, listen to other subsystems' status , and request status changes in other subsystems. Definitions of these object types are:

Status objects: (also called providers) are any objects that use the CAL reporting mechanisms to convey current state or parameter information and whose report header and destination address are configured to bind with a listener object.

Listener objects: are objects that receive reports from status objects of the context and have logic to modify the status in objects of other associated contexts based on the value(s) received. A listener object does not report.

Request objects: are any objects that send requests to change the values of a status object. A request object may change the value of a status object by sending a request.

Shared sensors: are devices that contain a sensor context designed to share the sensor information with subsystems and devices. This is illustrated in Figure 4.10

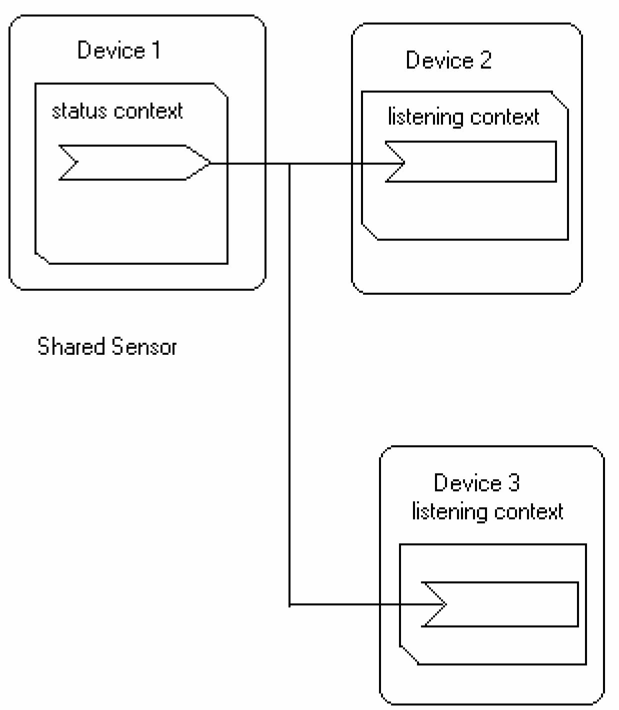


Figure 4.10 A Shared Sensor Sending Information to Two Listening Contexts

When a sensor context reports the HomePnP broadcast destination, the information is sent to any device that wishes to listen. To receive the sensor information, the listening device must possesse a context containing a sensor listening object. In the case of multiple sensors of the same type, a listening context may come to listen to a certain sensor by adjusting its context number to match that of the desired sensor.

4.4.4 Interoperability

Subsytems can interoperate within their own subsystem or with other subsystems. CAL context models allow interoperation between contexts within a subsystem (intrasubsystem) and across subsystems (intersubsystem) as illustrated in Figure 4.11

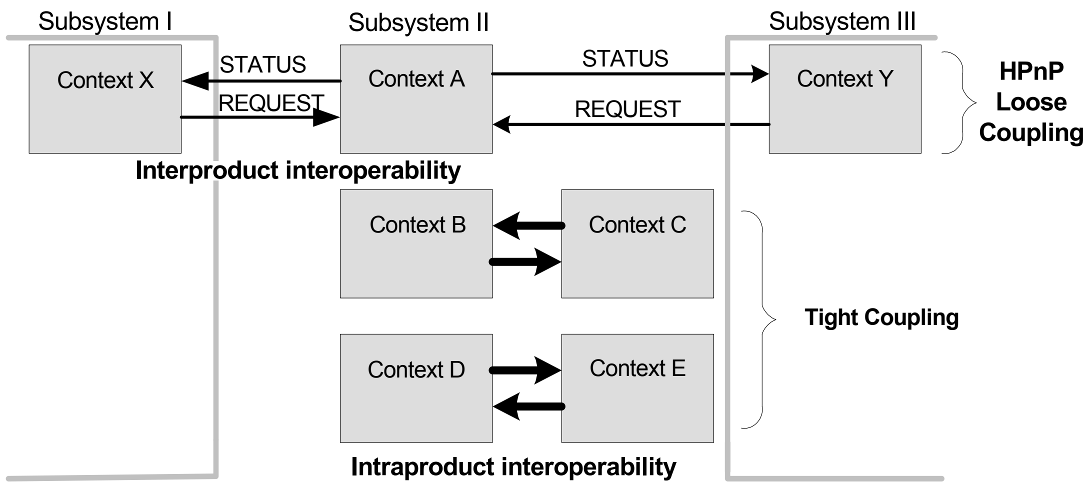


Figure 4.11 Basic model of inter and intra subsystem interoperability

4.4.4.1 Intersystem Interoperability

The loose coupling and default binding concept in HomePnP are realized within intersubsystems interoperability by supplying contexts inside each subsystem that are loosely coupled to contexts existing in other subsystems for exchange of general request , status, and state information.

Each subsystem treats of intercommunications by providing one or more contexts that specifically provide status and possible control information to and from one or more contexts in other industry group.

Default binding: is a key mechanism for interoperation among HomePnP products that use CAL's reporting mechanism. Parameters and state change information to be shared with other products is reported when the information changes by broadcasting to predetermined context and object types. It is supplied in all HomePnP products, enabling entry-level interoperability without customization.

Loose coupling: Status information from status objects, supplied by default binding is trasmitted to all other interested HomePnP subsystem in the home. The status object does not care on what ever other subsystems are installed and listening. Interested peer subsystems can listen to information and change their own behavior per their own unique design. This loose coupling permits HomePnP products to be gradually installed by the homeowner. In the same manner, vendors can design interoperable HomePnP products without the necessity of having knowledge of other vendors' products. The least requirement for loose coupling is that the broadcast address is to be used as the destination address of a CAL reporting object in the transmitting node. The distinction between destinations is based on the transmitted CAL context class, context number, and object identifiers. A listener can benefit of this information by instantiating the correct context and object.

4.4.4.2 Intrasubsystem interoperation

HomePnP systems may utilize reports to specific objects when needed. In these cases, the sender; in addition to the context, object, and instance variable, must know the address of the receiver. This is called tight coupling and is usefull for reducing broadcast traffic and for messages requiring immediate acknowledgment .When using tight coupling, a sending device may transmit its information to a precise receiving device. This necessitates an installation routine in the transmitter to acquire an address (unit or group) of the destination device.

Intrasubsystem communication generally relies on tight coupling between contexts since messages are specific to devices working together inside the subsystem. In this mode of communication, concern is about status and control. For example, the thermostat to the heating / cooling equipment, the light switch to the light, the security sensor to the security panel, and so on.

4.4.5 State Vector

An important mechanism for HomePnp interoperability is the state vector. This allows information to be shared by each subsystem so that other subsystems may listen as desired by only instantiating an appropriate listener object to rceive the desired state information. High level state information should be abstracted in order that listening subsystems are not required to understand all the details on how a particular subsystem is built. For example, it is desirable to know that an environmental control is operating in a heating mode without knowing how heat is delivered.

To enable evolution in the type of state information that are broadcast and received, HomePnp specifies extensible hierarchical state vectors in the sense that each succeeding level supplies specialization of the previous level. Regarding the designs of these state vectors, listeners of thes subsystems can interpret them only to the level understood or desired.

4.5 Definition of Interoperability Constructs

Fundamental HomePnP interoperability subsystem is constructed using two building blocks: a status object and a listening object. A HomePnP status object is any object that utilizes the CAL reporting mechanism to send and/or receive current information, and whose report header and destination address is default configured to bind with a listener object. A HomePnp listener object is any object that receives reports from status objects of one context and possesses logic to change status of another associated context based on the value received. A listener does not report.

The HomePnP specification defines a request object for requesting changes in state. A request object is any object that transmit requests to modify the value of a status object using CAL reporting mechanism which consists of three supporting instance variables: report_header, report_address, and report_condition that are available in the object issuing the reporting. Figure 4.12 represents the icons for the status, listener, and request objects. Status object #2 is the same as the status object #1 except that it supports status change request.

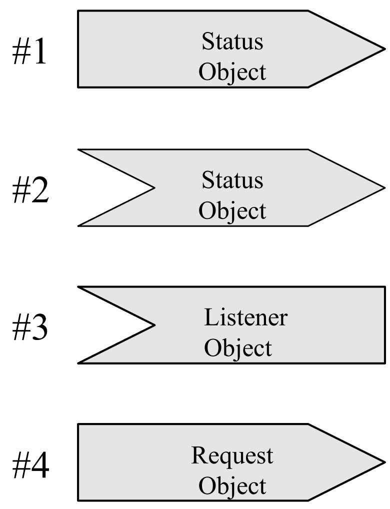


Figure 4.12 HomePnP Status, Listener, and Request Objects

4.5.1 Subsystem model

In figure 4.13 is illustrated a simple subsystem model constructed from objects described in figure 4.12. In this model, status object#1 is responsible for reporting subsystem #1's state information in state vector notation. Listener object #1 and #2 are responsible for monitoring state information from other HomePnP subsystems and modifying state of subsystem #1 if necessary.

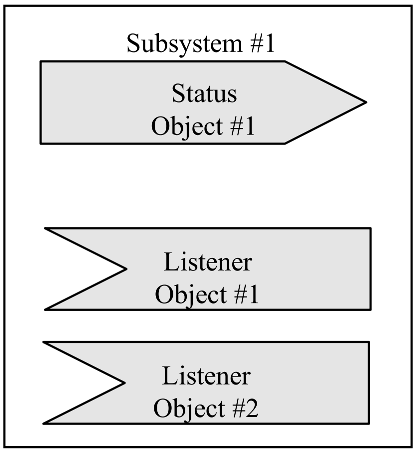


Figure 4.13 Simple Subsystem Model

Figure 4.14 shows a variation of simple subsystem model. In this model, status object #1 is capable of accepting state change request from a remote source. Status object #1 will evaluate the request and check if the status of subsystem #2 should be modified.

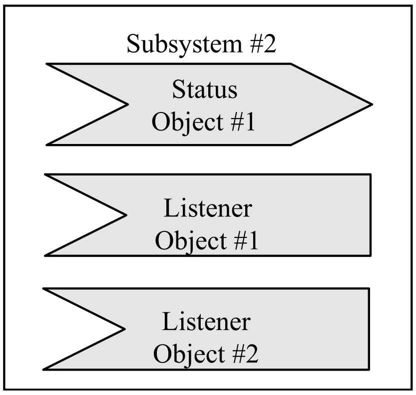


Figure 4.14 Variation of simple subsystem model

4.5.2 Connecting Request, Status, and Listener Objects.

HomePnP connects request, status, and listener objects as shown in Figure 4.15

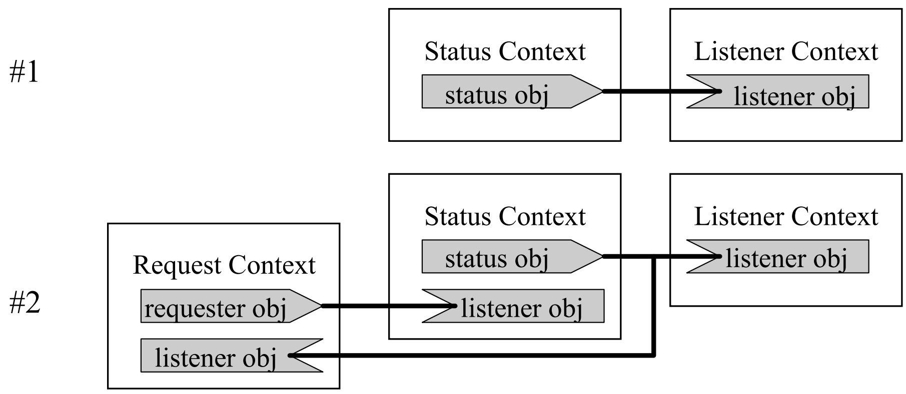


Figure 4.15 Connecting Request, Status, and Listener Objects

Model #1 shows a status object reporting information to one (or more) listener object (s). Model #2 shows a request object reporting value change request to a status and listener object pair. The status object in turn reports any modified value to one (or more) listener object including in this case, feedback to the requesting context.

4.5.3 Intersubsystem Interoperability

CAL reporting mechanism is used by subsystems to broadcast information. It is configured to transmit the value of primary instance variable information or any change. The information is addressed to the appropriate class of CAL context objects, and instance variables according to subsystem construct standards. Reported information is broadcast to the HomePnp broadcast destination address by the transport layer to all peer HomePnp systems present inside the home. Figure 4.16 represents two HomePnp subsystems, A and B that broadcast information from status objects. Also represented are two HomePnP subsystems, C and D, provided with listener objects. Subsystem C contains a listener object for subsystems A and B. Subscriber subsystems C and D listen to information from provider subsystems to determine desired behavior.

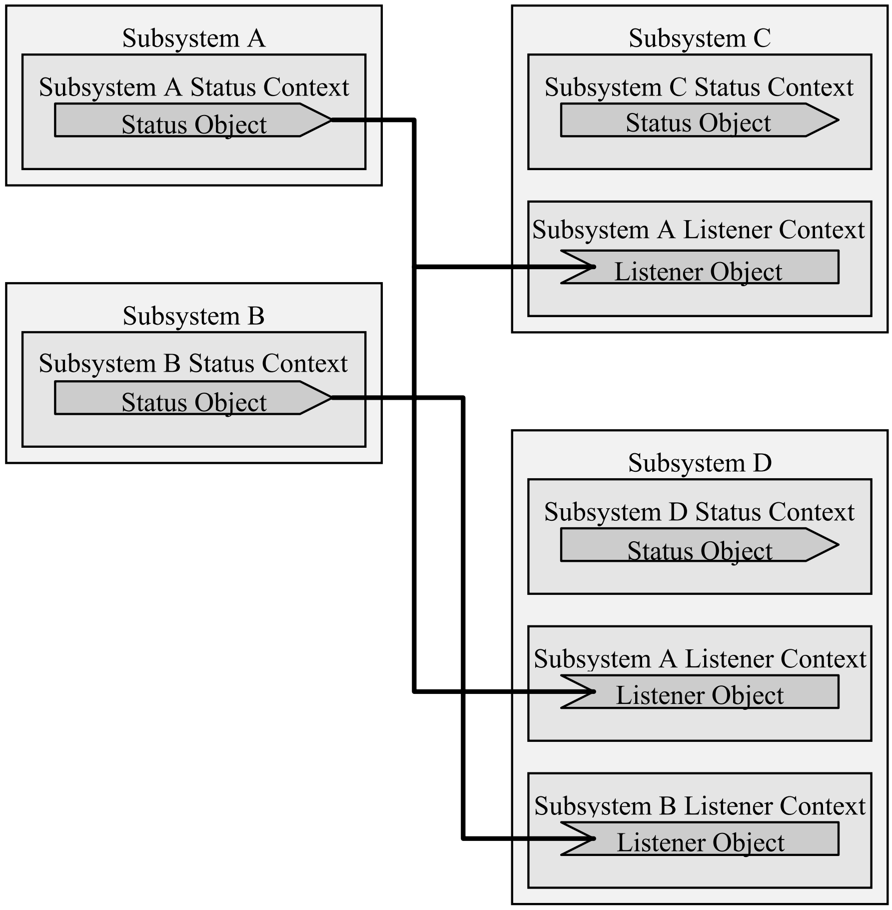


Figure 4.16 HomePnP broadcasting to Multiple Listeners

4.6 House Mode

Another context in HomePnP is used to enable users to implement functions related to their desire about how a home should be operated. In other words, this context sets a goal. This context, the House Mode, gives information about the occupancy of the home and the expected duration of an occupancy state. Occupants can push " Occupied" or "Unoccupied" panel button upon arrival or departure. The ways of how to use a home is expressed in state vector notation. Status of current house mode is issued from the House Mode object within the House Mode context that can be sent to all listener devices in the home using the HomePnP broadcast address. HomePnP subsystems needing House Mode state information instantiate this context with a House Mode listener object and listen for messages broadcastt from House Mode status objects: the task of each subsystem is to choose a behavior or a strategy that best fulfill the user's desire as reporting by the House Mode status object. This mechanism allows a simple coordinated way for users to operate their home. A House Mode listener object is included in House Mode context in order to maintain synchronization with other House Mode status objects that may be instantiated within the same home. Figure 4.17 shows a model of different HomePnP devices connected in a system configuration.

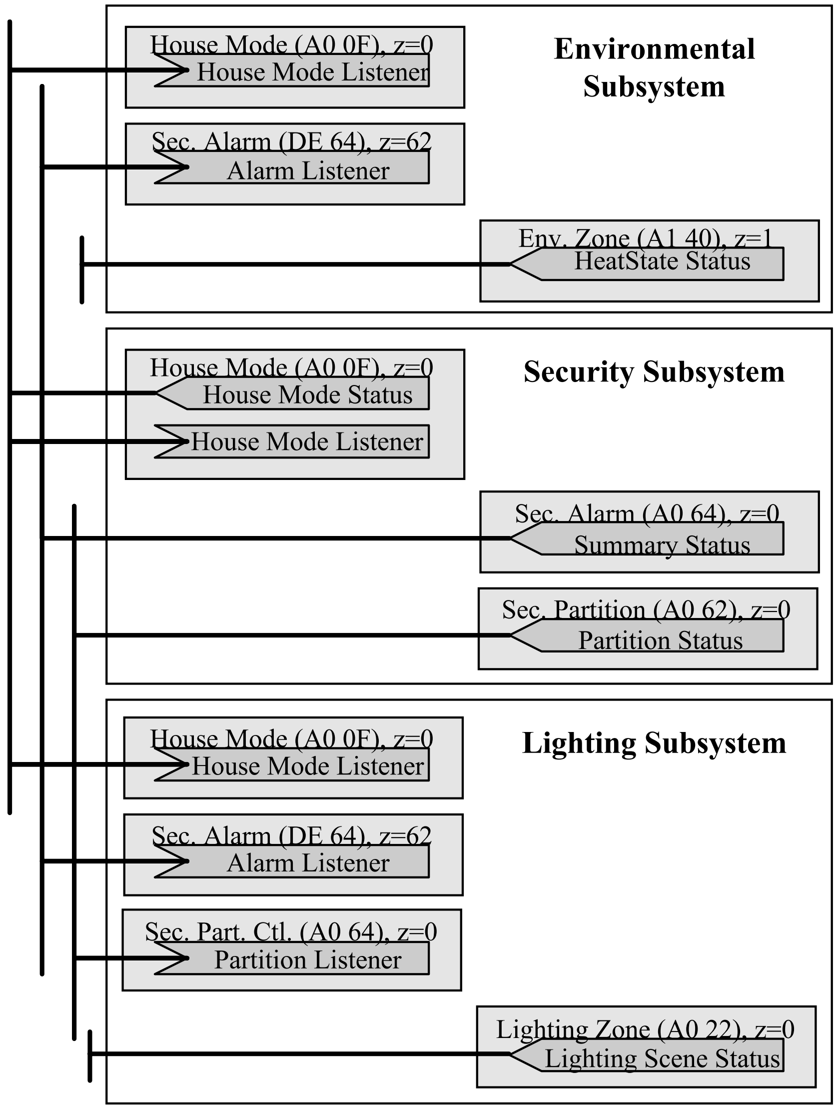


Figure 4.17 Typical HomePnP Devices

In figure 4.17, a partial HomePnP environmental device, a partial lighting device, and a partial security device are represented. Each of the subsystems that is shown reports its state information. The environmental subsystem reports state information from the environmental status objects within its environmental zone context. The lighting subsystem reports its lighting scene status from the lighting scene status objct within the lighting zone context. The security subsystem reports its state information from its partition status object within its security partition context. House Mode contexts are also presented; the House Mode status object located within the House Mode context in the security subsystem is in charge of reporting the House Mode status as determined by the user to all other HomePnP subsystems. In this manner, all HomePnP subsystems are aware of the homeowner's desires about the operations of the home.

House Mode messages give information about the occupancy of the home and the activities of the occupants. "Occupied, Unoccupied", "Occupied. High Activity", and "Unoccupied Vacation" are some types of information supplied by a House Mode subsystems. House Mode subsystems are a special case; regarding the use of context number which is shared by all of them. The reason is : the same set of House mode vectors applies across a house uniformly [24].

4.7 Conclusion

Home Automation, as a conclusion, can be viewed as the sum of procedures and information that focus on the interaction between devices at the application level. It specifies on what a device must do to be easily instalable and to operate with other products build to its specifications. Home Automation specifications are the primary documents that a designer and the manufacturers acquire to build interoperable products for the home and to the same extent to office and business buildings. HomePnP , which is a result of seeking efforts to design more intelligent devices, is a very open and versatile system that allows a huge domain of applications.

In the industry world, there exists the Home Automation counterpart that is the Industry Automation integrated in the industrial plants [25].

CHAPTER 5

Implementation:

5.1 Introduction

This chapter deals with implementation of a whole system for controling lighting actions (on/off, diming). A detail of the pratical goals for the project is discussed and how these goals have been elaborated into different steps. Three layers have bee realized in this work relying on the three distinguished theoretical aspects: the powerline communication, the Spread Spectrum carrier technology and the associated modulation type, and the Home Automation. The lower layer is the physical layer that comprises the following circuits: the converter from UST (unit symbol time) to chirp, the amplifier, the filter, and the coupling to the mains. The second physical layer is in charge of converting binary bits of information to UST‘s. The third layer is the transport layer that sets the packets frames resulting from the higher layers up to the application layer.

5.2 Practical goals

The main goals of this project were “Implementation of the physical layer for lighting control” using conventional controling methods and components to a level where multiple lamp fixtures arranged in a matrix fashion were to be turned on and off regarding certain stated situations such as occupied, short or long vacancy, night or day, etc…

After processing through the research and the theory stages of the project into initial implementation, it became evident that much more can be done about controling lighting fixtures, and thus conserving energy. Power line as communication chanel is gaining in improvement and is spreading over many areas of utilisation. Modulation techniques are numerous and selected on different basis that are set to fulfill the required achievement. These basis range from communication speed, band requirement, used media , to robustness. Morever, Home Automation can be used to manage a wide network composed of devices of different function such as lighting, utility management, HVAC, security, environement, computing, and leisure.

Finally, in Algeria, three main areas of interest that are lighting, security, and utility management will be the potential applications for the present implementations. After the description of the implementation of the first and second physical layer, in the next section, aspects of the lighting mentioned above will be depicted and prepared as material for constructing some illustrative message packets that take place on the third layer.

5.3 Physical Layers Design

The chirp, which is the main signal in Spread Spectrum Carrier technology has been defined by Intellon by giving its shape and duration (ie :100µs). 360 normalized points values are listed in a table(table A-2 of appendix A2) ranging from –0.5 to +0.5 . To obtain the practical chirp waveform , somme transformations must be done using these values.

The part which is responsible for generating the true chirp is the Digital to Analog Converter (8-bit DAC 0808 shownon the General Block Diagram in Figure 5.8). Hence, 360 times 8-bit binary values must be applied successively in the period of time of 100µs. These 360 x 8-bit binary values or bytes are to be stored in a ROM since they do not change.

The true chirp is a waveform whose magnitude varies from –7v to +7v, so the reference voltages for the DAC are set to 10V and –10V and the binary values chould change from 11111111 (FFh in hexadecimal notation) to 10000000 (80h) for the negative values of the waveform and from 10000000 (80h) to 00000000 (00h) for the positive values.

To obtain the binary values from the values given in table A-2, each given value is to be multiplied by ten and augmented by five and finally divided by 0.039 (ie:10v divided by 2^8 or 256) . Then, the resulting number is converted to an hexadecimal 8-bit binary number or byte. These last points values are used to form the complete chirp waveform (and also the 180^0 phase shifted chirp waveform by taking the binary one's complement of these values). The simulated chirp (with Multisim7) and the practical chirp are illustrated on Figures 5.1 and 5.2

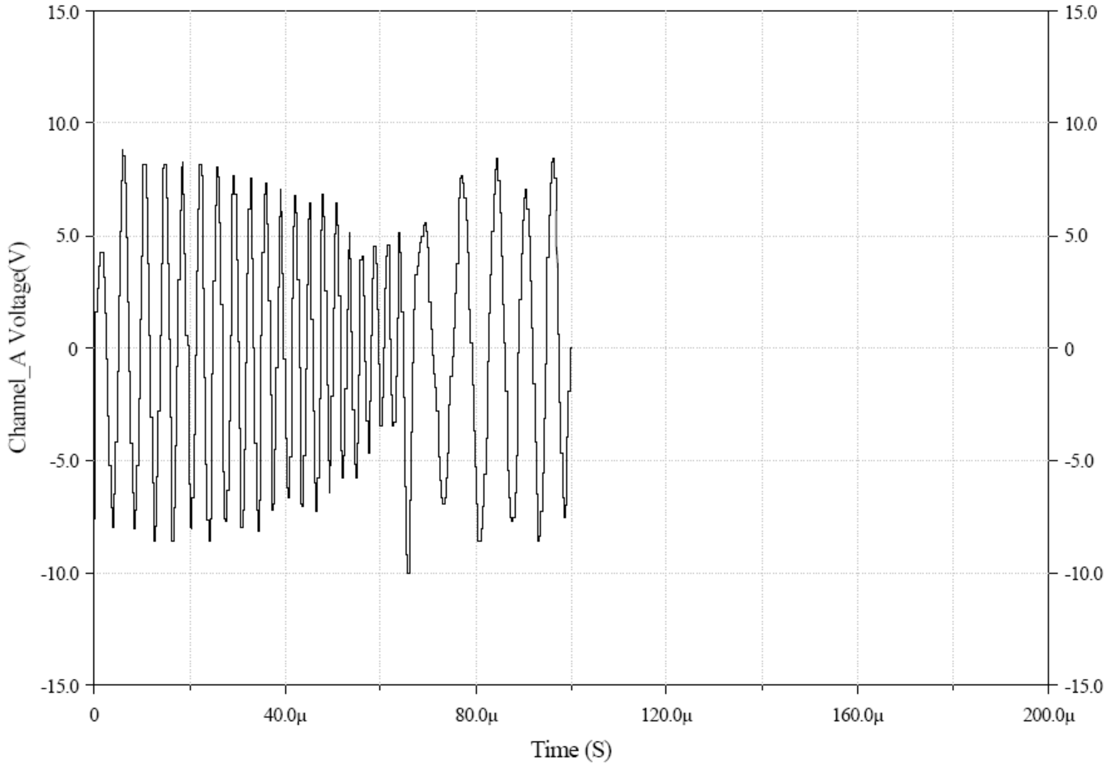


Figure 5.1 Simulated Chirp

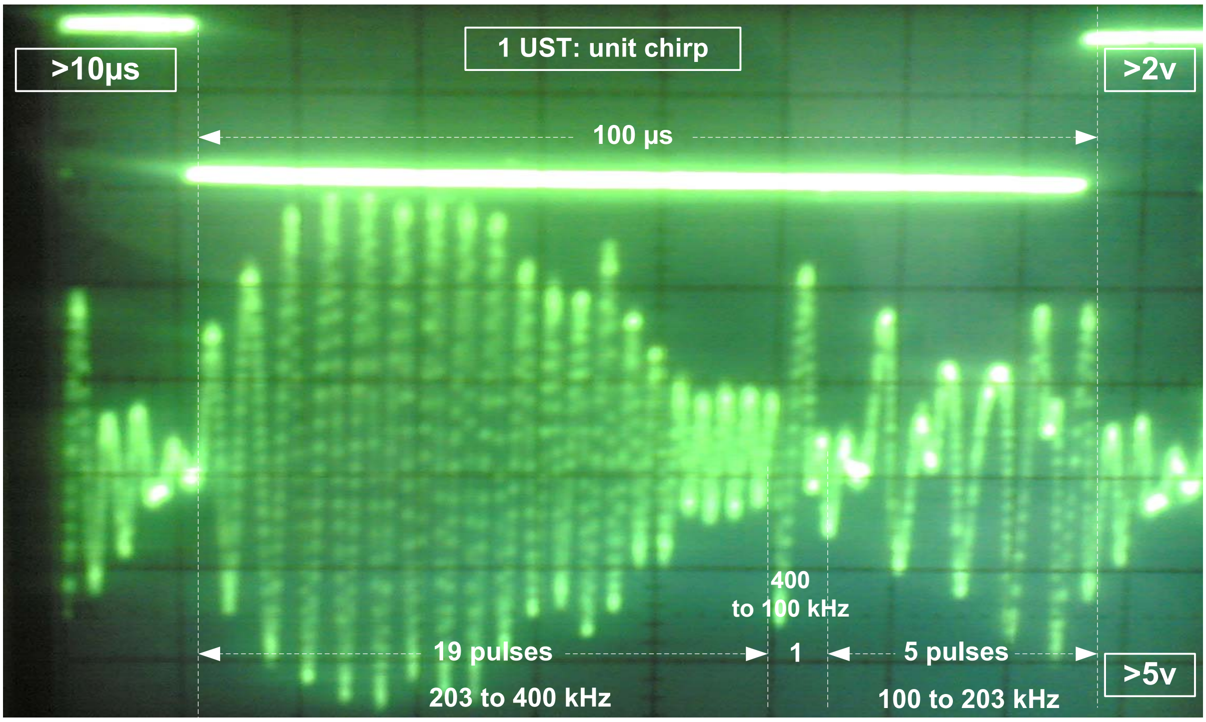


Figure 5.2 Practical Chirp

Along with 00's, the chirp waveforms are selected to generate the four required states stated in chapter three : Superior state, Inferior state, SuperiorØ1, and SuperiorØ2. A Superior state (during the preamble section) is stored as a complete chirp waveform plus 00's for the time length of 14µs accounted for the quiet time(ie: 50 times 00's), while an Inferior state is stored as 00's during the whole time length accounting for one unit symbol time plus the quiet time (ie:360 +50 times 00's). SuperiorØ1 is stored as a complete chirp waveform (360 points values), and SuperiorØ2 is stored as a 180^o phase shifted SuperiorØ1 (360 points values). Figures 5.3 to 5.7 illustrate both the simulated and pratically obtained waveforms for the preamble (ARK modulation) and packet(PRK modulation) stream of chirps.

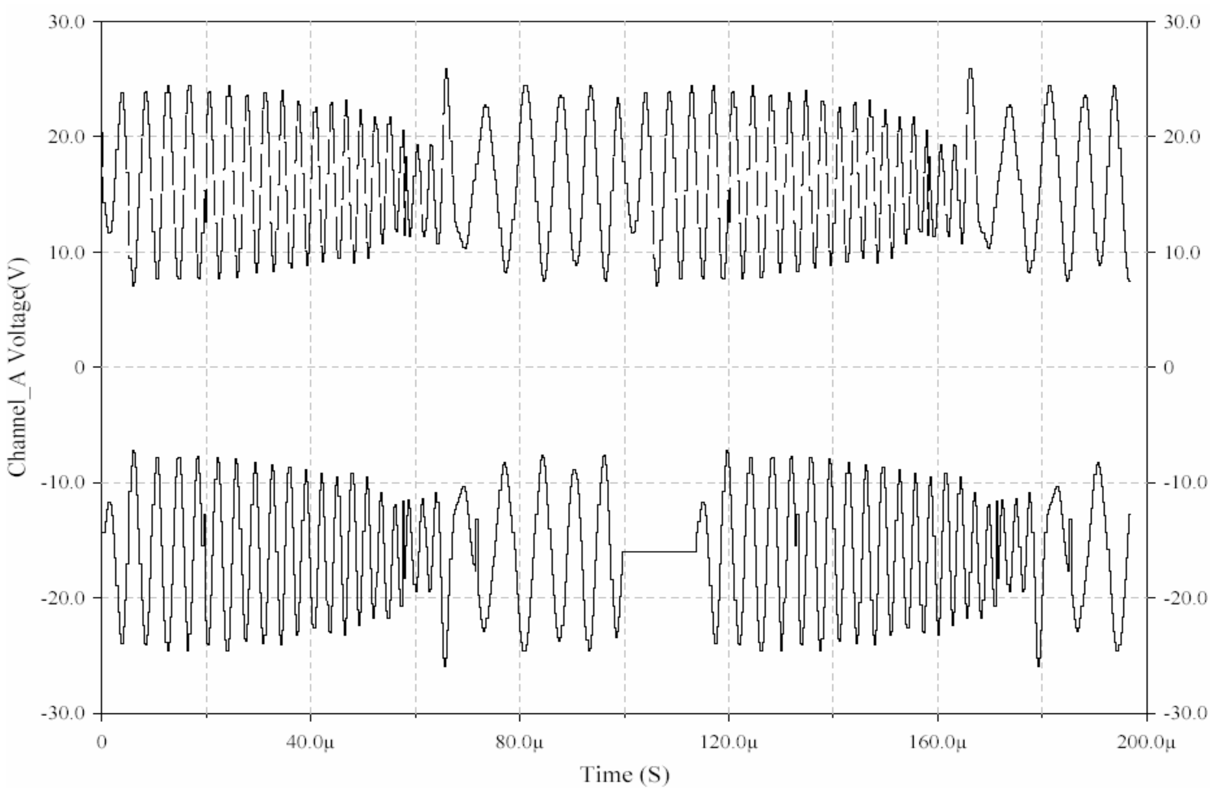


Figure 5.3 PRK and ASK modulation of symbol "0".

The top waveform shows the "0" symbol transmitted during packet transmission, while the bottom waveform shows transmission of "0" during the preamble transmission knowing that "0" requires the transmission of two consecutive UST's.

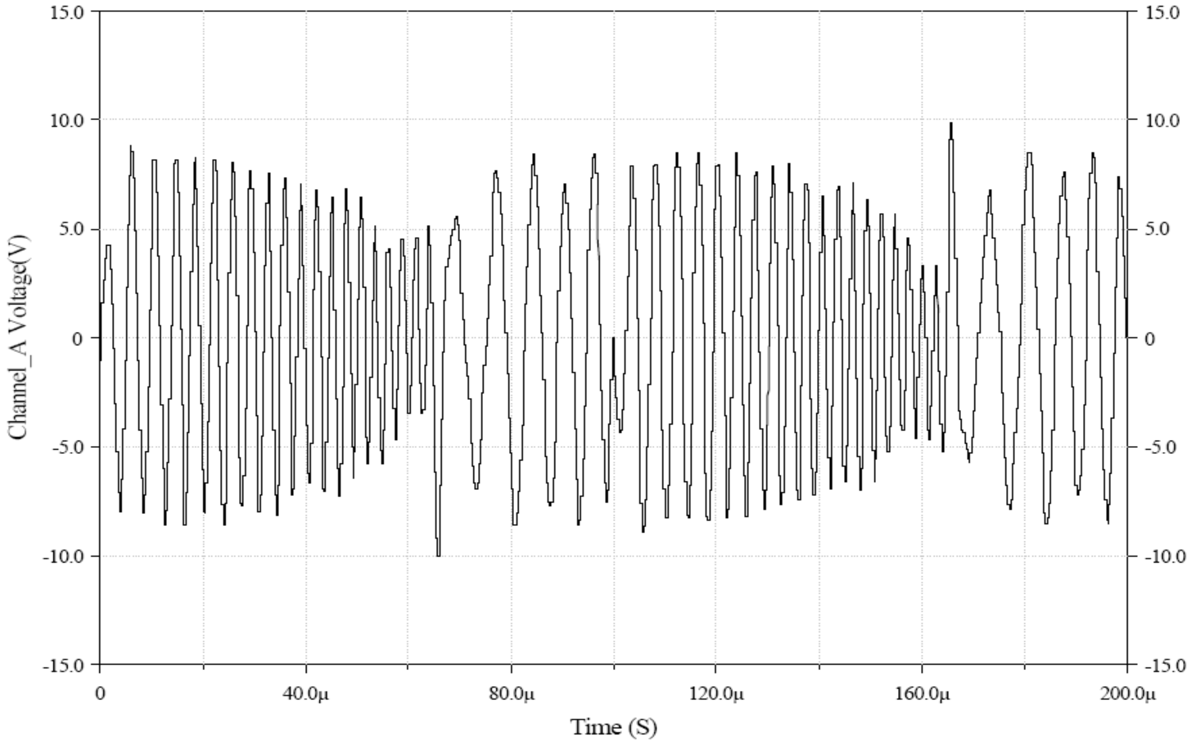


Figure 5.4 transmission of two consecutive "1" in a packet message.

Here two chirps with a phase shift of 180^0 are to be transmitted for the two ones.

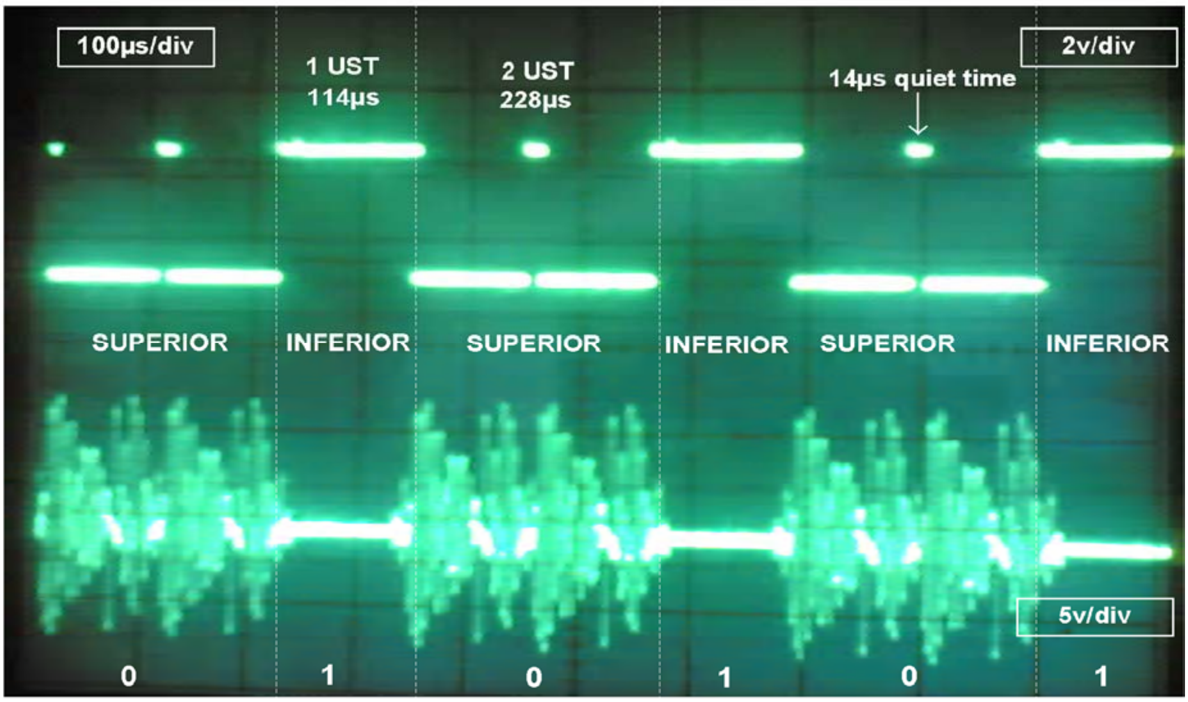


Figure 5.5 Preamble Transmission of 010101

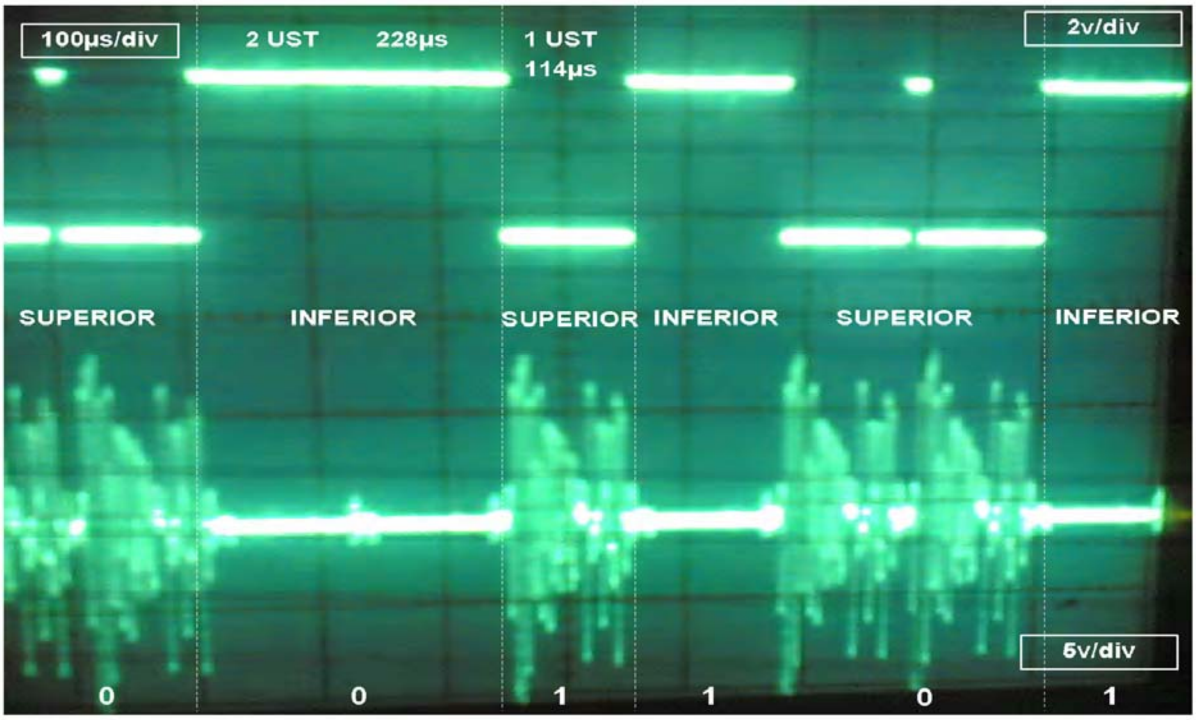


Figure 5.6 Preamble Transmission of 001101

Figure 5.5 and 5.6 , above,show two different patterns for a preamble data. It can be seen that alternatively symbols "0" and symbol "1" can take superior or inferior state.

Figure 5.7, below, represents the transmission of a packet data. PRK modulation is used in this case. Symbol "1" is transmitted as one chirp in either phase (phase1 or phase2) while symbol "0" is transmitted as two consecutive chirps of same phase (two phase1 or two phase2).

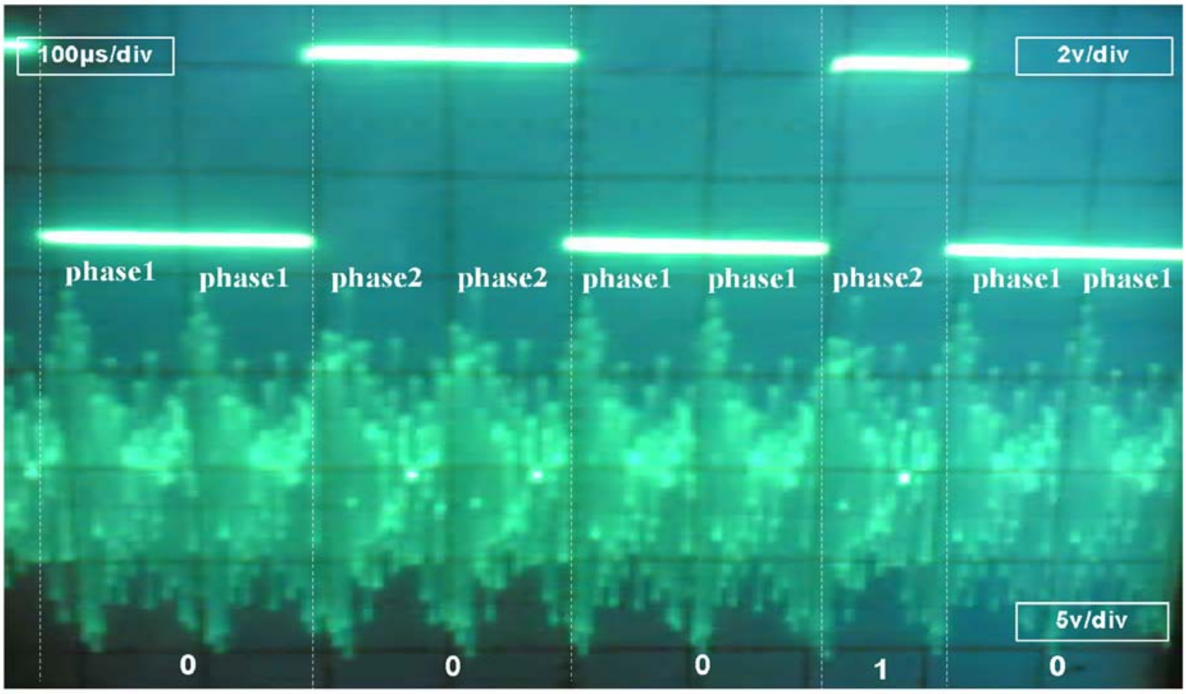


Figure 5.7 Packet Transmission of 00010

The implementation of the two first physical layers that are the realization of the chirps generator , the code symbols generator and the circuits for filtering, amplifying and coupling to the power line is illustrated globaly on the General Block Diagram (see Fig.5.8) and in details in three schematic diagrams namely CKT1 Gen Time Sync (Fig.5.9), CKT2_Gen_Code_Conv (Fig.5.10), and CKT3_Chirp_Generator (Fig.5.11)

The different parts to be realized are:

1) **Timing and Counters circuit :** designed to generate the convenient clock period in order to obtain 100 µs for an unit symbol time which is the time reference in the type of modulation used in this project.. The number of clock units necessary to obtain 100 µs must be 360 since the entire frequency swept chirp is defined by 360 points or values . Therefore one clock period is 100µs/360 which is about 0.28 µs. The value of the crystal quartz should be 1/0.28 10^{-6}s which is 3571428.57 Hz. The choosen available crystal close to this valus is of 3579.45 kHz. Counters clocked by this defined unit

clock must divide by 360 to get the one unit symbol time of 100µs and by 410 to obtain the one unit symbol time plus the quiet time of 14µs to have 114µs in the case of transmitting or receiving the preamble data pattern.

2) **Logic Unit :** is the circuit that generates three signals for synchronization that are C1, C2, and R0. C1 is the signal that is the clock triggering for each unit symbol time transmitted during the sending of a packet data pattern. C2 allows the transmission of one unit symbol time augmented by 14µs of quiet time in the transmission of a preamble data type. It can be recalled here that for the four different symbols ("1", "0", "EOP", and "EOF"), a multiple of unit symbol time is generated in the case of a packet data and a multiple of unit symbol time plus the quiet time is generated in the case of a preamble data. R0 along with C1 or C2 resets the counters at count 360 or count 410 respectively.

3) **SSC Code Generator Converter:** is the major part of the second physical layer that generates the four smybols. Under the synchronization of C1 and C2, the state of the binary data, and the pattern of preamble or packet data, this unit will control the ROM output where are stored the different data values required for generating Superior and Inferior states for the preamble data, and SuperiorØ1 and SuperiorØ2 states for the packet data. This layer is the testing plateforme for the Testing Unit and the destination plateforme for the third layer that is the source of message packets to be transmitted.

4) **ROM :** storage component where are stored the corresponding hexdecimal values for the 360 evenly spaced points values to form the chirp waveform and the hex values for the other 180° phase shifted chirp waveform (360 points values) .

5) **DAC :**converts chirp waveform data to an analogue waveform with a 10V peak-to-peak.

6) **Filter :** is used to band pass only the 100kHz-400kHz chirp signal and remove all other high or low frequency signal or noise resulting from the circuit itself or from the mains.

7) **Amplifier :** amplifies the chirp waveform to 14V peak-to-peak waveform.

8) **Coupler :** couples the chirp signal to be transmitted to another node onto the mains, and

also receive chirp signals from other nodes.

9) **Receiver :** the receiver (Figure 5.12) uses the same techniques as the transmitter. It generates the same chirps that must be correlated with received chirps into the matched filter stage after their sampling and detection.

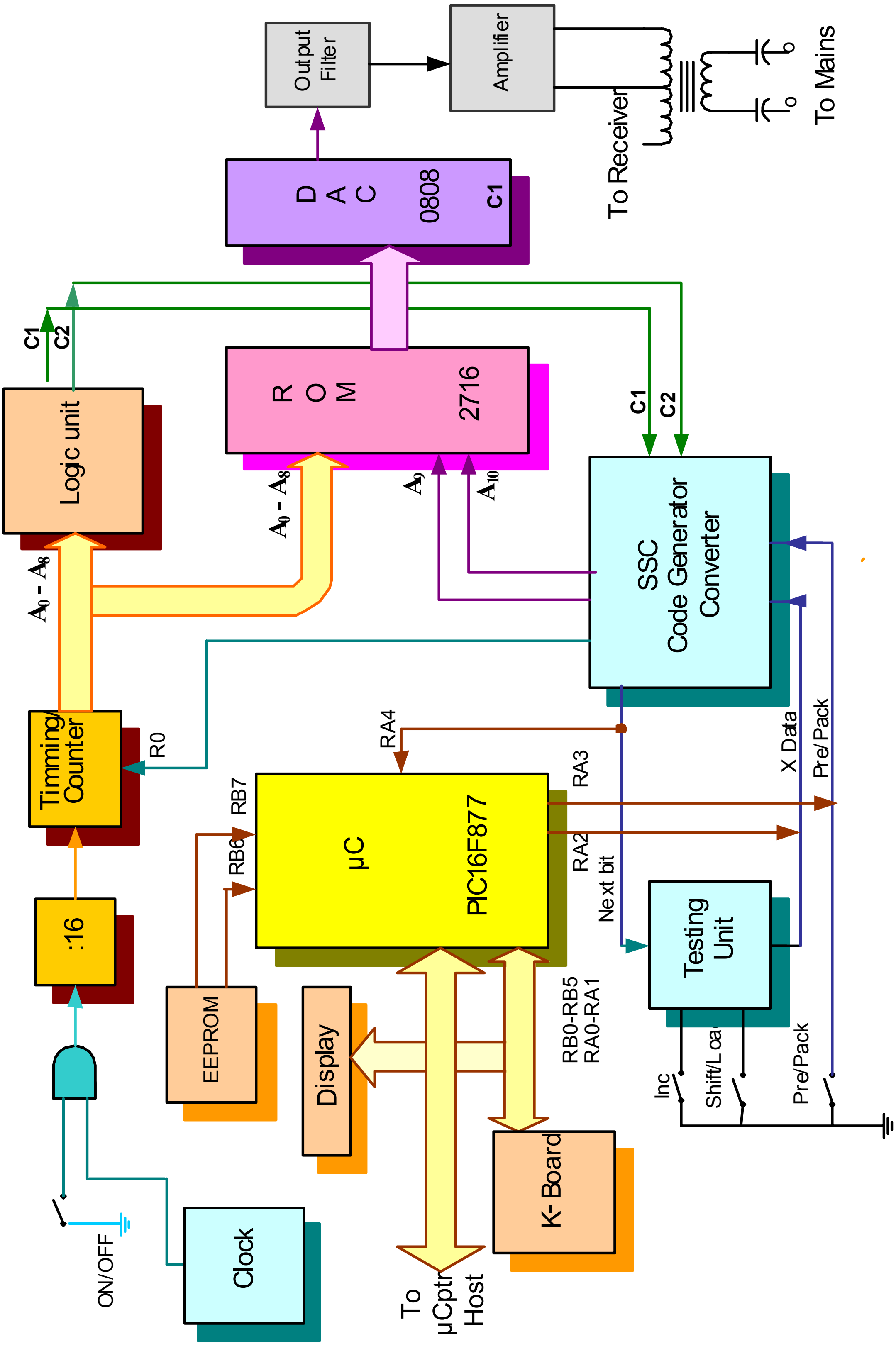


Fig-5.8 General block diagram

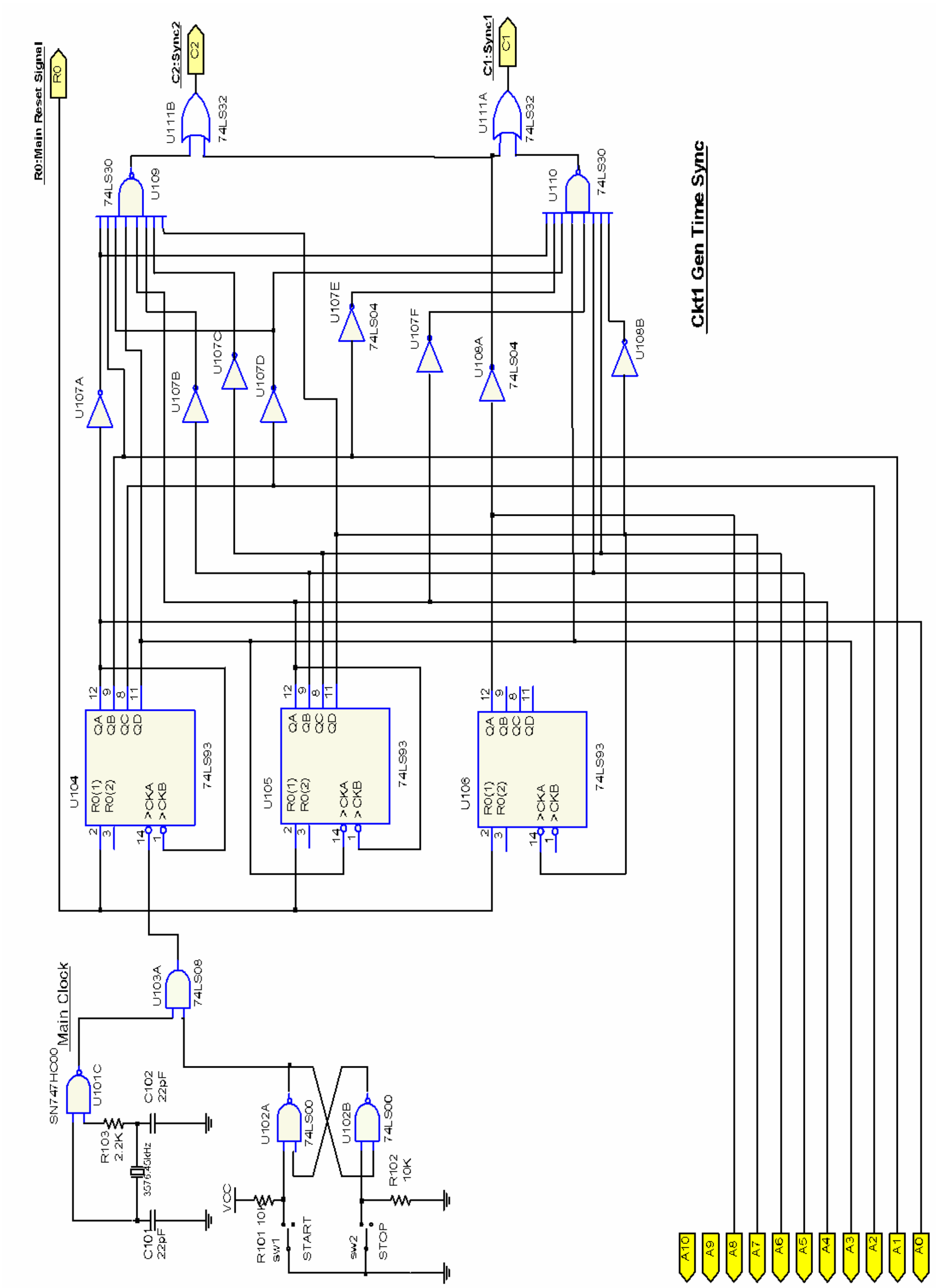


Fig 5.9 Circuit of time generation and synchronization

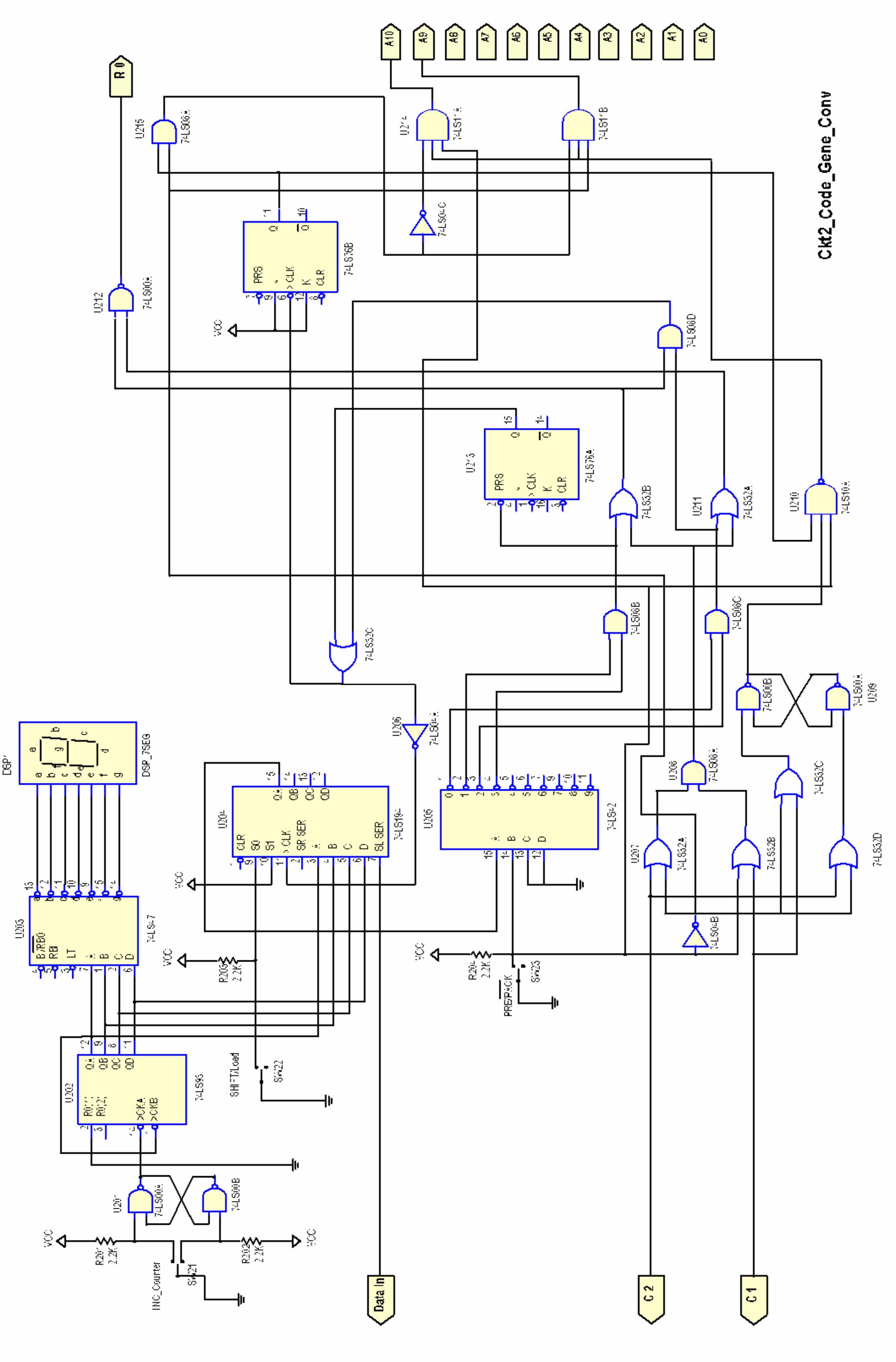


Fig 5.10 Code generation and conversion circuit

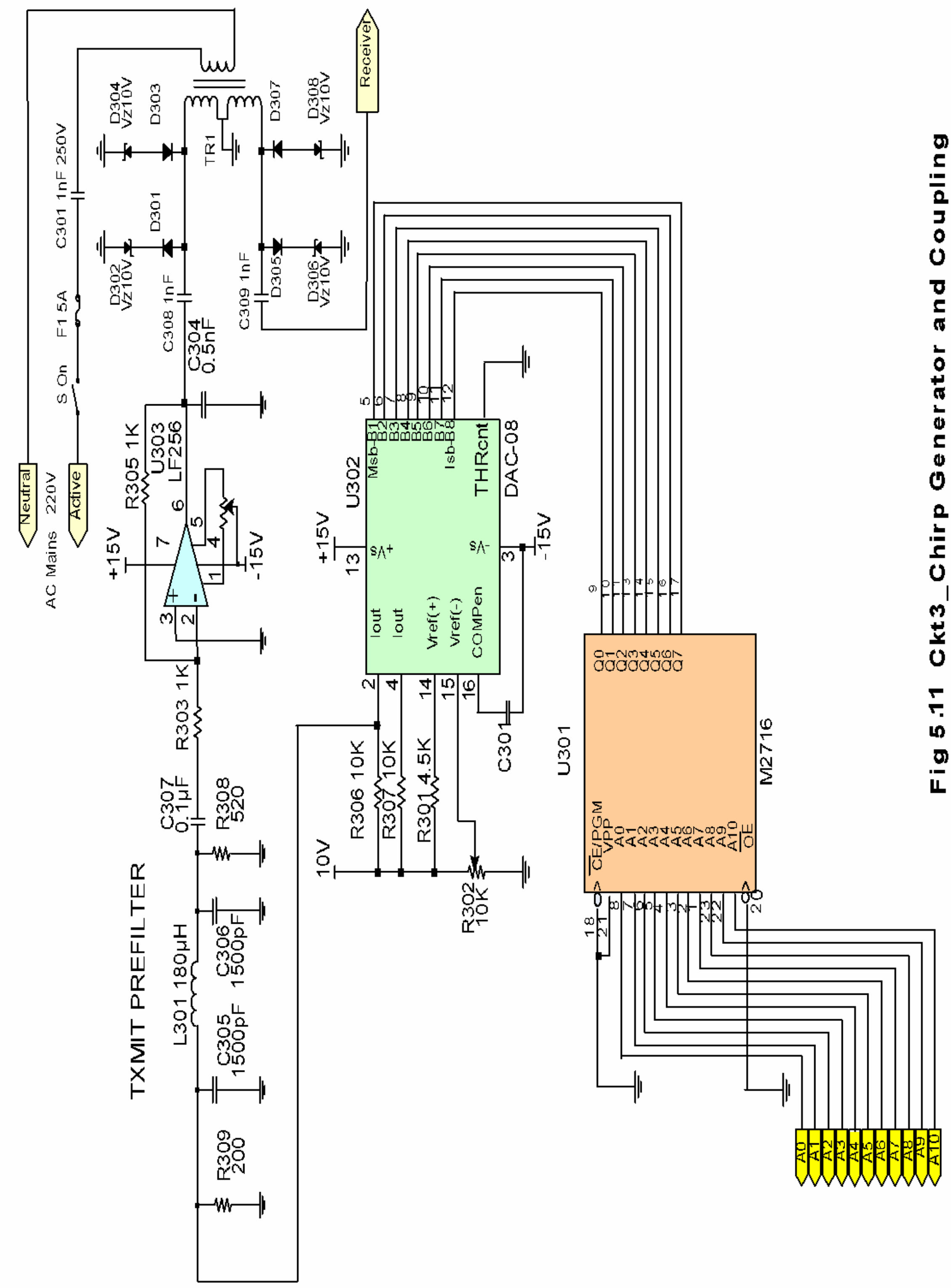


Fig 5.11 Ckt3_Chirp Generator and Coupling

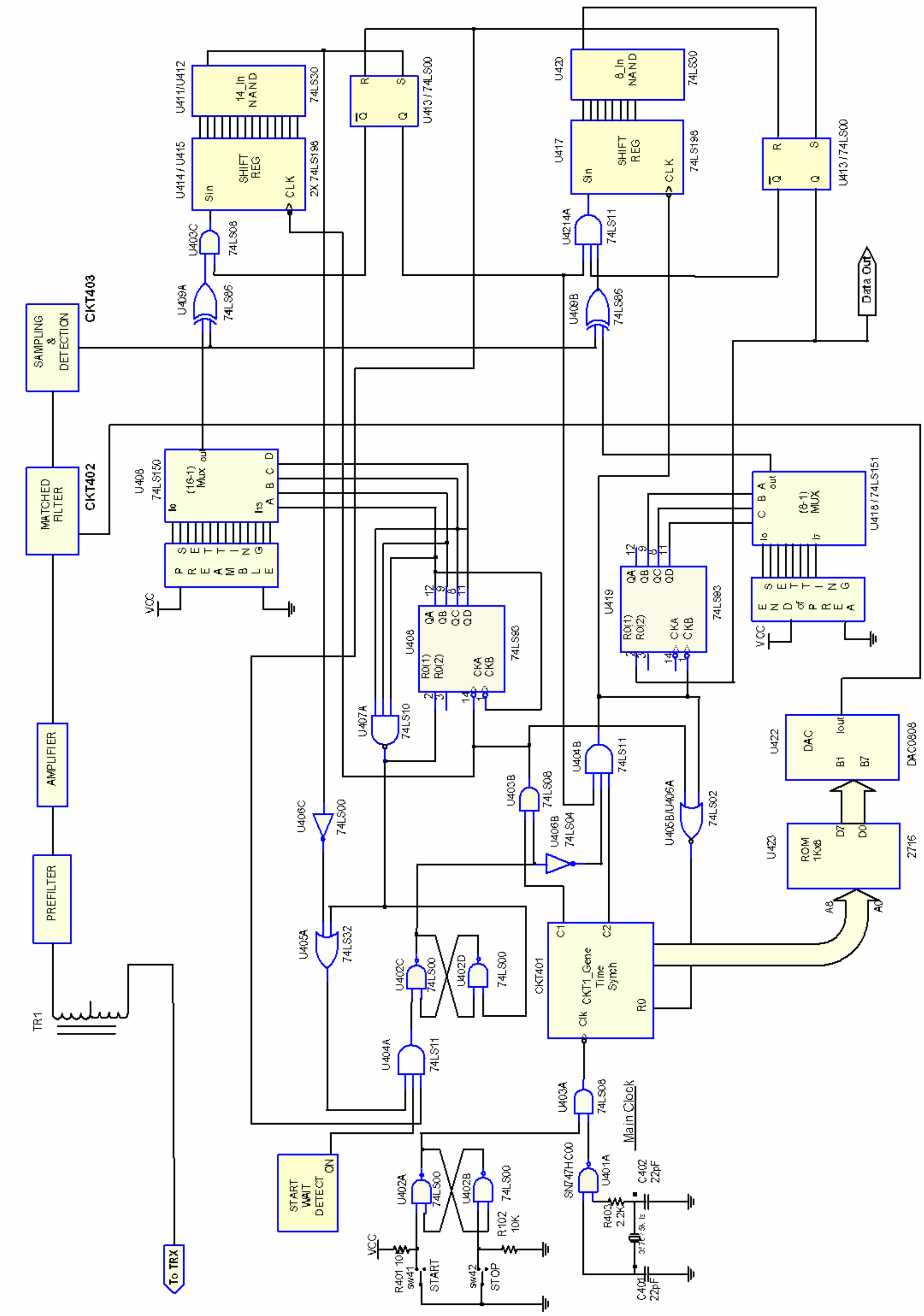


Figure 5.12 Receiver Circuit

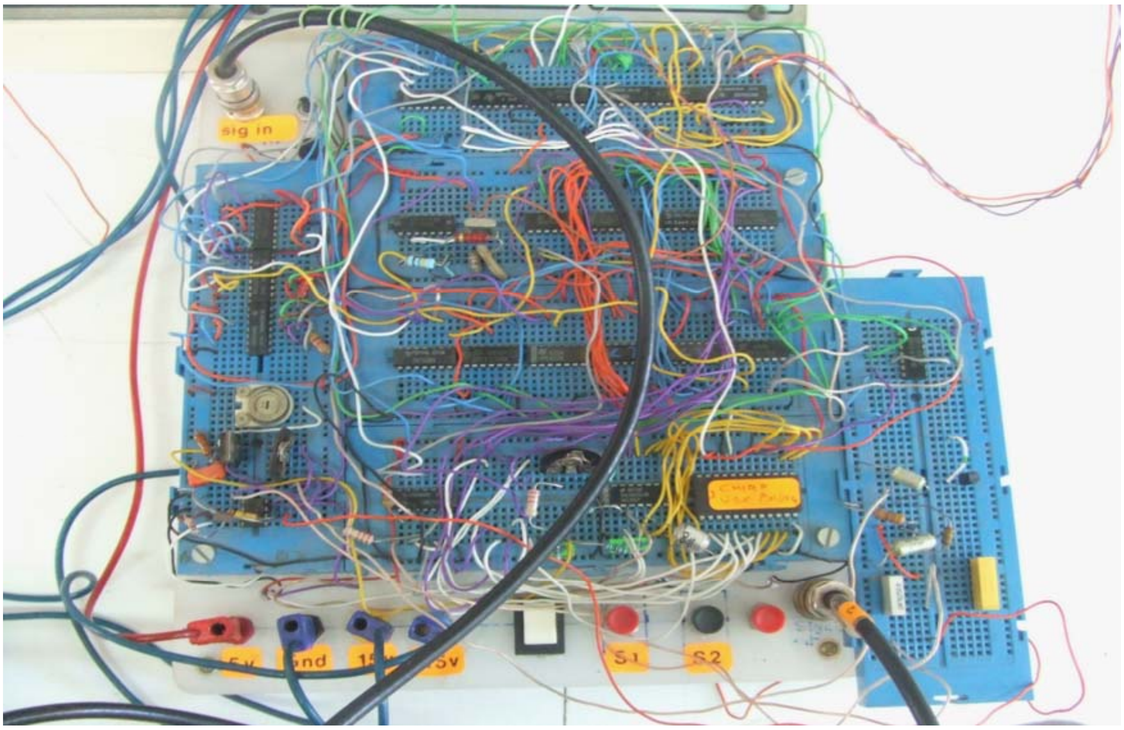


Figure 5.13 Photography of the transmitter

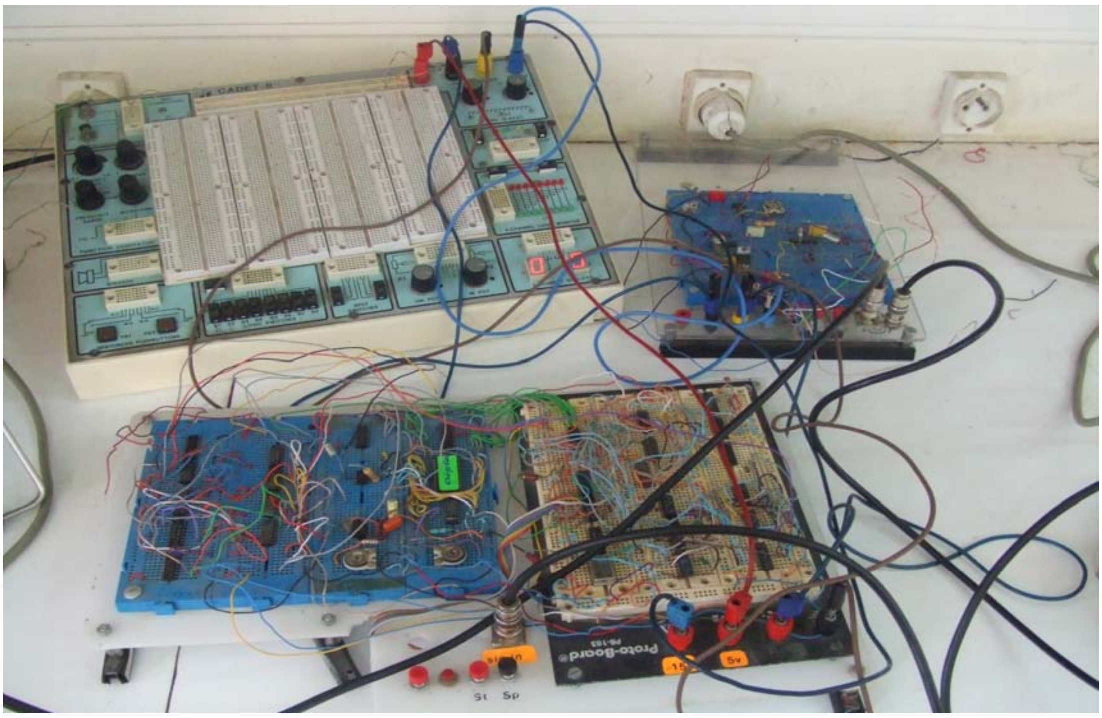


Figure 5.14 Photography of the receiver circuit

5.4 Packet Construction :

This section deals mainly on building messages under the Home Automation and HomePnP specifications. Also it uses the associated CAL programming language. In this project, only this level of layer is implemented. So higher levels are not in this scope and were briefly described and mentioned in chapter 4. These higher levels are; the Layer System Management, the Data Link Layer, and the Application layer.

The constructed message packets are implemented and routed to the destination layer (the second physical layer) by the Microcontroller PIC16F877 shown in Fig.5.8. This Microcontroller serves also as an interface between any CEBus device and a Microcomputer for applications setup and for employing higher layer schemes.

A CEBus packet frame (for PL and RF) can be depicted into several parts that are the Link Protocol Data Unit (LPDU), the Network Protocol Data Unit (NPDU), the Application Protocol Data Unit (APDU) and the CAL message. Figure 5.13 shows details of a packet structure illustrating the different parts [26].

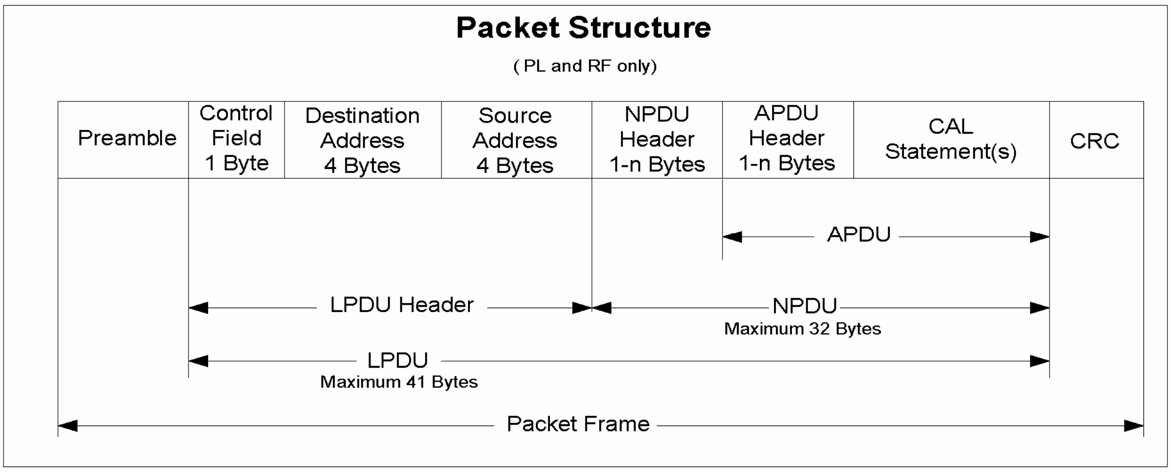


Figure 5.13 Packet Structure

5.4.1 Link Protocol Data Unit (LPDU)

The LPDU consists of the Control Field and the source and destination addresses. The Control Field specifies the packet type, packet priority, and service class to the Data Link Layer (DLL). Table 5.1 gives a bit wise description of the Control Field

Table 5.1. LPDU-Control Field

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sequence Number	Service class	Reserved	Packet Priority		Packet Type		

<u>Packet Type (bit 2,1 and 0)</u>
000 IACK
001 ACK_DATA
010 UNACK_DATA
011 *
100 FAILURE
101 ADDR_ACK_DATA
110 ADDR_IACK
111 ADDR_UNACK_DATA

<u>Packet Priority (bit 4 and 3)</u>
00 High
01 Standard
10 Deferred
11 *

<u>Service Class (bit 6)</u>
0 Basic
1 Extended

<u>Sequence Number (bit 7)</u>
Alternates each time a New Packet is sent to a destination address.

The packet type sets the form of Data Link Layer service. The DLL is in charge of all channel acquisition, timing, and packet receipt verification.

Packet priority is used by the DLL to set the channel access priority timing. To obtain access to a channel a node first listens for channel activity (carrier sense). If there is an activity, the node has to wait until the activity is completed, then after a predetermined time period based on priority augmented by a random amount of time the node can make an attempt to acquire channel access by transmitting a random number packet preamble intended for Contention Resolution. In the absence of contention, the packet is transmitted. In the case of contention presence, the node must give up and wait for a predetermined amount of time before a new trial of channel access and transmission attempt. The earliest time a packet with the highest priority can start is one millisecond after the previous packet ends.

Two exceptions exist: the first one is for a retry, and the second is for an acknowledgement. An acknowledgement must start no later than 200µs after the termination of the packet to be acknowledged. A retry is transmitted 600µs after the previous packet end.

The sequence number, one single bit, is alternated for each packet sent to a destination address enabling the DLL to distinguish a received packet as a copy and avoid passing the packet up the stack to the application layer [26][27].

5.4.2 Destination and Source Address

Destination is four byte long divided into two portions: the system address and the Media Access Control (MAC), also more familiarly named House Code and Unit Code. When the Unit Code is zero, it means a House broadcast address, all nodes will respond because this is regarded as global address. Destination and Source address have same formatting and are transmitted in the order. The address is put in the packet in reverse order from the least significant bit of the least significant byte of the Unit Code to the most significant bit of the most significant byte of the House Code. In this manner, the DLL can suppress leading zeros to lessen the effective transmission time of the packet and improve network throughoutput .

5.4.3 Network Protocol Data Unit (NPDU) Header

The Network Protocol Data Unit (NPDU) Header is used to specify how the packet is sent. It consists of six fields: Privilege, Routing, Packet Flag, Extended service, Allowed Media, and Brouter. Table 5.2 provides a bit-oriented description of the NPDU Header

Table 5.2- NPDU Header

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Privilege	Routing		Packet Flag	Extended Service	Allowed Media	Brouter Subfield	

Privilege
0 Unprivileged
1 Privileged
Routing
00 Request_ID
01 ID_Packet
10 Directory Route
11 Flood_Route
Packet Flag
0 First Packet
1 Only Packet

Extended Services
0 No Extended Services
1 Extended Services Octet to Follow
Allowed Media
0 This Media Only
1 Allowed Media Octet to Follow
Brouter
00 Brouter Address
01 First Brouter Address Presence
10 Second Brouter Address Presence
11 First and Second Brouter Address Presence

The privilege field is devoted to system management related packets. The routing field is used to send an ID packet, request the recipient to send an ID packet, and select directory or flood routing from a router. An ID packet is sent out by a configured device, whenever it is powered on a sign-on message or when requested by a router. A router uses the ID packet to keep a list of nodes for each supported media. The packet flag is used to indicate if this is the only packet or the first packet of a multi-packet message. Long messages can be divided into several packets since the maximum packet length is 41 bytes (with nine used for control and addressing, leaving 32 bytes for the NPDU including any CAL statements).

The extended service field specifies that additional NPDU byte(s) will follow with additional NPDU services.

The Allowed Media field indicates to routers and brouters if they should route the message to another media.

The brouter field controls routing of packets originating or terminating on wireless media. It is a device necessary to cross between wireless and wired media [26][27]. For example one may want with the help of a handheld IR remote control to send commands, using a TV as a brouter, to the VCR and stereo receiver via the power line.

5.4.4 Application Protocol Data Unit (APDU) Header

The Application Protocol Dat Unit(APDU) header specifies how and if the receiving application layer should respond to the packet. There exist three field in the APDU: Mode, Type, and Invoke ID.Table 5.3 gives the bit description of the APDU.

Table 5.3- APDU Header

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Mode	Type			Invoke ID		

Reserved		**Invoke ID**	
1	Must be 1	**000**	A three bit incrementing identifier used for packet tracking.
Mode			
000	Not Used	**001**	
001	Reject	**010**	
010	Result	**011**	
011	Receipt Acknowledge	**100**	
100	Implicit Invoke	**101**	
101	Explicit Invoke	**110**	
110	Conditional Invoke	**111**	
111	Explicit retry		

The mode field indicates if the APDU will use multiple bytes or not. Most messages use the Basic Fixed length APDU mode.

The type field is of seven values: Reject, Result, Receipt, Acknowledge, Implicit Invoke, Explicit Invoke, Conditional Invoke, and Explicit retry.

Invoke ID is a three bit field incremented (and rolled over) for each new transmitted message to a destination address [26][27].

Distinction between the LPDU packet type and the APDU type is to be pointed out. The DLL acknowledgement, if requested in the LPDU packet type field, takes place regardless of the APDU type and without the application knowledge if the application requests acknowledged service. As far as the application layer is concerned it is communicating with the application layer or the receiving node with the same being true for each lower and higher layer.

5.4.5 CAL Device Model

CEBus uses a hierarchical model to describe each node. Each node includes two or more contexts, each made up of two or more objects. Each object includes one or more Instance Variables (IVs) [24].

5.3.5.1 Universal Context:

The first context in every node is named the Universal Context (Appendix A, page A-3) and has nothing to do with normal operation of the concerned device. The condition is that the device must be a CEBus-compatible product; the Universal Context is numbered 00 and its task is to control the device's presence on the CEBus Network. The Universal Context contains two objects: the node control object (object 0) and the context control object (object 1).

The node control object consists of IVs to hold universal device information such as the device address, manufacturer name, and other device management information. The context control object possesses only one IV called object list which gives the list of object IDs for this context. Every context is composed of one or more IVs that control or publish certain aspects of the device [26].

5.4.5.2 Other Contexts:

CEBus defines contexts which can be grouped to define every device. For instance, the Lighting Control context numbered 21 (see table A-1 in appendix A) contains parameters used to define a light switch. The Lighting context has two objects. The context control object is required to be the first object (object 1) as in every context with the exception of the Universal Context (table A-3 in appendix A). In this case, the context control object has one IV which is the object_list containing a list of the different objects in this context. Table 5.4 shows the different objects necessary to configure and write the message to control light level using Lighting Context 21. The list to be defined in the context control (object 01, class 02) in this context is 02010702. This can be read as the Lighting Context 21 has a CEBus object of class 02 for the first (01) object and a CEBus object of class 07 (analog control: light level control) in the second (02) object. The current_value is required in the light control object in order to be CEBus compatible [26].

Table 5.4 – Universal Context and Lighting Context [26].

ID	CONTEXT					
00	**UNIVERSAL**					
	NO	OBJECT				CLASS
	01	NODE CONTROL (DEVICE CONTROL)				01
		IV	NAME	PS	TYPE	
		s	Serial_#	R	string	
		h	System_addr	R/W	data	
		a	Mac_addr	R/W	data	
		g	Group_addr	R/W	data	
		n	Manuf_name	R	string	
		w	Power	R	boolean	
		l	On_offline	R/W	boolean	
		o	Contex_list	R	data	
		i	Setup	R	numeric	
		u	User_feedback	R/W	numeric	
		p	Product_name	R/W	string	
		f	configured	R/W	boolean	
		r	Controller_present	R/W	boolean	
		G	Default_group_addr	R/W	data	
		N	Repeat_enable	R/W	boolean	
		t	Config_master	R/W	boolean	
		H	Report_header	R/W	data	
		A	Dest_adress	R/W	data	
	02	CONTEXT CONTROL				02
		IV	NAME	PS	TYPE	
		o	Object_list	R	data	
21	**LIGHTING**					
	NO	OBJECT				CLASS
	01	CONTEXT CONTROL				02
		IV	NAME	PS	TYPA	
		o	Object_list	R	data	
	02	ANALOG CONTROL (LIGHT LEVEL CONTROL)				07
		IV	NAME	PS	TYPE	
		C	Current_value	R/W	numeric	
		s	Saved_value	R/W	numeric	
		r	Step_rate	R/W	numeric	
		S	Step_size	R/W	numeric	
		f	Feature_select	R/W	numeric	

Object 1 → Lighting object 01; Context control object → class 02

Object 2 → Lighting object 02; Context control (Analog control) → class 07

Table A-3 (see appendix A , pages A-3; A-11) gives the CAL object list (or class in contexts' tables). From this list, the CAL object 07 (class 07) is an analog control object and has 14 IVs (Lighting Context 21 table description) . Regarding the type of analog control, part of these IVs are used. In this example, five IVs are used. The current_value stores the current dim value in percent (0-100). The saved_value is used to temporarly save the current_value. The step_rate and step_size are used to set the ramp rate of the current_value IV used for diming and feature_select is used to manipulate the current_value IV and control the light.

5.4.5.3 CAL Method

CAL Methods are used to implement operations on CAL instance variables. Table 5.5 lists the CAL methods and their hexadecimal values

Table 5.5- CAL Method list [26].

Value (Hex)	Mnemonic	Basic Syntax	DataType
40	nop		
41	**setOFF**	IV	B
42	**setON**	IV	B
43	**getValue**	IV	BNC
44	**get Array**	IV[, [<offset>], <count>]	D
45	**setValue**	IV	BNC
46	**setArray**	IV[, [<offset>], <data>]	D
47	add	IV1, IV2, [IV3]	N
48	increment	IV [, <number>]	N
49	subtract	IV1, IV2, [IV3]	N
4A	decrement	IV [,<number>]	N
4B	compare	IV1, IV2	BNCD
4C	comparei	IV1, <data>	BNCD
4D	copyValue	IV1, IV2 [, <context>, <object>]	BNCD
4E	swap	IV1, IV2	BNCD
52	exit	[<error number>]	
53	alias	<allias ID> [<string>]	
54	**inherit**	IV, <value>	D
55	**disinherit**	IV, <value>	D
56	if	<boolean>BEGIN<message list>[else clause]END	
57	do	<boolean>BEGIN<message list>END	
58	while	<boolean>BEGIN<message list>END	
59	repeat	<boolean>BEGIN<message list>END	
5A	build	<macro ID>BEGIN<message list>END	

Mnemonics in BOLD are required for minimum CEBus implementation.

“,” is F5 delimiter. B: Boolean, N:Numerical, D:Data, C: Strings

5.4.5.4 CAL Tokens

CAL Tokens are used as programming constructs and for delimiting data; table 5.6 lists the CAL Tokens and their hexadecimal value.

Table 5. 6- CAL Tokens

Name	Value	Name	Value	Name	Value
DO	57	EQ	E8	DELIMITER	F5
WHILE	58	NEQ	E9	ESCAPE	F6
REPEAT	59	ELSIF	EA	BEGIN	F7
BUILD	5A	ELSE	EB	END	F8
AND	E0	LITERAL	EC	END_OF_CMD	F9
OR	E1	DELTA	ED	END_OF_LIST	FA
NOT	E2	PARAMETER	EE	END_OF_MSG	FB
XOR	E3	NULL	F0	END_OF_FILE	FC
GT	E4	MINIMUM	F1	Error	FD
GTE	E5	MAXIMUM	F2	Completed	FE
LT	E6	DEFAULT	F3		
LTE	E7	DATA	F4		

5.4.5.5 CAL Data Types

There exist four data types in CAL statements: Strings, Data, Numeric, and Boolean. Strings are delimited by CAL tokens or are at the end of a packet and are not zero terminated. Data are array oriented. Numerics are strings of ASCII numbers (example: the three bytes 31h 30h 30h represent the number 100. Boolean type is always true or false and is represented by the byte 01h for true or the byte 00h for false

5.4.6 Packet Building and CAL Message Writing

For a light switch under CEBus, there can be many different operations. It can be turned on and off, set to a dim level, brought to a ramp level. Also, its serial number can be read and its device address changed. To build a packet, the following steps are undertaken. In the LPDU Control Field, the packet priority will be set to standard and the packet type to ADDR_UNACK_DATA. All other fields will be zero and the resulting control byte is 0Fh. There is no control on the sequence numbre since this is set by the DLL. To have an illustration of building packet, let it be assumed that the light switch has a House code of 5 and a Unit code of 1. The controller (the transmitting node) will have a House code of 2 and a

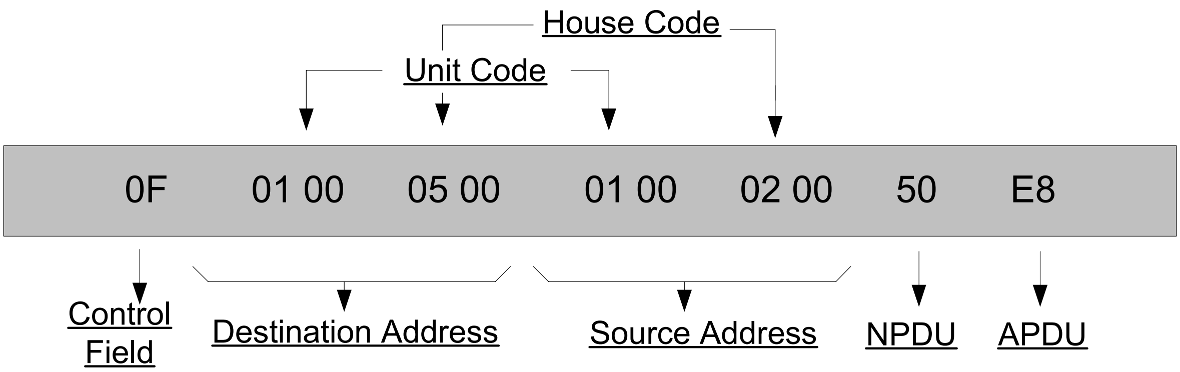
Unit code of 1. The NPDU is choosen for unprivileged, and directory routed service on this media only. The resulting NPDU, then, will have a value of 50h [23][26][27].

The APDU will be a single byte with a value betwween E8h and Efh. This is to specify a mode of basic one byte fixed and a type of explicit invoke. The invoke ID is incremented for each packet sent.

In this coming examples, the first 11 bytes are the same with the exception of the 11th byte, where the Invoke ID incremented. Depicting each byte according to the above steps described in packet building section, the 11 bytes would be:

0F 01 00 05 00 01 00 02 00 50 E8

and depicted as follows:



The first byte is the Control Field of the LPDU header as shown on Figure 5.6. The next four bytes are the destination address followed by the source address in right to left order. Theses addresses along with the Control Field make up the LPDU header. The next two bytes are the NPDU and the APDU headers.

5.4.6.1 ON Message

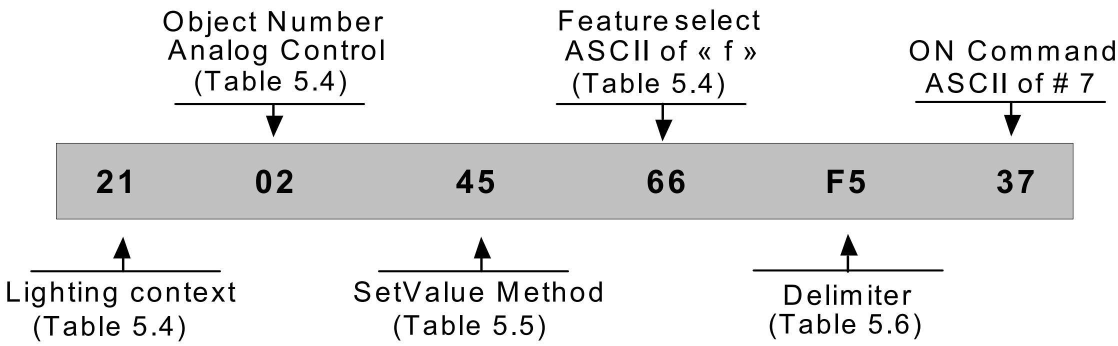
After writing the headers, the CAL message is to be written regarding the command to be executed. To turn on a light, severals parameters must be set, IVs defined, and object selected from the Lighting contexts (see Table A-3 in Appendix A). Numbers and IVs codes are writen under the ASCII code.

The ON command uses the setvalue method to send a value of 37h to the feature_select IV. In this case ,it has the effect of setting the current value to 100 by the definition of feature_select. The bytes are : **21 02 45 66 F5 37** .

21 is the ID of the lighting context . 02 is the object number of the analog control, 45 is the SetValue method, 66 is the feature_select IV(ASCII “f”) , F5 is a delimiter and 37 is the ASCII representation of the number “7”. The resulting CAL message is as follows:

21 02 45 66 F5 37

and is descibed as:



The complete packet would be then:

OF 01 00 05 00 01 00 02 00 50 E8 21 02 45 66 F5 37

The construction of the response to the transmitted CAL message is as follows:

0F 01 00 02 00 01 00 05 00 50 D0 FE

The LPDU Control Field (0F) shows a standard packet priority and a packet type of ADDR_UNACK_DATA which does not require a response from the DLL to acknowledge packet receipt. The source and destination are reversed since the addressed device is now sending to the control part. The NPDU (50) is the same as transmitted. The APDU (D0) has the same mode but the type field shows it is a Result with the result as (FE) which is the “completed” CAL token.

5.4.6.2 Off Message

Next, the CAL message to turn the light off can be written following the same procedure. The packet is quasi identical to the previous one(turning the light on). The difference lies on the feature_select that is changed to 33h and the Invoke ID is incremented by one. By writing 33h to the feature_select, current_value is saved in the saved_value prior to setting the current_value to 0.

In this manner, the light would be restored to the previous dim setting. The result packet is the same except that the Invoke ID matches the Invoke ID that has been sent. As a consequence, the Invoke ID takes its usefulness due the fact that for several commands issued to this light switch, and that since the result packets are all identical except for the Invoke ID, this gives the possibility to track the responses to the packets sent.

The complete packet for the turn off command is then:

0F 01 00 05 00 01 00 02 00 50 E9 21 02 45 66 F5 33

and the response is:

0F 01 00 02 00 01 00 05 00 50 D1 FE

5.4.6.3 Diming Message

To write a CAL message packet in order to dim the light, the current_value IV is to be set to thr dim level. For instance, 50% is the desired level; in this case, the packet is:

21 02 45 43 F5 35 30 and depicted as:

21 _ ID of Lighting Context

02_ Object number of the analog control

45_Set_value method

43_Current_value IV (ASCII "c")

F5_Delimiter

35 30_ is the ASCII representation of the digits "5" and "0" or 50%

The resulting complete packet is:

0F 01 00 05 00 01 00 02 00 40 EA 21 02 45 43 F5 35 30

The response packet is the same except the Invoke ID.

0F 01 00 02 00 01 00 05 00 50 D2 FE

5.3.6.4 Serial Number: Use of Universal Context.

One of the uses of the Universal Context is the writing and reading of the serial number of a device. The serial number can be determined from the Universal context in object 1 that is the node control object (Appendix A, page A-3). The eleventh first bytes of the transmit packet are the same. The CAL command to follow is: **00 01 43 73.** This can be described as:

00: Uninersal Context

01: Object 1 is the node control object

43: get_value methode **73**: IV “s” for serial number

The complete packet is:

0F 01 00 05 00 01 00 02 00 50 EB 00 01 43 73

The response is:

0F 01 00 02 00 01 00 05 00 50 D3 FE F5 54 30 30 30 30 30 30 30 30 35 39

After the complete token(FE) and the delimiter token (F5), appears the serial number under ASCII representation which can be read as “ T0000000059”.

The serial number is to placed on the manufacturer label and it provides a good way to communicate with the control unit for setup purposes. Normal communication uses the device address after it is set and the device configured. A broadcast message (for all nodes) using Conditional Invoke APDU type asks for the House Code in return if the Serial Number condition is met. The House code is an array value and must be configured using the methods and delimiters handling arrays.

The packet to get the House Code from the device with the Serial Number “T0000000059”can be :

0F 00 00 00 00 01 00 05 00 50 F0 00 01 56 73 E8 EC 54 30 30 30 30 30 30 30 30 35 39 F7 44 68 F8

Where

0F: control byte

00 00 00 00: destination address that is the system broadcast address

01 00 05 00: source address or the device address

50: NPDU

F0: APDU in the Conditional Invoke type

00: Universal Context

01: node control object

56: beginning of CAL message with IF token(56)

73: IV “s” for serial number

E8: equal token

54 30 30 30 30 30 30 30 30 35 39: serial number “T0000000059”

F7: begin token

44: GetArray method

68: House Code IV “h”

F8:end token

The above codes can be termed as: if the universal context object 1, and the serial number is equal to “T0000000059” then get the array value of House Code.

The response packet would be:

0F 01 00 02 00 01 00 05 00 D4 FE F4 32 F6 00 05

Where FE is the completed token, F4 is the data token, 32 (2 in ASCII code) is the number of data (ie:two data bytes following the data token), F6 is the escape token, and 00 05 is the looked House Code (the two data bytes).

5.5 Conclusion

The implementation of the practical part of this project has been achieved to the expected level of feasibility. The three main functions: power line communication, spread spectrum technique, and home automation have been implemented and/or tested individually and confirmed to work successfully with manual control. The practicals problems encountered were related to the coupling circuit whose performance could not be achieved to the desired level by using available wire and magnetic cores, and also to the non-availability of manufactured matched filters as integrated circuits. Alternative demodulating and despreading IC's (MC1496) have been used to manually test the received signals from the mains. Thus, efficiency of power line transmission has been tested experimentally. As a conclusion, the use of this media strongly relies on modulation/demodulation technique, the error detection/correction technique, and the coupling onto the power line.

The addition of software control, namely the higher layers and the desired application would constitute themes for a more advanced project.

After completion of the hardware part, some statements are to be made.. The different circuits have been designed using current integrated circuits (IC's).The most elaborated integrated circuits needed where the ROM, DAC, and µController. The realized circuits using these current circuits have worked very well, despite of their number. The obtained waveforms related to the generated chirps illustrate the achieved goal and the good behavior of the hardware. The shape of the chirp is close, to a great extent, to the shape illustrated and described in Chapter 3. Also, the same thing can be said about timing and voltage amplitude. Simulated chirps are shown besides the practical ones (section 5.3, figures 5.1 to 5.7). For the purposes of testing circuits individually or alltogether, emphasizing has been put on real time hardware experimentation. Simulated circuits could not give an overall working condition because of the required timing. As it can be seen on the simulated waveforms, only one or two chirps have been obtained and it has taken a large amount of time. At last it is worth to emphasize that in this work the physical layers are intended to be hardware realizations. The reasons are: there must be real-time control and response, the pattern of symbols and waveform are invariant and are best generated using hardware circuit without any software contribution, and the aim to alleviate the µController from the burden of basic tasks. Software control is devoted to packets message construction and writing applications. Published litterature on power line communication show that the field companies are designing specialized IC's that integrate the wider possible number of functions. These functions include the implementation of power line communication, the modulation techniques, the information coding and decoding, the error detection and correction techniques, and many networking control schemes. To increase the rate of data transmission most of the elaborated techniques of digital trasmission techniques such as the Orthogonal Frequency Division Multiplexing (OFDM)- a spread spectrum modulation technique- along with highly efficient algorithms for detecting and correcting errors are hardware implemented. This has resulted into the extremely great number of applications in various domains such as: industries, business, home, Internet, and entertainment.[4][29][30]

Chapter 6

The motivation behind the present work is energy saving which should be considered an issue of central importance to our country. In the vein, the use of the power line as a media of communication (and control) has been the objective of the present study. After the completion of this project regarding its aims and goals, I have gained knowledge of the issues facing energy conservation. These issues, technical and general have been presented in the theory section. I introduced possible use of power line communication technique, primarily for home automation that is suitable for energy conservation. The use of power line network, at the first thought, is not suitable for networking. There are indeed a number of considerable challenges facing PLC including interference, variable attenuation, and time varying characteristics. In meeting these challenges, for optimal performance a power line carrier communication system should be frequency diverse (using spread spectrum techniques), and possess robust error control techniques. Also careful consideration needs to be given to design issues such as the coupling network. Thus, the problems hindering the development of power line communication are important but not insurmountable.

The application of spread spectrum carrier technique has been implemented successfully. The choice for this technique stems from its higher ability to withstand the harsh environment existent in the power line. This achieved part comprises the physical layer and the physical layer symbol encoder. Altogether, these layers convey information from and to the power line in the form of swept chirps under the established encoding scheme. This practical part has been realized by using current and common integrated circuits. Furthermore, the achieved implementation has proved its feasibility and that its advantage viz availability, convenience, and lower costs overcome its disadvantages. And this will encourage further developments for its better use. Highly developed schemes for modulations, carriers, speed to be applied for the home automation and its derived HomePnP will lead to reliable integrated schemes.

One of the main challenge in this project was to acquire the necessary knowledge of home automation that can be implemented reliably in business building as well in residential houses. It lends itself to be used as the technique to control the energy consumption of the different devices and appliances. Furthermore, combination of power line communication techniques and automation is very appealing to energy suppliers in order to monitor from a distance energy metering of its customers and also help them correct their power network. This is at the heart of energy conservation policies (Demand Side Management). Sonelgaz is a potential user of these techniques with their buying and installing digital meters.

A description is given on how to implement certain tasks for lighting that stems from the lighting contexts. Contexts are the terminology used to describe the functions and the tasks that are operated within a device. And these functions and tasks can be utilized by other devices to perform altogether specific application as a system or subsystem. In view of the advantages of applying techniques that are well developed and that use recognized standards, home automation can be extended to the control of other elaborate functions such as: security, remote utility metering, and Demand Side Management. Work on the higher layers using specialized integrated circuit to be found in the market is suggested for further research. Also, tests of reliability and ruggedness on the power line network can be suggested as further work.

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Appendix A

Table A1 :Contexts List

GENERAL

00 Universal
02 User Interface
04 Data Channel
 Time
0E Time Monitor
0F House Mode

AUDIO/VIDEO

10 Audio Amp
11 Medium Transport
12 Tuner
13 Video Display
14 Audio Equalizer
15 Camera
17 Switch
18 A/V System
19 A/V System Control

LIGHTING

20 Light Sensor
21 Light
22 Lighting Scene
23 Light Sensor Status
24 Lighting Scene Request
25 Lighting Scene Status

HVAC

40 Environmental Zone
41 Environmental Sensor
42 Environmental Sensor Status
43 Environmental Zone Request
44 Environmental Zone Equipment
45 Environmental Zone Status
46 Humidification Zone Request
47 Humidification Zone
48 Humidification Zone Equipment

UTILITY

50 Utility Metering
51 Electric Monitor
52 Electric Status
53 Gas Monitor
54 Gas Status
55 Water Monitor
56 Water Status
57 Service Monitor
58 Service Status
5A Load Request
5B Load
5C Energy Management Request
5D Energy Management

SECURITY

60 Security Sensor
61 Security Zone
62 Security Partition
63 Security Partition Status
64 Alarm Status
65 Alarm
66 Security Partition Request
67 Security Sensor Status
68 Security Zone Status
69 Trouble
6! Trouble Status

APPLIANCE

70 Washer
72 Water heating
73 Dryer
74 Refrigerator/Freezer
75 Range
76 Oven
77 Coffee Maker

CONVENIENCE

80 Window
81 Window control
82 Door/gate
83 Door/gate control
84 Pool/Spa
85 Pool/Spa control
86 Bath
88 Fountain
8A Lift

Table A-2 Digitized 100 μs Waveform - 360 intervals (361 points)

0	0.0000	45	-0.4295	90	-0.0536	135	-0.3597	180	-0.1073	225	-0.1019	270	-0.0644	315	-0.3758
1	0.0816	46	-0.3944	91	0.1479	136	-0.3426	181	0.0898	226	-0.1727	271	-0.0214	316	-0.3865
	0.1328	47	-0.2861	92	0.3134	137	-0.2216	182	0.2509	227	-0.1645	272	0.0450	317	-0.3758
3	0.1827	48	-0.1417	93	0.4032	138	-0.0450	183	0.3223	228	-0.0615	273	0.1182	318	-0.3192
4	0.2149	49	0.0277	94	0.3829	139	0.1366	184	0.2717	229	0.0706	274	0.1903	319	-0.2377
5	0.2149	50	0.1922	95	0.2805	140	0.2936	185	0.1194	230	0.1922	275	0.2680	320	-0.1300
6	0.2041	51	0.3230	96	0.0953	141	0.3545	186	-0.0765	231	0.2578	276	0.3330	321	-0.0099
7	0.1585	52	0.4001	97	-0.0992	142	0.3048	187	-0.2281	232	0.2122	277	0.3760	322	0.1101
8	0.0784	53	0.4082	98	-0.2729	143	0.1651	188	-0.2899	233	0.0815	278	0.3836	323	0.2087
9	-0.0246	54	0.3351	99	-0.3790	144	-0.0235	189	-0.2405	234	-0.1116	279	0.3652	324	0.2857
10	-0.1479	55	0.1916	100	-0.3865	145	-0.1992	190	-0.0906	235	-0.3090	280	0.3330	325	0.3330
11	-0.2628	56	0.0225	101	-0.3174	146	-0.3111	191	0.0855	236	-0.4610	281	0.2849	326	0.3542
12	-0.3550	57	-0.1517	102	-0.1589	147	-0.3328	192	0.2163	237	-0.5000	282	0.2142	327	0.3437
13	-0.3973	58	-0.3040	103	0.0283	148	-0.2436	193	0.2578	238	-0.4600	283	0.1541	328	0.3099
14	-0.3973	59	-0.4053	104	0.2039	149	-0.0753	194	0.1963	239	-0.3383	284	0.0834	329	0.2498
15	-0.3257	60	-0.4295	105	0.3419	150	0.1111	195	0.0377	240	-0.1861	285	0.0126	330	0.1469
16	-0.2056	61	-0.3560	106	0.3867	151	0.2669	196	-0.1379	241	-0.0338	286	-0.0842	331	0.0447
17	-0.0533	62	-0.2197	107	0.3435	152	0.3385	197	-0.2578	242	0.0862	287	-0.1826	332	-0.0806
18	0.1161	63	-0.0397	108	0.1955	153	0.2986	198	-0.2899	243	0.1612	288	-0.2641	333	-0.2061
19	0.2619	64	0.1511	109	0.0135	154	0.1497	199	-0.2106	244	0.1827	289	-0.3436	334	-0.3261
20	0.3736	65	0.3067	110	-0.1777	155	-0.0441	200	-0.0608	245	0.2041	290	-0.3949	335	-0.3847
21	0.4404	66	0.4053	111	-0.3300	156	-0.2319	201	0.0939	246	0.2134	291	-0.4295	336	-0.4295
22	0.4301	67	0.4140	112	-0.3968	157	-0.3436	202	0.1929	247	0.2363	292	-0.4295	337	-0.4197
23	0.3652	68	0.3428	113	-0.3592	158	-0.3534	203	0.2041	248	0.2471	293	-0.4022	338	-0.3646
24	0.2442	69	0.2091	114	-0.2226	159	-0.2372	204	0.1154	249	0.2714	294	-0.3514	339	-0.2791
25	0.0997	70	0.0251	115	-0.0333	160	-0.0465	205	-0.0262	250	0.2793	295	-0.2821	340	-0.1586
26	-0.0529	71	-0.1636	116	0.1679	161	0.1443	206	-0.1610	251	0.2599	296	-0.2006	341	-0.0362
27	-0.2115	72	-0.3028	117	0.3104	162	0.2879	207	-0.2362	252	0.2213	297	-0.1202	342	0.0839
28	-0.3218	73	-0.3971	118	0.3760	163	0.3224	208	-0.2202	253	0.1613	298	-0.0269	343	0.2039
29	-0.3973	74	-0.4018	119	0.3520	164	0.2392	209	-0.1164	254	0.1013	299	0.0753	344	0.2962
30	-0.4008	75	-0.3310	120	0.1970	165	0.0663	210	0.0251	255	0.0413	300	0.1648	345	0.3670
31	-0.3596	76	-0.1904	121	-0.0002	166	-0.1424	211	0.1559	256	-0.0161	301	0.2606	346	0.4108
32	-0.2610	77	-0.0173	122	-0.2097	167	-0.2973	212	0.2239	257	-0.0536	302	0.3421	347	0.4189
33	-0.1148	78	0.1690	123	-0.3590	168	-0.3643	213	0.1887	258	-0.0858	303	0.3960	348	0.3781
34	0.0648	79	0.3120	124	-0.4078	169	-0.2894	214	0.0855	259	-0.1400	304	0.4189	349	0.3059
35	0.2065	80	0.4082	125	-0.3412	170	-0.1157	215	-0.0369	260	-0.1932	305	0.4082	350	0.1803
36	0.3373	81	0.3867	126	-0.1846	171	0.0871	216	-0.1417	261	-0.2437	306	0.3738	351	0.0312
37	0.4082	82	0.2915	127	0.0255	172	0.2640	217	-0.1717	262	-0.2930	307	0.3008	352	-0.1211
38	0.4082	83	0.1316	128	0.2122	173	0.3424	218	-0.1099	263	-0.3328	308	0.2068	353	-0.2349
39	0.3334	84	-0.0686	129	0.3430	174	0.2908	219	-0.0006	264	-0.3436	309	0.0975	354	-0.3321
40	0.1922	85	-0.2594	130	0.3652	175	0.1266	220	0.1301	265	-0.3322	310	0.0096	355	-0.3752
41	0.0277	86	-0.3827	131	0.2746	176	-0.0813	221	0.2072	266	-0.2899	311	-0.0981	356	-0.3474
42	-0.1524	87	-0.4295	132	0.1053	177	-0.2519	222	0.2285	267	-0.2362	312	-0.1875	357	-0.2874
43	-0.2968	88	-0.3796	133	-0.1035	178	-0.3221	223	0.1508	268	-0.1844	313	-0.2684	358	-0.1970
44	-0.3963	89	-0.2444	134	-0.2753	179	-0.2640	224	0.0235	269	-0.1244	314	-0.3319	359	-0.0985
														360	0.0000

Table A-3: CAL-IV lists

UNIVERSAL	0

This context contains the Node Control Object and is present in all CEBus compliant (and HomePnP) products.

01	Node Control Object			(01) Node Control
	Contains IVs that apply to the entire node including address, node capability, configuration, and node power.			
IV	R/W	Type	Name	Context Function
w	R/W	b	power	device power, 0 = OFF, 1 = ON
l	R/W	b	on_offLine	1 = online, 0 = offline
s	R	c	serial_#	18 character (max) serial number
n	R	c	manuf_name	manuf. product name
m	R	c	manuf_model	manuf. product model
c	R	n	product_class	Product class number
p	R/W	c	product_name/location	Product name
h	R/W	d	**system_address**	16 bit system address
a	R/W	d	**mac_address**	16 bit unit address
g	R/W	d	group_address(s)	zero or more 16 bit group addr.
b	R	n	capability_class	0,1,2,3...
reset	R/W	b	reset	resets device to factory defaults
o	R	d	**context_list**	list of contexts used in product
f	R/W	b	**configured**	1 = address configured
i	R	n	**setup**	used during configuration
u	R/W	n	**user_feedback**	user interface IV during config.
t	R/W	b	config_master	indicated node is configuring
d	R	d	source_mac_addr	unit addr. of last received pkt
e	R	d	source_system_addr	system addr of last received pkt
v	R	c	conformance_level	transport type/ver./HPnp ver.
k	R/W	d	authentication keys	one or more keys
R	R/W	d	reporting_condition	Allows reporting on the state of one of the IVs in this object
H	R/W	b	reporting_header	
A	R	n	reporting_address	
P	R/W	d	previous_value	

02	Context Control Object			(02) Context control
	The context control object for this context.			
IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	Not used
f	R/W	b	context_configured	Not used
t	R	c	type	Not used
n	R/W	c	name_location	node location name text
l	R	n	local_zone_number	Not used

03	Event Manager			(16) Data Memory
	This object is intended to store code (programs, CAL statements, etc.) that may be executed upon a predefined event in the node.			
IV	R/W	Type	Name	Context Function
a	R	n	Size_of_memory	size of program
b	R	n	Length_of_record	length of program
C	R/W	n	**current_index**	current event condition pointer
I	R/W	d	**item_list**	list of events

House Mode — 0F

Contains object to send and receive the current home mode information.
Used for subsystem (intracontext) communications of high level state information.

01 Context Control Object — (02) Context control

The context control object for this context.

IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	b	context_configured	1 = instance configured
t	R	c	type	type identifier of context
n	R/W	c	name_location	ASCII name or location of context
l	R	n	local_instance	Internal number of the context

02 House Mode Status — (14) Keypad

Generates a state vector for the current house mode.
Always binds to object 3 of this context

IV	R/W	Type	Name	Context Function
C	R	c	**current_key**	The house state vector to send
k	R/W	b	new_key	not used
P	R	c	previous_key	Previous value of C
R	R/W	d	reporting_condition	C' <delta> 0
H	R/W	d	report_header	<cntx #> 0F 03 setValue 'I' F5
A	R/W	d	report_address	SA,0000

03 House Mode Listener — (15) List Memory

Used to monitor the current house mode vector from other subsystems

IV	R/W	Type	Name	Context Function
a	R	n	length_of_list	1
b	R	n	Length_of_item	24
C	R/W	n	**current_item**	Always 0
I	R/W	c	**item_list**	received house mode state vector

LIGHT IV Definitions — 21

Light Context selected Object IV definitions used when the Light Context is used in a lighting control application.

02	Light Level Control		(07) Analog Control
IV	Name	Value	Description
S	step_size	0-100	% brightness change that will occur during
			each step_rate time
r	step_rate	0 - 255	Time per step. Time in seconds that each
			step_size change will occur.
			0 means instantaneous change.
t	end_value_trans_time	0-9999	The time in seconds to transition from the
			current_value to the end_value light levels.
C	current_value	0-100	Current actual brightness level
e	end_value	0-100	Desired brightness level. Current_value will
			change to this value based on
			end_value_trans_time
s	saved_value	0-100	The last saved value generated as a result
			of selecting one of the feature IV values
f	feature	0-N	Optional light control feature
		0	No feature selected/stop feature
		1	Ramp brightness to maximum
		2	Ramp brightness to minimum
		3	current_value->saved_value and turn off
		4	current_value->saved_value and ramp off
		5	Turn on to saved_value
		6	Ramp on to saved_value
		7	Turn on to local brightness level
		8	Ramp on to local brightness level
		9	Set current brightness to minimum
		10	current_value->saved_value and FLASH
		11-99	Reserved for future use. Values >99 are
			available for manufacturer use.

LIGHTING SCENE — 22

Used to define and select predefined lighting scenes in a lighting control device.

01 Context Control Object — (02) Context control

The context control object for this context.

IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	b	context_configured	1 = instance configured
t	R	c	type	type identifier of context
n	R/W	c	name_location	Name or location of context
l	R	n	local_zone_number	Internal number of the context

02 Scene Selection — (09) Multi_position Switch

Selects from one of several lighting scenes. Predefined positions for all lights on and all lights off.

IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	Total number of scenes (N)
C	R/W	b	**current_position**	0-N
D	R	b	default_position	0 = all zones off
F	R	d	function_of_positions	0 = ALL ZONES OFF
				1 = ALL ZONES ON
				2 = predefined scene 1
				3 = predefined scene 2
				4 = predefined scene 3
				etc.
p	R/W	b	persistence	

03 Scene Level — (07) Analog Control

Optional overall scene brightness level. Used to modify brightness level of lights selected in current scene.

IV	R/W	Type	Name	Context Function
U	R	n	units_of_measure	8 = percent of full scale
S	R	n	step_size	
r	R	n	step_rate	
N	R	n	min_value	0 = minimum brightness
M	R	n	max_value	100 = maximum brightness
D	R	n	default_value	100 = maximum brightness
C	R/W	n	**current_value**	

04	Current Scene			(0A) Multi_state Sensor
	The current scene in use by the context. Binds with object 02 in the Lighting Scene Status context.			
	IV	R/W	Type	Name	Context Function

IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	Total number of scenes (N)
C	R	n	**current_position**	0-N
F	R	d	function_of_positions	
P	R	n	previous_position	
R	R/W	d	reporting_condition	C' <DELTA> 0
H	R/W	d	report_header	<cntx #> 25 02 setValue C f5
A	R/W	d	report_address	

05 Scene List — **(15) List Memory**

Item record storage for each light in each scene.

IV	R/W	Type	Name	Context Function
a	R	n	length_of_list	Number of records (scenes) in list
b	R	n	Length_of_item	Length of item record (20)
C	R/W	n	**current_item**	Current light/scene record
I	R/W	d	**item_list**	Scene "records"

06 Zone List — **(16) Data Memory**

Item record storage for each zone used in scenes. Each record contains the group or node address of light(s) in zone.
There may be multiple records for each zone

IV	R/W	Type	Name	Context Function
a	R	n	Size_of_memory	3 X max number of records
b	R	n	Length_of_record	3 bytes
C	R/W	n	**current_index**	Pointer to zone record
I	R/W	d	**item_list**	zone record list

LIGHT SENSOR Status 23

Contains objects to receive a measured light level from the Light Sensor context. Should be used in devices needing to know the level of the outside light level or a selected inside level.

01 Context Control Object — (02) Context control

The context control object for this context.

IV	R/W	Type	Name	Context Function
o	R	d	object_list	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	b	context_configured	1 = instance configured
t	R	c	type	type identifier of context
n	R/W	c	name_location	ASCII name or location
l	R	n	local_zone_number	Internal number of the context

02 Light Level — (07) Analog Control

Used to store the received light level from the Light Sensor context.

IV	R/W	Type	Name	Context Function
U	R	n	units_of_measure	8 = percent full scale
S	R	n	step_size	measurement increments
r	R	n	step_rate	
N	R	n	min_value	0 = dark (no light)
M	R	n	max_value	100 = maximum brightness
D	R	n	default_value	0 = Default brightness
C	R	n	**current_value**	Current brightness

04 Occupancy State — (05) Binary Switch

Used to indicate the presence of a person in a room or space. Usually set from the Occupancy State sensor in the Lighting Sensor Context.

IV	R/W	Type	Name	Context Function
C	R	b	**current_state**	1 = occupancy detected
D	R	b	default_position	1 = occupied/0 = unoccupied
F	R	d	function_of_states	1 = occupied/0 = unoccupied
p	R/W	b	persistence	

LIGHTING SCENE Request | 24

Used to define and select predefined lighting scenes in a lighting control device.

01 Context Control Object — (02) Context control

The context control object for this context.

IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	b	context_configured	1 = instance configured
t	R	c	type	type identifier of context
n	R/W	c	name_location	ASCII name or location of context
l	R	n	local_instance	Internal number of the context

02 Scene Selection — (0A) Multi_state Sensor

Selects from one of several lighting scenes. Predefined positions for all lights on and all lights off.

IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	Total number of scenes (N)
C	R/W	b	**current_position**	0-N
D	R	b	default_position	0 = all lights off
F	R	d	function_of_positions	0 = ALL LIGHTS OFF
				1 = ALL LIGHT ON
				2 = predefined scene 1
				3 = predefined scene 2
				4 = predefined scene 3
P	R	n	previous_position	
R	R/W	d	reporting_condition	C <DELTA> 0
H	R/W	d	report_header	<cntx #> 22 02 setValue C f5
A	R/W	d	report_address	

03 Scene Level — (08) Analog Sensor

Optional overall scene brightness level. Used to modify brightness level of zones selected in current scene.

IV	R/W	Type	Name	Context Function
U	R	n	units_of_measure	8 = percent of full scale
S	R	n	step_size	
N	R	n	min_value	0 = minimum brightness
M	R	n	max_value	100 = maximum brightness
C	R	n	**current_value**	Desired brightness level for scene
P	R	n	previous_value	
R	R/W	d	reporting_condition	C' <DELTA> 0
H	R/W	d	report_header	<cntx #> 22 03 setValue C f5
A	R/W	d	report_address	

LIGHTING SCENE Status	25

Used to monitor the current lighting scene in a Lighting Scene context.

01	Context Control Object			(02) Context control
	The context control object for this context.			
IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	b	context_configured	1 = instance configured
t	R	c	type	type identifier of context
n	R/W	c	name_location	ASCII name or location
l	R	n	local_instance	Internal number of the context

02	Current Scene			(09) Multi_position Switch
	Monitors the current scene in a lighting scene context. *Reported to by object 04 of context 22.*			
IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	Total number of scenes (N)
C	R/W	b	**current_position**	0-N
D	R	b	default_position	0 = all zones off
F	R	d	function_of_positions	0 = ALL ZONES OFF
				1 = ALL ZONES ON
				2 = predefined scene 1
				3 = predefined scene 2
				4 = predefined scene 3
				etc.
p	R/W	b	persistence	

SECURITY SENSOR — 60

Contains the necessary objects to model the operation of a security sensor. Sensors are output devices only, providing an indication of the sensor state to the Security Sensor Status (67) context.

01	Context Control Object			(02) Context control
	The context control object for this context.			
IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	b	context_configured	1 = instance configured
t	R	c	type	type identifier of context
n	R/W	c	name_location	ASCII name or location of context
l	R	n	local_instance	Internal number of the context

02	Sensor Data			(0A) Multi_state Sensor
	Indicates the current output state of the sensor. Outputs an eight bit value that depends on the sensor type.			
IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	total number of sensor states
C	R	n	**current_position**	Sensor output value
F	R	d	function_of_positions	See IV definitions
P	R	n	previous_position	
R	R/W	d	reporting_condition	C <DELTA> X
H	R/W	d	report_header	<cntx #> 67 02 setValue C f5
A	R/W	d	report_address	SA, NA

03	Control/Status			(09) Multi_position Switch
	Optional combination Control and Status input object. Value of current_position dependent on sensor type			
IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	total control/status states
D	R	n	default_position	power up status condition
C	R/W	n	**current_position**	Current control/status data
F	R	d	function_of_positions	
p	R/W	b	persistence	

04	Sensor Trouble			(0A) Multi_state Sensor
	Optional additional trouble indication independent of the sensor data.			
IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	total trouble values
C	R	n	**current_position**	trouble code
F	R	d	function_of_positions	
P	R	n	previous_position	
R	R/W	d	reporting_condition	C <DELTA> 0
H	R/W	d	report_header	<cntx #> 67 04 setValue C f5
A	R/W	d	report_address	SA, NA

Security Zone 61

Contains the objects to control and monitor one security zone.

01	Context Control Object			(02) Context control
	The context control object for this context.			
IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	b	context_configured	1 = instance configured
t	R	c	type	type identifier of context
n	R/W	c	name_location	ASCII name or location of context
l	R	n	local_instance	Internal number of the context
02	**Zone Status**			**(14) Keypad**
	Indicates the current status of the zone.			
IV	R/W	Type	Name	Context Function
C	R	c	**current_key**	Status vector
k	R/W	b	new_key	1 when vector changes
P	R	c	previous_key	
R	R/W	d	reporting_condition	c <delta> 0
H	R/W	d	report_header	68 02 setValue C
A	R/W	d	report_address	
03	**Zone State Request**			**(09) Multi_position Switch**
	Input from Security Zone Status context to control the operation of this zone			
IV	R/W	Type	Name	Context Function
n	R	n	**number_of_positions**	3
D	R	n	default_position	1 = armed?
C	R/W	n	**current_position**	current zone mode
F	R	d	function_of_positions	0 = bypassed
				1 = armed
				2 = monitor

Utility Meter	50

Provides the necessary objects for utility (electric, gas, water) metering and/or monitoring.

01	**Context Control Object**			**(02) Context control**
The context control object for this context.				
IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	n	context_configured	1 = instance configured
t	R	c	type	E = electric utility meter
				G = gas utility meter
				W = water utility meter
n	R/W	c	name_location	Name or location of context
l	R	n	local_zone_number	Internal number of the context

02	**Meter Tables**			**(16) Data Memory**
Used to access the utility meter tables. Table data is accessed using macro numbers. Use of object IV's is not required.				
IV	R/W	Type	Name	Context Function
a	R	n	Size_of_memory	Not used
b	R	n	Length_of_record	Not used
C	R/W	n	current_index	Not used
I	R/W	d	item_list	Not used

03	**Interval Data**			**(16) Data Memory**
Optional storage area for interval data storage. Not recommended for new product development.				
IV	R/W	Type	Name	Context Function
a	R	n	Size_of_memory	
b	R	n	Length_of_record	
C	R/W	n	**current_index**	
I	R/W	d	**item_list**	

04	Meter memory data			(16) Data Memory
	Optional storage area for meter data storage. Not recommended for new product development.			
IV	R/W	Type	Name	Context Function
a	R	n	Size_of_memory	
b	R	n	Length_of_record	
C	R/W	n	**current_index**	
I	R/W	d	**item_list**	

05	Utility Clock			(1D) Clock
	Current meter time.			
IV	R/W	Type	Name	Context Function
C	R/W	c	current_time	Current utility time
t	R/W	c	hh_mm_ss	
h	R/W	n	hour	
m	R/W	n	minute	
s	R/W	n	second	
e	R/W	c	dd_mm_yy	
d	R/W	n	day	
n	R/W	n	month	
y	R/W	n	year	
w	R/W	n	day_of_week	
z	R/W	n	time_zone	
r	R/W	b	run_edit	1 = run, 0 = edit
a	R/W	b	savings_time	
P	R	n	previous_time	
R	R/W	d	reporting_condition	
H	R/W	d	report_header	
A	R/W	d	report_address	
l	**R/W**	**d**	**Ltime_date_3**	5 byte time since 01/01/70 00:00:00 4 MS bytes: binary minutes 1 LSbyte: binary seconds

Electric Monitor 51

Provides the necessary objects for monitoring of electric service parameters either for the utility service, or for an individual electric load or device.

01	Context Control Object			(02) Context control
The context control object for this context.				
IV	R/W	Type	Name	Context Function
o	R	d	**object_list**	list of objects used in context
z	R/W	n	instance	instance number of context
f	R/W	n	context_configured	1 = instance configured
t	R	c	type	E = electric utility monitoring
				e = electric load monitoring
n	R/W	c	name_location	Name or location of context
l	R	n	local_zone_number	Internal number of the context

02	Electric Power Demand			(08) Analog Sensor
The real time electric power demand in kilowatts. Measurement interval is up to the manufacturer				
IV	R/W	Type	Name	Context Function
U	R	n	units_of_measure	23 = kilowatts
S	R	n	step_size	Smallest measurement size
N	R	n	min_value	0 watts
M	R	n	max_value	Largest watt value
C	R	n	**current_value**	Current demand
i	R/W	n	measurement_interval	measurement interval in seconds
P	R	n	previous_value	
R	R/W	d	reporting_condition	C <delta> 0
H	R/W	d	report_header	<cntx #> 52 02 serValue C f5
A	R/W	d	report_address	SA, 0000

03	Electric Interval Demand			(07) Analog Control
Provies the electric power consumption of the load over an interval.				
IV	R/W	Type	Name	Context Function
U	R	n	units_of_measure	9 = kilowatt- hour
S	R	n	step_size	smallest KWH increment
r	R	n	step_rate	
N	R	n	minimum value	0 KWh
M	R	n	maximim value	largest accumlated value
D	R	n	default_value	0
C	R/W	n	**current value**	Accumulated energy reading
P	R	n	previous_value	
R	R/W	d	reporting_condition	C <delta> 0
H	R/W	d	report_header	<cntx #> 52 03 serValue C f5
A	R/W	d	report_address	SA, 0000

04	Electric Cumulative Demand			(08) Analog Sensor
	Provies the electric power consumption of the load since it was installed Value is not resettable.			
	IV	R/W	Type	Name	Context Function
	U	R	n	units_of_measure	9 = kilowatt- hour
	S	R	n	step_size	smallest KWH increment
	N	R	n	minimum value	0 KWh
	M	R	n	maximim value	largest accumlated value
	C	R	n	**current value**	Accumulated energy reading
	P	R	n	previous_value	
	R	R/W	d	reporting_condition	C <delta> 0
	H	R/W	d	report_header	<cntx #> 52 04 serValue C f5
	A	R/W	d	report_address	SA, 0000

05	Electric Peak Demand				(07) Analog Control
	Measures the highest demand value during the interval since last reset.				
	IV	R/W	Type	Name	Context Function
	U	R	n	units_of_measure	23 = kilowatts
	S	R	n	step_size	smallest KW increment
	r	R	n	step_rate	
	N	R	n	minimum value	0 KW
	M	R	n	maximim value	largest peak value
	D	R	n	default_value	0
	C	R/W	n	**current value**	KW peak value
	P	R	n	previous_value	
	R	R/W	d	reporting_condition	C <delta> 0
	H	R/W	d	report_header	<cntx #> 52 05 serValue C f5
	A	R/W	d	report_address	SA, 0000

06	Total Electric Current				(08) Analog Sensor
	Total instantaneous AC electric current usage (all phases). The default units are ampers.				
	IV	R/W	Type	Name	Context Function
	U	R	n	units_of_measure	25 = amps
	S	R	n	step_size	Smallest measurement size
	N	R	n	min_value	0 ampers
	M	R	n	max_value	Largest current measurement
	C	R	n	**current_value**	Current in ampers
	P	R	n	previous_value	
	R	R/W	d	reporting_condition	C <delta> 0
	H	R/W	d	report_header	<cntx #> 52 06 serValue C f5
	A	R/W	d	report_address	SA, 0000