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Prototype for Process Control in Residential Environments, Supported by Power Line Communications

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Abstract

Objectives: This article describes the development and implementation of a domotic system communication using as channel domiciliary mains (110 V/60 Hz) to control one or more devices used at home, from the study of the low-proposed stress as a means of data transport. **Methodology:** The control is performed by software developed in C++ Builder and installed on a PC, using a microcontroller for addressing and two cards PLC 101s-12A for coupling to the line and the FSK modulation for data transmission. **Findings:** By analyzing the behavior of the system, evaluating the relationship between the behavior of the channel (mains) and data transmitted as well as the cost/benefit ratio to establish the advantages of the prototype to other technologies offered by the current market, it is determined to be a viable proposal to be implemented in households. **Applications/Improvements:** The system can be used to control devices in residential and industrial environments using the electric network as a physical transmission medium, an aspect that can be considered of great importance when designing and implementing a home automation control solution. For future research work it is suggested the design of prototypes that allow establishing alternative communication processes and coexisting with PLC, in order to generate mechanisms of redundancy and efficiency during the periods of transmission and control of processes.

Keywords: Attenuation, Control, Harmonic Distortion, Home Automation, Modulation FSK, Noise, Power Line Communication (PLC), Power Supply

1. Introduction

The low-voltage power grid has become the best means of transmission for control and home automation because it is not necessary to install additional wiring to existing, considerably reducing costs[1,2]. A home automation level, the most widely used protocol in recent times has been X10 due to the low cost of the devices, but presenting serious problems of attenuation and little capacity for addressing, which has made other more robust protocols, mainly used to level industry in Europe and the United States are being applied at home, with the only drawback being very costly implementation[3].

The global trend in home automation suggests that the X10 protocol is displaced in the market for protocols that provide better options, but this has not been given yet because of their high costs, although they have lately emerged companies that develop products for communications through lines power are a good alternative for low-cost solutions. In the technological aspect, the implemented system provides the ability to manage network features, such as noise, attenuation, distortion

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and impedance, being in line with current standards in domotics.

Proposals like this allow you to develop products of very good performance and low-cost developed by unknown in the Western market, which in the hands of skilled in electronic engineering can be improved and supplemented companies, for use in multiple applications and be able to compete in a market like Colombia.

1.1 Technologies for Automation Level

Home automation is the set of automated systems that provide a home energy management services, security, welfare and communication, which can be integrated by means of internal and external communication networks, wire or wireless[4]. Among the best known means of transmission include:

- Lines power distribution (PLC).
- Copperpair.
- Coaxial.
- Optical fiber.
- Infrared.

1.2 Communication Protocols

- Batibus: It is a totally open protocol. A level of access, this protocol uses CSMA-CA technique (carrier sense multiple access with collision avoidance). The BatiBUS devices have micro-switches circular or mini-keyboards to assign a physical and logical address that identifies each device connected to the bus[5].
- EIB: The European Installation Bus or EIB is a home automation system developed under the auspices of the European Union. It is based on the OSI level structure and has a decentralized architecture. It can operate on physical media such as twisted pair, power line, radio frequency and infrared, with transmission speeds of 1200, 2400 and 9600 bps[6].
- EHS: EHS (European Home System) is an open standard protocol. It is based on a topology of OSI levels. It is designed to operate on physical media such as twisted pair, coaxial, power lines, radio and infrared, but currently used twisted pair to a transmission speed of 48 Kbps and the power line at 2400 bps[7].
- KONNEX: Konnex is the union of three European associations: EIBA (European Installation Bus Association), Batibus Club International and EHSA (European Home Systems Association). Physically it can run over twisted pair (9600 bps), power lines (1200/2400 bps) and radiofrequency (2400 bps).
- X10: It is one of the oldest protocols used in home automation applications. The transceiver X-10 is pending zero crossings of the sine wave of 60 Hz from the mains to insert an instant after a very short burst signal in a fixed frequency. Transmitters can address up to 256 receivers[8].
- CEBus (Consumer Electrinic Bus): Developed by the EIA (Electronics Industry Association) American[9]. CEBus transmits data using carrier currents, in spread spectrum modulation and transmitting one or more bits within a burst signal (400 KHz and 100 KHz) of duration 100 microseconds. The average transmission rate is 7500 bps.
- LonWorks: Developed by Echelon, is based on a microcontroller called Neuron Chip can be configured to act as an interface of various transceivers and operate at different bit rates[10]. LonWorks can operate over RS-485 opto-isolated, coupled to a coaxial cable or twisted pair with a transformer, on carrier currents and optical fiber.

2. Materials and Methods

2.1 Characteristics of Low Voltage Grid Electrical Network Topology

- Generation plant: It is where the network begins; It consists of an electrical generator that converts hydraulic energy into electricity.
- High-voltage substation: Used to make the change to transmit to distribute the electrical current. This change is made by making a voltage transformation (reduction) to suit the characteristics of the distribution lines of medium and low voltage.
- Distribution Transformer: low voltage installations for users (110V ~/60 Hz Colombia, 220V ~/50 Hz Europe) is responsible for converting media
- Distributionlines [eleven]:
- A high Voltage withstand voltage between 110 and 380 KV and its primary use is to transport electricity over long distances.
- Medium voltage: The voltage levels are between 10 and 30 KV. They are used to transport electrical power to rural areas, cities and industries. Typical distances are between 5 and lying 25 Km.

- Low voltage: This is the final part of the distribution network. They carry the electrical signal to the user outlet (115V-220V/60 Hz). Typical distances are typically between 100 and 500 meters.

2.2 Powerline as a Communication Medium

When using power lines as communication medium reveals features such as noise, attenuation, impedance and harmonic distortion[12].

- Noise: It may be of four types: 1. Synchronized with the mains noise, the usual cause are triacs and silicon controlled rectifiers; 2. Spectrum noise produced by engines; 3. Impulsive noise, it occurs by closing and opening electrical contacts; and 4. Noise not synchronized with a network frequency, their main sources are televisions and computer monitors.
- Attenuation: Load impedances of devices not equalized with the lead impedances at high frequencies, thus reflections and standing waves causing high losses at certain frequencies are created. Furthermore, due to the response of the power line is quite variable with the frequency, distortion occurs in the signal, inter-symbol interference which causes.
- Impedance: For maximum power transfer from the source to the load (no reflected energy), a transmission line must be terminated in a purely resistive load equal to the characteristic impedance of the line. The windings of the transformers, cables access to housing, internal wiring and electrical loads itself determine the impedance.
- Harmonic distortion: Harmonics are distortions of the sinusoidal waves of voltage or current electrical systems due to the use of fillers with nonlinear impedance, ferromagnetic materials and generally the use of computers required to perform switching in normal operation. Their appearance creates problems such as increased active power losses, surges, malfunction protection, insulation damage, and deterioration of dielectrics and reduced service life of the equipment.

2.3 FSK (Frequency Shift Key)

The modulation used for data transmission via the low voltage line was coherent FSK (Frequency Shift Keying) and minimum continuous phase shift. It works with carriers at frequencies of 81.5 and 82.5 KHZ[13].

2.4 Protocol

A transmitter, a receiver: For communication system two modules were built. A central PC used to manage software user interface. Communication between the PC and the transmitter module is done through the serial port and the EIA232 standard using or also known as RS-232. Communication is serial, asynchronous and half-duplex. The data bits are transmitted serially (one after another), the transmission is bidirectional but not simultaneously and speed previously agreed between them. Data frames have 1 start bit, 8 data bits, 1 stop bit and no parity.

A protocol was designed to interpret the data transmitted and sent. This protocol works as follows: Ship one or two frames, depending on the complexity of the action to execute, which are composed of 8 bits of data and divided into 3 parts. In the first frame, the 4 most significant bits are assigned to identify each of the living areas (kitchen, dining room, living room, etc.), allowing up to 16 zones. The following 3 bits are used to identify the function to be performed (monitoring environments, all or individual control) and the least significant bit was used for error detection parity criterion. In the second frame, the four most significant bits are used to identify the device to be controlled (bulb, television, curtains, coffee, etc.).

2.5 Design Prototype

To implement the domotic system two modules, one for transmitting and one for receiving data, based mainly on two cards manufactured by ArchNet International Limited and with reference PLC 101s-12A were constructed. These cards worked together with HC908GP32 Motorola microcontroller which is responsible for implementing the actions on the devices and also verifies the current status of each of them and informs the user. Control is exercised by the user through software installed on a PC as shown in Figure 1.

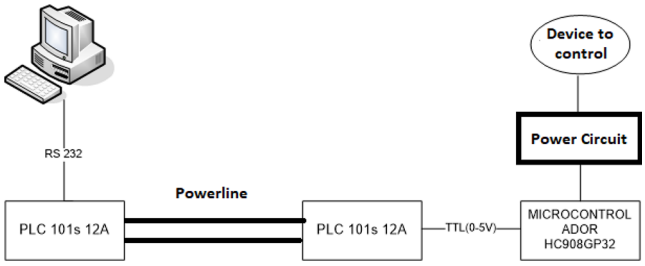

Figure 1. System diagram.

2.5.1 Hardware

- Computer (PC): It is the base station control device housing, where you can observe and control the state of these remotely. The PC performs a physical interface between the system and control software, using the serial port to exchange information with the devices.
- Cards PLC 101s - 12A: The PLC 101s-12A Figure 2 is a device used to transfer and receive data via the mains. The modules provide a bidirectional data transmission and half-duplex via low voltage lines (V <250V ~/50-60 Hz). Uses FSK (Frequency Shift Key) as carrier modulation technique to 82 KHz, which ensures high noise immunity and more reliable communication. Furthermore, the transmission speed can be varied between 600, 1200, 2400 and 4800 bps. It has a coupling circuit to the power network that allows direct and easy connection and implements RS232 standard and as TTL levels (0-5 V) for coupling external devices (PC, microcontroller). In Table 1 describes the technical specifications of the PLC 101s-12A card.

The coupling unit allows the injection-extraction of data in the low voltage network, creating insulation between the circuit direct current and alternating current circuit by means of medium-frequency transformer and pass filter - high for block signal 110 V/60 Hz. It also has protection against short circuits and power surges.

2.5.2 Microcontroller

The microcontroller used was a HC908GP32 Motorola programmed using the WINIDE application that manages a low-level language (assembler). Its functions are in charge of receiving data sent from a central PC via the mains, executing commands such as starting and stopping devices, and providing information about the current status of each. In addition, the microcontroller uses the SCI (Serial Communications Interface) module to exchange data with the PLC 101s-12A card.

The characteristics of HC908GP32 are 8 MHz frequency internal bus, 32 Kbytes of flash memory, 512 bytes of RAM, accumulator 8-bit pointer 16-bit index register 16-bit, 16 addressing modes and 64Kbytes of memory space (data /Program).

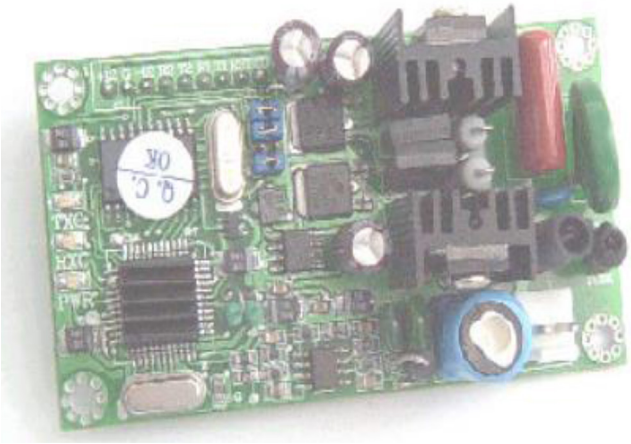

Figure 2. PLC 101s-card 12A.

Table 1. Specifications PLC 101s-12A

Description	PLC 101s-12A
Voltage	± 12 V
Currentconsumption	500 mA
Levels data I/O	TTL (0-5 V) / RS232
Carrier frequency	82 Khz. ± 0.3 Khz.
Signal Modulation	FSK
Baudrat	600/1200/2400/ 4800 bps (selectable)
Data packetsize	<1 Kbyte
AC Voltage	250 V ~
Maximum communication distance (No load ideal line)	>500 m
Operating Temperature	-20°/ + 50°C
Temperature range	-40°/ + 85°C
RH	5-95%
Dimensions (LxWxH)	78 X 52 X 25 mm

2.5.3 Power Supply

Each prototype module has a dual power source ± 12 V is responsible for providing the voltage and required current to the system.

2.5.4 Relay

When the control signal is received by the microcontroller that is responsible for executing the action that is assigned, lighting or turning off each of its ports, but this action cannot control devices as these handle large voltages (110V ~/60Hz). Therefore, relays are used, as shown in Figure 3, which allow a coupling between the ports of the microcontroller and devices.

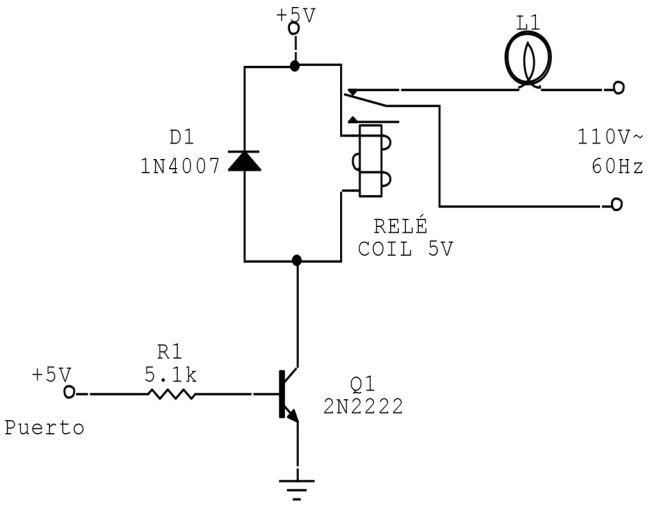

Figure 3. Schematic relay circuit.

2.6 Software

The programming tool used for software development was C++ Builder. When you run the program the PC establishes a connection with devices to control, reporting the current status of each of them and enabling the control buttons. These buttons contain the image of the device with your current status is identified and grouped by areas (living room, bedroom, kitchen, etc.), simulating the location of each of them inside the house. In addition, you can create environments with predefined states, which allow you to manipulate multiple devices from a button without having to change the status of each individually. Figure 4 shows the configuration window of each environment.

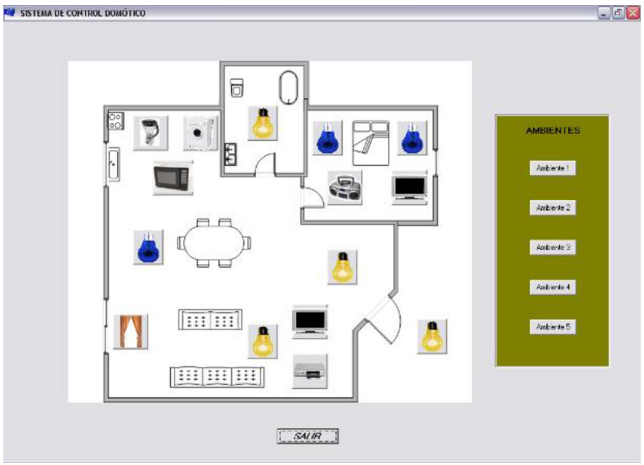

Figure 4. Control software.

3. Results

To find a relationship between the behaviors of the channel (mains) and the transmitted data in two tests which are transmitted through an electrical network in good condition (Test 1) and in bad condition (Test 2) were performed. Furthermore, the transmission rate 600, 1200, 2400, 4800 bps and the distance to a limit of 230 m was varied. They measure the amplitude of the output signal of the transmitter and the amplitude of the signal received by the receiver bandwidth is taken and communication quality, and succeeded in identifying the degree of deterioration to which it is subjected due to attenuation, noise and harmonic distortion present in the power line.

When transmitting the signal on the network in good condition it was observed that the amplitude for each speed was held constant and the attenuation effect did not reach affect the signal to 230 m (Figure 5). The increased bandwidth due to the change of the transmission rate but was constant with increasing distance (Figure 6). Although the presence of ripple in the signal indicated that there was noise in the channel, these harmonics were not enough to have any negative effect on communication. Although the attenuation increases with distance, the system can have a 100% reliable communication to 230 m and thinking that can be transmitted at higher distances through electrical networks in good condition (Figure 7).

However, by having a network spoiled it was observed the appearance of a capacitive effect, so that the modulated signal is amplified because the system enters into resonance with the power line and generating the receiver cannot demodulate. Additionally, increasing the distance the capacitive effect grows and the problem of signal amplification also increases, causing the bandwidth of the signal changes with increasing distance and the receiver becomes saturated and unable to demodulate the signal. Communication quality for this test is very low presenting errors to 40m and total loss of signal to 110 m for all cases.

3.1 Noise

The types of noises observed in Figure 8 were synchronized noise, background, impulsive and unsynchronized. Synchronized noise was presented at a frequency range of up to 3 Khz. FSK modulation scheme was used with

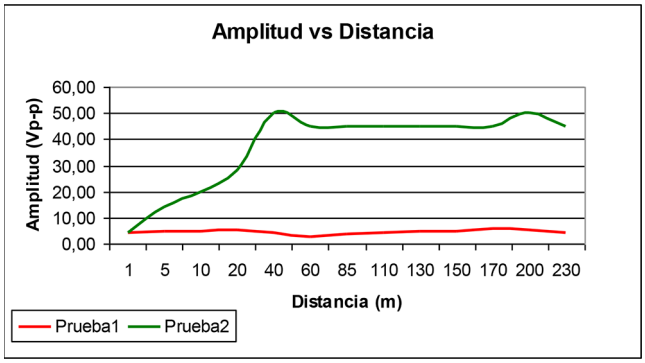

Figure 5. Amplitude vs. distance to 600 bps.

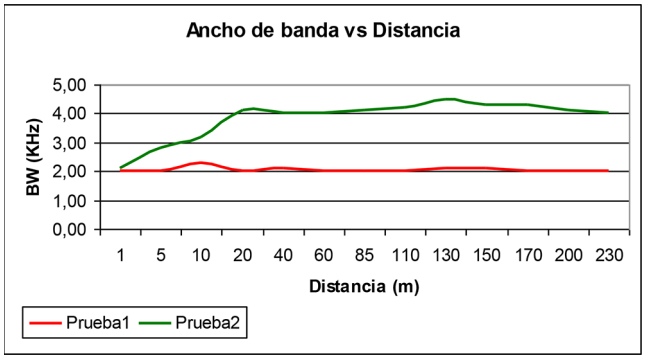

Figure 6. Bandwidth vs. distance to 600 bps.

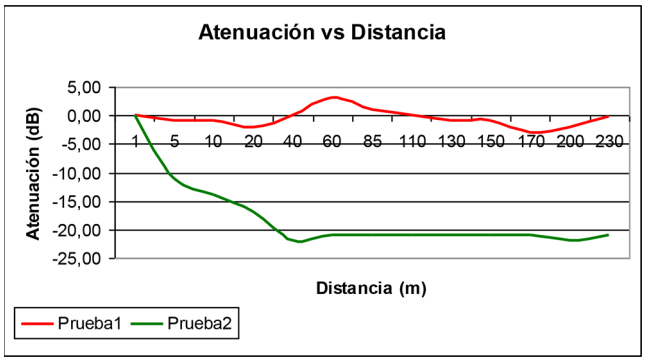

Figure 7. Attenuation vs. distance to 600 bps.

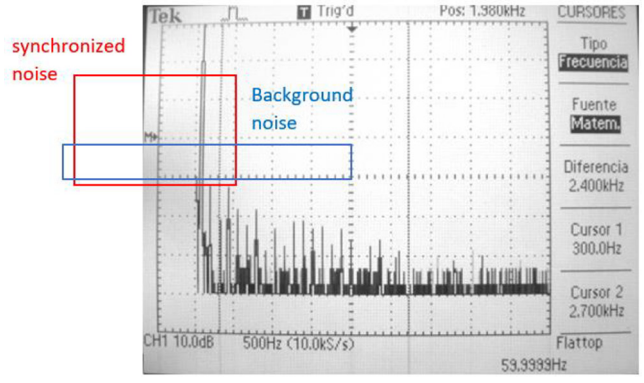

Figure 8. synchronized noise.

carrier 82 Khz to combat this kind of noise to avoid being near frequencies where they occur.

Or background noise spectrum is provided inherently in the electrical conductors due to manufacturing these materials, the interconnections within the network and poor physical condition of drivers. This noise is usually low-level but long distances where the information signal is attenuated, makes communication is affected. System error detection that allows retransmission signal was used to fix it.

Noise unsynchronized, was avoided transmitting data at a different frequency (82 KHz) frequency sweep televisions, monitors and its multiples.

Impulsive noise. The pulses have very fast rise and are impossible to filter them. Its effect is reduced by error detection code for rebroadcast as they arise.

3.2 Analysis Cost-Benefit

The prototype implemented consists of a power supply circuit, a coupling-modulation-demodulation and control. The total cost of the prototype includes the cost of each device used for the construction of each circuit, plus shipping costs, taxes and the value of the transfer made to purchase cards 101s-12A PLC. In addition, an estimated cost for labor and research time. Adding all these amounts have to develop the prototype has a total cost of $ 185.

3.3 Comparing Technologies

The developed prototype is compared with three of the most popular technologies in the home automation field using as a means of transmitting the low voltage power grid. In Table 2 a comparison is made between the most commercial modules of these technologies and that provide the same automation options of the prototype carried out.

By relying on comparing prices and features of each technology, one can say that technologies such as CEBus and Lonworks have features that allow achieve greater transmission distance or establish more secure and reliable communications or handle a large number of devices being able to make large controls and different designs, but their high costs make are not in a position to compete with the local market since they are oversized, so the prototype developed is an alternative way for good performance, low cost and meets the needs of automation in an existing home.

Table 2. Comparison cost technologies

Description	X-10	CEBus	LonWorks	Prototype
kit	PC interface CM11RS232 + Micromodule MW12	HeadStart Suite	Do not give Power line Builder 3.1	Modulo ModuloRemote PC +
Maker	Marmitek	Domosys	Echelon	Authors
No. devices	256	-	32385	256
Price	277611	2368211	15.696100	555240

4. Conclusions

It was found that an impaired power line, with different types of conductors and mismatches performed, generates a capacitive effect worsens with increasing distance, producing changes in the signal and system malfunction. The home automation control system designed in this project not only allows an ON-OFF control but has the potential to expand into other applications such as control dimmable light (Dimmer) and a total control of the system from a different place to the housing over the Internet.

5. References

1. Problems of Infocommunications. Science and Technology. 2017 4th International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S and T 2017). Proceedings of a meeting held. (IEEE); 2017. p. 579–84.
2. Alvarez R, Araque J, Sierra JE. A novel smart home energy management system: Architecture and Optimization Model. Indian Journal of Science and Technology. 2017; 10(26): 1–8. https://doi.org/10.17485/ijst/2017/v10i26/110684
3. Hallak G, Bumiller G, Swart TG. PLC for home and industry automation. Power Line Communications. UK: John Wiley and Sons, Ltd; 2016. p. 449–72. https://doi.org/10.1002/9781118676684.ch7
4. Miori V, Tarrini L, Manca M, Tolomei G. An open standard solution for domotic interoperability. IEEE Transactions on Consumer Electronics. 2006; 52(1):97–103. https://doi.org/10.1109/TCE.2006.1605032
5. Hooi TC, Singh M, Siah YK, Ahmad ARB. Building low-cost intelligent building components with Controller Area Network (CAN) bus. Proceedings of IEEE Region 10 International Conference on Electrical and Electronic Technology. TENCON 2001 (Cat. No.01CH37239). 2001; 1:466–8.
6. Werthschulte K, Schneider F. Linking devices to the European Installation Bus. Proceedings of the 18th IEEE Instrumentation and Measurement Technology Conference. Rediscovering Measurement in the Age of Informatics (Cat. No.01CH 37188). 2001; 2:827–32.
7. Cavalieri S, Mirabella O. Small EHS: Proposal for a profile of the European Home System protocol. Proceedings of IEEE International Conference on Industrial Technology 2000 (IEEE Cat. No.00TH8482). 2000; 1:486–90.
8. Barker S, Irwin D, Shenoy P. Pervasive energy monitoring and control through low-bandwidth power line communication. IEEE Internet of Things Journal. 2017; 4(5):1349–59. https://doi.org/10.1109/JIOT.2017.2703916
9. Ni B, Wu M, Liu Y. Design of embedded home network gateway for CEBus based on ARM. IEEE International Conference on Industrial Informatics. IEEE; 2006. p. 1380–4. https://doi.org/10.1109/INDIN.2006.275617
10. Chen H, Zhu Y, Wu J. Design RFCS with LonWorks technology in Internet of Things manufacturing. 3rd Smart Cloud Networks and Systems (SCNS). IEEE; 2016. p. 1–5. https://doi.org/10.1109/SCNS.2016.7870559
11. Vesga-Ferreira JC, Granados-Acuna G, Vesga-Barrera JA. Allocation of medium access order over Power Line Communications (PLC) supported on weighted voting games. Indian Journal of Science and Technology. 2017; 10(24):1–14. https://doi.org/10.17485/ijst/2017/v10i24/102667
12. Nicholson JR, Malack JA. RF impedance of power lines and line impedance stabilization networks in conducted interference measurements. IEEE Transactions on Electromagnetic Compatibility. 1973; 15(2):84–6. https://doi.org/10.1109/TEMC.1973.303254
13. Mishra DK, Saini LM. CPLD based FSK modem for narrowband power line communication. 2nd International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB). IEEE; 2016. p. 318–21. https://doi.org/10.1109/AEEICB.2016.7538300