



POWER LINE COMMUNICATION

A dissertation submitted
to Istanbul Arel University in partial
fulfillment of the requirements for the
Bachelor's Degree

Submitted by
Egemen Recep Çalışkan

2013

Title in all caps

Dissertation written by
Egemen Recep Çalışkan

Approved by

_____, Chair, Dissertation Committee

_____, Members, Dissertation Committee

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ACKNOWLEDGEMENTS

I would like to thank my supervisor, Doç. Dr. Hasan Hüseyin Balık for the patient guidance and advice. I would also like to thank all my family and friends who supported me for this study.

Egemen Recep Çalışkan

2013

Istanbul Arel University, Istanbul

CHAPTER 1

1.1 Introduction

Power line communication (also known PLC) is the voice or data communication between two points over power lines. The system uses power lines that are already installed in our buildings. At first PLC used for voice communication in American Army in 1918 [7]. Today, we are using PLC for narrow and broadband data communications.

At this study, PLC receiver and transmitter has been designed for controlling a high voltage power line. A button used for input in transmitter and a led used for output instead of a relay in receiver circuit.

CHAPTER 2

2.1 Power Lines

Electricity has to be different voltage levels for more efficient and safe use everywhere. The high voltage can transmit easily and cheaply. The long wires have a so much resistance so it causes power line loss. Current has to be low and voltage has to be high on power lines for minimizing power loss. However, the high voltage is not safe at domestic usage. The transformers decrease the high voltage to make it suitable for home use. You can see below the voltages used by countries at figure 2.1.

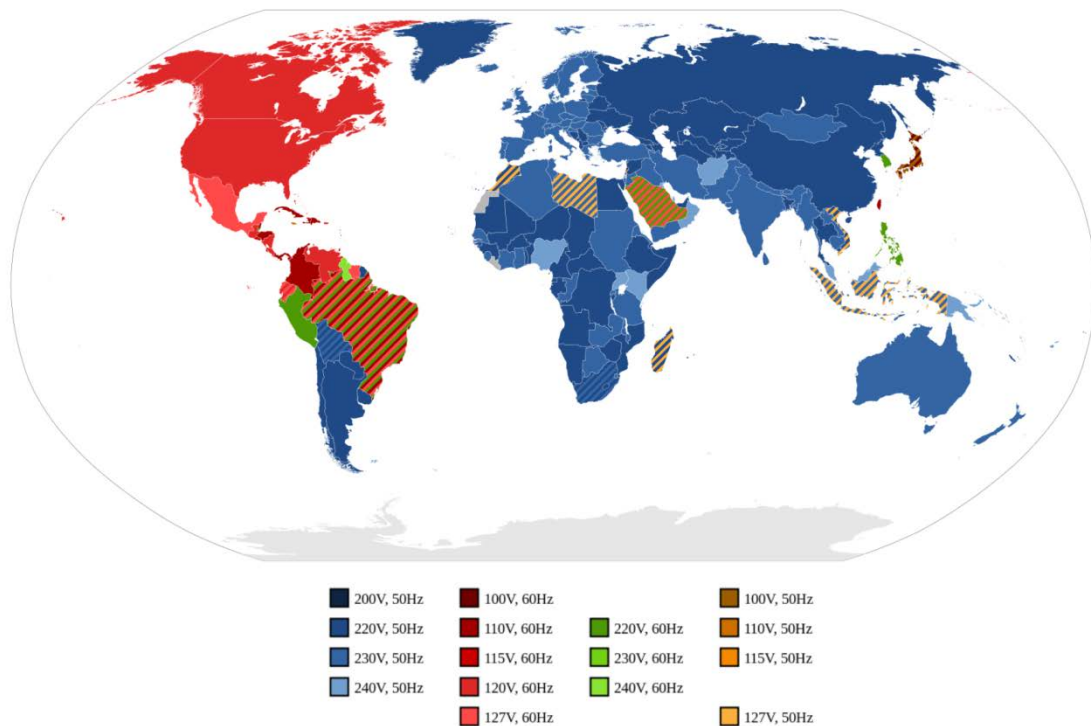


Figure 2.1 Countries Nominal Power Network Voltage and Frequency [6].

2.2 General Modulation Techniques for Communication

Communication is the process of accurately data transfer between two places. For communication, there must be at least one receiver, a transmitter and a transmission medium. Transmission medium can be air, wire or fiber cable.

Modulation is process for moving a signal in a transmission medium via a high frequency periodic signal. High frequency signal called carrier frequency [1]. Data signal can change of carrier frequency's amplitude, frequency or phase values. These are general ways for modulation.

At the continuous wave operation, if the carrier is a continuous periodic wave and the data signal is analog, this is called: Amplitude modulation (AM), Frequency modulation (FM) and Phase modulation (PM). If the data signal is digital these are: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK).

This graduation project based on digital communication techniques; therefore this section describes only the digital communication techniques.

2.2.1 Amplitude Shift Keying (ASK)

At amplitude shift keying, every bits changes the carrier signal's amplitude. If the data bit is logic "1" then output is equal to carrier signal otherwise output is zero.

ASK is so sensitive for noise and propagation conditions. ASK is inexpensive and simple modulation type than other modulation types. This modulation is shown in figure 2.2 (b).

2.2.2 Frequency Shift Keying (FSK)

At frequency shift keying, the data signal's every bits change the carrier signal's frequency. For instance, if the data bit is logic "1" then output gives 80 kHz sinusoidal wave and for logic "0" gives 70 kHz sinusoidal wave.

FSK has many application areas in our daily-life (e.g. radio, modem , fax). FSK is very immune to noise. Because noise can change the signals amplitude but it can't change the signals frequency easily. This modulation is shown in figure 2.2 (c).

2.2.3 Phase Shift Keying (PSK)

At phase shift keying, the data bits change the carrier signal's phase. Generally PSK uses two different angles for communication. For instance, if the data signal's bit digital "0" output sinusoidal wave's phase angle 0° and for digital "1" phase angle 180° . So two different angles can transmit 1 bit and four or more angle can transmit 2 or more bit at 1-cycle. Quadrature Phase-Shift Keying (QPSK) uses four phase and QPSK is the most known PSK type.

Bluetooth, wireless modems, satellite TV receivers and RFID cards uses advanced PSK types. This modulation is shown in Figure 2.2 (d).

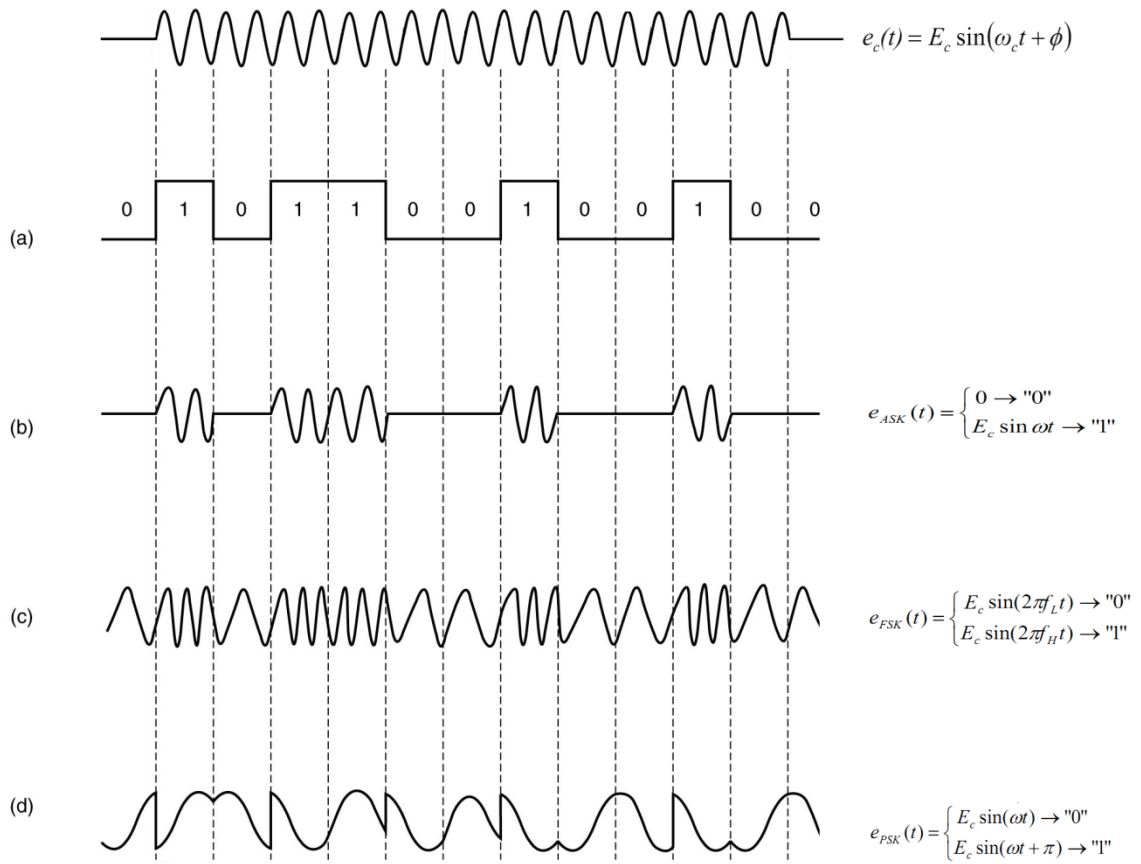


Figure 2.2 Digital Communication Techniques and Their Expressions.

2.3 Directions of Data Transmission

Data transmission can be in both directions at the same time that is called full-duplex as shown in Figure 2.3 (b). It can be in one direction but not at the same time that is called half-duplex shown in Figure 2.3 (c). If the data transfer in one-way that is called simplex Figure 2.3 (a) [2].

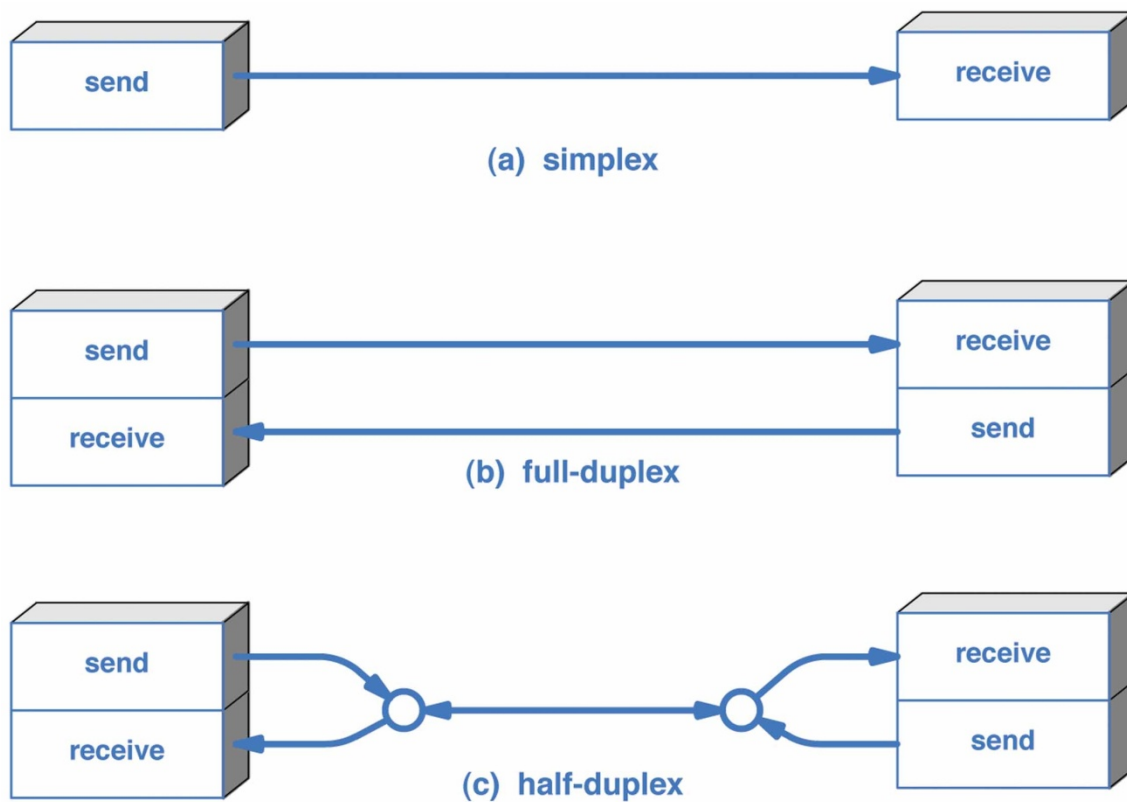


Figure 2.3 Directions of Data Transmission [2].

2.4 Synchronous, Asynchronous Communication

Synchronous transfer is when data is generated at a constant rate using a shared periodic clock. The data and control signals are generated relative to the clock edge. The transmitting device sends the clock signal to the receiving device [3].

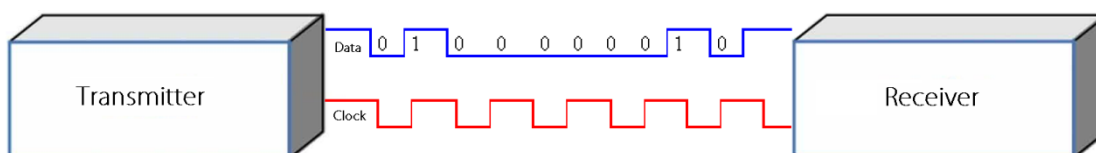


Figure 2.4 Synchronous Communication

Asynchronous transfer is when data is sent using handshaking signals. There is no shared clock. Start and stop bits synchronize communication between the two devices.

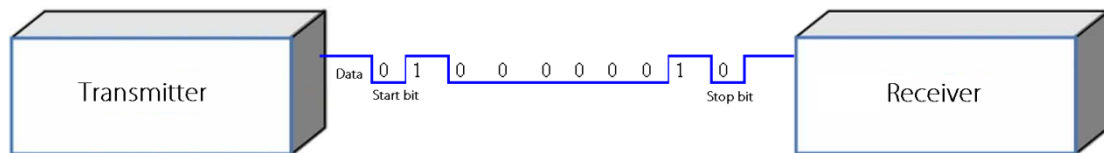


Figure 2.5 Asynchronous Communication

Chapter 3

3.1 Fundamentals of the Power Line Communication

Power line communication (also known PLC) is the voice or data communication between two points over power lines. The system uses power lines that are already installed in our house. There is no need to lay cable for PLC. It does not create the clutter of cables at home automation applications. For this reason PLC is the best home automation solution.

3.2 History of PLC

Power line communication is not a brand new invention. At first PLC used for voice communication in American Army in 1918. Then Germany and Europe used for control high voltage lines. PLC started with simplex but later times duplex communication is used for PLC. Today, we are using PLC for narrow and broadband data communications.

3.3 Application Areas

Even today, PLC is using for home automation systems, internet distribution, automatic meter reading by energy providers, and low-quality voice transmission.

3.4 The standards of PLC

All devices are connected to the same line for plc. The standards were established to avoid interference with communication. The European Committee for Electrotechnical Standardization in Brussels (CENELEC) published the standard EN 50065-1. That is determine bands and power limits between 3Khz -148Khz @116 dB (μ V). These standards also apply to Europe and Germany. There are basically four different bands for PLC.

- A-band (3 kHz - 95 kHz)
- B-band (95 kHz - 125 kHz)
- C-band (125 kHz - 140 kHz)
- D-band (140 kHz - 148.5 kHz)

We can see frequency ranges and maximum transmission levels for power line communication according to CENELEC 50065-1 standard.

Table 3.1 Frequency ranges for PLC communication according to EN 50065-1 [5]

Band	Frequency Range	Maximum Transmission Level	Usage Areas
A	3khz - 95khz	134db (μ V)	Available for electric distribution companies use only
B	95khz - 125khz	116db (μ V) - 134db (μ V)	Available for consumers with no restriction
C	125khz - 140khz	116db (μ V) - 134db (μ V)	Available for consumes only with media access protocol
D	140khz - 148.5khz	116db (μ V) - 134db (μ V)	Available for consumers with no restriction

Chapter 4

4.1 Coupling with Power Line

PLC circuit must be insulated from power line, which is very important for human health and for the operation of the circuit. For this purpose, circuits have high frequency transformers, coupling capacitors and fuses for short circuit protection.

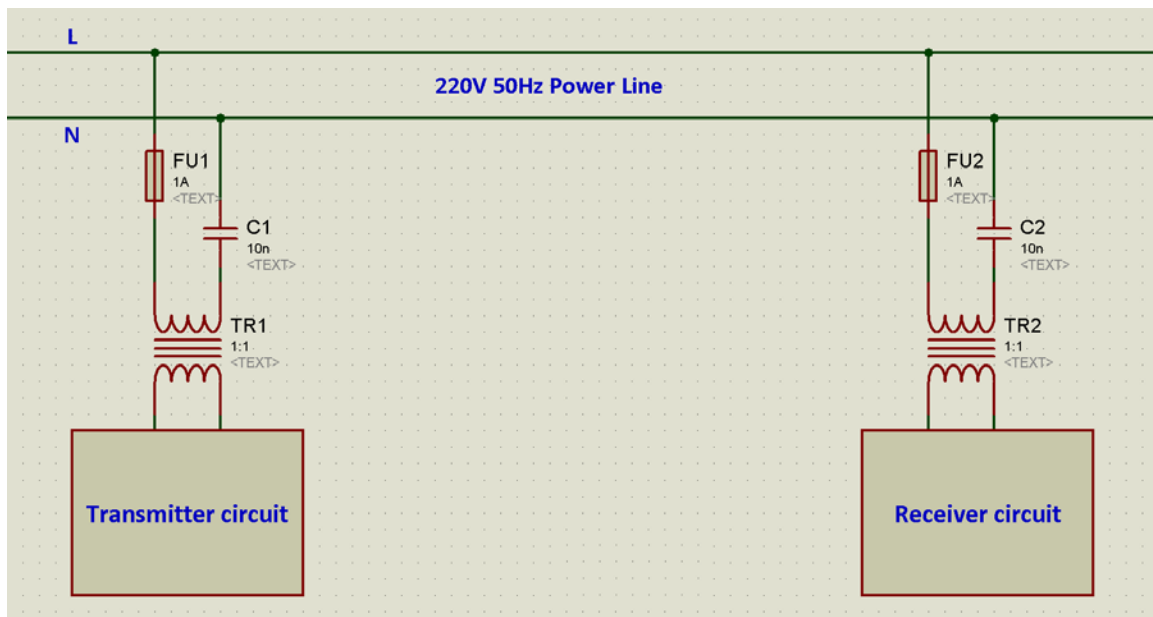


Figure 4.1 Coupling with Power Line

4.2 Generating FSK Signal

XR-2206 function generator was used at plc transmitter circuit from Exar company. This ic generates sine, square, and triangle waves between 0.01Hz and 1Mhz with very low distortion. This function generator was used for producing two different FSK signal ,these are 70 and 80Khz. Function generator changes the output frequency according to

input's state 1 or 0. The function generator output gives very limited power so this output not enough for driving a transformer. For this reason it uses a opamp for driving transformer.

4.3 Demodulating FSK Signal

The power lines have noise at every frequencies. All electrical devices are produces noises on power lines. Also long and un-insulated cables acting as TV, radio or a GSM antenna. We have to filter all these unwanted noises to obtain our carrier signal. In the receiver circuit was used three order high pass RC filter and a LC filter for that. And we apply the filtered input signal to PLL to obtain demodulated data output.

4.4 Hardware Designs and Calculations

In this project, we are going to design power line communication transmitter and receiver for an electric company to control remotely high voltage lines away. We're going to use a simple button for input, and a led instead of a relay that controls the high-voltage line. We choose the working frequency range between 70khz and 80khz. When the button pressed led going to light up. When the button is not pressed led will be off state. Our project is an experimental so high-speed data transfer is not the case. But it may be performed with lower communication speeds 100 or 300 baudrate.

4.4.1 Transmitter

The XR-2206 is our FSK modulator. It modulates the data signal to carrier signal. FSK modulation has two different frequencies.

These frequencies are adjust by timing capacitor between 5-6 pins and timing resistors 7-8 pins to ground. You can see typical FSK modulator circuit for XR-2206 below.

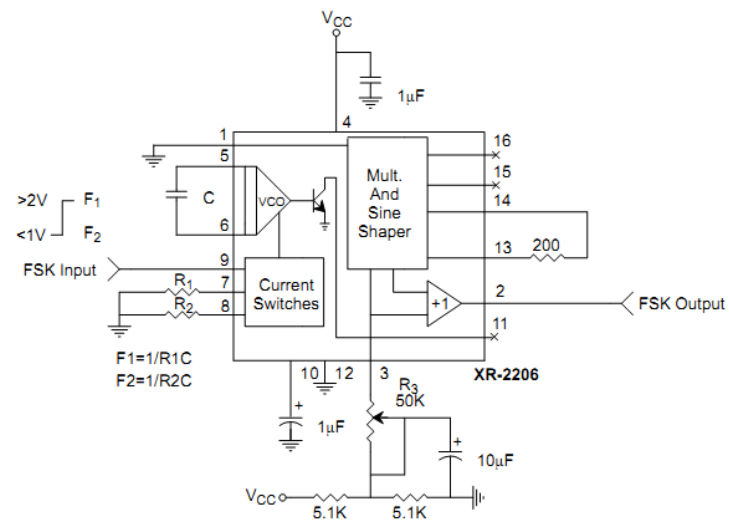


Figure 4.2 Sinusoidal FSK Generator [8]

You can see FSK input voltage levels for Frequency 1 and Frequency 2 in figure 4.2. For this project FSK frequencies were selected 70 khz and 80khz. Frequencies can be calculated with

We cannot find the exact that resistor values. Resistors are producing at certain fixed values. We can adjust these exact resistor values with a 2.2k Ω resistor and a serial connected 5k Ω potentiometer.

The transmitter uses a general purpose operational amplifier from Texas Instruments for driving the transformer. The output signal gain can be adjust with RV3 potentiometer. TL082 has two independent operational amplifiers inside a case that can be seen in the Figure 4.3 below.

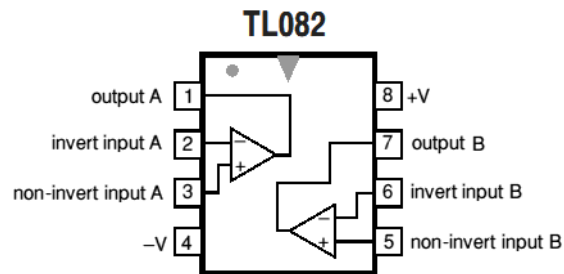


Figure 4.3 TL082 Operational Amplifier [9]

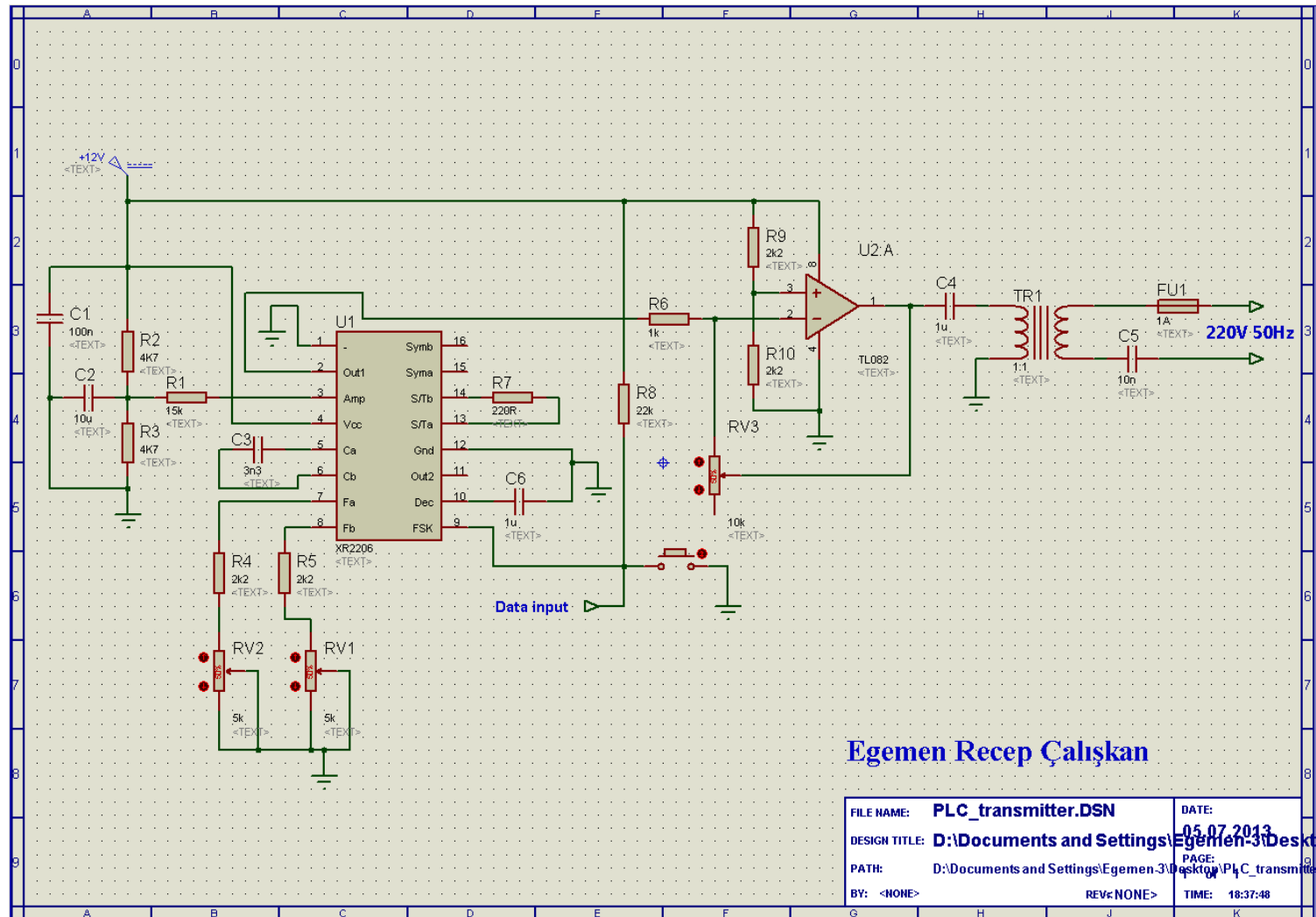


Figure 4.4 PLC Transmitter Circuit Schematic

4.4.2 Receiver

In the receiver, the signal was filtered over the third order high pass RC filter and then amplified 22 times by the op-amp. After that, the output was filtered by LC bandpass filter. Finally this signal is applied to the PLL. The PLL and op-amp gives the data output. PLC receiver circuit can be seen in the Figure 4.6.

You can see frequency response of the third order high pass RC filter at Figure 4.5.

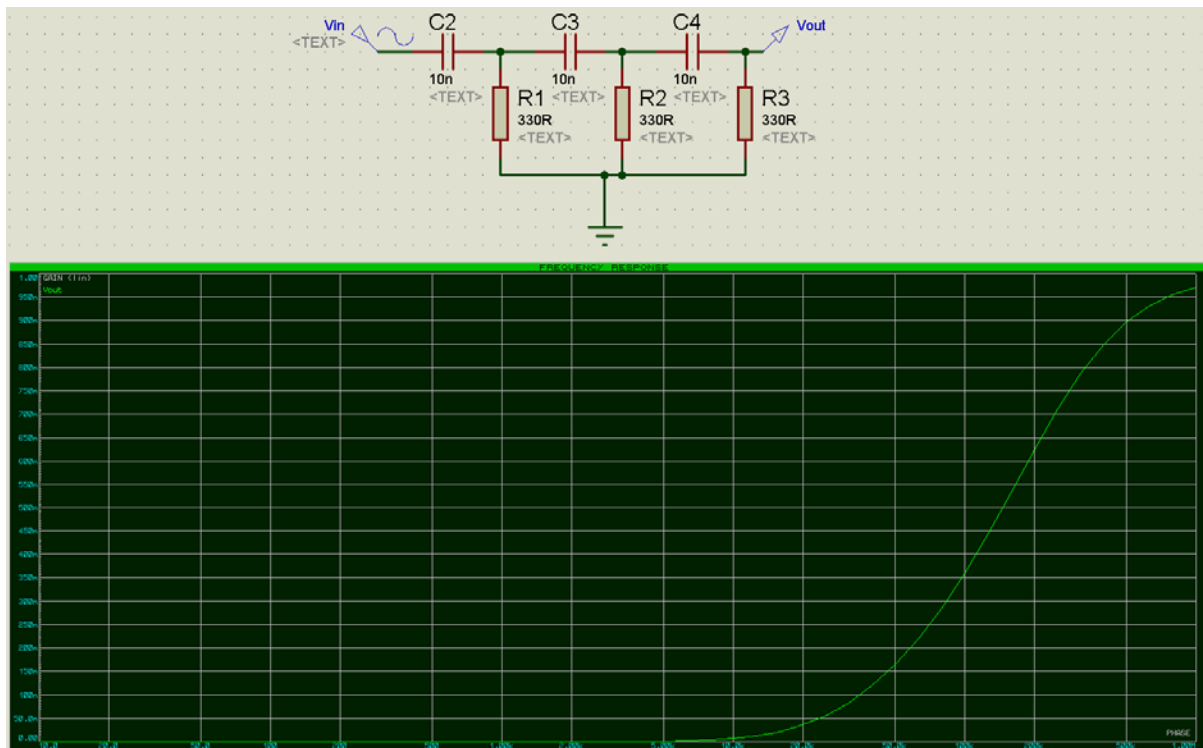


Figure 4.5 Frequency Response of the Third Order High Pass RC Filter

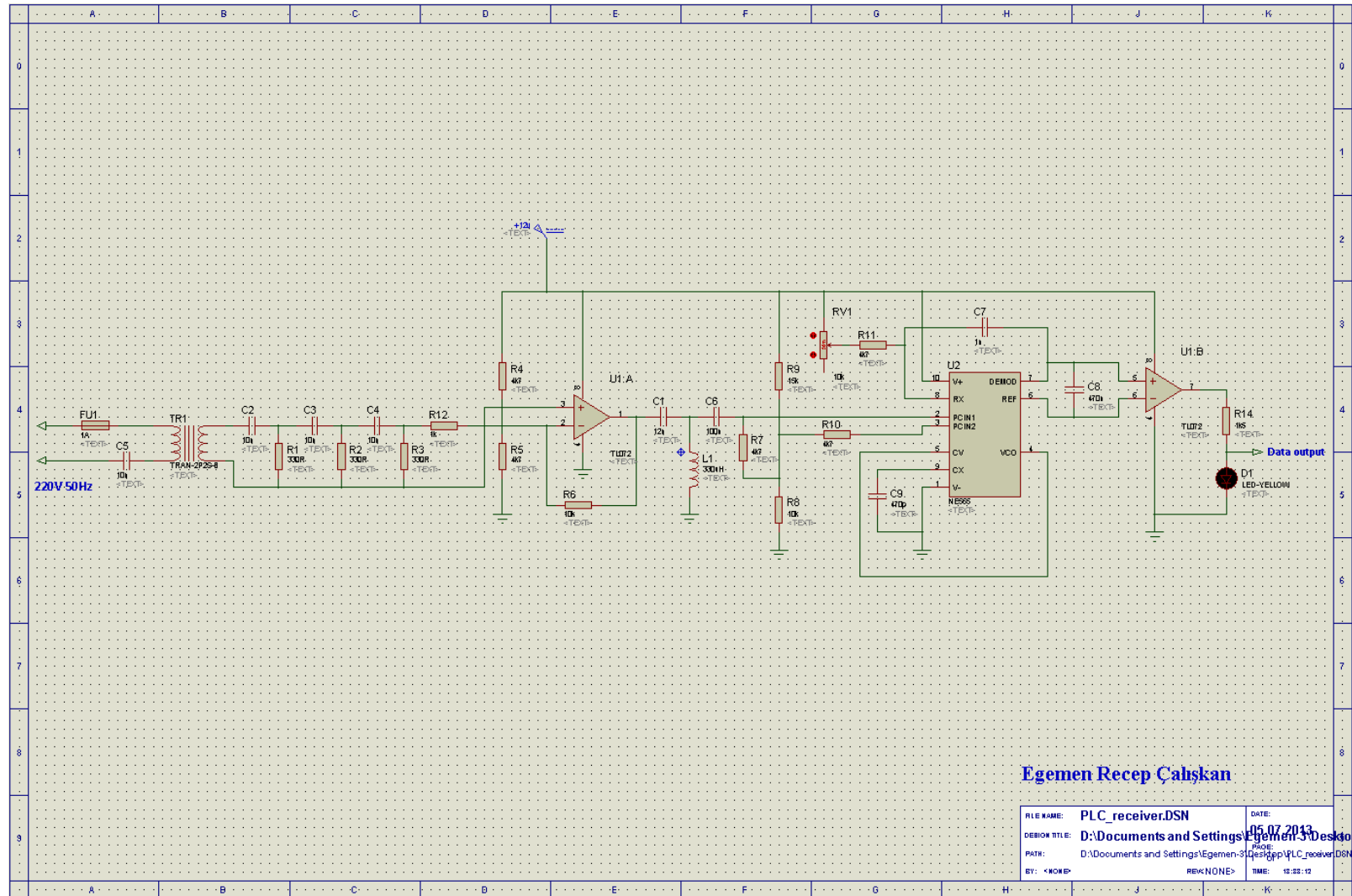


Figure 4.6 PLC Receiver Circuit Schematic

And you can see frequency response of band pass filter at Figure 4.7

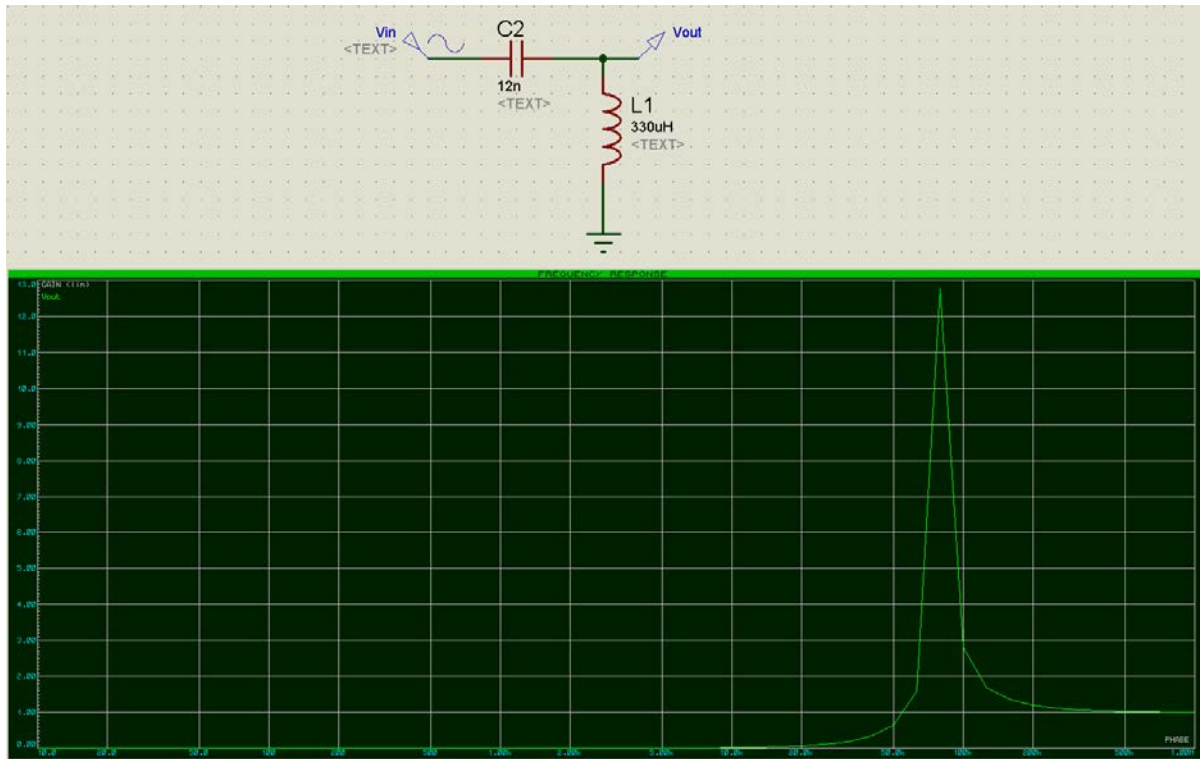


Figure 4.7 Frequency Response of the Band Pass LC Filter

We can find center frequency of the LC band pass filter with

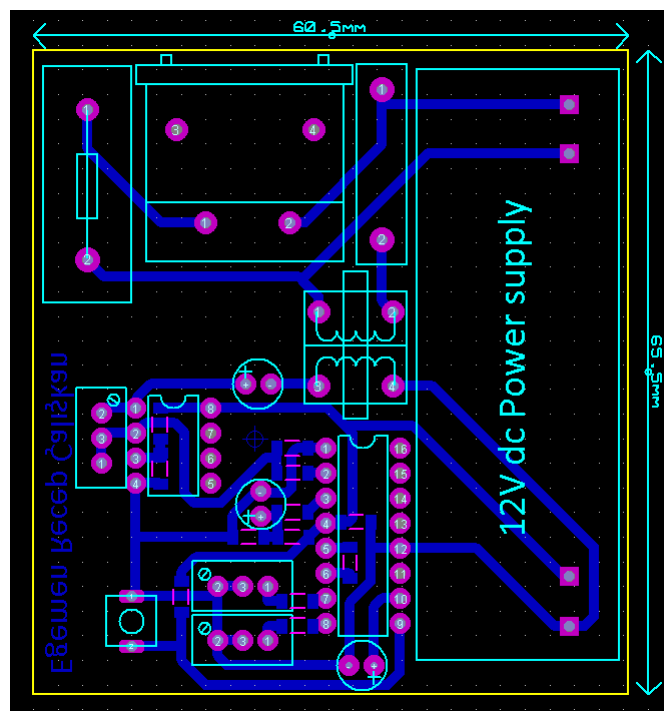


Figure 4.8 PLC Transmitter Circuit PCB Layout

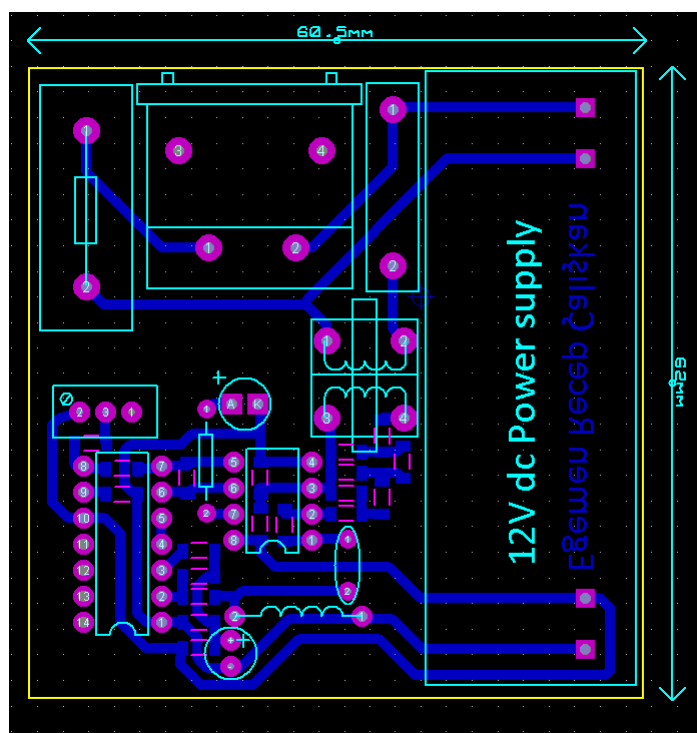


Figure 4.9 PLC Receiver Circuit PCB Layout

Chapter 5

5.1 Tests and Results

Many times measurements were made during circuit design with oscilloscope.

The transmitter output signal 80 kHz in figure 5.1 and 70 kHz can be seen in figure 5.2.

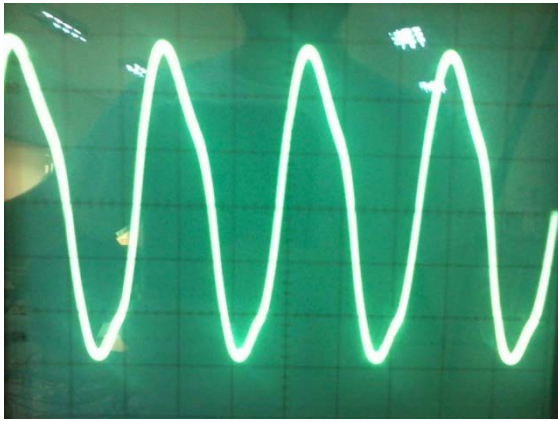


Figure 5.1 Transmitter Output @ 80khz

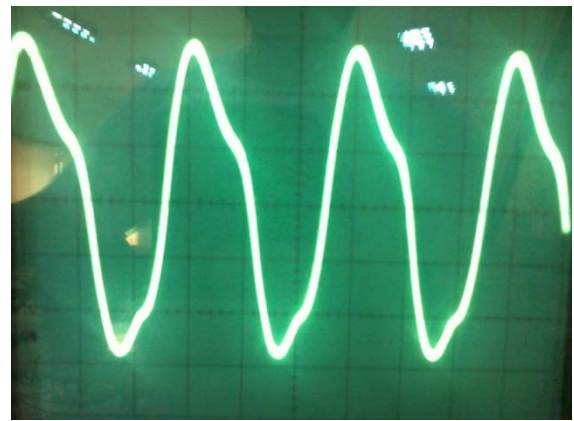


Figure 5.2 Transmitter Output @ 70khz

You can see the receiver's filtered transformer outputs when the circuits connected the noisy power line in figure 5.3 and 5.4.

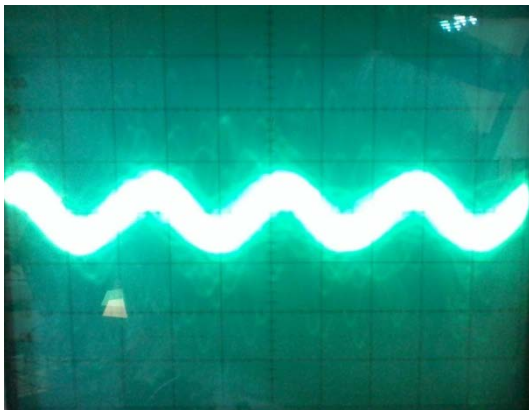


Figure 5.3 Receiver Input @ 80khz

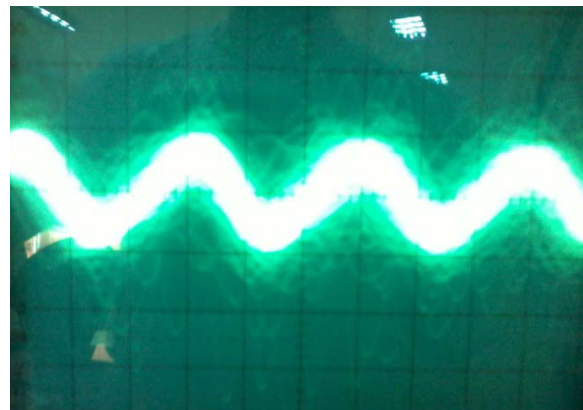


Figure 5.4 Receiver Input @ 70khz

5.2 Conclusions

Power Line Communication can be used for home automation systems with slow baud rates. There is limited usage area. PLC is very sensitive to noise and high-quality communication is not possible all the time. The filters weaken carrier signal too much on the same power line, that situation makes communication very difficult. Electric motors, switches make too much noise on power line. Another factor that makes it hard to communicate in long lines.

5.3 Recommendations for Future Designs

PLC can be used to slow data transfer where there is a very critical communications with a very narrow-band filter. Power saving lamps and line filters decrease the communication speed. Automatic gain control should be added to the receiver input to work properly with the short and long distance. If the received signal is processed by a DSP with FFT algorithms, we will get better results. Speed can be increased by using multiple narrow bands. Nowadays, Wi-fi, GPRS modems and RF transceivers may be preferred instead of PLC after evaluating the conditions.

REFERENCES

- [1] Communication Systems Engineering (2nd Edition), John G. Proakis ,Masoud Salehi ,2002,ISBN 0-13-061793-8
- [2] <http://www.dcs.bbk.ac.uk/~ptw/teaching/IWT/data-comms/slide18.html>
- [3] <http://www.ni.com/white-paper/6552/en>
- [4] http://www.domologic.de/download/pdf/konnex_pl132_en.pdf
- [5] EN50065-1, “Signaling on low-voltage electrical installations in the frequency range 3 kHz to 148.5kHz”, CENELEC; Genevre, July 1993
- [6] http://en.wikipedia.org/wiki/File:Weltkarte_der_Netzspannungen_und_Netzfrequenzen.svg
- [7] [http://www.ieeeahn.org/wiki/index.php/Telephony_over_Power_Lines_\(Early_History\)](http://www.ieeeahn.org/wiki/index.php/Telephony_over_Power_Lines_(Early_History))
- [8] http://www.jaycar.com.au/images_uploaded/XR2206V1.PDF
- [9] <http://www.ti.com/lit/ds/symlink/tl082-n.pdf>
- [10] <http://www.ti.com/lit/ds/snosbu1b/snosbu1b.pdf> (LM565 PLL datasheet)