Smart Power Factor Correction

Darrel Dotterer
Luke Nicol
Vinicius Pereira Pio
Manuel Salazar Paramo

11/26/13

Senior Design Project 491W

Abstract

The Smart Power Factor Corrector device will help promote cleaner energy by eliminating reactive power in household appliances. As the world moves towards a “greener” future, devices that optimize energy transfer will become more prevalent. Our device will constantly correct the power factor of household loads so that the current being drawn by the system will be minimized. This device will also be able to be used on a wide range of appliances.

The device will consist of sensors to collect data from the main power line to determine power factor and peak power usage. This data will be processed by the microcontroller that will calculate power factor and reactive power. Using these calculated values, the microcontroller will control switches to a bank of corrective shunt capacitors. Our device will update every second to ensure maximum power efficiency. The device will be able to send data wirelessly to an IP address and allow the user to watch over the devices work. Our progress so far consists on: the development of a Schmitt trigger, power factor correction testing, and software coding.

Tables of Contents

List of Figures

List of Tables

I. Introduction

A. Background

Nowadays a lot of effort is being put towards research related to sustainable energy. Companies try every day to adapt themselves to this new market force and its tendency.
Through the aid of science, we develop different ways to produce energy, like solar panels or wind power. And also different kinds of consumption, this is the case of the electric cars. However besides everything that already exist, what can be improved?

The first publications on economic efficiency of reactive power compensation appeared in the third decade of the 20th century. Reactive power compensation is mainly used in power distribution networks, for reducing energy losses, improving voltage profile in medium and low voltage networks, and improving reactive power balance in 110 kV distribution network. It is very commonly used in the industrial areas, places where they have high consumptions of energy, and as result they are charged for this reactive energy.

However, can you imagine bringing some of those advantages to the low voltage network? The AC power used by large household devices comes with both active and reactive power. The reactive power is not the main power used by these devices. Some technologies have been developed in order to solve this problem, as for example, static VAR compensators employing thyristor switched capacitors and thyristor controlled reactors to provide or absorb the required reactive power.

Correcting this reactive power is done easily by connecting capacitors in parallel with the load. Capacitors are most frequently installed in:

1. High voltage/medium voltage (HV/MV) stations, being the main Feeding Point (MFP) of the medium voltage network, as can be seen in (Figure 1).

2. Network switchboards (NS).
3. Medium voltage/low voltage (MV/LV) stations on the low voltage terminals of transformer.

Figure 1- Capacitors being used to correct the power factor in industries

The power factor is an electric load parameter that is used for defining explicit ratio between active and reactive power. Power factor in Low Voltage (LV) networks range from 0.6 during the summer nights (load minimum) to 0.9-0.95 during the winter evenings, when the load is at a maximum. During wintertime, there is an increase of reactive power loads due to the high usage of heating devices. Power line losses directly depend on load as a function of time (daytime and season). [1] We have talked about how power factor works and how we are wasting energy when the power factor is not being corrected. Every household generates reactive power which wastes energy. Our device is designed to reduce the reactive power generated in household appliances. We can focus on fixing the power factor from appliances that generates the most reactive power in the house.

Figure 2 shows how 31% of the energy being used is from heating the house. 12% of energy consumption is from heating water and another 12% is for cooling areas in the house from the air conditioner. Only three main appliances make up around 55% of the total power consumed in a household. That data represents that we can work with the half electrical consumption of the house using the Smart power factor corrector in just a few devices, because the heating and the cooling are the biggest responsible for the energy consumptions in homes.

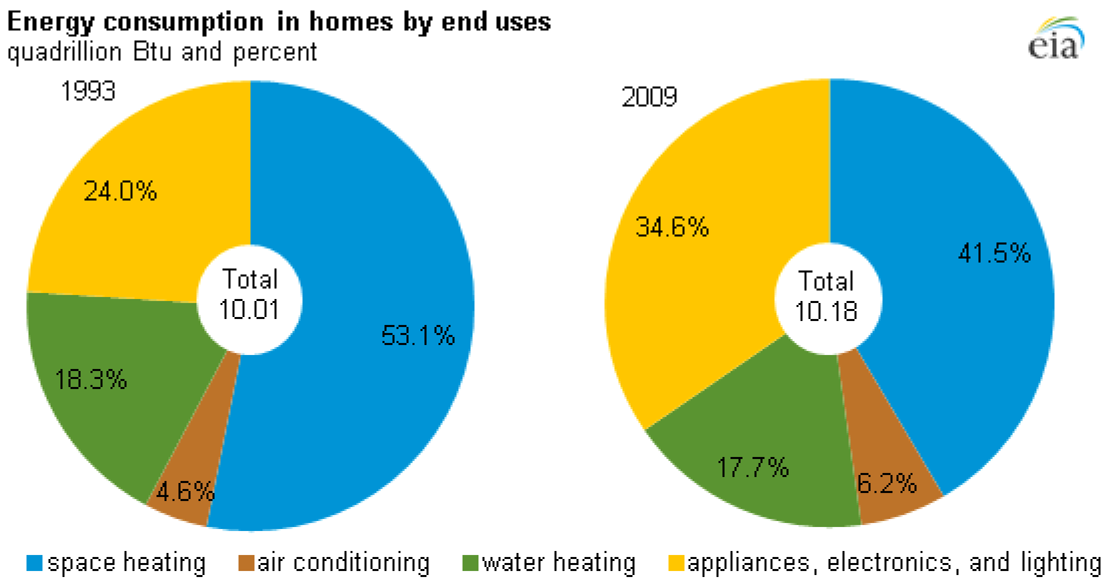


Figure 2-Utility Bill Cost Breakdown

Also measures and quantified evaluations performed in power network and using the described reactive power compensating method in the depth of LV feeder, indicate that losses caused by the reactive power are around 8 % of all technical losses in middle and low voltage network. The same losses in low voltage networks are even around 18 %. [1]

Doing that we can obtain some relevant improvements in our electric circuit, for example:

- The closer the power factor is towards the unity power factor than current decreases.
- Drawing less current will lead to fewer losses due to thermal heating in transmission lines.
- This will lead to less stress on the materials and less power used.

After all, the explanation of this project is very simple, because fewer losses mean more efficiency and less current means less cost on materials. The result is increased savings which translates into less expenditure.

B. Purpose

The consumption of energy is something that every society has to deal with. Lots of ideas have emerged with the aim of saving money in utilities' bills. The smart power factor corrector can help the consumer by saving them money in household energy costs. It is also applicable to bigger consumptions, such as factories and commercial establishments. The Smart Power Factor corrector will be focused on the common devices of our houses that consume reactive power such as air conditioners and refrigerators, reducing this reactive power and decreasing the losses, which implies savings for consumer.

C. Literature Review

i. Prior Work

The reactive energy is a really common subject when we talk about electricity. It is a problem that, since the use of electrical motors, engineers have tried to solve. In order to save money (saving energy) and to avoid overloads in the processing and generating lines, different ways of compensating the reactive power has been created. Most of these ways are based around using capacitors.

The reactive power is compensated in all factories, making these factories more efficient. The problem of the reactive power appears with one-phase systems and with three-phase systems. The market contains plenty of devices to correct the reactive power, for one-phase or three phase systems. Most of the products on the market focus the correction in putting in parallel capacitors big enough to compensate an averaged amount of reactive power. The construction of the device changes between one-phase and three-phase systems, but the idea is the same. So these products are separated in two types, products designed for variable correction and products designed for fixed correction. The product has to be able to manage a specific voltage and current, and deal with overvoltages and overcurrents.

The different products for correcting reactive energy can be used for global compensation, partial compensation and individual compensation. One example of the products of the market for low voltage networks are the capacitors VarPlusCan (Figure 3) (fixed compensation) and VarPlusBox (Figure 4) (variable compensation), built by Schneider Electric. Both of them are built for three-phase systems. Schneider Electric Company recommends using fixed correction in those installations in which the reactive power does not exceed the 15% of the nominal power of the transformer, and variable correction if this reactive power overcomes the 15% of the nominal power of the transformer [2]. But these considerations would affect if our device were built for industries or high consumptions such as hotels.

Also, Eaton Powering Business Worldwide currently produces a product that corrects power factor using shunting capacitors. Unlike our project, Eaton provides power factor correction for industrial purposes that draw a high amount of power. They also do not provide a constantly updating system so the power factor can fluctuate with time. Our system will be similar to the one Eaton manufacturer's [3] but it would be on a smaller scale and be able to keep the power factor more constant. This solution of using corrective capacitors seems to be the most used and practical way to correct power factor.

Figure 3-Varplus Can Capacitors (Schneider Electrics)

Figure 4-Varplus Box Capacitors (Schneider Electrics)

ii. Patents

1.- Patent of ENDESA ENERGÍA, S.A.U., company from Spain that works in the electrical market. Inventor: AGRELO REGUEIRA, Juan Luis

This patent describes a device destined for low consumptions, consumptions below 15 kW. The device is designed for a global compensation of the reactive power. It would measure the power factor in the circuit breaker box, and a signal would be sent to a device connected to an electric outlet via PLC (power line communications) or RF radiofrequency. [4]

2.- Reactive power compensation control system, United States Patent 3754184.

Inventor: STONE, David W

This patent is designed for three-phase systems. It is designed for dynamic loads. A bank of capacitors is connected in parallel with the load, and a control circuit controls the connections. [5]

3.- Reactive power compensation to minimize step voltage changes and transients, United States Patent 06900619. Inventors: Arnold P Kehrli, John A Diaz De Leon II, Douglas C Folts

This patent consists on a device that corrects a quantity of reactive power, measuring it each second, and using a controller switch to correct the reactive power [6]

iii. Relevant Codes and Standards

Relevant codes and standards should be accomplished in order to develop our project. Some of the most important are: IEEE Standard C37.26 and .The first one consists of describing three methods to measure the power factor of inductive low-voltages, the methods could be used at any frequency and basically they are Ratio Method, DC decrement method and Phase relationship method (this is the one that is going to be used). The second standard breaks the power measurements into components that can characterize three things: the useful real power delivered to the load, the reactive power that can be compensated with conventional power factor correction, and the power components that require other methods of compensation (such as active filters).

- IEEE Standard 802.11, 2007-Wireless [2]
    - o Standard for Information Technology which states that our devices must operate in a 2.4 GHz ISM band and have a maximum data transfer rate of 54 Mbits/s.
- IEEE Standards 1-2000 [2]
    - o -General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation
- IEEE Standards 18-2012 [2]
    - o Power capacitors rated 216 V or higher, 2.5 kVAR or more, and designed for shunt connection to alternating-current transmission and distribution systems operating at a nominal frequency of 50 Hz or 60 Hz, are considered.
- IEEE Standards 1459-2000 [2]
    - o Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions

- IEEE Standard C37.26 [2]

  o IEEE Guide for Methods of Power Factor Measurement for Low-Voltage Inductive Test Circuits [2]

II. Problem Definition

A. Problem Statement

Reactive power is only necessary in small amounts for household appliances. Lower power factors can dramatically increase the required current to power the appliance. Everyday energy is being wasted by the lagging power factor in household appliances. Fixing this problem will result in a reduced amount of current used by these appliances. When every household benefits from these fixes, we can reduce the overall amount of power being used per day. The copper in transmission lines is based around how much current is designed to flow through those lines. With less current being drawn, we could save in the material costs of the line. Correcting from a .6 power factor to a power factor of .85, we can save up to 28% in current drawn, Formulas [1.1 - 1.2 - 1.3]. This can lead to an estimated 15% cost reduction for wiring materials in a typical construction of a house. This can lead to savings of over $1000 for the materials costs in the wiring of a house. Refer to Appendices C1 for the average costs of housing construction components in the US.

B. Project Requirements

The Smart Power Factor Corrector is a device whose main objective is to compensate reactive energy. In order to accomplish this objective, the requirements of the project are the next ones:

1.-Performance

The Smart Power Factor Corrector is a single-phase device. It is designed for low voltage networks, such as houses (120 V, 60 Hz). It is designed to provide a variable response, thanks to the switches and the Arduino based program. In order to correct a variable amount of reactive power, lots of capacitors will be connected in parallel to achieve this variable amount of reactive energy. The switches will be stepper motors, controlled by an Arduino program. The device will work providing an individual compensation to the load to which it is connected, such as refrigerators or other common consumptions.

2.-Reliability

The device is based on a reliable technology. The capacitors can be broken due to overvoltages or overcurrents. But the capacitors chosen are supposed to be able to deal with common overvoltages of the network. But if a capacitors breaks due to one of these reasons, there is not any risk. This is because the capacitors are connected in parallel, and this kind of capacitors when they suffer overvoltages, they explode internally but with any risk. It is a really small explosion, and once the capacitor stops working, it becomes isolated thanks to the parallel connection. The device can be disconnected in any time, so the replacement of the broken capacitor should not suppose a problem.

3.-Costs

The device must be profitable for the costumer. This implies that the first Smart Power Factor Corrector can be expensive, but as a long term business, we have to decrease the costs in order to make it profitable and to be an attractive product to the costumer. The selling price of the product should be close to the hundred dollars, an attractive price for a costumer that looks to save money in the energy bill. The price of producing the device should be about 80 dollars in order to take a profit of 20 dollar per unit.

4.-Serviceability

The Smart Power Factor Corrector has been designed for the use on household devices, mainly focusing on devices that have low power factors (0.6-0.8) and electrical motors, such as the refrigerator or the air conditioner. It will be connected in parallel with these devices, correcting the reactive power individually. It will mostly work in 120 V and 60 Hz, but it will be able to endure overvoltages and overcurrents for short times. It will help decrease the current in the device, as well as the losses.

C. Constraints

The constraints are boundaries on your design and design process, basically it is something that limits or restricts something, or your freedom to do something. There is a list of constraints that could be found in our project:

1. Time
2. Ethical
3. Safety
4. Budget
5. Codes

1- Time. Possibly one of the most overlooked constraints in any design project is time. Particularly, for this project many factors created time constraints. All the research must be finished within 3 months and we should include the prototype in this period. Moreover, we should have done our working demo by May as deadline.

2- Ethical. Ethical constraints can be identified by using the IEEE code of ethics [7]. For example, designs should consider safety and health of workers, consumers, and/or the public or products implicitly using patent protected designs/concepts. More specifically, in this case safety is being taken in consideration as constraint, because the human is a resistance by itself and working with considerable voltages may produces dangerous currents pass through. In addition, as a group we have to respect the use of patents that are involved in the development of this project.

3- Safety. Our research and the data that we can work with are very limited in order to follow safety procedures. At the beginning the Smart Power Team is going to deal with low sources of voltage, around 10 V, in order to check if the program and connections are working correctly.

The Smart Power Factor Corrector will be built in an aluminum box. This box has to be big enough to include the essential equipment and the security devices required. Also this box has to be isolated and connected to ground to avoid any kind of risk in case of touching it. To protect the device, the box will include a thermal-magnetic circuit breaker that will flip in case of a short circuit or overvoltage.

A main constraint we have is making the physical dimensions of the final project as small as possible so that it can be implemented inside homes and not be extremely noticeable. However putting the components too close together could cause the high voltages to transfer to the low voltage components and break those components. When designing our device, we will need to only include essential equipment and make the box big enough to hold all the components with enough room but small enough to be aesthetically pleasing.

4- Budget. There are three devices which basically defines our project's budget, they are the Arduino Shield (90$), the transformer (50$) and the motor run capacitor (60$). The other option for a switch is using a thyristor as a switch instead of physical switches. The problem with a thyristor would be that it would require another transformer to step up the current from the microcontroller to turn the thyristor on. The thyristor also would make our overall design cost at least five times as much. As an overall project our budget limit is not limited by a fixed price as long as it is something reasonable, our estimative to accomplish the final result is to spend 300$.

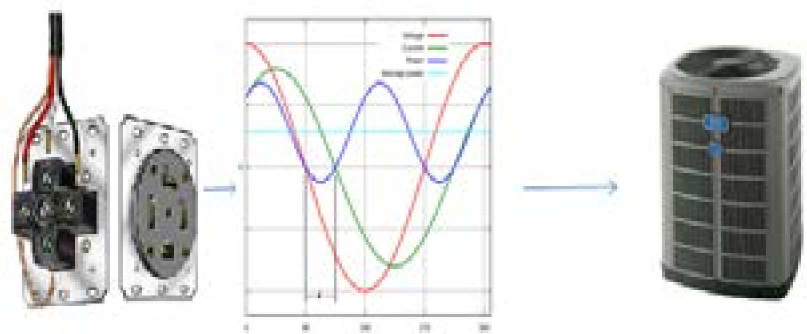
5- Codes. Many codes and standards are applied to the problem and are administered by IEEE or OSHA, for more information look at the I.C.ii section of this proposal.

III. Design Specifications

A. Design Overview and Deliverables

The Smart Power Factor device will be able to constantly correct and monitor the power factor of high power usage appliances in households. This device will be able to be easily tailored to specific household appliances and be able to correct the power factor up to the maximum allowed limit specified by the appliance's manufacturer. The Smart Power Factor device will be able to update and correct the power factor every second. Along with correcting power, it will be able to send data wirelessly and allow users to monitor their device from anywhere. Figure 5 shows the voltage (red), current (green), and power signal (dark blue) leaving the wall entering an appliance. Before the power factor correcting device, the voltage and current has a phase shift. After the power factor correcting device, the current and voltage have zero phase shift. In a real world situations, the phase shift cannot be zero, but as you can see from the concept diagram, the power signal increases from the before correction to the after signal. Figure 6 is a block diagram of what the device will be consisting of. First, we will retrieve a signal from the main input into sensors consisting of a Schmitt Trigger, current sensor and voltage transformer. The voltages and currents need to be lowered to an amount that can be read by the microcontroller. The transformer will output into the input of the Schmitt Trigger. The microcontroller will take the output of the Schmitt Trigger and will process the signal through an algorithm. This signal will determine the amount of lag and we can convert that data into the amount of capacitance required to correct the power factor. The microcontroller will send outputs to switches that will turn switches on or off depending on how much capacitance is required for that moment of time. Along with sending data into the switches to change the capacitance, the microcontroller will be sending data to a wireless system. This wireless system is an attachment to the microcontroller which will send a wireless signal to some monitoring display and display the power factor and any other useful information.

Before



After

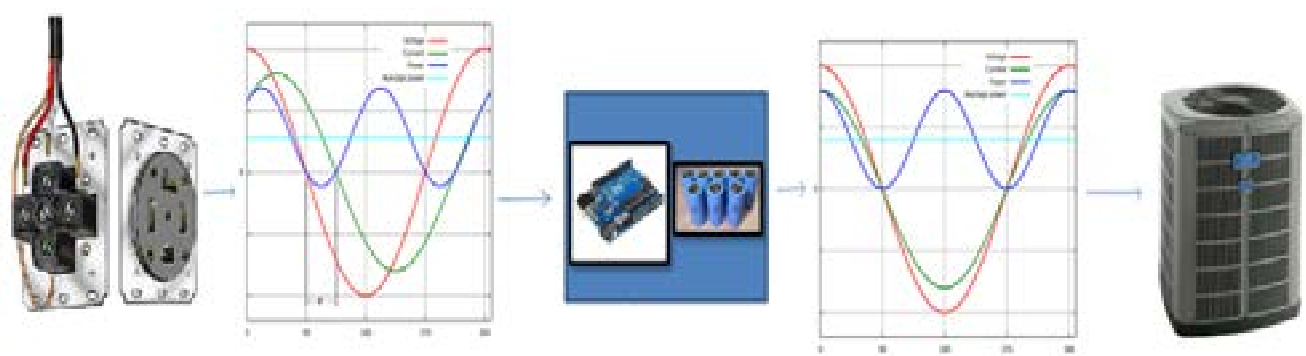


Figure 5-Concept Diagram

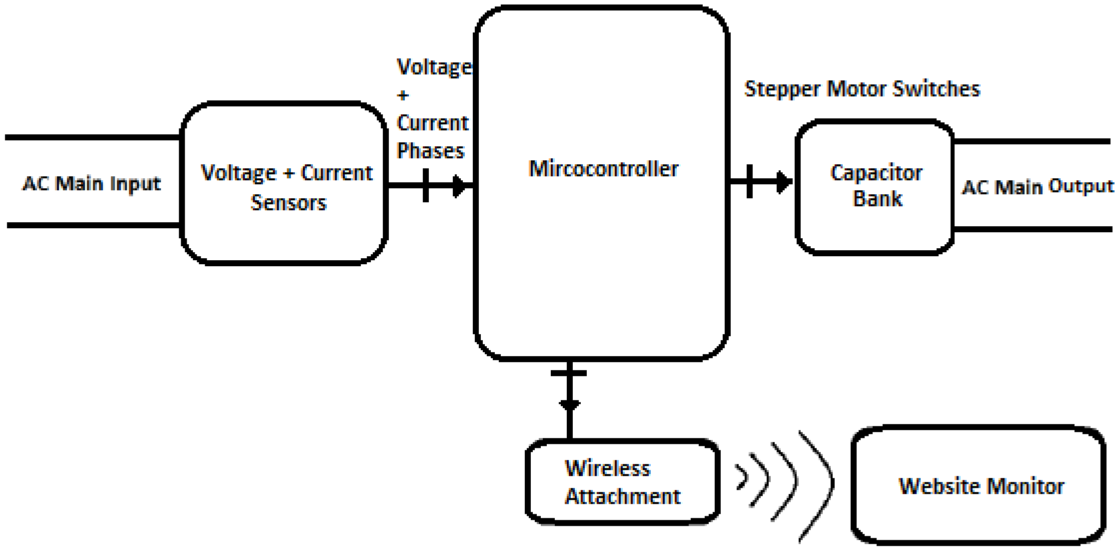


Figure 6-Block Diagram

Figure 7 shows a detailed algorithm program we will be using with the microcontroller. The algorithm will first focus on the inputs of the microcontroller. The step down ratio of the transformers will be known so that we can calculate the actual value of the current and voltage of the main power line. The algorithm will also take into effect the phase change of the voltage transformers to accurately calculate the power factor by using a Schmitt Trigger. The onboard Arduino 10-bit ADC will be used and allow us to record data for a set amount of time and then process the phase difference and calculate the power factor. The outputs of the microcontroller will be the switches and the wireless transmission. The wireless transmission will be done through the Arduino shield which has pre-written code. The code will also take into account how long the capacitor will need to discharge its electrical energy to prevent arcing.

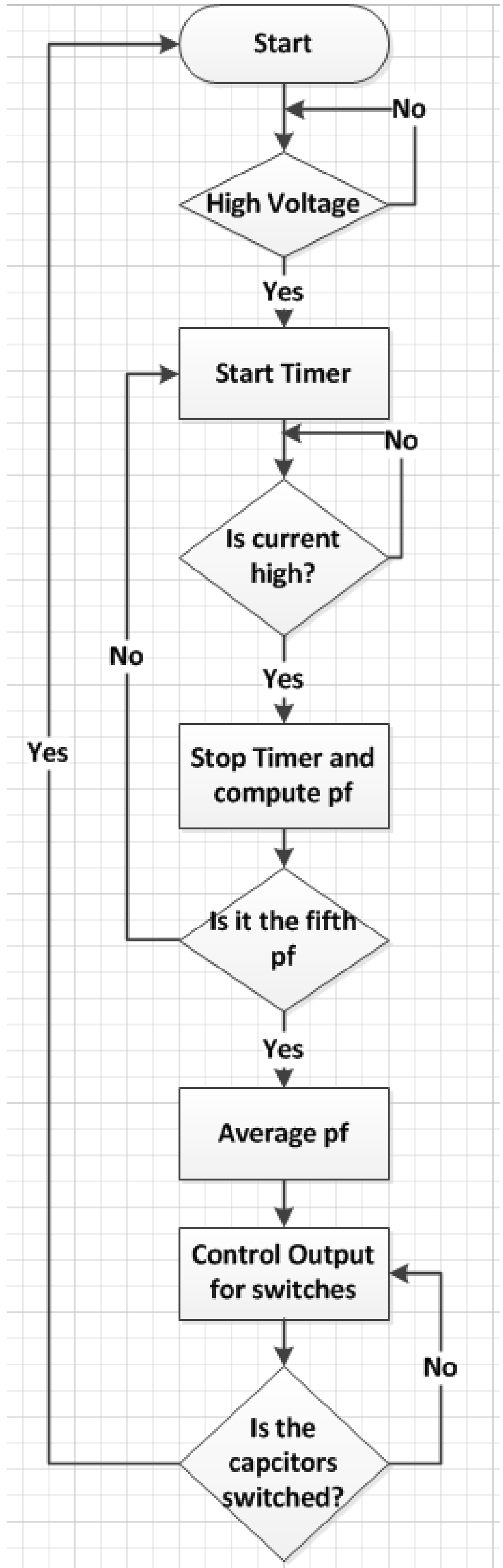


Figure 7-Program Algorithm

B. Functional Specifications

The power factor corrector is a product that has the ability to correct power factor of a wide range of appliances and will be able to be monitored wirelessly and display this data online.

Functional Specifications

- Supplies a power factor correction based upon capacitive load suitable to a variety of appliances.
- Supplies connections between capacitors and microcontroller through thyristors switches
- Uses Arduino algorithm to calculate required capacitance to correct power factor
- Provides corrections to the power factor, with updates as often as every 1 s.
- Uses Arduino-shield-based 802.11b wireless communication to provide display information
- Provides a web-based display that includes: uncorrected power factor, corrected power factor, current, and power usage.

Physical Specifications

- Has dimensions: 1’ x 1’ x 0.5’
- Power correction device components contained in metal casing to shield from interference and increase safety and aesthetics.
- Capacitor bank contained within metal casing connected to switches
- Use Arduino-board attachable components for 802.11b wireless communications

IV. Design Results

A. System Design

The Smart Power Factor Corrector will be comprised of three main subsystems. The sensor subsystem will be used to determine and send to the microcontroller the phase shift between the sinusoidal voltage and current of the main line as well as the magnitude of the current. The second subsystem is the microcontroller. This subsystem will take the information from the sensors and calculate the power factor and reactive power of the load. Then the microcontroller will output signals used to capacitor banks to correct the power. The last subsystem will be transmitting the data, such as power factor and power usage, via WiFi so that we can view the data online. This will be done with the Arduino WiFi shield that attaches to the Arduino. The code for transmission of data is provided with the purchase of the hardware and the only things we need to do is specify where and what info from the microcontroller we want to send.

The main feature of the Smart Power Factor Corrector will be keeping the power factor above a preset value and check and update the correction every second. A major concern of the project is the switching of capacitors and the arcing that can occur if the capacitors are not fully discharged. With the capacitors we are using, we estimate that if we wait for one second before switching on and off capacitors, the capacitors will be fully discharged. We will also need to make sure in our box of components to completely separate the low and high voltage parts to ensure voltage doesn't jump over and damage the equipment. We want to make this box as small as possible to easily be integrated into a household environment however, the smaller we make the box, the greater the chance of voltages jumping to other areas of the device. To remedy this, we have decided the box to be 1'x1'x6". This will still allow the device to be of a modest size but allow for the integrity of the box to be intact. This still needs to be tested.

B. Subsystem Design

1. Sensor Subsystem

The subsystem will provide signals indicating the difference in phase between the sinusoidal voltage and current to the microcontroller. The sensor subsystem will first step down the voltage and current from the 120V and up to 20 A to the limits of the microcontroller which are 5V and 50 mA.

The voltage will be brought down to 5V with a voltage transformer. The transformed voltage will go into a Schmitt Trigger and then into the microcontroller. The phase shift due to the transformer will be accounted for by the coding algorithm. The current sensor will be done with the ACS712 Breakout. This device can handle current up to 20A and outputs an analog voltage output signal that varies linearly with sensed current [8]. This will allow for us to know when the voltage and current pass through zero and the microcontroller can account for that time difference.

2. Microcontroller Subsystem

The microcontroller will be where the data from the sensors are used to calculate the power factor and reactive power of the load. The microcontroller will also need to be able to control switches that will turn on and off switches to the capacitor banks.

The microcontroller chosen by the Smart Power Factor Team is the Arduino Uno rev 3. The reason we chose the Arduino over other microcontrollers is because of the large number of configurable input/output ports and the easily attachable Arduino Wi-Fi shield. The power factor can be easily calculated by having the time delay and frequency of the signal. The reactive power will then be calculated using the power factor and the magnitude of the power of the load. With the reactive power, we can find the amount of capacitance needed to correct the power factor. The microcontroller will turn switches on and off to vary the capacitance needed.

Schematic of the circuit design can be seen in the appendix. Figure 8 illustrates the overall flow of the sensor subsystem. Important Specifications:

- Arduino Uno rev3 [9]
  - Flash Memory32 KB (ATmega328) of which 0.5 KB used by boot loader
  - SRAM2 KB (ATmega328)
  - EEPROM1 KB (ATmega328)
  - Clock Speed16 MHz
  - 10 bit ADC

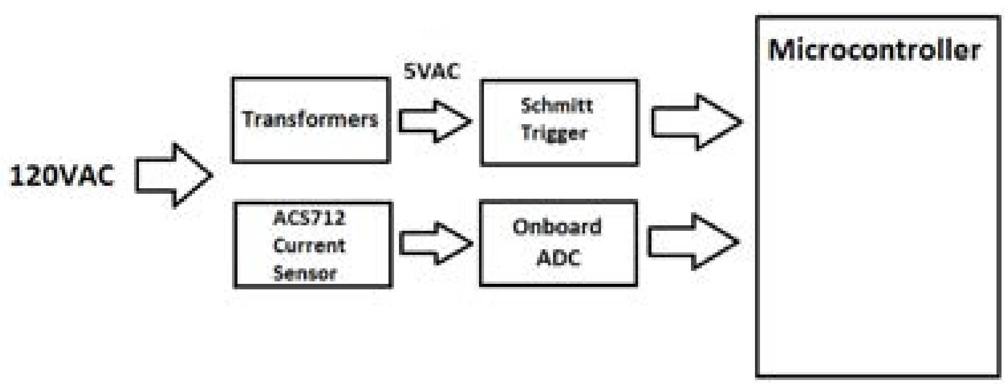


Figure 8-Sensor Subsystem

3. Transmitting Data Subsystem

The Smart Power Factor Corrector may be in an area not easily accessible and therefore we will need a way to remotely view the data. The device will need to be able to send out calculated power factor and current readings.

The easiest way is to attach an Arduino WiFi shield to the device. The shield allows for easy access to the internet and also comes with its own software. We will use it to send power factor, current, and power usage. The Arduino Shield data shield can be found in the appendix. Important Specifications:

- Arduino Shield [10]
    - Connection via: 802.11b/g networks
    - Encryption types: WEP and WPA2 Personal
    - Connection with Arduino on SPI port
    - On-board micro SD slot
    - Mini-USB for updating WiFi shield firmware

V. Design Plan

A. Stage 1- Research

B. Stage 2- Design

For us to find the phase difference between the voltage and current, we must determine when the voltage and the current become positive. To do this we use Schmitt triggers like in figure 9.

C. Stage 3- Prototype Construction

To find when the voltage and current become positive, we will use a Schmitt trigger.

D. Stage 4- Testing

Figure 9 shows the experimental results we gained from building a Schmitt Trigger.

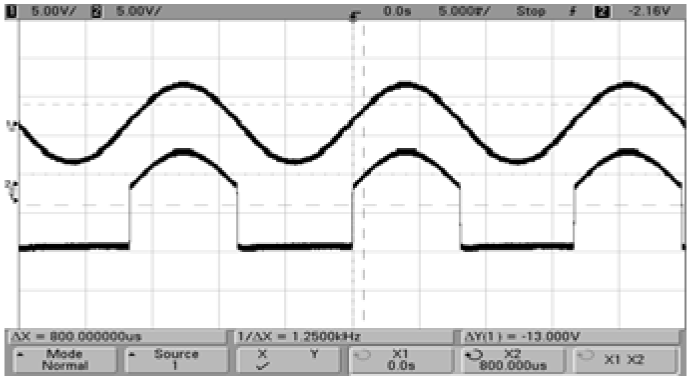


Figure 9-Schmitt Trigger Experiment Data

To simulate an inductive load, we applied a 10 V peak to peak voltage from the waveform generator to four 24 mH inductors in series. Figure 10 shows the theoretical multisim representation of the circuit. Figure 11 shows the uncorrected power factor on the left and the corrected power factor on the right. This was done by hand to show that our calculations are correct and will work for our design.

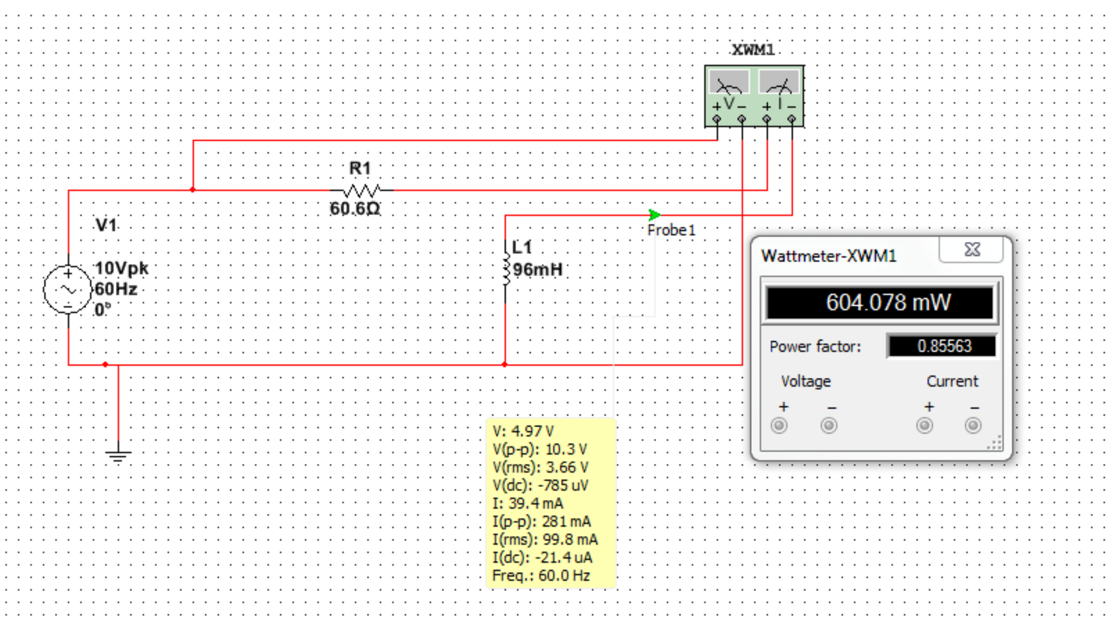


Figure 10-Multisim Circuit Representation

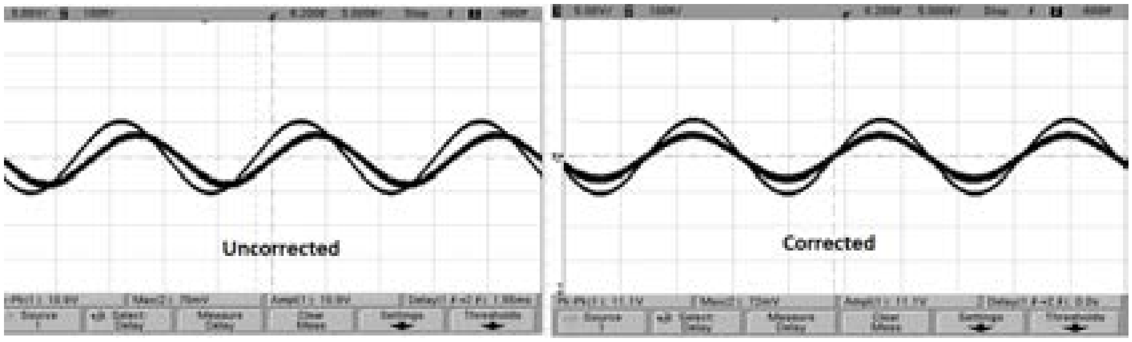


Figure 11-Experimental Results

E. Stage 5- Documentation

F. Schedule

Figure 12 shows our scheduled goals and production task on the left. On the right of Figure 12, our Gantt chart shows us a visual overlook of our schedule to get a better understanding of our time to work on the project. We have started programming and have made a Schmitt Trigger that will detect when the voltage is high. Along with programming, we have done testing by fixing the power factor on a set of low power factor. Our next step is to incorporate the microcontroller to turn the switch on and off. One important date to look forward to is the Open House on the 6th of December.

Gantt Chart

	Task Name	Duratic
1	Class Time(Proposal)	3 hrs
2	Class Time (Proposal)	3 hrs
3	Project Proposal Rough Draft	
4	Work on Presentation	3 hrs
5	Work on Presentation	3 hrs
6	Project Proposal Due	17 days
7	Project Proposal Presentation	11 days
8	Research about power factor	3 hrs
9	Research microcontroller	3 hrs
10	Research Transformers	3 hrs
11	Research Switches	3 hrs
12	Research Programming	3 hrs
13	Research	3 hrs
14	Work on Proposal Redo	3 hrs
15	Work on Proposal Redo	3 hrs
16	Start programming/Start on PDR	3 hrs
17	Work on PDR written report	3 hrs
18	Work on PDR written report/ programming	3 hrs
19	Order Parts/ Work on PDR	3 hrs
20	Work on Poster/Power Factor Testing	3 hrs
21	Finalize PRD/Programming	3 hrs
22	Work on Poster	3 hrs
23	Poster Draft Due/Programming	1 day
24	Work on PDR written report	3 hrs
25	Preliminary Design Review Written Report Due	32 days
26	Prepare for Open House	3 hrs
27	Prepare for Open House	8 hrs
28	Prepare for Open House	3 hrs
29	Open House- PDR	24 hrs
30	Portfolio and Design Documentation Binders Due	1 day

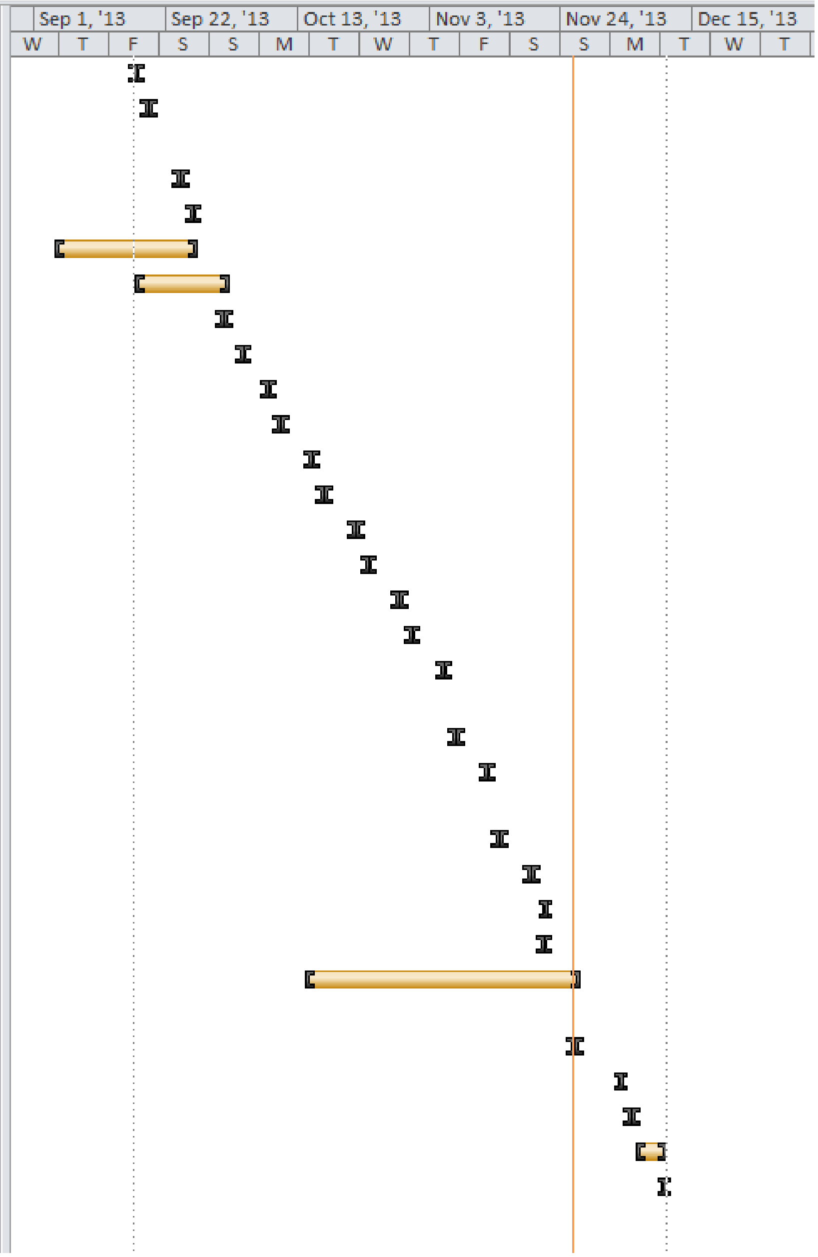


Figure 12-Design Schedule + Gantt Chart

G. Budget

Table 1 shows the total cost it will take to make our device. It also has the cost of each component of the device. Some necessary parts are the Arduino and Arduino Shield for the Wi-Fi capabilities. The stepper motor, capacitors, and aluminum box are fixed in cost. Manufactures might able to find these same parts at a reduced cost and make our device more cost effective.

Table 1-Budget

Parts	Cost
Arduino Uno Rev3	$30
Transformers	$50
Stepper Motors	$20
Arduino Shield	$90
Aluminum Box	$10
240V Motor Run Capacitor	$60
Miscellaneous	$40
	Total Cost: $300

H. Personnel

Refer to appendices A1 for resumes of each team member.

- Specializing in the electronics aspects:

<u>Luke Nicol- Software Manager</u>

The main task is developing an algorithm that will make the device easily adaptable to different household appliances. Also, the software manager will be responsible for the development and implementation of the control aspect of the microcontroller.

Darrel Dotterer- Project Manager

The project manager will be overall in charge of the project but will mostly focus on keeping the project on track with the design schedule. He will also help with interfacing the microcontroller by picking out stepper motors and working with the wireless data transmission through the Arduino shield.

- Specializing in the power aspect:

Vinicius Pereira Pio- Chief Editor

The chief editor will be providing support on all the electrical issues of the project. He will work on the final look of the device as a product to be sold to consumers, and he is responsible for the day by day work of the group.

Manuel Salazar Paramo- Technical Expert

The technical expert will be focusing on the main aspects of the device construction. He will work on the construction of the device, paying special attention to issues related with security when handling electrical devices and avoiding accidents. He will focus on the construction of the device depending on how much reactive power the device will have to generate.

VI. References

[1] Marinko Stojkov, Kruno Trupinic, Darko Poleto ,“Reduction Of Power And Voltage Losses In Low Voltage Networks By Reactive Power Compensating” Proceedings Of The18th International Conference On Electricity Distribution, June 2005.

[2]Dixon, J.; Moran, L.; Rodriguez, J.; Domke, R., "Reactive Power Compensation Technologies: State-Of-The-Art Review," Proceedings Of The IEEE, Vol.93, No.12, Pp. 2144-2164, December 2005.

[3] (No Author), Design It Right: "Power Factor Correction A Guide For The Plant Engineer. Eaton Powering Business Worldwide, Nov. 2010.

[4] Agrelo Regueira, Juan Luis, "Sistema De Compensación De Potencia Reactiva, De Especial Aplicación En Viviendas", Endesa S.A.E Patent, Feb. 2013.

[5] Stone David W, "Reactive Power Compensation Control System", Patent 3754184, 21 August 1972.

[6] Arnold P Kehrli, John A Diaz De Leon II, Douglas C Folts, "Reactive Power Compensation To Minimize Step Voltage Changes And Transients", Patent 06900619, Nov. 1999

[7] Mike W. Martin And Roland Schinzinger, Ethics In Engineering, 4th Editio, 2004.

[8] "Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor" Allegro Datasheet.
(accessed Nov 26, 2013 *https://www.sparkfun.com/datasheets/breakoutboards/0712.pdf*)

[9] "Arduino Uno," Arduino Online Product Information
(accessed Nov 26, 2013 *http://arduino.cc/en/Main/arduinoBoardUno*)

[10] "Arduino WiFi Shield," Arduino Online Product Information
(accessed Nov 26, 2013 *http://arduino.cc/en/main/arduinowifishield*)

VII. Appendices

A.1 Formulas

Formula 1.1

$$S = V \cdot I^*$$

Formula 1.2

φ_V is the angle of the voltage signal. φ_i is the angle of the current signal

$$P \cdot \left(\tan\left((\varphi_v - \varphi_i)\right) - \tan((\varphi_v - \varphi_i)')\right) = Qc$$

Where Q_c is the reactive power the capacitor must provide; and $(\phi_V - \phi_i)'$ is angle we want for the power factor to be corrected. P is the power being delivered to the load.

Formula 1.3

$$C = \frac{Qc}{V^2 \cdot 2\pi \cdot f}$$

C is defined as the capacitance, V is defined as the voltage, and f is defined as the frequency. Q_c is the reactive power the capacitor provides.

B.1 Resumes

Darrel M. Dotterer
5998 Alcala Park
San Diego, CA 92110
(555) 555-5555
darreldotterer@sandiego.edu

EDUCATION

University of San Diego San Diego, CA
BS/BA in Electrical Engineering Expected December 2015
• Minor in Mathematics
• GPA: 2.86

Relevant Coursework

Circuits Probability and Statistics Signals and Systems
Electronics Programming Microcomputers
Systems Logic Design Materials Science

Engineering Design Projects

Served on 2-4 member teams and submitted formal documentation for each project:
• Designed and programmed power factor corrector

SKILLS

• Proficient in Microsoft Office Programs: Word, Excel, PowerPoint, Visio
• Proficient in PSpice, VHDL, Xilinx, Assembly
• Experience with programming/interfacing a PIC18 microprocessor, C++, MatLab, MathCad, Multisim

EXPERIENCE

This is my fourth year in the NROTC. This program requires me to take leadership positions throughout the four years that I stayed at University of San Diego. I have had billets that have ranged from color guard coordinator to alumni coordinator. As color guard coordinator, I was responsible for coordinating over forty color guard events with groups all across San Diego.

AFFILIATIONS

• NROTC
• Institute of Electrical and Electronic Engineers

Europass Curriculum Vitae

Personal information

First name(s) / Surname(s)	SALAZAR, Manuel
Address(es)	177 Camino de Hoyarrasa, Alcobendas, Madrid, Spain
Telephone(s)	Fixed: +34 91 6250035 Mobile: +34 649924013 +1 6199619885
Fax(es)	
E-mail	manuelsalazarp@outlook.com
Nationality	Spanish
Date of birth	10/04/91
Gender	Male

Desired employment / Occupational field

Electromechanical engineer

Work experience

Dates	Summer 2007, Summer 2008
Occupation or position held	Work in a Hotel, section of internal distribution
Main activities and responsibilities	In charge of the relation with the suppliers. I used to deal with different suppliers each day from different companies
Type of business or sector	Hotel Logistics

Education and training

Dates	From 2009- not finished, expected to graduate in engineering From 1996 to 2009
Title of qualification awarded	Electrical Mechanical Engineering (in progress) School degree
Principal subjects/occupational skills covered	Spanish language, foreign languages (english and french), mathematics, physics Physical education, sports (football and rugby) **Occupational** Science applied to engineering Computer knowledge: C++ programming, Word, Excell, Access, SPSS, Autocad, Matlab, Fluent Basic economics knowledge
Name and type of organisation providing education and training	University of San Diego Universidad Pontifica Comillas ICAI (school of engineering) Nuestra Señora del Recuerdo school
Level in national or international classification	Level 6 Spain

Personal skills and competences

Mother tongue(s)	Spanish

Other language(s) English and french

Self-assessment

European level (*)

Language	Understanding: Listening	Understanding: Reading	Speaking: Spoken interaction	Speaking: Spoken production	Writing
English	B2	C1	B2	C1	B2
French	B2	C1	C1	C1	B2

(*) Common European Framework of Reference for Languages

Social skills and competences

Team spirit. Good communication skills. Obtained along the degree. An engineering degree requires a lot of teamwork.
Adaptable to other cultures. I have travel to different countries around the world, and I have learnt something from each one

Organisational skills and competences

Leadership. It comes from my time in sport teams. I have always played sports in wich you have to work in team, and in many times I had to take assume control over the situation.
Sense of organisation

Technical skills and competences

Good command on machines related with electromechanical processes

Computer skills and competences

Good command on Microsoft Office (word, excel, access and power point)
C++, SPSS, Autocad, Matlab, Fluent knowledge

Artistic skills and competences

Piano player, through training. Still playing

Driving licence

Category B

Luke E. Nicol
11618 Sun Road
Stockton, CA 95215
(209)-471-2432
luke.e.nicol@gmail.com

Education

University of San Diego — San Diego, CA
BS/BA in Electrical Engineering — Expected December 2014

- Minor in Mathematics
- Minor in Naval Science
- GPA: 3.1

Relevant Coursework

Circuits	Electronics	Systems Logic Design
Probability and Statistics	Programming	Materials Science
Signals and Systems	Microcomputers	Modern Physics

Engineering Design Projects

Served on 2-4 member teams and submitted formal documentation for each project:

- Designed and programmed a two FPGA boards and used RS232 protocol to send data between boards.

Skills

- Proficient in Microsoft Office Programs: Word, Excel, PowerPoint, Visio, Access
- Proficient in Multisim, VHDL, Xilinx
- Experience with programming/interfacing a PIC18, and Arduino microprocessor, C++, MatLab, MathCad
- Experience with Linux Operating Systems

Experience

Midshipman, United States Navy Reserve — August 2010

- Various leadership positions where I was accountable for a platoon of 30 members
- Training in high intensity environments

Technician Assistant, Pro A/V Home Install, Stockton, CA — Summers 09-11

- Assisted technicians installing home theater systems by running wires in attics
- Programmed universal remotes for use with receivers

Affiliations

- USD Rugby Club
- Institute of Electrical and Electronic Engineers
- NROTC San Diego

Vinicius Pereira Pio

Goshen Street, 1357-B
San Diego CA 92110-1452, US
Date of Birth: 05-18-1992

v.pereirapio@gmail.com
(+1) 619 452 9592

PROFESSIONAL EXPERIENCES

Gonway Social Network — Madrid, Spain, 2012 - 2013

Communications Manager. Promotion of Gonway and diffusion of its webpage.
Administration of the companies' relations with various Spanish Universities.
Collaboration in planning and execution sectors.

Private Teacher — Madrid, Spain, 2010-2011

- Mathematics, Physics and Chemistry teacher for high-school students.

ACADEMIC AND UNIVERSITY EDUCATION

University of San Diego — San Diego, US, Currently

- Fourth year of Electromechanical Engineering (Electrical Specialization)

Universidad Pontificia de Comillas (ICAI) — Madrid, Spain, 2010-2013

- First, second and Third year of Electromechanical Engineering.
  - Dean's list: Electrical Machines

Bienaventurada Virgen Maria School — Madrid, Spain, 2009-2010

- Baccalaureate.
  - Excellence Scholarship from the Ministry of Education of Madrid
  - Combined average grade with Selectivity Exam (S.A.T): 12.8 out of 14
  - Average Grade: Outstanding A+

Santiago College — Santiago de Chile, Chile, 2008-2009

- Baccalaureate.
  - Average grade: Outstanding A+
  - Outstanding Award in Mathematics and Chemistry

Ensino Fundamental Sigma School — Brasilia, Brazil, 2004-2008

- Secondary Education (E.S.O.)

OTHER EXPERIENCES

English courses at Bell School.	Cambridge, England	2011
Spanish courses	Santiago de Chile, Chile	2008
Debate Tournament 'ONU Jr.', University of Estácio de Sá, (Champion)	Rio de Janeiro, Brazil	2007
Voluntary work at underdeveloped communities in Chile		2009
Member of "Bienaventurada Virgen Maria" football team		2009-2010
Class Delegate in ICAI		2010-2012
Member of the Faculty Council in Santiago College		2009

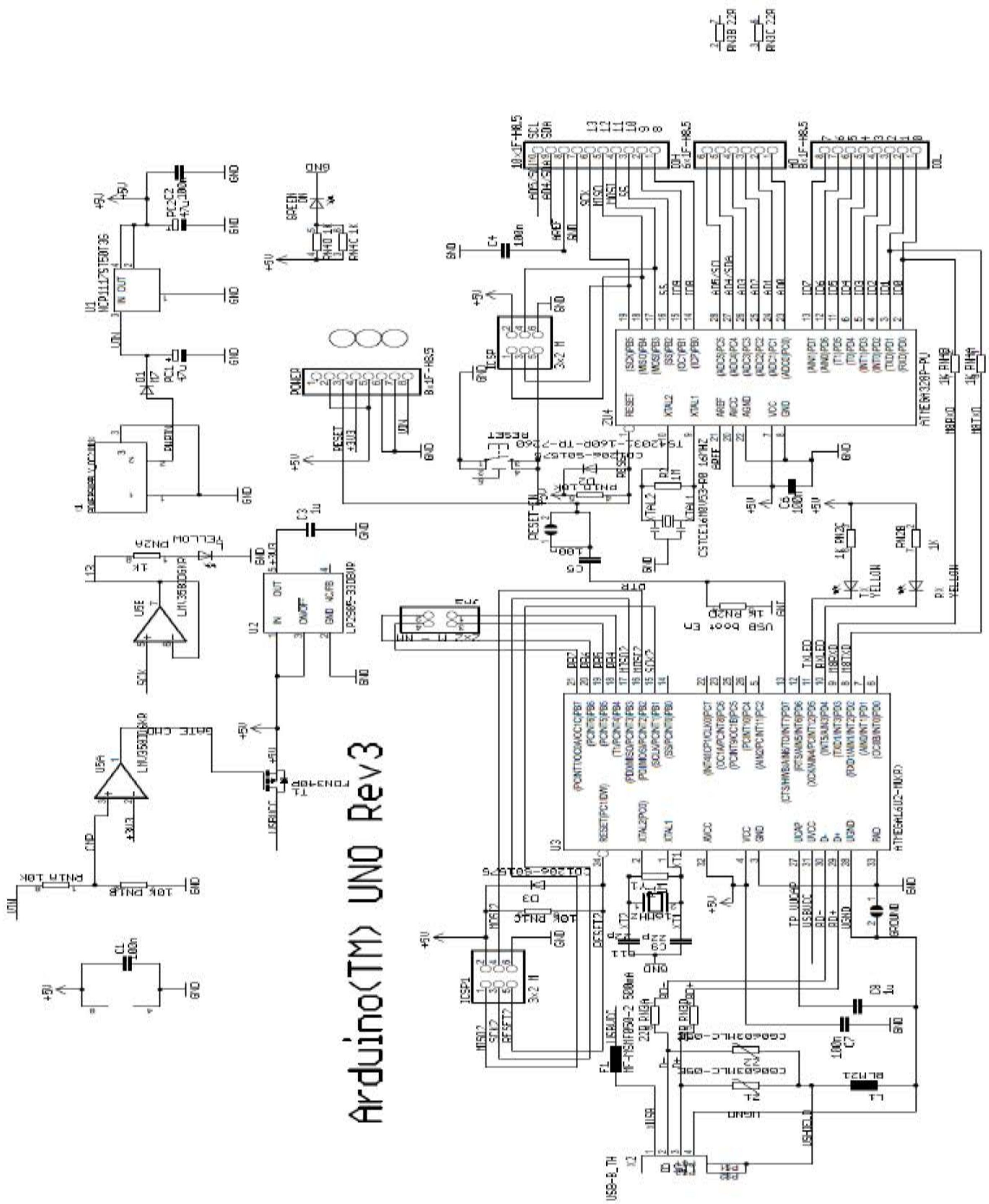
LANGUAGES AND OTHER SKILLS

- **Portuguese**: Native.
- **Espanish: Fluent.**
- **English**: High Level.
- **German**: Basic level.
- **Computer Knowledge**: MS-Office, SPSS, Derive, AutoCAD, Solid-Edge, C+, Matlab.

PERSONAL INTERESTS

Hobbies: travelling, theater, sports (soccerball and volleyball) and music.
Personal character: open, cheerful, sociable and committed.
Professional character: demanding, willing, constant and an enthusiastic team-worker.

C.1 Datasheet



D.1 Average Household construction costs

Table 1. Single Family Price and Cost Breakdowns 2011 National Results		
	Average Lot Size:	20,614 sq ft
	Average Finished Area:	2,311 sq ft
I. Sale Price Breakdown	**Average**	**Share of Price**
A. Finished Lot Cost (including financing cost)	$67,551	21.7%
B. Total Construction Cost	$184,125	59.3%
C. Financing Cost	$6,669	2.1%
D. Overhead and General Expenses	$16,306	5.2%
E. Marketing Cost	$4,645	1.5%
F. Sales Commission	$10,174	3.3%
G. Profit	$21,148	6.8%
Total Sales Price	**$310,619**	**100.0%**
II. Construction Cost Breakdown	**Average**	**Share of Construction Cost**
Building Permit Fees	$3,107	1.7%
Impact Fee	$2,850	1.5%
Water and Sewer Inspection	$2,952	1.6%
Excavation, Foundation, and Backfill	$17,034	9.3%
Steel	$1,012	0.5%
Framing and Trusses	$24,904	13.5%
Sheathing	$2,142	1.2%
Windows	$6,148	3.3%
Exterior Doors	$2,150	1.2%
Interior Doors and Hardware	$2,883	1.6%
Stairs	$1,052	0.6%
Roof Shingles	$5,256	2.9%
Siding	$8,739	4.7%
Gutters and Downspouts	$870	0.5%
Plumbing	$10,990	6.0%
Electrical Wiring	$8,034	4.4%
Lighting Fixtures	$2,193	1.2%
HVAC	$8,760	4.8%
Insulation	$3,399	1.8%
Drywall	$8,125	4.4%
Painting	$6,005	3.3%
Cabinets and Countertops	$10,395	5.6%
Appliances	$3,619	2.0%
Tiles and Carpet	$8,363	4.5%
Trim Material	$3,736	2.0%
Landscaping and Sodding	$6,491	3.5%
Wood Deck or Patio	$1,918	1.0%
Asphalt Driveway	$2,729	1.5%
Other	$19,487	10.6%
Total	**$184,125**	**100.0%**