Smart Power Factor Corrector

Team Members:

Luke Nicol

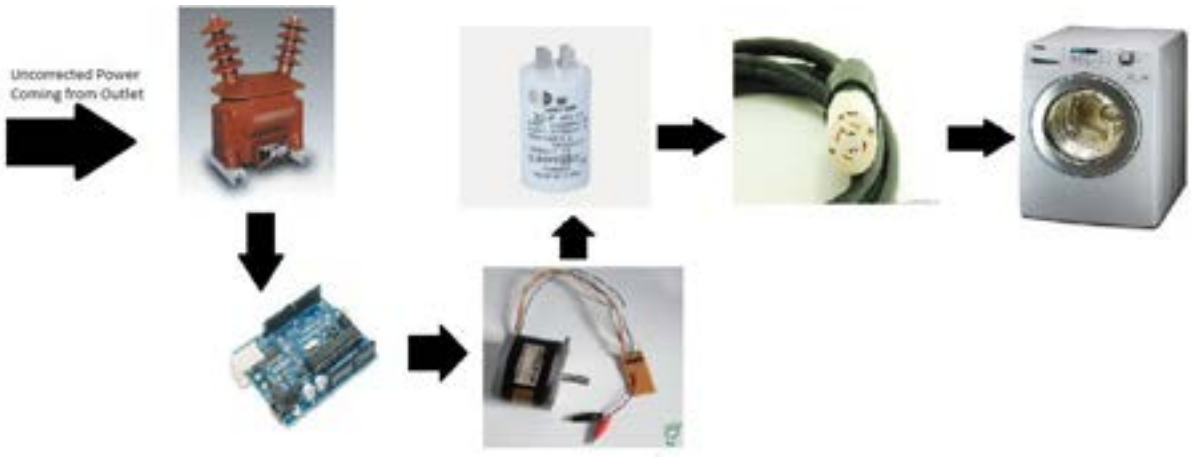
Manuel Salazar Paramo

Vinicius Pereia Pio

Darrel Dotterer

Sponsor: Dr. Kim

ELEC 491W



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1. Introduction/Background

1.1 Introduction

This proposal was sparked by an idea that was brought up by Dr. Kim at the University of San Diego to reduce the amount of reactive power use in household appliances. The power team seeks to make a device that will correct the power factor and will reduce the reactive power used on appliances that consume large amounts of power. This project will help save power. It will also reduce the amount of wiring needed to send energy.

1.2 Background

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. Correcting this reactive power is done easily by connecting capacitors in parallel with the load. The closer the power factor is towards the unity factor than the less current is drawn. 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. These are the equations we will be using for our calculations and for the design of our device.

$$S = P + jQ$$

Q is defined the reactive power which is responsible for the electromagnetic fields. P is the active power.

This is the electrical power that can be converted into mechanical power and heat losses.

$$pf = \cos(\varphi_v - \varphi_i)$$

Pf is the power factor. φ_v is the angle of the voltage signal. φ_i is the angle of the current signal.

$$S = V * I^*$$

By improving the power factor, we decrease the amount of current needed to give the same amount of active power.

$$\mathrm{P} * (\tan((\varphi_v - \varphi_i)) - \tan((\varphi_v - \varphi_i)')) = \mathrm{Q}_c$$

Where, Q_c is the reactive power the capacitor must provide, and $(\varphi_v - \varphi_i)'$ is angle we want for the power factor to be corrected. Figure 1 gives a visual perspective of how the power factor is corrected.

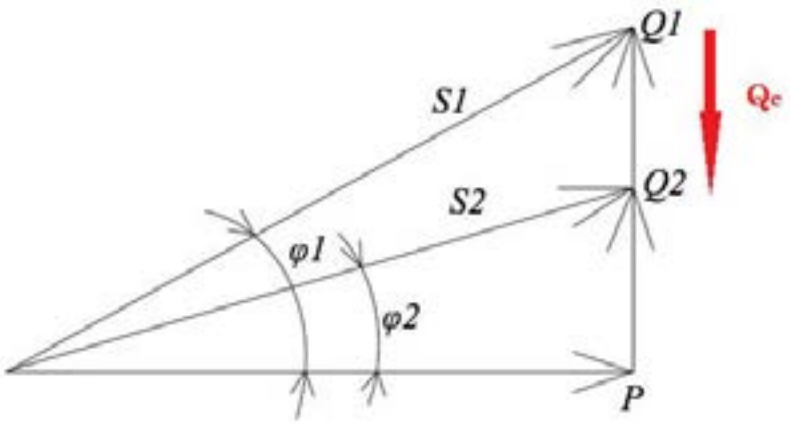

Figure 1 Trigonometric View of Power Factor

2. 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.

3. Scope of Work

3.1 Overview

Main Design Sections:

- Converting the high voltages and currents from the main power line to lower values for the Arduino
- Reliable ADC conversion times with the Arduino to obtain accurate power factor computations
- Control algorithms for the stepper motor using power factor data
- Wireless data transmitting and viewing

3.2 Design Schematics

Figure 2 shows a basic idea of how we approach the problem and connect the device to the appliance being used. The Smart Power Factor Correction device will be a device installed on large household devices to correct the reactive power delivered to the load. The device will consist of a way to constantly measure the power factor of the load. This data will be sent to a microcontroller that will control switches. The switches control how many capacitors are connected in parallel to the load and can be changed constantly to allow for a better power factor and less current being drawn. The microcontroller will also be sending data to allow for monitoring of the power factor. This will allow a way to determine certain instances that cause larger power factors and predict these instances to correct them easily. The device will take into account "arcing" due to capacitors switching.

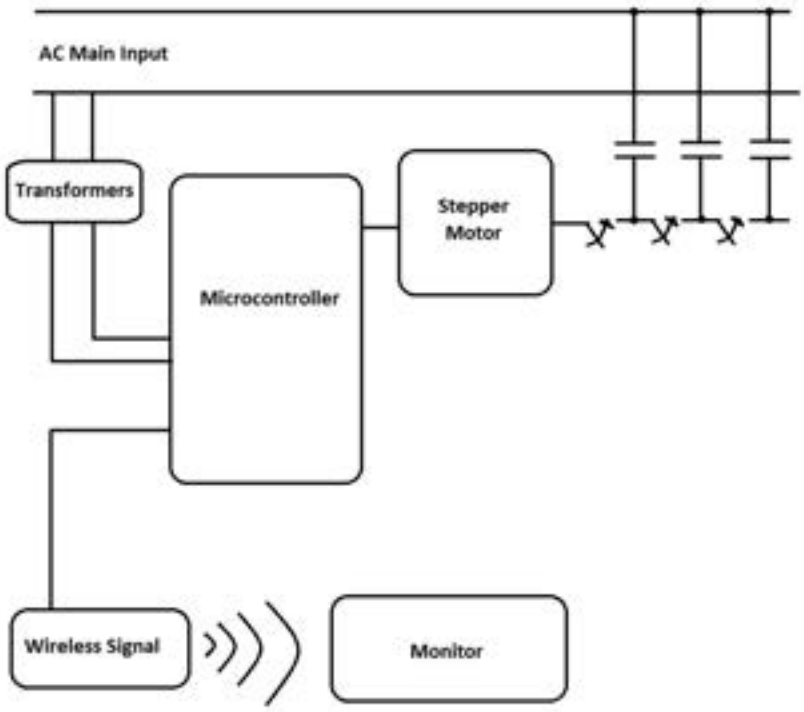

Figure 2- Block Diagram of the Design

3.21 Internet Access

There are attachable board components available that are used specifically to allow the microcontroller to connect to the internet wirelessly. The Arduino “shield” is a great example of this use and we plan on using it in our design.

3.22 Physical Dimensions

We want to create an aluminum box that will contain our design in a neat and protected fashion. The box will contain the transformers, the capacitors, stepper motor, and microcontroller including the Arduino shield. We estimate the box to be one foot by one foot by half a foot. This will allow for less outside interference and become a safer unit.

3.3 Literature Review

We will be using a power book *Electrical Machines and Devices* sixth edition by Jesus Fraile Mora Published by McGraw Hill in 2008 as a reference. Along with that, we have will be using the Arduino uno rev3 data sheet. Refer to appendices B1 for data sheets.

For Arduino programming problems, we will be using Getting Started with Arduino 2nd Edition by Banzi, Massimo.

3.31 Codes

The important codes for the PSSD system are those relating to safety of wireless communications between systems. Relevant codes are stated below:

- **IEEE Standard 802.11, 2007-Wireless**
    - 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.

3.4 Alternatives

Using a capacitor bank to correct the power factor is a common practice. The other way to correct the power factor is using Variable Speed Drives (VSDs). VSDs are a solid device that change the input AC voltage and makes the signal voltage and frequency variable. This would allow for us to correct the power. A main advantage of using VSDs as opposed to capacitors is the elimination of harmonic currents. Capacitors can magnify the harmonic currents and will absorb and overheat. However, VSDs only work in a three phase voltage system and we will be working with single-phase voltage.

3.42 Restraints

One restraint we have is the arcing of the quick removal and addition of capacitors in parallel. This may create a delay from charging the capacitor.

3.5 Proposed Solution

The device will have a current and voltage transformer to convert the high voltages and currents into smaller, more manageable magnitudes for the microcontroller to handle. These voltages and currents will then go through a comparator that will send a logic “true” to the microcontroller when the currents and voltages go from being negative values to positive values. This will allow us to find the time difference between the current and voltage of the main line and determine the power factor. The outputs of the microcontroller will be connected to a wireless signal to display the data being collected through the internet like power factor and total power usage and to a stepper motor. The stepper motor will control the switches that are connected to the capacitors. The microcontroller will be able to change the amount of capacitance based on current data from the inputs. All these components will be setup in a box to reduce interference of outside factors. Data will be sent wirelessly via an Arduino shield to record and monitor the power factor and complex power reduced over the internet.

This solution is the best solution because not only is it the simplest solution to design and make but also the most efficient way to correct the power factor.

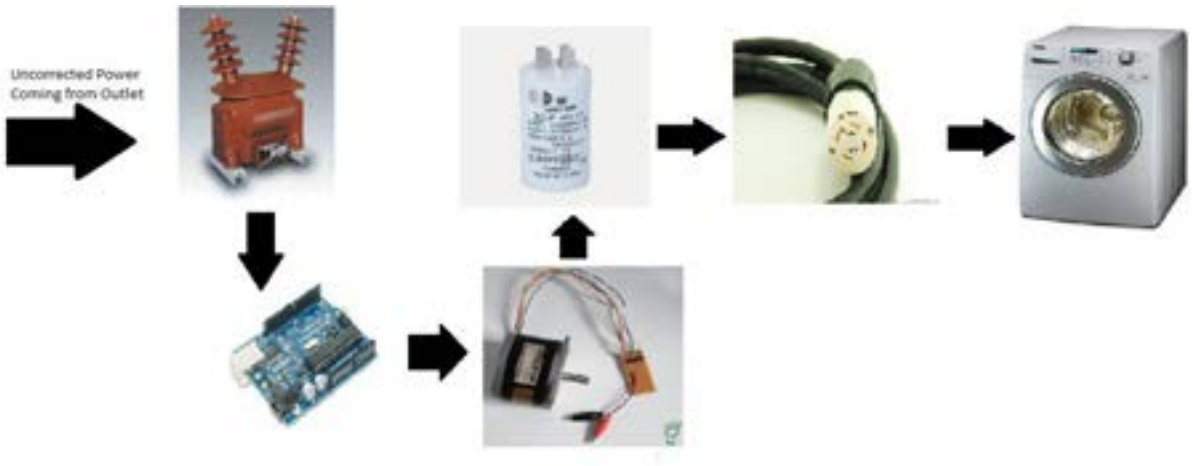

Figure 3- Concept Diagram

4. Design Plan

Research

The research will start by determining which house hold appliances generate the most reactive power. Once we determine which house hold appliances we want to correct, then we want to find the currents and voltages for that appliance.

Interfacing the Microcontroller

We will want to start by finding parts to interface the microcontroller. Finding a voltage converter that will convert lower levels of voltages to voltages up to 240V may be our first challenge. Along with voltage converters, we need to find the range of capacitors that are required to fix a wide range of power factors. Once we complete the task of smart power factor correcting, we will add a wireless component to allow the ability to monitor the device through the internet. Our first step for programming is creating an algorithm that will complete the design in a quick and realistic manner. Then the algorithm must be turned into code that can be used by the microcontroller.

Testing

This testing section may take some time. The program will require large amounts of debugging and there will be many trials to perfect the program as much as possible.

5. Personnel

Refer to appendices A1 for resumes of each team member.

Specialize in the electronics aspects:

Luke Nicol- Program Manager

Darrel Dotterer- Project Manager

Specialize in the power aspect:

Vinicius Pereira Pio- Chief Editor

Manuel Salazar Paramo- Technical Expert

6. Design schedule

Task Mode	Task Name	Duration	Start	Finish
	Class Time(Proposal)	3 hrs	Tue 9/17/13	Tue 9/17/13
	Class Time (Proposal)	3 hrs	Thu 9/19/13	Thu 9/19/13
	Project Proposal Rough Draft			
	Work on Presentation	3 hrs	Tue 9/24/13	Tue 9/24/13
	Work on Presentation	3 hrs	Thu 9/26/13	Thu 9/26/13
	Project Proposal Due	17 days	Wed 9/4/13	Thu 9/26/13
	Project Proposal Presentation	11 days	Tue 9/17/13	Tue 10/1/13
	Research	3 hrs	Tue 10/1/13	Tue 10/1/13
	Research	3 hrs	Fri 10/4/13	Fri 10/4/13
	Research	3 hrs	Tue 10/8/13	Tue 10/8/13
	Interfacing Microcontroller	3 hrs	Thu 10/10/13	Thu 10/10/13
	Program	3 hrs	Tue 10/15/13	Tue 10/15/13
	Program	3 hrs	Thu 10/17/13	Thu 10/17/13
	Program	3 hrs	Tue 10/22/13	Tue 10/22/13
	Testing Power Factor	3 hrs	Thu 10/24/13	Thu 10/24/13
	Testing Device	3 hrs	Tue 10/29/13	Tue 10/29/13
	Wireless Research	3 hrs	Thu 10/31/13	Thu 10/31/13
	Setup Wireless	3 hrs	Tue 11/5/13	Tue 11/5/13
	Interface Wireless	3 hrs	Thu 11/7/13	Thu 11/7/13
	Setup website or app	3 hrs	Tue 11/12/13	Tue 11/12/13
	Setup Website or App	3 hrs	Thu 11/14/13	Thu 11/14/13
	Wireless Research	3 hrs	Tue 11/19/13	Tue 11/19/13
	Class Time	3 hrs	Thu 11/21/13	Thu 11/21/13
	Preliminary Design Review Written Report Due	32 days	Mon 10/14/13	Tue 11/26/13
	Class Time	3 hrs	Tue 11/26/13	Tue 11/26/13
	Class Time	8 hrs	Tue 12/3/13	Tue 12/3/13
	Class Time	3 hrs	Thu 12/5/13	Thu 12/5/13
	Open House- PDR	24 hrs	Fri 12/6/13	Tue 12/10/13
	Portfolio and Design Documentation Binders Due	1 day	Tue 12/10/13	Tue 12/10/13

Figure 4- Design Shedule

6.1 Gantt Chart of Design Schedule

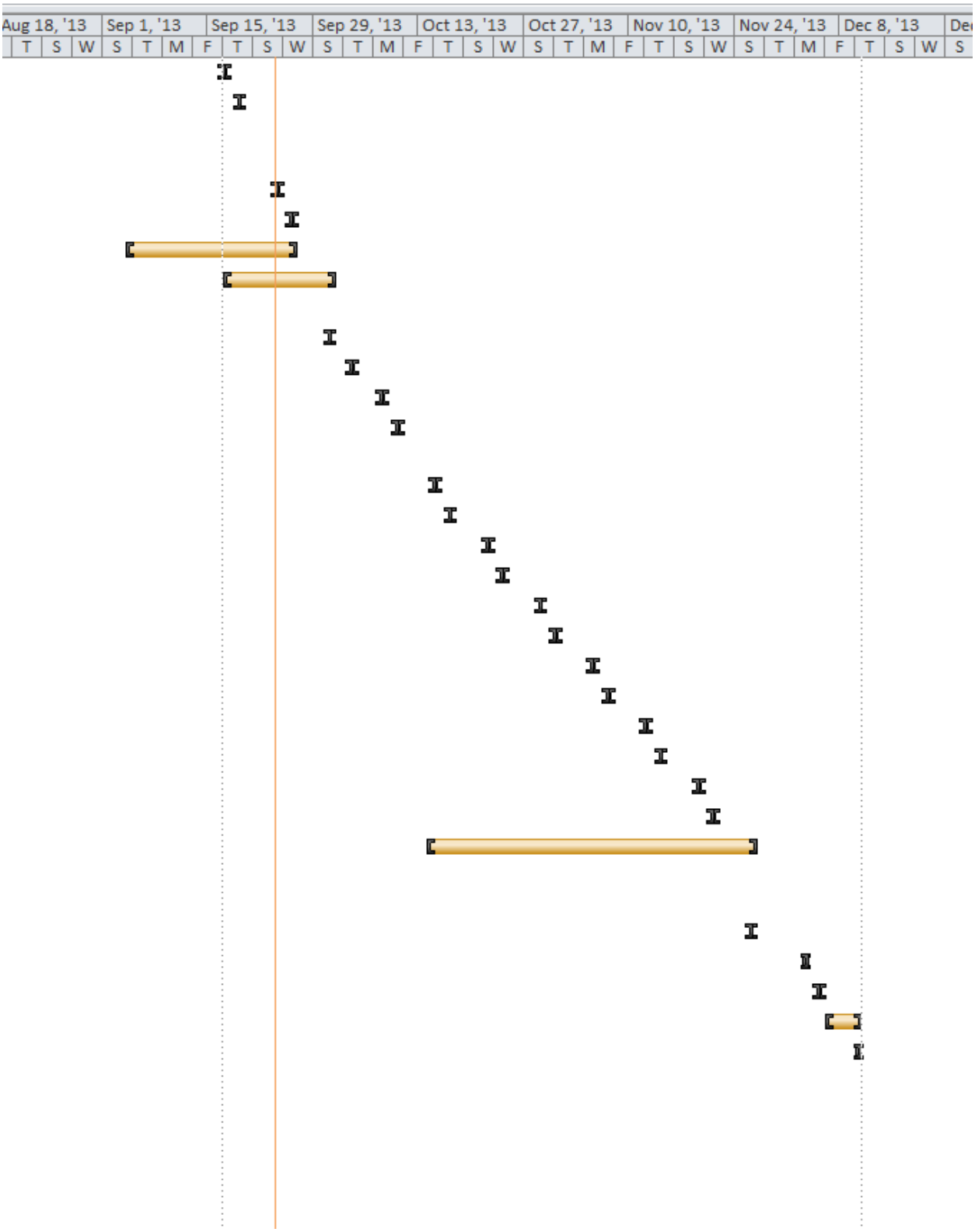

Figure 5- Gantt Chart

7. Budget

Our budget in table one is an estimate. Our definite parts are the Arduino and Arduino Shield for the Wi-Fi capabilities that will be needed. The stepper motor, capacitors, and aluminum box are essentials that will not change in cost. Through research and the design process, we will finalize a budget.

Part	Cost
Arduino Uno rev 3	$30
3 phase extension cords	$50
Stepper motor	$20
Arduino Shield	$90
Aluminum Box	$10
240V Motor Run Capacitors	$60
Miscellaneous	$40
	Total Cost: $300

8. References

"The Average Annual Electricity." *The Average Annual Electricity*. U.S. Energy Information Adminitration, 19 Mar. 2013. Web. 26 Sept. 2013.

Mohankumar, D. "Power Factor Correction." *ElectroSchematicscom RSS*. N.p., n.d. Web. 26 Sept. 2013.

Pan; Denghai (Shenzhen, CN). Power Factor Correction Converter and Power Factor Correction Conversion Device. Huawei Technologies Co., Ltd. (Shenzhen, CN), assignee. Patent 8531854. 21 Aug. 2012. Print.

"Power Factor Correction." *Design It RIght*. Eaton Powering Business Worldwide, Nov. 2010. Web. 26 Sept. 2013.

Barsoum, Nader. "PIC Micro Controller for Power Factor." *IEEE Xplore*. The Computer Society, 2007. Web. 26 Sept. 2013.

9. Appendices

A1- 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	Understanding				Speaking				Writing	
European level (*)	Listening		Reading		Spoken interaction		Spoken production			
Language	English	B2		C1		B2		C1		B2
Language	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
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. — 2012 - 2013

Private Teacher — Madrid, Spain
- Mathematics, Physics and Chemistry teacher for high-school students. — 2010-2011

ACADEMIC AND UNIVERSITY EDUCATION

University of San Diego — San Diego, US
- Fourth year of Electromechanical Engineering (Electrical Specialization) — Currently

Universidad Pontificia de Comillas (ICAI) — Madrid, Spain
- First, second and Third year of Electromechanical Engineering. — 2010-2013
  - Dean's list: Electrical Machines

Bienaventurada Virgen Maria School — Madrid, Spain
- Baccalaureate. — 2009-2010
  - 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
- Baccalaureate. — 2008-2009
  - Average grade: Outstanding A+
  - Outstanding Award in Mathematics and Chemistry

Ensino Fundamental Sigma School — Brasilia, Brazil
- Secondary Education (E.S.O.) — 2004-2008

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 María" 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.
- **Espanith**: 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.

B1- Datasheets