Phasor Measurement Unit (PMU)

ECE 445 Project Proposal

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1 Introduction

1.1 Statement of Purpose

This project was deemed appropriate due to current status of PMUs; existing PMUs have proven to be very expensive and bulky. With cheaper price and more compact size, we hope to distribute increased number of units across the U.S. power grid. Ultimately, relevant industries will be able to monitor the status of the grid, potentially increasing the stability of the grid.

1.2 Objectives

Goals:

- Successfully acquire/calculate data with GPS timestamp
- Deploy PMUs across the country

Functions:

- Sample voltage and calculate phase, frequency, and RMS voltage magnitude with
- GPS timestamp
- Output/save data to a web server
- LEDs to show status of the PMU

Benefits:

- Real- time monitoring the state of the U.S. power grid will enable avoidance of blackouts
- Ability to be deployed world-wide due to cost and size benefits.
- Will assist with higher level PMU research due to its open-box nature

Features:

- Compact size
- Cheaper than current PMUs

- Easy setup
- Data can be observed anywhere with computer access

2 Design

2.1 Block Diagram

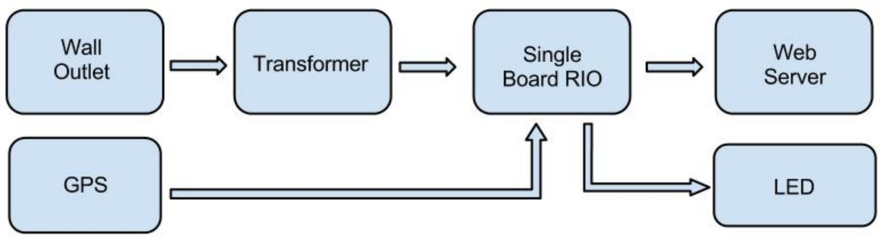

Figure 1: Block Diagram Showing Dataflow

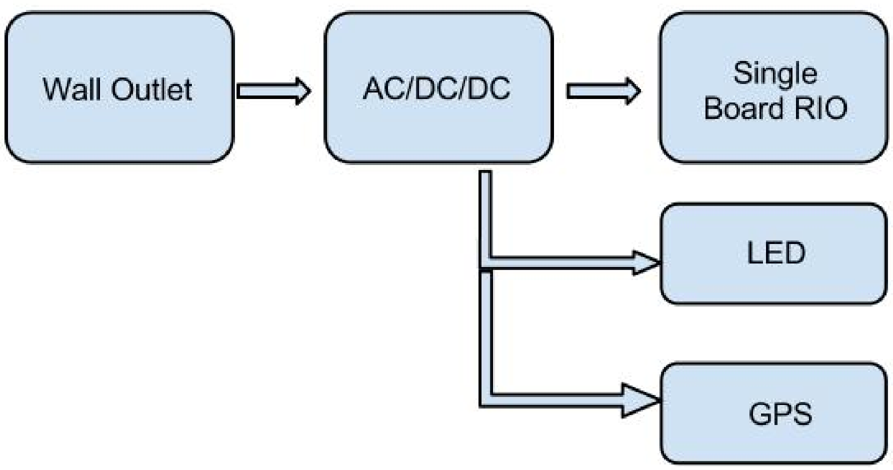

Figure 2: Block Diagram Showing Powerflow

2.2 Block Descriptions

- Wall Outlet:

  Any wall outlet is a viable source of data sampling. It will connect to a transformer via modified NIMA5-15.

- Transformer:

  Transformer will be used to step down the wall voltage to a voltage that can be sampled from the Single Board RIO. Desired transformer will step down 110VRMS to 5VRMS. This will be compatible with the sbRIO specification of -10 to 10V sample range.

- GPS:

  The GPS will output National Maritime Electronics Association (NMEA) GPRMC data sentence, along with a 5V pulse each second. Both data will be inputs to the Single Board RIO.

- Single Board RIO (sbRIO):

  Single Board RIO will take GPS data, GPS pulse, and stepped down wall voltage to calculate RMS value, frequency, and phase with precise timestamp. Waveform of the sampled voltage will also be output.

- LED:

  Two LEDs will show the status of the PMU. If data is correctly being output from the sbRIO, green LED will light up. Otherwise, a red LED will be lit.

- Web Server:

  Data generated from the sbRIO will be uploaded to a web server. This will allow for the data to be observed anywhere.

- AC/DC/DC Converter:

  This block will convert 110VRMS wall voltage to a 10VDC and 5VDC to power the sbRIO, LEDs, and the GPS.

3 Requirements and Verification

3.1 Requirements of Each Block

Block	Requirements	Verification
Transformer	Must step down wall voltage from 120 V RMS to 5 V RMS in order to satisfy the +-10 V analog input of the sbRIO	An oscilloscope will be used to ensure the stepped-down voltage is within the analog input range
GPS	It must accurately generate a square wave with a rising edge at the beginning of each second	The GPS signal will be verified using an oscilloscope
Single Board RIO	The FPGA inside the sbRIO calculates the frequency, voltage magnitude and time stamps it using the GPS signal, transmits data to a web server and controls the output LED	The operation of the sbRIO will be checked on the computer since it is software related
Web Server	Continuously received data from the sbRIO, as long as sbRIO is powered on	Checking the web server will ensure data from sbRIO is correctly stored online
LED	LED is on when data is transmitted to the server	If data is stored on the server, LED must be on
AC/DC/DC	The AC/DC/DC converter uses wall voltage to power the sbRIO, LED, and GPS unit; sbRIO input voltage from converter must be 19-30V DC with a ripple less than 20 mV and maximum input current of 1.8 A; LED voltage must be 4 V DC with current below its maximum rated current; GPS must be powered by 5 V DC	Use an oscilloscope to check that AC/DC/DC outputs are within the required ranges, as stated in the middle column for each component LED current can be limited using a series resistor

3.2 Tolerence Analysis

The National Electrical Code (NEC) says the standard for the wall voltage is 120 V +- 5%. This gives a range of 114 V to 126 V. However, in order to accommodate outliers, we will design our power converter to operate from a voltage source range of 112 V to 128 V. The sbRIO-9632 user guide dictates that the power supply ripple must be less than 20 mV.

Since there is a step down of voltage from the wall outlet to the analog input of the FPGA, an error factor naturally exist. The accuracy of the voltage measurement is essential. However, since the FPGA is accurate up to 6220 μ V at the highest voltage range (-10V to 10V), this would mean that the FPGA can theoretically be accurate up to 0.06% To bring the error factor to low as possible, an Agilent Technologies oscilloscope will be used to make sure that this voltage is accurate up to 0.1%.

4 Cost Analysis

The cost associated with this project is calculated with 1.

$$\Sigma Cost = Labor + Parts \tag{1}$$

First, the necessary components need to be calculated. The components are as follows:

- National Instrument SbRIO 9632 ($940)
- Garmin GPS 18x LVC ($80)
- Power Converter
  - PCB ($70 from retailer or $0 from school)
  - 10 Nichicon Capacitors ($2 each)
  - 2 UC 3843 PWM ($.25 each)
  - Nema 5-15 calbe ($3.50)
  - 10 .5W Resisitors ($.50 each)
  - 3 Inductors ($4 each)

- 2 Transformers ($10 each)

- Case ($20)

Using these components, the total parts cost is $1171.

The other cost associated with the production is labor. Although students working on the project are not paid, a theoretical dream salary and the time spent for development is taken into the cost. This is different from the actual cost of labor for assembly and is much higher. While assuming that the salary of an engineer is $35/hour, taking three engineers 30 hours each, time 2.5, the estimated cost for labor to produce one PMU is $7875.

The total cost of the project is to $9046 to produce one PMU.

4.1 Schedule

The schedule for the project is as follows. Most due dates are due at the end of the week.

Date	Event	Person
Feb 6	Finish proposals.	Everyone
Feb 11	Finish converter calculation	Kenta
	Simulate converter	Bogdan
Feb 18	Try methods for storing data on web server	Andy
	Start building converter	Bogdan, Kenta
Feb 25	Start programming data acquisition/signal processing	Andy
	Test converter	Bogdan,Kenta
Mar 4	Make PCB on Eagle CAD and order	Kenta
Mar 11	Acquire PCB, finalize converter	Bogdan, Kenta
	Finish programming	Andy
Mar 18	Test program with sBRIO.	Andy
	Hookup webserver	Andy, Bogdan, Kenta
Apr 1	Finalize PMU with casing	Andy, Bogdan, Kenta
Apr 8	Debug	Andy, Bogdan, Kenta
Apr 15	Write paper	Andy, Bogdan, Kenta
Apr 22	Demo	Andy, Bogdan, Kenta
Apr 29	Presentation	Andy, Bogdan, Kenta