Initial Project and Group Identification Document

I. Title

Harmonic Analysis for Quality of Service (HAQS)

II. Participants

Group 19 Members:

- Brian Angiel (Electrical Engineering)
- Nick Hellenbrand (Electrical Engineering)
- Louis Hofer (Computer Engineering)
- Kevin White (Electrical Engineering).

Supervisor:
Dr. Chung Yong Chan

Sponsor:
Texas Instruments

III. Project Narrative

A. Motivation

This project was inspired by the need to determine the quality of power provided by power services. An ideal power signal is a perfect 60 Hz sinusoid with no harmonic content to distort it, but these power signals do not occur in real world applications. As nonlinear elements such as diodes and transistors began appearing in modern day electronics, power signals began to contain harmonic distortion as the nonlinear elements draw currents and voltages that are not perfectly sinusoidal.

These distortions cause some of the transferred signal to exist at different harmonic frequencies. The power transferred through these frequencies is unable to be used by most components within electronic devices today, causing some power transferred to be wasted or even damage components in the device. When harmonic distortion is measured, one can determine if the power being paid for is being supplied in a usable amount at the desired 60 Hz frequency and if the outlet is safe to use to power a nonlinear load. These harmonic distortions can also be summed up into what is called the Total Harmonic Distortion (THD), a metric used to evaluate Quality of Service when supplying power.

B. Description

Given such a motivation, this project aims to evaluate the THD of the waveforms provided by common mains power outlets. THD is a ratio of the square root of the sum of the signal’s harmonic amplitudes squared and the amplitude of the first harmonic. Ideally, only the first harmonic has an amplitude; any harmonic amplitude after that should be zero.

The exact equation is given below:

$$THD = \sqrt{\sum_{n=2}^{\infty}\left(\frac{H_n}{H_1}\right)^2} \cdot 100\% ,$$

where H_n is the amplitude of the signal’s harmonics, from the second harmonic to the *n*th harmonic. For our purposes, *n* is fifty one; and the measured value of THD will provide the value by which we quantify the Quality of Service provided by mains power outlets.

The system will calculate the THD by discretizing the output of the power outlet using an analog-to-digital converter and sending the discretized signal to the microcontroller. The microcontroller will use the Fast Fourier Transform to obtain the frequency response and the separate harmonic content of the sampled waveform. The microcontroller will then conduct an analysis of the first fifty-one voltage and current harmonics to calculate the THD. This value will then be displayed on the LCD for the user to view.

The user will be able to use the physical interface to cycle through the harmonic content information to see where the amplitude spikes that cause THD are occurring. The system will also save the information to an SD card to be uploaded to and viewed on a computer at a later time.

C. Existing Products

When researching for meters that perform harmonic analysis, we have found that there are already existing products that are able to perform the task we have set out to accomplish. An exemplary meter that already exists is the AEMC PowerPad® III Model 8333. This AEMC meter is able to measure both single or three phase power THD and measure the current and voltage of the neutral wire present in the three phase wye configuration that would ideally have no voltage. The ability to measure both single or three phase power will make the device versatile enough to measure a three phase power outlet, or the more common single phase power outlet seen almost everywhere inside commercial buildings, and was one of the first design choices that we addressed.

When examining features that were not relevant to power metering, common design choices were seen in many of the meters we researched. Most meters were able to be powered by batteries that were internally rechargeable or replaceable, be powered by an AC adaptor or cable, save data to internal memory, output the saved data through usb or removable media, and generate graphs to visually display the relevant data. We have taken note of these common design choices and have included many of these options in our own design.

The more pertinent feature to our project that we noticed from the various meters is the range of harmonic analysis. The meters that we have seen are designed to measure up to the 50th harmonic of the voltage and current waveforms. Given the design specification from TI, our project's main difference from the other available meters will be to measure and analyze the voltage and current waveforms up to the 51st harmonic.

IV. Constraints

TI has specified that the system must show the harmonic contents of the wall outlet output voltage and current; utilize an analog-to-digital converter and a microcontroller; and display four to six digits on the LCD and the lowest possible current consumption during microcontroller stand-by or microcontroller ALWAYS ON conditions. Furthermore, TI requires that the system pay special attention to the subharmonics (5-10 Hz), as those can be the most problematic.

The system is constrained to measuring output from an operational 60 Hz, 120 VRMS power outlet. The system will not be weatherproof; thus, it is constrained to dry environment conditions.

V. System Requirements

Functionality:

The device shall be compatible with NEMA 5-15 and NEMA 5-20 wall outlets.

The minimum current consumption shall be displayed on the LCD.

The device shall faithfully digitize the analog signal provided by the power outlet under test.

The device shall not let its own power consumption interfere with the QoS calculations.

The device shall compute the Fourier Transform of the discrete signal in order to analyze the harmonic content of the output voltage and current up to the 51st harmonic.

The calculated THD value shall be displayed on an LCD as a percentage.

The device shall display the harmonic content of the AC source on the LCD.

The device shall reliably produce consistent results after repeated usage.

Older data shall not interfere with the current data.

The device should prevent damage to itself in the event of an electrical surge.

The software shall conform to the signature of the selected Fast Fourier Transform library.

The system shall run independent of an operating system.

The system shall save analysis information to removable storage media.

The system shall be capable of three-phase metering analysis.

The system shall utilize safety measures for operation in adverse weather conditions.

Form Factor:

The device shall be light enough to avoid potentially destructive stress while plugged into a wall outlet.

The device shall be sealed to prevent damage caused by sand, dust, and similar particles.

The device shall weigh no more than one pound.

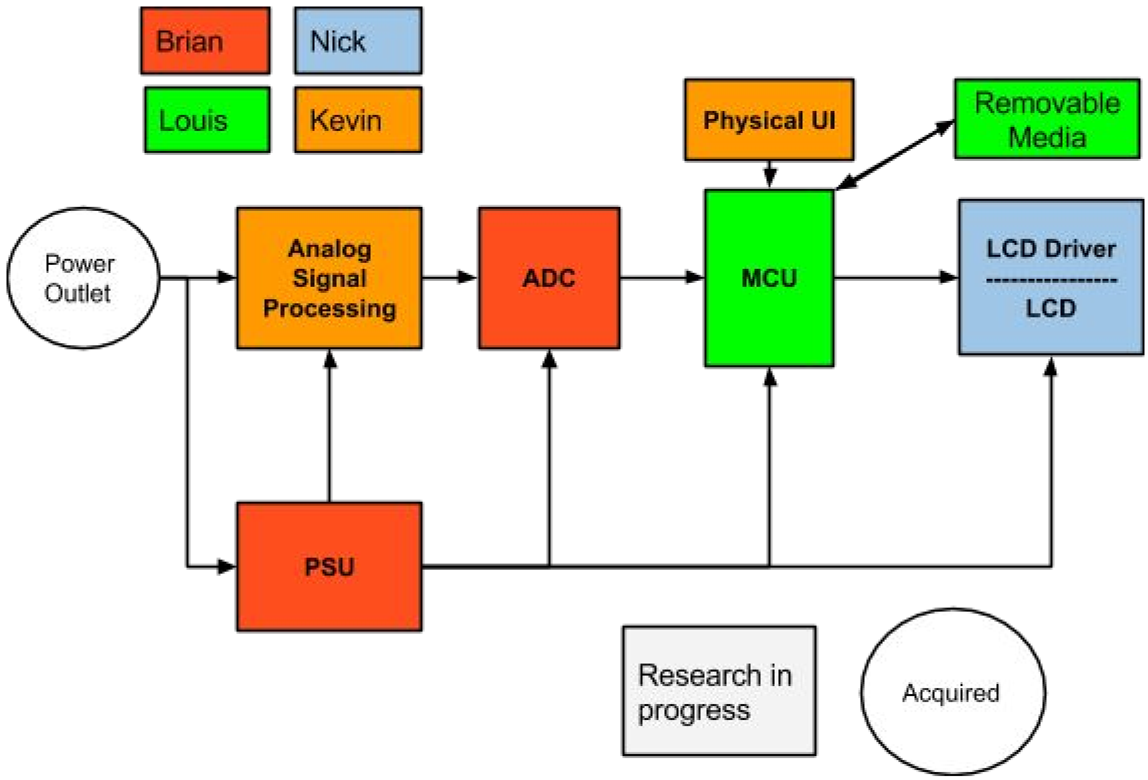
The device shall be no more than 3” deep, 5” wide, and 7” long.

Standards:

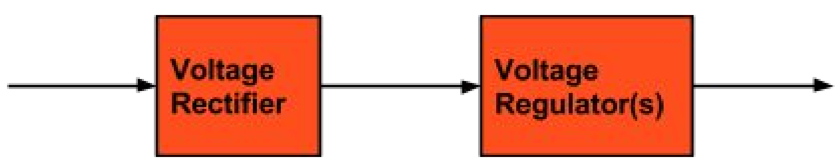
The system shall adhere to IEEE electrical safety standards.

The system shall adhere to ANSI metering standards.

VI. Block Diagrams



PSU Block Diagram



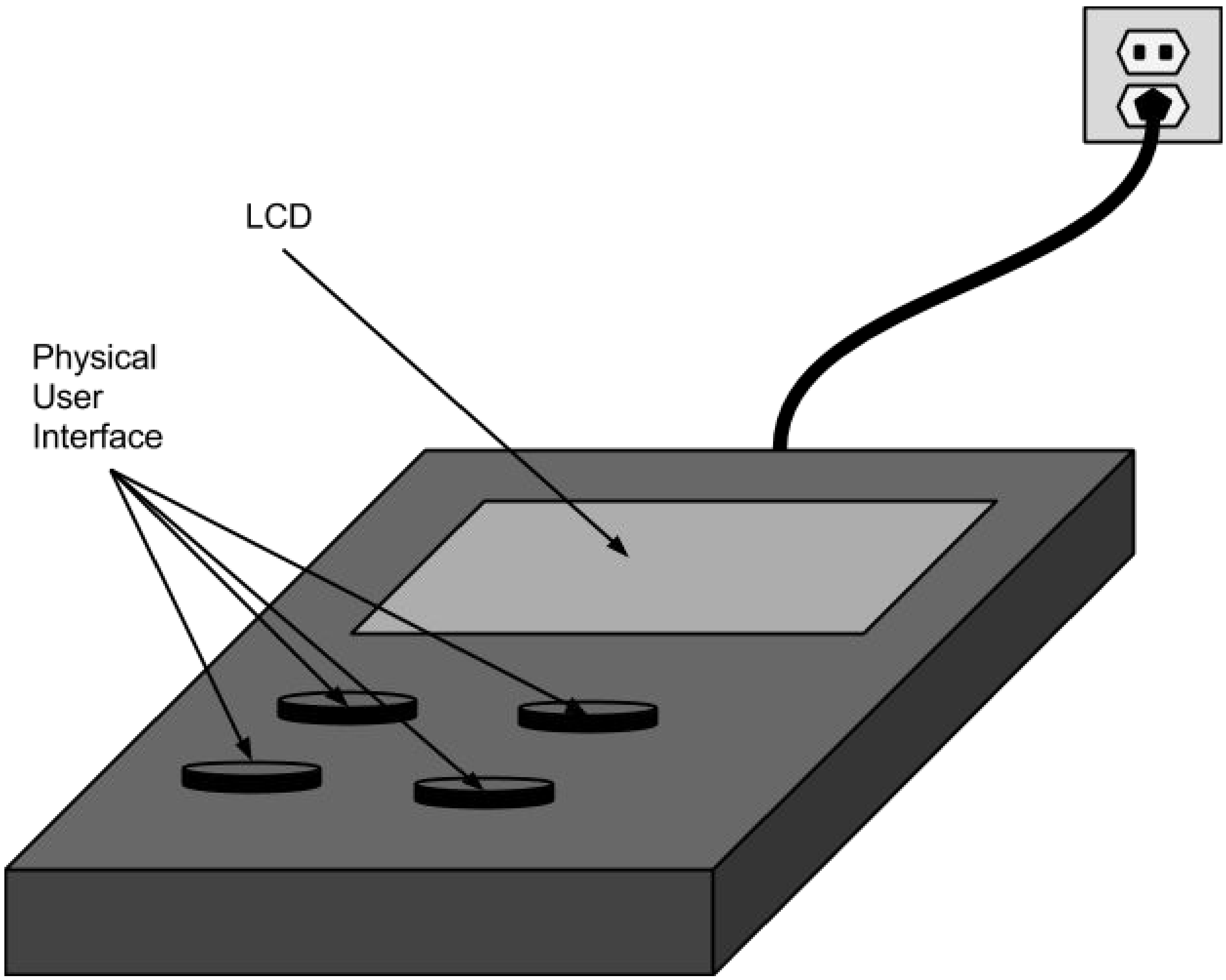
Block Diagram Inputs and Outputs

Block	Input	Output
PSU	AC Voltage	Regulated DC Voltage
Analog Signal Processing	AC Voltages and Currents	Attenuated and filtered AC Voltages and Currents
ADC	Attenuated and filtered AC Voltages and Currents	Digital representation of the AC Voltages and Currents
MCU	Digital representation of the AC Voltages and Currents; UI; PSU	Harmonic information; FFT and QoS data
LCD	Harmonic information	Harmonic spectrum
UI	User Input	Controls
Removable Media	FFT and QoS data to be saved	FFT and QoS data to be read

VII. Block Diagram Acronyms

Acronym	Definition
PSU	Power Supply Unit
ADC	Analog-to-Digital Converter
MCU	Microcontroller
LCD	Liquid Crystal Display
UI	User Interface

VIII. Prototype Model



VIII. Project Budget and Financing

Item	Cost	Financing
Three-Phase Meter TIDM-F6779	$300	TI
Analog-to-Digital Converter ADS131E08	$15	TI
MSP432P401R Launchpad	$13	TI
Microcontroller MSP432P401R	$15	TI
SD Card Launchpad BoosterPack	$10	TBD
LCD Driver	$50	TBD
3.5” LCD NTSC/PAL TFT 3.5” Display	$50	TBD
Various Hardware	$50	TBD
Printed Circuit Board	$40	TBD

IX. Milestones

Week 1-2 -- Form Group
Week 2 -- Finalize Block Diagram, Divide and Conquer [Definition]
Week 3 -- Initial Document Complete

Week 2-6 -- Complete individual research [Research]
Week 9-12 -- Design process [Design]

Week 1 -- Acquire hardware ⇨⇘
Week 2 -- Design and purchase PCBs [Prototype] ⇨ Senior Design II
Week 3-6 -- Complete prototype ⇨⇗
Prototype Revisions -- Depends on the revision [Test] ⇨⇗