DIY Digital AC Watt Meter

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by

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Table of Contents

Introduction .............................................................................................................................................. 3

Abstract .................................................................................................................................................. 3

Problem .................................................................................................................................................. 3

Solution .................................................................................................................................................. 3

**Methodology** ................................................................................................................................... 4

Analog signal Conditioning .................................................................................................................. 5

Inducing Signal Waveforms ................................................................................................................. 5

Precision Rectifiers ............................................................................................................................... 5

PCB Design ............................................................................................................................................ 7

Signal Processing ......................................................................................................................................... 8

Analog to Digital Conversion .................................................................................................................. 8

Interpreting Waveforms ........................................................................................................................ 9

LCD Display .......................................................................................................................................... 9

**Testing and Calibration** .................................................................................................................. 10

Data Observations ............................................................................................................................... 10

Test Data .............................................................................................................................................. 12

Gant Chart ........................................................................................................................................... 14

Budget .................................................................................................................................................. 14

Embellishments ..................................................................................................................................... 15

Conclusion ........................................................................................................................................... 15

Source Code ......................................................................................................................................... 15

Data Sheets ......................................................................................................................................... 20

References .......................................................................................................................................... 22

Table of Figures .................................................................................................................................... 23
Introduction

This manual and the accompanying project are the culmination of my undergraduate education at the University of Cincinnati in Electrical Engineering Technology. I chose to design and produce a practical, useful, digital single phase AC watt meter that can be consistently replicated.

Abstract

As technology advances and mid-high tech devices become more readily available to engineering and technology students as well as hobbyists there is an increasing need for reliable, cost effective test equipment. Digital AC Watt Meters are one of these increasingly useful pieces of equipment. There are currently many models of Digital AC Watt Meters available that have an impressive amount of capability and functionality. These models are expensive, and often have unnecessary capabilities considering the typical applications of undergraduate students and hobbyists. This project arose from the need for an inexpensive, functionally appropriate alternative to currently available Digital AC Watt Meters.

Problem

Currently available Digital AC Watt Meters that work in the 115V, 1-10 amp range are costly, not within the practical price range of electronic enthusiasts and engineering students.

Residential AC Watt Meters are available but they are specially tasked (i.e. Home Energy Monitoring Kits, Measure Power at the Plug, Measure Power of Whole House). These meters do not fit the typical applications of the students or electronic enthusiasts and cannot be configured to devices they were not intended to work with.

There are currently many models of Digital AC Watt Meters available and being used in industrial settings. Most industrial watt meters have three phase measuring capability, advanced functionality and data logging capability. The less expensive versions of these watt meters are permanently installed to their system/application and prices can vary from 200 to 1000 dollars. Being permanently affixed to their application makes them impractical for students, hobbyists and electronics enthusiasts. There are portable versions of industrial watt meters available; however they are cost preventive for most individuals to purchase, ranging in price from 1000 to 3000 dollars.

Solution

The DIY Digital AC Watt Meter is an Arduino Mega 2560 microcontroller controlled system that reads current and voltage in an AC system. It calculates and displays the power, current, voltage and phase of a single phase AC circuit on a Liquid Crystal Display (LCD). The watt meter has been designed with readily available and reasonably low priced components to keep cost down. The watt meter is suitable for use in the rotating machinery lab at the University of Cincinnati as well as a future project for students enrolled in Elements of Applied Design and the Circuits class series. The watt meter has an effective working range of 60 – 140VAC, 0.030 – 3 Amps, 60Hz.
Methodology

The DIY Digital AC Watt Meter consists of three main sections: analog signal conditioning, embedded signal processing and LCD display output. Figure 1.1 (see below) visually details the operation of the DIY Digital AC Watt Meter. Voltage and current representative wave forms are induced from the AC circuit then conditioned and digitally read by the Arduino Mega 2560. The Arduino Mega is programmed to interpret the digital wave forms then calculate and output power, voltage, current and phase of the active AC circuit. The output module of the watt meter is a 5 volt 20 x 4 LCD, based on the HD44780.

![Figure 1.1: DIY Digital AC Watt Meter Flow Chart](image-url)
Analog Signal Conditioning

The front end of the DIY Digital AC Wattmeter accomplishes two tasks; induce voltage and current representative wave forms from the AC circuit and condition those signals to an acceptable voltage level in order to be read by the ADC onboard the Arduino Mega 2560.

**Inducing Signal Waveforms**

Two iron core transformers were are used to induce the current and voltage waveforms. Both transformers primary windings rated at 115v and secondary windings are 6.5v providing a step gain of approximately 18.

The current waveform inducing transformer circuit is connected to the AC circuit via its secondary 6.5v coil across an inline 1/10 ohm power resistor (see figure 1.2). The power resistor induces the current wave form (1mV = 10mAmp). The transformer then provides the current wave signal a gain of 18. The signal is then conditioned by a precision rectifying circuit (see Precision Rectification).

The voltage waveform inducing transformer is connected with its primary coil across the source voltage creating an 18 to 1v scale wave form of the voltage signal (see figure 1.2). The signal is then conditioned by a precision rectifying circuit (see Precision Rectification).

![Figure 1.2: Simplified view of analog signal processing circuit, DC power sources omitted.](image)

**Precision Rectification**

Precision rectifiers are capable of rectifying mille volt signals that would be lost in the 0.7 volt drop of conventional diode rectifiers.

Precision half-wave rectification is implemented after the signal wave forms are induced due to the potentially low current wave signal level (50mV-3Volts). Full wave
rectification is not necessary to accurately model voltage and current waveforms and calculate the power, voltage, current and power factor of the active AC circuit (See Signal Processing).

Gain of the voltage and current signals are set on the precision rectifiers to scale the signal voltages into the acceptable 0 to 5 Volt range of the ADC’s that are used to model waveforms digitally (See Signal Processing). Current wave signal gain is 1. The voltage signal gain is 0.6 to dampen the signal in order to avoid saturating the ADC.

The precision rectifiers are designed around the 741 op amp and provide a +/- 12 volt reference voltage by a DCH010512DN7 dual +/- 12 Volt supply. The DCH010512DN7 is sourced 5v by the Arduino Mega 2560. Figure 1.3 is a schematic of the precision rectification circuitry and its reference voltage supply. (See: Data Sheets for DCH010512DN7 specifications.)
PCB Design

The printed circuit board for the DIY Digital Watt Meter is designed to mate with terminal strips on the top of the Arduino Mega 2560 for a compact modular design. The PCB consists of the precision rectifier circuits based on the 741 op amp and +/- 12 volt reference for the amplifiers. Power is sourced directly from the Arduino board. Figure 1.3 above is the schematic of the PCB design. Figure 1.4 below shows the physical layout of the PCB.

Figure 1.4: PCB Layout
Signal Processing

The properly conditioned signals are read via the Arduino Mega 2560’s onboard ADC’s and stored digital wave forms. Once the voltage and current signals have been converted to digital waveforms, software determines magnitude and phase difference. Power is calculated and displayed via the LCD display with voltage, current and power factor.

Figure 2.1 shows the flow chart of the DIY Digital Watt Meter software. The Arduino Mega 2560 uses a C++ based programing language (See Source Code).

Figure 2.1: DIY Watt Meter Software Flow Chart.

Analog to Digital Converters and Signal Reading

The onboard ADC’s of the Arduino Mega 2560 have an input range of 0 – 5 volts and 10 bits of resolution (4.88 mille volts per step). Two ADC’s are used to sample the waveforms. Every other sample is current/voltage. The sample rate is approximately 240 microseconds per two samples (one voltage wave sample and one current wave sample). The time difference between consecutive samples is negligible. Max error of the phase
margin calculation using this methodology is 0.72%. Therefore, it is negligible for the purposes of the device.

**Interpreting Digital Wave Forms**

The digital wave forms are stored in two arrays. These arrays contain the ADC step values of the wave forms. Arrays are indexed to find the ADC peak step value of voltage and current. These values are converted to their equivalent real current and real voltage value from the AC circuit. This is accomplished by multiplying the ADC step level by the equivalent AC current or voltage level. One current ADC step = .0021 Amps, one voltage ADC step = .1773 volts.

By tracking the number of samples between voltage peak and current peak (sampleDelta) phase difference is determined. There are 73.34 samples taken per 60Hz cycle. With a value for sampleDelta phase margin is calculated using Formula 2.1.

Formula: 2.1 – sampleDelta*(360/73.34) = PhaseMargin(degrees)

Power factor is calculated using the measured value of phase margin. Power is then determined by the product of current magnitude, voltage magnitude and power factor. Values for Power, Power Factor, Voltage and Current are then relayed to and displayed on the LCD display via an 8-bit MPU interphase.

**LCD Display**

The Liquid Cristal Display is the output module of the DIY Digital Watt Meter. The LCD used for the DIY Meter is a 4x20 character display based on the Hitachi HD44780 (See: Data Sheets for Hitachi HD44780 specifications). Figure 2.2 shows the LCD output module of the DIY meter.

![Figure 2.2: LCD Output Module](image-url)
Testing and Calibration

Below figures 3.1 and 3.2 show the test setup for the DIY Digital AC Watt Meter. The DIY meter is connected with the current waveform inducing circuitry connected across the 1/10 Ohm power resistor. The power resistor is connected in line with the load. The voltage waveform inducing transformer is connected across the supply voltage as discussed previously in the analog conditioning section.

Data Observations

The DIY Digital AC Wattmeter functions well with purely resistive loads. The average error for power calculation when compared to the lab watt meter is 3.1%. The current calculation of the DIY meter had an average error of 1.9% on purely resistive loads. The voltage reading
error was consistently less that 0.5%. Power factor calculated relative accurate to 0.98 and error of 2%.

Inductive and capacitive loads had unexpected effect on the current signal path. Below 300 mille volts the current waveform is tracked fairly accurately with an average error of less than 4%. The power factor was also derived relatively accurately; power factor has more significant error that any other component of the system. The estimated power factor comparison is observed on an oscilloscope displaying the current and voltage waveforms as seen below in figure 3.3.

Figure 3.3: Voltage and Current Waveform
Table 1: Test Data

Table 1: DIY Digital Watt Meter - Loaded AC Circuit Test

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power (Watts)</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-meter</td>
<td>V-DIY</td>
<td>I-meter</td>
<td>I-DIY</td>
<td>DIY</td>
</tr>
<tr>
<td>60</td>
<td>60.1</td>
<td>0.174</td>
<td>0.174</td>
<td>0.98</td>
</tr>
<tr>
<td>80</td>
<td>80.1</td>
<td>0.231</td>
<td>0.237</td>
<td>0.98</td>
</tr>
<tr>
<td>100</td>
<td>100.3</td>
<td>0.29</td>
<td>0.296</td>
<td>0.98</td>
</tr>
<tr>
<td>120.6</td>
<td>120.5</td>
<td>0.346</td>
<td>0.359</td>
<td>0.98</td>
</tr>
<tr>
<td>60</td>
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<td></td>
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</tr>
<tr>
<td>100.3</td>
<td>99.99</td>
<td>0.497</td>
<td>0.506</td>
<td>0.98</td>
</tr>
<tr>
<td>120</td>
<td>119.8</td>
<td>0.606</td>
<td>0.6</td>
<td>0.98</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>80</td>
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<td></td>
</tr>
<tr>
<td>120</td>
<td>119.5</td>
<td>1.071</td>
<td>1.041</td>
<td>0.98</td>
</tr>
<tr>
<td>Capacitive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60.2</td>
<td>60.1</td>
<td>0.145</td>
<td>0.151</td>
<td>-0.67</td>
</tr>
<tr>
<td>79.9</td>
<td>79.6</td>
<td>0.193</td>
<td>0.201</td>
<td>-0.67</td>
</tr>
<tr>
<td>100.9</td>
<td>100.5</td>
<td>0.244</td>
<td>0.256</td>
<td>-0.67</td>
</tr>
<tr>
<td>120.4</td>
<td>120</td>
<td>0.292</td>
<td>0.306</td>
<td>-0.7</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100.9</td>
<td>100.5</td>
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<td>-0.14 to -0.05</td>
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<td>0.537</td>
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</tr>
<tr>
<td>Inductive</td>
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<td></td>
</tr>
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<td>99.4</td>
<td>0.226</td>
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<td>0.9</td>
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<tr>
<td>120.2</td>
<td>119.8</td>
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<td>0.298</td>
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<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>100.1</td>
<td>99.8</td>
<td>0.419</td>
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<td>0.45</td>
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<td>120.2</td>
<td>119.8</td>
<td>0.511</td>
<td>0.525</td>
<td>0.5</td>
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</table>

Resistive loads are in series with the L,C loads.
<table>
<thead>
<tr>
<th>Voltage</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power (Watts)</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-meter</td>
<td>V-DIY</td>
<td>I-meter</td>
<td>I-DIY</td>
<td>DIY</td>
</tr>
<tr>
<td>Resistive</td>
<td>60</td>
<td>60.1</td>
<td>0.174</td>
<td>0.174</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>80.1</td>
<td>0.231</td>
<td>0.237</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100.3</td>
<td>0.29</td>
<td>0.296</td>
</tr>
<tr>
<td></td>
<td>120.6</td>
<td>120.5</td>
<td>0.346</td>
<td>0.359</td>
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<tr>
<td></td>
<td>60</td>
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<td>60</td>
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<tr>
<td></td>
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<td>100.3</td>
<td>0.497</td>
<td>0.506</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>119.8</td>
<td>0.606</td>
<td>0.6</td>
</tr>
<tr>
<td>Capacitive</td>
<td>60.2</td>
<td>60.1</td>
<td>0.145</td>
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</tr>
<tr>
<td></td>
<td>79.9</td>
<td>79.6</td>
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<td>100.9</td>
<td>100.5</td>
<td>0.244</td>
<td>0.256</td>
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<td>120.4</td>
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<td>0.292</td>
<td>0.306</td>
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<td>60</td>
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<td></td>
<td>100.9</td>
<td>100.5</td>
<td>0.44</td>
<td>0.449</td>
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<tr>
<td></td>
<td>120.5</td>
<td>120</td>
<td>0.572</td>
<td>0.537</td>
</tr>
<tr>
<td>Inductive</td>
<td>60.1</td>
<td>59.9</td>
<td>0.13</td>
<td>0.144</td>
</tr>
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<td></td>
<td>80</td>
<td>79.7</td>
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<td></td>
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<td>119.8</td>
<td>0.275</td>
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<td>119.8</td>
<td>0.511</td>
<td>0.525</td>
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<tr>
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<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Gant Chart

Figure 4.1 below shows the time line and development process used to create the DIY Digital AC Watt Meter of excellent quality.

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project Approval</td>
<td>1 day</td>
<td>Thu 9/23/10</td>
</tr>
<tr>
<td>2</td>
<td>Final Proposal</td>
<td>52 days</td>
<td>Thu 9/23/10</td>
</tr>
<tr>
<td>3</td>
<td>Research</td>
<td>247 days</td>
<td>Thu 9/14/10</td>
</tr>
<tr>
<td>4</td>
<td>Component Selection/Purchase</td>
<td>26 days</td>
<td>Fri 12/3/10</td>
</tr>
<tr>
<td>5</td>
<td>PCB Design</td>
<td>37 days</td>
<td>Thu 11/18/10</td>
</tr>
<tr>
<td>6</td>
<td>Software Design/Testing</td>
<td>83.5 days</td>
<td>Thu 11/18/10</td>
</tr>
<tr>
<td>7</td>
<td>PCB Population/Testing</td>
<td>27 days</td>
<td>Fri 1/14/11</td>
</tr>
<tr>
<td>8</td>
<td>Demo Day</td>
<td>2 day</td>
<td>Fri 3/28/11</td>
</tr>
<tr>
<td>9</td>
<td>System Testing/Debug</td>
<td>49 days</td>
<td>Mon 1/31/11</td>
</tr>
<tr>
<td>10</td>
<td>Tech Expo Preparation</td>
<td>15 days</td>
<td>Fri 4/15/11</td>
</tr>
</tbody>
</table>

Figure 4.1: Gantt chart for the development and construction of DIY Digital Watt Meter.

Budget

The components required for the DIY Digital AC Watt Meter are estimated in Table 2. It’s reasonable to conclude that a batch of 10 DIY meters could be made for approximately 50 dollars each. Much of the below cost is due to the overly expensive microcontroller and shipping cost.

Table 2: Budget

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Supplier</th>
<th>Cost Per</th>
<th>Qty.</th>
<th>Cost</th>
</tr>
</thead>
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<tr>
<td>C1, C5, C6</td>
<td>4.7uf, 0805</td>
<td>Debco</td>
<td>$0.10</td>
<td>4</td>
<td>$0.40</td>
</tr>
<tr>
<td>C2, C3, C4</td>
<td>0.1uf, 0805</td>
<td>Debco</td>
<td>$0.10</td>
<td>4</td>
<td>$0.40</td>
</tr>
<tr>
<td>D1, D2, D3, D4</td>
<td>1N4001</td>
<td>Debco</td>
<td>$0.40</td>
<td>4</td>
<td>$1.60</td>
</tr>
<tr>
<td>J1</td>
<td>0.1” Header 1x6</td>
<td>Debco</td>
<td>$0.20</td>
<td>1</td>
<td>$0.20</td>
</tr>
<tr>
<td>J2</td>
<td>0.1” Header 1x8</td>
<td>Debco</td>
<td>$0.20</td>
<td>1</td>
<td>$0.20</td>
</tr>
<tr>
<td>J3</td>
<td>0.1” Header 1x2</td>
<td>Debco</td>
<td>$0.20</td>
<td>1</td>
<td>$0.20</td>
</tr>
<tr>
<td>R1, R3, R5, R7</td>
<td>10k pot</td>
<td>Debco</td>
<td>$0.25</td>
<td>4</td>
<td>$1.00</td>
</tr>
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<td>R2</td>
<td>----ohms, 0805</td>
<td>Digikey</td>
<td>$0.40</td>
<td>1</td>
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<td>----ohms, 0805</td>
<td>Digikey</td>
<td>$0.40</td>
<td>1</td>
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<td>----ohms, 0805</td>
<td>Digikey</td>
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<td>1</td>
<td>$0.40</td>
</tr>
<tr>
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<td>Digikey</td>
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<td>LM741</td>
<td>Digikey</td>
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<td>Digikey</td>
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<tr>
<td>PCB Fabrication</td>
<td>PCB Express</td>
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<tr>
<td>LCD</td>
<td>Amazon.com</td>
<td>$20.00</td>
<td>1</td>
<td>$20.00</td>
<td></td>
</tr>
</tbody>
</table>

Total First Run Cost = $161.00
**Embellishments**

The addition of a second stage current waveform ADC would allow the meter to be calibrated to a higher resolution at low current levels and enable the meter to accurately measure a larger range of current (10mA-10Amps). Data logging and data averaging functionality would greatly increase the functionality of the DIY Digital Watt Meter.

**Conclusion**

The DIY Digital AC Watt Meter is an effective, low cost solution to measuring single phase AC power within its operational parameters. While providing a low cost solution for AC power reading, the DIY Digital Watt Meter serves as a reasonably priced, educational DIY project for future students with substantial room for expansion.

**Source Code**

/*  Curtis Dietrich  
**  DIY Digital Watt Meter  
**  Senior Design  
**  Advisor: Professor Stepp  
*/

#include <LiquidCrystal.h>
LiquidCrystal lcd(47, 48, 49, 50, 51, 52, 53);

int backLight = 46;  // pin 46 will control the backlight

int magPassV = 200;
int magPassI = 200;
int magV = 0;
int magCountV = 0;
int magI = 0;
int magCountI = 0;
double power = 0;
double powerFactor;
double phase;
int countDelta;
int adcVolts[255];
int adcCurrent[255];
double voltage;
double current;
double Iess = .0021;
double Vess = .1773;
int hardCodePhase = 45;

void setup() {
    Serial.begin(9600);
pinMode(backLight, OUTPUT);
digitalWrite(backLight, HIGH); // turn backlight on. Replace 'HIGH' with 'LOW' to turn it off.
}

void loop() {
  // Calculates the sampling time delay in microseconds, need to clock the execution time of the
  // sampling loop and subtract that from time delay. Most likely be Negligible.
  // 100 samples per cycle for a 60 hz signal.

  // Next 3 lines neligable micro Ts is
  // convert to int, will be rounded down to nearest microsec, negligible.
  // float ts = 1000000.0*1.0/(60.0*100.0); // =~166us
  // int microDelay = ts;

  // Reading sample values for voltage
  for (int i=0; i < 255; i++){
    adcCurrent[i] = analogRead(A4);
    adcVolts[i] = analogRead(A0);
  }
  // delayMicroseconds(microDelay);
  // delay(1);

  // Finding Magnitude
  magV=0;
  magI=0;
  magCountV = 0;
  magCountI = 0;
  for (int i=0; i < 255; i++){
    if (adcCurrent[i] > magI){
      magI = adcCurrent[i];
      magCountI = i;
    }
    if (magV < adcVolts[i]){  
      magV = adcVolts[i];
      magCountV = i;
    }
  }
  magPassV = magV;
  magPassI = magI;

  // finding phase
  countDelta = abs(magCountI - magCountV);
  while (countDelta > 73){
    countDelta = countDelta - 73;
  }
// Real Phase unconstant setup. WAS DIVEIDED BY 73 NOW 75
phase = countDelta * 360 / 73;

// HardCode Phase Calculation for xxxxxxxxxxxxxxxxx phase hard code
// phase = hardCodePhase;
// POWER

powerFactor = abs(cos( phase / 180 * 3.1459)); // XXXXXXXXXXXXXXXXXX Math
voltage = ( magV * Vess );
current = ( magI * less );

power = voltage * current * powerFactor;

// write adc read values
/*
Serial.println("Volts");

for (int i=0; i < 255; i++){
    Serial.print(adcVolts[i], DEC);
    Serial.println();
}
Serial.println("Current");

for (int i=0; i < 255; i++){
    Serial.print(adcCurrent[i], DEC);
    Serial.print(" ");
    Serial.print(magI);
    Serial.print(" ");
    Serial.print(magV);
    Serial.println();
}
*/

// converting magnitude to real values
// calibrateCountV = calibrateCountV - magCountV;
// calibrateCountI = calibrateCountI - magCountI;

pinMode(backLight, OUTPUT);
digitalWrite(backLight, HIGH); // turn backlight on. Replace 'HIGH' with 'LOW' to turn it off.
lcd.begin(20,4);  // columns, rows. use 16,2 for a 16x2 LCD, etc.
lcd.clear();      // set cursor to column 0, row 0 (the first row)

lcd.setCursor(0,0);
lcd.print("W: ");  // start with a blank screen
lcd.setCursor(4,0);   // set cursor to column 0, row 0 (the first row)
lcd.print(power, DEC);
lcd.setCursor(0,1);
lcd.print("PF: ");  //XXXXXXXX
//  lcd.print("PH: ");          //******
lcd.setCursor(4,1);
//  lcd.print(phase, DEC);      //******
lcd.print(powerFactor, DEC);  //XXXXXXXXx
lcd.setCursor(0,2);
lcd.print("I: ");  // start with a blank screen
lcd.setCursor(3,2);
lcd.print(magPassI, DEC);
lcd.setCursor(10,2);         // set cursor to column 0, row 3
lcd.print(current, DEC);
lcd.setCursor(0,3);

lcd.setCursor(0,0);            // columns, rows. use 16,2 for a 16x2 LCD, etc.
lcd.clear();                  // set cursor to column 0, row 0 (the first row)
lcd.setCursor(0,0);           // start with a blank screen
lcd.setCursor(6,0);           // set cursor to column 0, row 0 (the first row)
lcd.print(power, DEC);       // change this text to whatever you like. keep it clean.
lcd.setCursor(3,1);
lcd.print("PF: ");             // set cursor to column 0, row 3
lcd.setCursor(7,1);
//  lcd.print(phase, DEC);      //******
lcd.print(powerFactor, DEC);
lcd.setCursor(0,2);
lcd.print("I: ");
lcd.setCursor(3,2);
lcd.print(magPassI, DEC);
lcd.setCursor(10,2);         // set cursor to column 0, row 3
lcd.print(current, DEC);
lcd.setCursor(0,3);
lcd.print("V:"); // start with a blank screen
lcd.setCursor(3,3);
lcd.print(magPassV, DEC);
lcd.setCursor(10,3); // set cursor to column 0, row 3
lcd.print(voltage, DEC);
delay(500);
*/
}
LM741
Operational Amplifier

General Description
The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct plug-in replacements for the 769C, LM201, MC1458 and 748 in most applications. The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations. The LM741C is identical to the LM741/LM741A except that the LM741C has its performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Features

Connection Diagrams

Metal Can Package

OFFSET NULL

INVERTING INPUT

NON-INVERTING INPUT

OUTPUT

Note 1: LM741H is available per JUV85/101/01
Order Number LM741H, LM741H/883 (Note 1), LM741AH/883 or LM741CH
See NS Package Number H08C

Ceramic Flatpak

OFFSET NULL

V+

V−

 NC

LM741W

Order Number LM741W/883
See NS Package Number W10A

Dual-In-Line or S.O. Package

OFFSET NULL

INVERTING INPUT

NON-INVERTING INPUT

OUTPUT

Order Number LM741J, LM741J/885, LM741CN
See NS Package Number J08A, M08A or N08E

Typical Application

Offset Nulling Circuit

LM741

OUTPUT

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MINIATURE, 1-W, 3-kV ISOLATED UNREGULATED DC/DC CONVERTERS

FEATURES
- Up To 78% Efficiency
- 3-kVDC Isolation
- UL60950 Certified Product
- Industry Standard Footprint
- JEDEC SIP-7 Package

DESCRIPTION
The DCH01 series is a family of miniature, 1-W, 3-kV isolated DC/DC converters. Featured in an industry standard SIP-7 footprint, the DCH01 series requires minimal external components, reducing board space. The DCH01 series provides both single and dual split-supply outputs.

The use of a highly integrated package design results in highly reliable products with high power densities. High performance and small size makes the DCH01 suitable for a wide range of applications including signal chain applications and ground loop elimination.

APPLICATIONS
- Point-of-Use Power Conversion
- Ground Loop Elimination
- Data Acquisition
- Industrial Control and Instrumentation
- Test Equipment™

Single Output Block Diagram

Dual Output Block Diagram

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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Table of Figures

Figure 1.1: DIY Digital AC Watt Meter Flow Chart ................................................................. 4
Figure 1.2: Simplified view of analog signal processing circuit, DC power sources omitted .... 5
Figure 1.3: Precision Rectifier Circuit – Front End PCB schematic .................................... 6
Figure 1.4: PCB Layout ........................................................................................................... 7
Figure 2.1: DIY Watt Meter Software Flow Chart ................................................................. 8
Figure 2.2: LCD Output Module ........................................................................................... 9
Figure 3.1: Load AC Circuit Test Setup .............................................................................. 10
Figure 3.2: Load AC Circuit Test Setup .............................................................................. 10
Figure 3.3: Voltage and Current Waveform ....................................................................... 11
Figure 4.1: Gantt chart for the development and construction of DIY Digital Watt Meter ..... 14

Table 1: DIY Digital Watt Meter - Loaded AC Circuit Test .................................................. 13
Table 2: Budget .................................................................................................................... 14