ECE Senior Project Status Report

for

Scalable Regulated Three Phase Rectifier

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Project Status Report

Intro

A scalable three phase rectifier was originally designed by Herb Hess and Richard Wall to utilize input AC voltage zero-crossing detection and phase-locked-loop technology to produce a scaled and regulated DC voltage output controlled by means of an embedded microcontroller. This desired output DC voltage magnitude could be specified by means of an up/down switch, selectable by the user. New technologies have been recently developed to increase the accuracy and efficiency of this system. With the obsolescence of the Intel 87C196KD-20 microcontroller, which was included in the original design, brings the need for a newer and more widely-available processor replacement. These newer technologies include an upgrade to a Microchip PIC16C74B microcontroller system, as well as employing new methods for zero-crossing detection as outlined in Richard Wall’s 2003 paper entitled “Simple Methods for Zero Crossing Detection.” A phase locked loop (PLL) implementation in the original processor is used to ensure accurate signal phase attainment. The application of these newer components and techniques is the main purpose of the system design.

Scope

The overall scope of this senior design project has remained virtually the same since its conception. The individual subsystems involved within the entire three phase rectifier system have been broken into three main categories. First is the MATLAB system model that is used to simulate the functions of the phase locked loop implemented within the microcontroller. Next is the design and programming of the new PIC microcontroller to function as the original Intel controller did with added processing power. The implementation and testing of the remaining circuitry hardware components is the final subsystem that will be discussed within the scope section of this report. The design of these subsystems has been carried out in parallel with each other to achieve the primary and secondary objectives of the main project scope.

MATLAB Model

An important aspect of the project that is beneficial to gaining a better understanding the behavior and functioning properties of the software-implemented phase locked loop system is the MATLAB simulation model. It can be used to gain much knowledge regarding how each individual functions of the PLL work together to successfully operate as intended. Accuracy is a main goal of the simulation model, to ensure a thorough software design. A primary objective of the MATLAB simulation model portion of the project is to refine the existing model created in spring 2004 such that it can accurately predict the next possible input voltage zero crossing time period with minimal error and miscalculation. Once the model for the phase locked loop has the ability to carry out this function accurately and reliably will the model be complete and in its most useful state. Secondary objectives of the model include testing for accuracy in comparison to the implemented software PLL such that the actual software algorithm closely matches the constructed simulation model. This would include attempting to “fake” the PLL in several ways to observe its overall stability and ability to correct itself. These objectives together will produce a successful system model.
PIC

The upgrading and retooling of the original three phase rectification microcontroller will continue according to the original plan. A primary objective of the microcontroller design is to have the software algorithm successfully capture an input signal time period (based on detected zero crossings) and fire 6 separate output pulses based on the input signal time period and desired output DC voltage. This is perhaps the most essential element of the software design. Implementation of the phase locked loop capture algorithm within the upgraded processor is another primary objective of the project design. A secondary objective of the processor design includes the incorporation of the user interface (keypad and LCD) as well as the debugging, testing, and prototyping of the microcontroller programming. This process is very important to ensure code that not only functions as intended, but continues to do so under a variety of conditions and user scenarios. The datasheet provided for the PIC microcontroller (see appendix F) is detailed and contains specific data and information regarding programming individual pin functions and precise algorithms provided by the processor manufacturer. This has been very helpful in understanding and utilizing the many features and characteristics that are available for this processor.

HARDWARE

The hardware components have been obtained and are currently undergoing testing for performance and accuracy to ensure a beneficial design. The chosen components were selected based upon efficiency, compatibility, and overall cost. A primary objective in this aspect is to complete the testing of each individual component. For this testing process, all of the critical physical values and attributes necessary in fully understanding the component's function and inherent behavior have been obtained from each device’s respective data sheet, (as seen in the appendix). These values allow the designer to verify that each individual component can successfully attribute to an effective overall system design. The components will initially be assembled on a protoboard from which initial hardware testing can be carried out to ensure a successful network. This protoboard configuration will allow us to gain specific and important information regarding the best possible component locations. This data will be used to develop a printed circuit board (PCB) design, which is a secondary objective of the component aspect of the overall design.
Schedule

Break Down Structures – Major tasks break down into small tasks

Table I. Linear Responsibility Chart

<table>
<thead>
<tr>
<th>Linear Responsibility Chart</th>
<th>Tao</th>
<th>Tyler</th>
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<tbody>
<tr>
<td>Electrical Design</td>
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<td>1</td>
</tr>
<tr>
<td>MATLAB Model</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Test Software</td>
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<td>1</td>
</tr>
<tr>
<td>Test Hardware</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Prototype Test</td>
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<td>1</td>
</tr>
<tr>
<td>Fabrication</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Design Reviews w/ client</td>
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<td>1</td>
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<tr>
<td>Reports</td>
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<td>1</td>
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</tbody>
</table>

Key:
1 = Primary
2 = Support/work
<table>
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<tr>
<th>Task</th>
<th>Planned Duration (days)</th>
<th>Percent of Total</th>
<th>Status (see key)</th>
<th>Credit (days)</th>
</tr>
</thead>
<tbody>
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<td>MATLAB Model</td>
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<td>PIC Implementation</td>
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<td>Fabrication</td>
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<tr>
<td>Test Plan</td>
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<tr>
<td>Execute Test Plan</td>
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<td>19.8%</td>
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</tbody>
</table>

Key: 0 = Not Started, No Credit, 1 = In Process, 1/3 Credit, 2 = Completed, Full Credit

Note: Matlab model and PIC implementation will be worked as parallel process
Budget
As far as the budget stands for this semester, the total cost that will be considered to spend this semester is about $100 dollars. This cost will be used on a printed circuit board device.
Appendix A. Characteristics of LM393 Comparator chip
Part number: LM393MFS-ND
• Power supply voltage: $V_{CC} = \pm 18V$ or 36V
• Supply current: $I_{CC} = 0.6\ mA$ – $2.5\ mA$
• Input voltage: $-0.3\ V$ to $+36\ V$
• Operating Temperature: 0 degree C – 70 degree C

Appendix B. Characteristics of 6 x SCRs
Part number: S4025R
• Rated Current: 25A
• Rated Voltage: 400 V
• Gate Trigger Current: 1mA to 35mA

Appendix C. Characteristics of LCD screen
Part number: ACM1601H Series
• 16 Characters x 1Lines
• 5x7 Dot Matrix Character + Cursor
• HD44780 Equivalent LCD Controller/driver Built-In
• Input voltage: 0V to +5V
• Operating temperature: 0 degree to 50 degree

Appendix D. Characteristics of 4x4 Key Pad
Part Number: 152063
• 9-pin 0.100’ headers
• 4x4 matrix keypad
• Fully sealed snap dome contact
• For indoor or outdoor use
• Contact rating: 24VDC@10mA resistive
• Recommended connector: P/N103190 header and P/N 100765
• size(housing): 4.7”w x 1.7”Hx0.4”T

Appendix E. Characteristics of Microchip PICDEM2
• 18, 28, and 40pin DIP sockets.
• On board +5V regulator for direct input from 9V, 100mA AC/DC wall adapter or hooks for a +5V, 100mA regulated DC supply
• RS-232 socket and associated hardware for direct connection to an RS-232 interface.
• Three push button switches for external stimulus and Reset
• Green power on indicator LED
• Four red LEDs connected to PortB
• Jumper J6 to disconnect LED from PortB
• 4MHz canned crystal oscillator
• 32.768KHz crystal for Timer1 clock operation
• Jumper J7 to disconnect on board RC oscillator
• LCD display
• Prototype area for user hardware
Appendix F. Characteristics of PIC16C74 processor
Microchip PIC16C74B Specifications:

- **Resources:**
  - 4 K x 14 words of Program Memory
  - 192 x 8 bytes of Data Memory (RAM)
  - High performance RISC CPU
  - 22 I/O ports
  - 8-bit timer/counter with 8-bit prescaler
  - 16-bit timer/counter with prescaler
  - DC - 20 MHz clock input
  - PWM max. resolution is 10-bit

- **Electrical Ratings:**
  - Ambient Operating Temperature: -55 deg C to 125 deg C
  - Pin Voltage Range: 0.3 V to +7.5 V
  - Maximum Supply Output Current: 300 mA
  - Maximum Supply Input Current: 250 mA
  - Max Current Sunk by All Ports: 200 mA
  - Power Consumption: < 5 mA @ 5V, 4 MHz
    - 23 mcA typical @ 3V, 32 kHz
  - Typical Standby Current: < 1.2 mcA

Appendix G. Characteristics of 12Vdc Power Supply
Part number: 232PS4

- Input: 120VAC/60Hz
- Output: Unregulated 12VDC@500mA, with Tinned Stripped leads, lead with white tracer (+) positive
- Size: 2.3x2.1x1.6 in (5.9x5.4x4cm)
- 5.5ft(1.5m) cable.

Appendix H. Characteristics of Enerpro FC-AUX60
Part number: Enerpro FC-AUX60

Appendix I. Characteristics of 7805 Voltage Regulator
Part number: LM340T -5.0-ND

- Input Voltage: 7.5V – 20V
- Output Voltage: 4.8V to 5.2
- Output current: < or = 1A
- Vendor: National Semiconductor
- Regulator Type: Linear