Project Title: Porcelain Mug Warmer for Restaurant Chain

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- Dr. Hosni Abu-Mulaweh          Senior Design Advisor
- Dr. Abdullah Eroglu             Senior Design Advisor
- Dr. Carlos Arturo Pomalaza-Ráez Senior Design Coordinator
- IPFW                             Sponsor
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- Karl Furte from White Sell Associates Donator of our development boards
- Dilling Mechanical              Donator of our steel drawer and fan housing unit
Abstract

Our mission was to design a device that would warm porcelain mugs for a large restaurant chain. The objective was to pre-warm these mugs in order to keep a hot liquid beverage warmer for a longer period of time. It was required to design a system that would be easy to install and fit within the restaurant’s current cabinet dimensions. The mugs’ temperature was to be within a target range of 100°F to 135°F and not to exceed 135°F.

Our design illustrated the concept of convection to heat the mugs using a resistive heating element and water-proof fans. A fan housing unit was designed to levitate the fans away from the heating element and act as a support structure for a commercial dishwasher tray. We also implemented a control system that would run our system through a heating or cooling cycle using a temperature sensor. It contained a microcontroller that would send signals to relays that would turn the fans and heating element on or off as needed.

To test our system, we assembled replicas of the cabinet and stainless steel drawer that exist in the current restaurants. Thermal couples were attached to key components of the system that would monitor their temperatures in order to program our microcontroller for the right timing cycles.

The cost for our system was found to be about $228 for one control unit and one heating tray. By separating the key components of the design, it was realized that it would be more cost effective for the consumer by only having have to buy one control unit and only the number of heating drawers desired.

Our recommendations would be to find better fans that could handle a higher temperature, find a better sealing rubber door to retain heat longer, use the restaurant’s actual mugs and cabinet to give more representative test results, develop a circuit board to replace the microcontroller development kit and perform more testing scenarios that would better fine tune the unit.
Section I. Detailed Description of the Selected Conceptual Design
Mechanical Design

The final design used the concept of forced convection. A resistive heating element was used in series with a fan to pull the heat from the heating element and onto the mugs. The idea was to package two separate components: a control system and a heating drawer unit. The heating drawer unit would consist of the stainless steel drawer already used in the restaurant. The only modification to this drawer was to add a handle to the front so that when the unit was on, employees would have a way to subtract mugs from the dishwasher tray without burning their hands. The resistive heating element would be attached to the steel drawer using an adhesive recommended by the manufacturer.

![Diagram of the drawer unit to be installed in the restaurant's cabinet.](image)

The heating drawer unit would also contain a fan housing unit. The housing unit was designed in order to levitate the four fans away from the heating element and provide a means to support the dishwasher tray. It was decided to use the same stainless steel used to make the drawers since it would resist corrosion from the wet dishwasher tray and mugs. The fan housing unit needed to be high enough off of the stainless steel drawer in order to allow air flow for the fans. This was accomplished by designing angled pieces that would act as legs. Smaller angled bracket placed in the corners of the unit were designed to hold the dishwasher tray in place so it wouldn’t slide around while opening and closing the steel drawer. A rendering for the housing unit is illustrated in Figure 1.

The idea behind the heating drawer unit was for the restaurant’s owner to replace their current stainless steel drawer with this heating drawer unit. It would have a wiring harness connection to simply attach it to the control box.
An electronic control box was developed to house the electronics outside of the cabinet. It was thought that the electronics would fare better in the ambient air of the restaurant than inside the warm cabinet air. The control box would be a place to mount the rocker on/off switch, the 10 amp fuse and the three LEDs. Since the design had to be easy to install, it was designed so that all the drawers would be wired to one electronic control box using wiring harness connectors. This would require the restaurant owner to attach the box to the bottom front lip of the cabinet, as shown in Figure 2, using screws. About a 1” hole would have to be drilled into the bottom front lip in order to connect the female connector of the wiring harness for the heating drawer unit to the male connector of the electronic control box.
Electrical Design

Table 1, below, shows the components used in the design and their corresponding model number. Spec sheets and AutoCAD drawings can be found in Appendices.

<table>
<thead>
<tr>
<th>Component</th>
<th>Distributor</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistive Element</td>
<td>McMaster-Carr</td>
<td>35765K153</td>
</tr>
<tr>
<td>Fan</td>
<td>Mouser Electronics</td>
<td>664AQ0912HBA70GL-LF</td>
</tr>
<tr>
<td>Rectifier</td>
<td>Mean Well Electronics</td>
<td>709D60A</td>
</tr>
<tr>
<td>Solid State Relay for Fans</td>
<td>Mouser Electronics</td>
<td>769-AQZ102</td>
</tr>
<tr>
<td>Solid State Relay for Heating</td>
<td>Mouser Electronics</td>
<td>558-PF240D25</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>Silicon Labs</td>
<td>C8051F340DK</td>
</tr>
<tr>
<td>Red LED</td>
<td>Mouser Electronics</td>
<td>645-558-0101-007F</td>
</tr>
<tr>
<td>Green LED</td>
<td>Mouser Electronics</td>
<td>645-558-0201-007F</td>
</tr>
<tr>
<td>Yellow LED</td>
<td>Mouser Electronics</td>
<td>645-558-0301-007F</td>
</tr>
</tbody>
</table>

*The rocker switch, the 10 amp fuse, the power cord and the temp sensor were donated and not enough is known of them to include them in the table.

The electrical system not only provides power but also controls the temperature of the system through a control cycle. The final components of the system consist of the component list above in Table 1. The components have been picked based off the power requirements needed to be supplied to the system. The system will also run through a cycle that will monitor temperature and turn on or turn off the system accordingly.

**Rectifier**

The rectifier, which converts alternating current to direct current, has a 56 W power rating and features dual voltage outputs at 12 V and 5 V. The dual outputs were a design decision based on the two voltages required by the components in the system. The rectifier is capable of providing a max of 4 A for the 5 V source and 3 A for the 12 V source.

**Heating Element**

The heating element was a 360 Watt 12’x12’ waterproof sheet that was powered by an alternating current.

**Fan Assembly**

The fan assembly will consist of four water-proof fans that will be wired in parallel. Each fan runs at 12V, 0.25A, and 3W. Each fan is capable of 53.5 CFM at a maximum rpm of 2900 with a noise level of 35dB. The fans were picked based on how much air was required to flow to the mugs to sufficiently heat them through convection to the desired temperature.
Solid State Relays

The first solid state relay was to be used for cycling the fans on and off. The turn on voltage was 1.5 to 5 volts and the pass through voltage is 12 volts. The second relay was used for cycling the heating element on and off. This relay had a turn on voltage of 3 to 15 volts and a pass through voltage of up to 265 volts alternating current.

Microcontroller

The microcontroller that will be used in the control circuit is the C8051F340DK. The microcontroller runs off 2.7 V- 5.4V power. This particular microcontroller has 40 I/O pin layout with 16 bit architecture, 64K ROM, and 4K RAM.

LEDs

The LEDs are to inform the employees when the unit is in its heating or cooling cycle and if a failure has occurred with the temp sensor. The yellow LED will inform that the system is heating. The green LED will inform that the mugs are in the desired target range and the system is in its cooling cycle. The red LED will inform that the temp sensor has had some form of a failure, i.e. damaged or unplugged.

Temp Sensor

The temp sensor will be mounted in the system to monitor the temperature of the mugs and relay data to the microcontroller. This data will be interpreted by the microcontroller and will turn on or off the system accordingly.
Figure 3. Schematic of control circuit
Section II. Prototype Building Process
Mechanical Design

A test cabinet was the first to be built. It was made out of medium-density fiberboard. The dimensions for the cabinet came from the restaurant’s current cabinet that would hold two stainless steel drawers. The team built the cabinet with fiberboard, screws and wood glue. A hole was drilled in the front bottom of the cabinet to bring the wires from the control box into the cabinet. A hole was also drilled into the back of the cabinet to pull the power cord through.

![Figure 4. Test cabinet with electrical housing box and sliders](image)

The stainless steel drawer was produced by Dilling Mechanical. The AutoCAD file that was sent to us by the restaurant was sent to Dilling and was fabricated to those specifications and dimensions.

![Figure 5. Stainless Steel Drawer with resistive heating element attached.](image)

The fan housing unit was also produced by Dilling Mechanical. An AutoCAD file was sent to their fabrication shop where they cut, drilled, bent and welded the steel to our specifications. For the initial design sent for fabrication, it was discovered that the fans were spaced too far away from the resistive heating element and did not permit the majority of the heat to be carried away from the heating element. A second design was created that brought the fans on top of the four corners of the heating element. This allowed the fans to transfer more of the heat produced by the heating element on to the mugs.
The steel drawers in the restaurant have sliders that are specially created for the drawer to sit on. Since we couldn’t replicate or buy these sliders for a reasonable price, regular drawer sliders were bought at Lowes and were installed onto the inside of the cabinet. The steel drawer was eventually just placed on top of the sliders since the slide mechanism of the slider couldn’t be retrofitted to the drawer because of the thickness of the steel.

A handle was attached to the front of the steel drawer by drilling the stainless steel with a specialized drill bit for steel and using gear oil to cool the bit as we drilled.

**Electrical Design**

The first step in the design was to place the heating element on the drawer. The fans were then mounted to the fan housing unit. Cable clips by 3M were used to route the wires away from the heating element for safety. The wires for the heating element and fans were wired to a quick disconnect connector to make installation easier for the restaurant.

A plastic electrical box was used to mount the electrical components. This box was mounted on the lower front edge of the cabinet due to concerns about the heat from the resistive element affecting the other components. An on/off switch, 10 amp fuse, and the LEDs were mounted to the front of the box.

The rectifier was mounted inside the electrical box using 3M Velcro strips. The fans, heating element and microcontroller were then wired to the rectifier.
The microcontroller and development kit were mounted inside the box opposite of the rectifier. The solid state relays, the LEDs, and the temperature sensor circuit were wired to the development board.

![Microcontroller development board with rectifier and LEDs.](image)

The temperature sensor was mounted above one of the fans on the fan housing unit. The sensor was wired to a voltage divider circuit which was then wired to the development board.

After all the components were mounted and connected a program was developed to control the circuit. The program was designed to read the analog voltage from the voltage divider circuit and based on that voltage either heat the mugs or shut the system off. As a backup, in case of a temperature sensor failure, the program would switch to a timer based control. The timing control would start in order to heat the mugs and would alert the user with the red LED. The system would still work with the backup timing control and heat the mugs to the proper temperature range. The red LED would indicate the unit needed to be serviced as soon as possible. The system is still safe to use when in timing control but the mugs might be a few degrees warmer or cooler than with temperature control.
Section III. Testing
Since the unit was to be temperature controlled, several places needed to be tested in order to find the most ideal place to attach the temperature sensor. It was decided to place the thermal couples in four different locations. Two were to monitor the temperature of the mugs and two were placed in order to find the ideal location for the temperature sensor. Since the mugs are set upside down in the dishwasher tray in order to be washed, the area that would receive most of the heat is the inside of the mug. Thus, it was determined to place the thermal couples on the mug to the inside bottom. The team decided that the warmest mug would be in the center of the dishwasher tray and the coolest mug would be on the perimeter of the tray by the door opening. Thus, a thermal couple was placed on a mug in the center of the tray and one was placed on a mug to the front of the cabinet. This would help set the time required to reach our upper and lower bounds of our temperature range. The two other locations were one above a fan in the air flow and one taped to the inside of the cabinet towards the back. The idea was to find a place that would most represent the T_inf used in our mathematical model used last semester. The thermal couple above the fans was also used to monitor the temperature that they operated at. Since the fans could only handle 150°F, it was decided that the temperature of the mugs couldn’t go much above 120°F to give us some leeway for the fans.

In order to monitor all of the thermal couples used, it was decided to use a DAQ board with a Labview program that would automatically take measurements for us. The Labview program was setup up to do four tasks:

1) Take measurements from the thermal couples
2) Write this data to a text file
3) Show the data as it comes in on a waveform
4) Show the numeric value for the mug in the middle

A screen shot of the program is shown in Figure 9.
A test procedure was established for using the DAQ board and the thermal couples.

1. Plug in the unit.
2. Make sure that the rubber door is hanging down covering the front of the cabinet.
3. Open “Senior Design.vi” on the desktop. This program will take temperature readings for the Middle Mug, the Outside Mug, Air Temp Above Fans and Temp Inside Cabinet every half second. A waveform graph is represented on the front panel to monitor the temperatures.
4. Hold down the “Ctrl” button and the “E” button at the same time. This will bring up the block diagram window.
5. Right click on the “DAQ assistant” block and select “properties” from the list.
6. Select “connection diagram” above the graph.
7. Connect the labeled thermal couples to the correct channels as shown in the connection diagram.
8. Hit “ok” when finished.
9. Hit the “run” button in the front panel. The program will ask you your desired name and location for the .lvm data file.
10. Turn on the unit using the green power button.
11. Allow the unit to run through as many cycles as you choose.
12. Hit the “stop” button on the front panel when finished.
13. Turn off the unit using the green power button.
14. Unplug the unit.
The testing was performed two different times. Each test was done with the maximum allowed number of mugs in a single dishwasher tray which is 24. Also, the entire system’s temperature started from ambient which was found to be about 20°C (68°F).

The first test was performed with no door or cover added to the front of the cabinet. This was done to see how the unit worked during the worst possible situation. Figure 10 shows the data collected for the test run. The data shows an initial heating cycle with a cooling cycle.

![Figure 10. Data for one heating and one cooling cycle without a door.](image)

From the data, it was shown that the mugs’ temperature barely made it over the lower bound of the target range.

The second test was performed with a rubber door added to the front of the cabinet. Figure 11 shows the data collected. It shows an initial heating cycle with 2 cooling and 2 reheat cycles.
It showed that the initial heating cycle to reach 120°F took about 30 minutes. The time it took to reach 100°F from cooling by natural convection took about 48 minutes and the time it took to reheat back to 120°F took 13 minutes.

It was noticed that the temperature increase we witnessed in the mugs varied linearly with time. Further, it was noticed that the surrounding air appeared to be increasing with time as well. These findings prompted a review of our initial analytical model which was based on lumped capacitance transient heat conduction. For a mug, the equation for this model was stated as:

\[ T = T_\infty - (T_\infty - T_i) \cdot e^{\left(\frac{-t}{\tau}\right)} \]  

EQ 1

where \( T \) was the instantaneous temperature of the mug, \( T_\infty \) was the surrounding air temperature, \( t \) was time, \( T_i \) was the initial temperature of the mug and \( \tau \) was equal to the equation:

\[ \tau = \frac{\rho V C_p}{h A_s} \]  

EQ 2

where \( \rho \) was the density of the mug, \( V \) was the volume of the mug, \( C_p \) was the specific heat of the mug, \( h \) was the heat transfer coefficient and \( A_s \) was the surface area of the mug. The use of this model assumed a constant surrounding temperature (\( T_\infty \)). However, we witnessed a varying surrounding temperature. Therefore, it was decided to modify our lumped capacitance spreadsheet, which calculated the temperature at a discrete time. The spreadsheet was modified such that the surrounding temperature witnessed during the experiment could be entered at a given time, \( t \). For comparison purposes, the data collected from the experiment was first plotted and then the revised analytical
model was plotted on the same graph, see Figure 12. From the plot of these two lines, it was found that
the analytical model could be further modified by changing the heat transfer coefficient, $h$. Unlike other
models, it is intended that our heat transfer coefficient encompasses other effects not explicitly
provided for in the model (e.g. radiation). Ultimately, it was determined that by varying the surrounding
temperature with time and using an $h = 7 \text{ W/m}^2\text{K}$, the analytical model coincided with the results
found from testing.

Figure 12. Shows the analytical data from our model plotted against the experimental data of the initial heating cycle

$y = 0.016x + 18.03$

$R^2 = 0.994$
Section IV. Evaluation and Recommendations
Cost Analysis

Below, the table shows the cost analysis for building the entire system.

Table 2. Cost Analysis for our Prototype

<table>
<thead>
<tr>
<th>Component</th>
<th>Distributor/Donator</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistive Heating Element</td>
<td>McMaster-Carr</td>
<td>59.29</td>
</tr>
<tr>
<td>Rectifier</td>
<td>Mean Well</td>
<td>43.48</td>
</tr>
<tr>
<td>Four Fans</td>
<td>Mouser Electronics</td>
<td>54.00</td>
</tr>
<tr>
<td>Fan Assembly</td>
<td>Dilling</td>
<td>Donated</td>
</tr>
<tr>
<td>Steel Drawer</td>
<td>Dilling</td>
<td>Donated</td>
</tr>
<tr>
<td>Microcontroller Kit</td>
<td>Silicon Labs</td>
<td>Donated</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>IPFW</td>
<td>Donated</td>
</tr>
<tr>
<td>Relay for Fans</td>
<td>Mouser Electronics</td>
<td>8.49</td>
</tr>
<tr>
<td>Relay for Heating Element</td>
<td>Mouser Electronics</td>
<td>20.01</td>
</tr>
<tr>
<td>3 LEDs</td>
<td>Mouser Electronics</td>
<td>4.08</td>
</tr>
<tr>
<td>Rocker Switch</td>
<td>Meister Cook</td>
<td>Donated</td>
</tr>
<tr>
<td>Power Cord</td>
<td>Meister Cook</td>
<td>Donated</td>
</tr>
<tr>
<td>10 amp Fuse</td>
<td>Meister Cook</td>
<td>Donated</td>
</tr>
<tr>
<td>Plastic Electronic Box</td>
<td>RadioShack</td>
<td>8.00</td>
</tr>
<tr>
<td>Handle for Drawer</td>
<td>Lowes</td>
<td>4.00</td>
</tr>
<tr>
<td>MDF</td>
<td>Lowes</td>
<td>45.98</td>
</tr>
<tr>
<td>Drawer Sliders</td>
<td>Lowes</td>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td>$260.27</td>
</tr>
</tbody>
</table>
The cost analysis for building a unit to be implemented in the restaurant is shown in the table below.

Table 3. Cost for one production prototype

<table>
<thead>
<tr>
<th>Component</th>
<th>Distributor</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistive Heating Element</td>
<td>McMaster-Carr</td>
<td>59.29</td>
</tr>
<tr>
<td>Rectifier</td>
<td>Mean Well</td>
<td>43.48</td>
</tr>
<tr>
<td>Four Fans</td>
<td>Mouser Electronics</td>
<td>54.00</td>
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<tr>
<td>Fan Assembly</td>
<td>Dilling</td>
<td>70.17</td>
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<tr>
<td>Microcontroller</td>
<td>Silicon Labs</td>
<td>4.00</td>
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<tr>
<td>Temperature Sensor</td>
<td>Mouser Electronics</td>
<td>0.50</td>
</tr>
<tr>
<td>Relay for Fans</td>
<td>Mouser Electronics</td>
<td>8.49</td>
</tr>
<tr>
<td>Relay for Heating Element</td>
<td>Mouser Electronics</td>
<td>20.01</td>
</tr>
<tr>
<td>3 LEDs</td>
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<td>Rocker Switch</td>
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<td>Power Cord</td>
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<tr>
<td>10 amp Fuse</td>
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<td>2.80</td>
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<tr>
<td>Circuit Board</td>
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</tr>
<tr>
<td>Plastic Electronic Box</td>
<td>RadioShack</td>
<td>8.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$301.27</strong></td>
</tr>
</tbody>
</table>

In the problem statement, it was declared that the mass production cost of a unit would need to be $250. But since we decided not to package the control system and the drawer unit together, this cost could be adjusted. The table below shows the cost analysis of one control system and one drawer unit.

Table 4. Production cost of 100 quantities of one control system and one drawer unit

<table>
<thead>
<tr>
<th>Component</th>
<th>Distributor</th>
<th>Cost</th>
</tr>
</thead>
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<tr>
<td>Resistive Heating Element</td>
<td>McMaster-Carr</td>
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<tr>
<td>Rectifier</td>
<td>Mean Well</td>
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<tr>
<td>Four Fans</td>
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<tr>
<td>Fan Assembly</td>
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<tr>
<td>Microcontroller</td>
<td>Silicon Labs</td>
<td>2.00</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>Mouser Electronics</td>
<td>0.20</td>
</tr>
<tr>
<td>Relay for Fans</td>
<td>Mouser Electronics</td>
<td>6.17</td>
</tr>
<tr>
<td>Relay for Heating Element</td>
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</tr>
<tr>
<td>3 LEDs</td>
<td>Mouser Electronics</td>
<td>2.76</td>
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<tr>
<td>Rocker Switch</td>
<td>Mouser Electronics</td>
<td>0.50</td>
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<tr>
<td>Power Cord</td>
<td>Mouser Electronics</td>
<td>4.07</td>
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<tr>
<td>10 amp Fuse</td>
<td>Mouser Electronics</td>
<td>1.59</td>
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<tr>
<td>Circuit Board</td>
<td>--</td>
<td>10.00</td>
</tr>
<tr>
<td>Plastic Electronic Box</td>
<td>RadioShack</td>
<td>5.60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$228.33</strong></td>
</tr>
</tbody>
</table>
Most restaurants would need two drawer units. The cost to add another drawer unit would be $177.03 if 100 quantities were produced. This means if the restaurant was considering buying 2 drawer units and 1 control unit, the total cost would be about $395. That’s $105 cheaper than our budget from the problem statement for two complete drawer units. These costs would also continue to decline if more units were to be produced than just 100.

Recommendations

There are some recommendations that the team would like to make. One would be to find better fans that would be able to handle the temperature to reach the upper bound of the target range. Maybe use metal fans that are still water resistant, but would fit in the budget. Another recommendation would be to use a better sealing door. This would help eliminate any warm air escaping to the restaurant environment. That may allow the unit to retain heat for longer and help reduce the cost for electricity. A third recommendation would be to use the actual mugs and cabinet that the restaurant currently uses. This would give more representative data of what would happen in the actual unit’s environment. Another recommendation would be to develop a circuit board for the system to replace the microcontroller development board. The last recommendation would be to complete more testing scenarios that would better fine tune the system. One scenario could be just testing one mug in the dishwasher tray or half a tray of mugs. This could give a better understanding of how the system would work as mugs were subtracted from the dishwasher tray. Another scenario could be preheating the system and then adding the mugs to see how much heat is lost to the surroundings. That could lead to maybe using different materials for the fan housing unit that could resist the heat but not retain it as much.
Conclusion

In conclusion, we felt that the design produced is a good first prototype restaurant quality product. Our final design used force air convection to preheat the mugs to a desired temperature range. Our system contained two parts: a control box and a heating drawer unit. The control box has the capacity to electronically control up to three heating drawer units that would allow the consumer versatility in the products that they could choose. This would lower the cost to the consumer and make it more affordable. We were able to implement our final design with few modifications. We also were able to test our system using thermal couples and LabVIEW. With varying T_inf in our lumped capacitance transient heat conduction model from last semester, we were able to show that our analytical model compared fairly to our test data. Through cost analysis, we were able to show that our design was under budget. Additionally, it was shown that our design met all of our requirements stated in our problem statement by not exceeding the upper bound of our temperature target range, being easy to install, and utilizing a control system to cycle the system on and off without user interference. With further testing and refinement, we feel the design would be a great product to introduce into the market.
References

<http://www.engineeringtoolbox.com/ceramics-properties-d_1227.html#bottom>


Appendices

Appendix A. AutoCAD Drawings for Cabinet, Steel Drawer and Fan Housing Unit

Cabinet Drawing
Steel Drawer Drawing

Fan Housing Drawing

Please drill holes as indicated and attach tabs to top of assembly.
### Appendix B. Data Sheets for Electrical Components

#### Rectifier

**60W Dual Output Switching Power Supply**

**D-60 Series**

**Features:**
- Universal AC input/Full range
- Protections: Short circuit/Over load/Over voltage
- Cooling by free air convection
- LED indicator for power on
- Fixed switching frequency at 54KHz
- 5 years warranty

#### Specification

<table>
<thead>
<tr>
<th>Model</th>
<th>D-60A</th>
<th>D-60B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Number</td>
<td>CH1</td>
<td>CH2</td>
</tr>
<tr>
<td>DC Voltage</td>
<td>5V</td>
<td>12V</td>
</tr>
<tr>
<td>Rated Current</td>
<td>4A</td>
<td>3A</td>
</tr>
<tr>
<td>Current Range</td>
<td>0.3 - 4A</td>
<td>0.2 - 4A</td>
</tr>
<tr>
<td>Rated Power</td>
<td>58W</td>
<td>58W</td>
</tr>
<tr>
<td>Ripple &amp; Noise (max.)</td>
<td>75mV/µp</td>
<td>150mV/µp</td>
</tr>
<tr>
<td>Voltage Adj. Range</td>
<td>CH1: 4.75 - 5.5V</td>
<td>CH1: 4.75 - 5.5V</td>
</tr>
<tr>
<td>Voltage Tolerance</td>
<td>±2.0%</td>
<td>±2.0%</td>
</tr>
<tr>
<td>Line Regulation</td>
<td>±0.5%</td>
<td>±0.5%</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>±0.5%</td>
<td>±0.5%</td>
</tr>
<tr>
<td>Setup, Rise Time</td>
<td>300µs, 30ms/230VAC</td>
<td>80ms, 50µs/115VAC at full load</td>
</tr>
<tr>
<td>Hold Time (Typ.)</td>
<td>60ms/230VAC</td>
<td>10ms/115VAC at full load</td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Range</td>
<td>55 - 265VAC</td>
<td>120 - 370VAC</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>47 - 63Hz</td>
<td>1%</td>
</tr>
<tr>
<td>Efficiency (Typ.)</td>
<td>73%</td>
<td>10%</td>
</tr>
<tr>
<td>AC Current (Typ.)</td>
<td>2A/115VAC</td>
<td>1A/230VAC</td>
</tr>
<tr>
<td>Input Current (Typ.)</td>
<td>C/O</td>
<td>O.C.</td>
</tr>
<tr>
<td>Leakage Current</td>
<td>&lt;3.5mA</td>
<td>240VAC</td>
</tr>
<tr>
<td><strong>Protection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over Load</td>
<td>105 ± 150% rated output power</td>
<td></td>
</tr>
<tr>
<td>Over Voltage</td>
<td>5V: ±5 ± 6.75V</td>
<td></td>
</tr>
<tr>
<td>Over Protection</td>
<td>Hiccup mode, recovers automatically after fault condition is removed.</td>
<td></td>
</tr>
<tr>
<td>Protection Type</td>
<td>Hiccup mode, recovers automatically after fault condition is removed.</td>
<td></td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working Temp.</td>
<td>-10 ~ +60°C (Refer to output load derating curve)</td>
<td></td>
</tr>
<tr>
<td>Working Humidity</td>
<td>20 ~ 95% RH non-condensing</td>
<td></td>
</tr>
<tr>
<td>Storage Temp.</td>
<td>-25 ~ 55°C, 10 ~ 95% RH</td>
<td></td>
</tr>
<tr>
<td>Temp. Coefficient</td>
<td>&lt;0.03%/°C (0 ~ 121°C)</td>
<td>&lt;0.04%/°C (0 ~ 121°C)</td>
</tr>
<tr>
<td>Vibration</td>
<td>10 ~ 55Hz, 2G, 5mm/100ms, each along X, Y, Z axes</td>
<td></td>
</tr>
<tr>
<td><strong>Safety &amp; EMC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UL, CE, CB, FCC, VDE, TRON, SEMKO, and CE Marking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety Standards</td>
<td>UL1012, UL60950, TUV EN60950 Approved</td>
<td></td>
</tr>
<tr>
<td>Wriststand Voltage</td>
<td>IP: OIP: 3kVAC</td>
<td>IP: OIP: 3kVAC</td>
</tr>
<tr>
<td>Isolation Resistance</td>
<td>IP: OIP: 100MΩ, 2000VDC</td>
<td></td>
</tr>
<tr>
<td>Compliance to</td>
<td>EN60022 Classes B, C, D, E, F, G, H, I, J, K, L</td>
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</tr>
<tr>
<td>Harmonic Current</td>
<td>HICM-3-2-3</td>
<td></td>
</tr>
<tr>
<td>EMS Immunity</td>
<td>Compliance to EN61000-4-2, 3, 4, 5, 6, 8, 11, ENV10204, ENV10204, Light industry level, criteria A</td>
<td></td>
</tr>
<tr>
<td>MTBF</td>
<td>301,2ks hrs min.</td>
<td></td>
</tr>
<tr>
<td>OTHERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimension</td>
<td>139 x 70 x 56mm (L x W x H)</td>
<td></td>
</tr>
<tr>
<td>Packing</td>
<td>0.94kg, 24pc ± 13.5kg, 75CUFT</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
1. All parameters not specifically mentioned are measured at 230VAC input, rated load, and 25°C, at ambient temperature.
2. Ripple and noise are measured at 300kHz of bandwidth by using a 12" tested pair wire terminated with a 1µF & 47µF parallel capacitor.
3. Tolerance includes set-up tolerance, line regulation, and load regulation.
4. The power supply is considered a component which will be installed into a final equipment. The final equipment must be re-certified that it still meets EMC directives.
Fans

All Products » Thermal Management » Fans & Blowers » AQ0912HB-A70GL-LF

Mouser Part #: 664-AQ0912HBA70GL-LF
Manufacturer Part #: AQ0912HB-A70GL-LF
Manufacturer: ADDA
Description: Fans & Blowers 92mm 12VDC 52.5CFM

Specifications

Manufacturer: ADDA
Product Category: Fans & Blowers
RoHS: Details
Current Type: DC
Supply Voltage: 12 V
Airflow: 53.5 CFM
Bearing Type: Ball
Noise: 35 dBA
Speed: 2900 RPM
Frame Dimensions (mm): 92 mm x 25 mm
Termination Style: Wire Leads
Power Rating: 3 W
Relay for Fans

Panasonic ideas for life

Slim type with high capacity up to 4A
DC load type also available

PhotoMOS Relays
Power 1 Form A
(AQZ100, 200)

FEATURES
1. Slim SIL4-pin package
(W) 3.5 x (D) 21.0 x (H) 12.5 mm
The compact size of the 4-pin SIL package allows high density mounting.
2. Extremely low on-resistance
3. Control low-level signal
Power Photo MOS relays feature extremely low closed-circuit offset voltage to enable control of low-level analog signals without distortion.
4. Low-level off state leakage current
of max. 10 μA
5. High I/O isolation voltage of 2,500 V
6. Eliminates the need for a counter electromotive protection diode in the drive circuit on the input side
7. Eliminates the need for a power supply to drive the power MOSFET
8. No restriction on mounting direction
9. Low thermoelectromotive force
10. Neither noise nor arcing at contact
11. Sockets are also available (PA1a-PS, PA1s-PS-H)
12. Can be installed on the RT-3 relay terminal (Power PhotoMOS relay type)

TYPICAL APPLICATIONS
• Railroad system, traffic signals
• Measuring instruments
• Industrial machines

Compliance with RoHS Directive

TYPES
1. DC type

<table>
<thead>
<tr>
<th>Output rating*</th>
<th>Package</th>
<th>Part No.</th>
<th>Packing quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load voltage</td>
<td>Load current</td>
<td></td>
<td>inner carton</td>
</tr>
<tr>
<td>60 V</td>
<td>2.6 A</td>
<td>AQZ7105</td>
<td>25 pcs.</td>
</tr>
<tr>
<td>200 V</td>
<td>1.3 A</td>
<td>AQZ7107</td>
<td></td>
</tr>
<tr>
<td>400 V</td>
<td>0.7 A</td>
<td>AQZ7108</td>
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</table>

* Load voltage and current of DC type: DC

2. AC/DC type

<table>
<thead>
<tr>
<th>Output rating*</th>
<th>Package</th>
<th>Part No.</th>
<th>Packing quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load voltage</td>
<td>Load current</td>
<td></td>
<td>inner carton</td>
</tr>
<tr>
<td>60 V</td>
<td>3.0 A</td>
<td>AQZ2102</td>
<td>25 pcs.</td>
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<tr>
<td>120 V</td>
<td>2.0 A</td>
<td>AQZ2103</td>
<td></td>
</tr>
<tr>
<td>200 V</td>
<td>1.0 A</td>
<td>AQZ2104</td>
<td></td>
</tr>
<tr>
<td>400 V</td>
<td>0.5 A</td>
<td>AQZ2105</td>
<td></td>
</tr>
</tbody>
</table>

* Load voltage and current of AC/DC type: AC/DC

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Relay for Heating Element

PF Series

- SIP SSR
- Ratings to 25A (forced air) @ 480 VAC
- SCR output for heavy industrial loads
- AC or DC control
- Zero-crossing (resistive loads) or random-fire (inductive loads) output

PRODUCT SELECTION

<table>
<thead>
<tr>
<th>Control Voltage</th>
<th>2EA</th>
<th>2EA</th>
<th>2EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-15 VDC</td>
<td>PF12400A2</td>
<td>PF12400B2</td>
<td>PF12000A2</td>
</tr>
<tr>
<td>12-30 VDC</td>
<td>PF12400A2</td>
<td>PF12400B2</td>
<td>PF12000A2</td>
</tr>
<tr>
<td>24-48 VAC</td>
<td>PF12400A2</td>
<td>PF12400B2</td>
<td>PF12000A2</td>
</tr>
<tr>
<td>48-96 VAC</td>
<td>PF12400A2</td>
<td>PF12400B2</td>
<td>PF12000A2</td>
</tr>
</tbody>
</table>

AVAILABLE OPTIONS

<table>
<thead>
<tr>
<th>Series</th>
<th>Control Voltage Range</th>
<th>Operating Voltage</th>
<th>Control Rating</th>
<th>Output Type</th>
<th>Ventilation</th>
<th>Output Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF</td>
<td>9-32 VDC (DC Control)</td>
<td>28V 48-120 VAC</td>
<td>15-32 A</td>
<td>25 A</td>
<td>Forced Air</td>
<td>10 A</td>
</tr>
<tr>
<td>E</td>
<td>9-32 VDC (DC Control)</td>
<td>28V 48-120 VAC</td>
<td>15-32 A</td>
<td>25 A</td>
<td>Forced Air</td>
<td>10 A</td>
</tr>
<tr>
<td>240</td>
<td>18-32 VDC (AC Control)</td>
<td>28V 48-120 VAC</td>
<td>15-32 A</td>
<td>25 A</td>
<td>Forced Air</td>
<td>10 A</td>
</tr>
<tr>
<td>D</td>
<td>18-32 VDC (AC Control)</td>
<td>28V 48-120 VAC</td>
<td>15-32 A</td>
<td>25 A</td>
<td>Forced Air</td>
<td>10 A</td>
</tr>
<tr>
<td>25</td>
<td>18-32 VDC (AC Control)</td>
<td>28V 48-120 VAC</td>
<td>15-32 A</td>
<td>25 A</td>
<td>Forced Air</td>
<td>10 A</td>
</tr>
<tr>
<td>R</td>
<td>18-32 VDC (AC Control)</td>
<td>28V 48-120 VAC</td>
<td>15-32 A</td>
<td>25 A</td>
<td>Forced Air</td>
<td>10 A</td>
</tr>
<tr>
<td>-B</td>
<td>18-32 VDC (AC Control)</td>
<td>28V 48-120 VAC</td>
<td>15-32 A</td>
<td>25 A</td>
<td>Forced Air</td>
<td>10 A</td>
</tr>
</tbody>
</table>

OUTPUT SPECIFICATIONS (1)

<table>
<thead>
<tr>
<th>Description</th>
<th>2EA</th>
<th>2EA</th>
<th>2EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage (V)</td>
<td>12 VDC</td>
<td>12 VDC</td>
<td>12 VDC</td>
</tr>
<tr>
<td>Temperature Derating (K)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Minimum On-State Current (2)(3)</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Maximum Surge Current (3)(4)</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Maximum Continuous Current (3)(4)</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Maximum Rated Output Power (W)</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

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Microcontroller

1. System Overview

C8051F340/1/2/3/4/5/6/7/8/9/A/B/C/D devices are fully integrated mixed-signal System-on-a-Chip MCUs. Highlighted features are listed below. Refer to Table 1.1 for specific product feature selection.

- High-speed pipelined 8051-compatible microcontroller core (up to 48 MIPS)
- In-system, full-speed, non-intrusive debug interface (on-chip)
- Universal Serial Bus (USB) Function Controller with eight flexible endpoint pipes, integrated receiver, and 1 kB FIFO RAM
- Supply Voltage Regulator
- True 10-bit 200 kspS differential / single-ended ADC with analog multiplexer
- On-chip Voltage Reference and Temperature Sensor
- On-chip Voltage Comparators (2)
- Precision internal calibrated 12 MHz internal oscillator and 4x clock multiplier
- Internal low-frequency oscillator for additional power savings
- Up to 64 kB of on-chip Flash memory
- Up to 4352 Bytes of on-chip RAM (256 + 4 kB)
- External Memory Interface (EMIF) available on 48-pin versions.
- SMBus/I2C, up to 2 UARTs, and Enhanced SPI serial interfaces implemented in hardware
- Four general-purpose 16-bit timers
- Programmable Counter/Timer Array (PCA) with five capture/compare modules and Watchdog Timer function
- On-chip Power-On Reset, \( V_{DD} \) Monitor, and Missing Clock Detector
- Up to 40 Port I/O (5 V tolerant)

With on-chip Power-On Reset, \( V_{DD} \) monitor, Voltage Regulator, Watchdog Timer, and clock oscillator, C8051F340/1/2/3/4/5/6/7/8/9/A/B/C/D devices are truly stand-alone System-on-a-Chip solutions. The Flash memory can be reprogrammed in-circuit, providing non-volatile data storage, and also allowing field upgrades of the 8051 firmware. User software has complete control of all peripherals, and may individually shut down any or all peripherals for power savings.

The on-chip Silicon Labs 2-Wire (C2) Development Interface allows non-intrusive (uses no on-chip resources), full speed, in-circuit debugging using the production MCU installed in the final application. This debug logic supports inspection and modification of memory and registers, setting breakpoints, single stepping, run and halt commands. All analog and digital peripherals are fully functional while debugging using C2. The two C2 interface pins can be shared with user functions, allowing in-system debugging without occupying package pins.

Each device is specified for 2.7–5.25 V operation over the industrial temperature range (−40 to +85 °C). For voltages above 3.6 V, the on-chip Voltage Regulator must be used. A minimum of 3.0 V is required for USB communication. The Port I/O and RST pins are tolerant of input signals up to 5 V. C8051F340/1/2/3/4/5/6/7/8/9/A/B/C/D devices are available in 48-pin TQFP, 32-pin LGFP, or 32-pin QFN packages. See Table 1.1, “Product Selection Guide,” on page 18 for feature and package choices.
### 3mm LED Panel Mount Indicator

**.156" Mounting Hole, Snap In Mounting**

**Dialight 558 Series**

**Characteristics:**
- Available with a variety of LEDs
- Designed for quick, positive insertions in panel from .787mm [.031] through 1.57mm [.062]. Black Recommended hole size from 3.36mm [.132] to 4.01mm [.158].
- Wire: 26 AWG
- Front panel mounting
- Uniform illumination
- Snap-in mounting requires no additional hardware
- IC compatible
- Housing meets UL94V-0
- High reliability: 100,000 hour life
- Black housing enhances LED contrast
- Straight terminals suitable for wire wrapping

**Custom Capabilities:**
Connectors and terminals can be added to wire leads

---

**Typical Operating Characteristics (T_{a}=25°C)**

| Part Number | Color | Termination Options | I [Peak Wavelength (nm)] | Zr (Ω) | R | F [R] | V [V] | Min. Reverse | Viewing Angle | Max. Forward | Temperature (°C) |
|-------------|-------|---------------------|--------------------------|-------|---|------|-----|----------|-------------|-------------|--------------|----------------|
| SB-30155-00 | R     | Straight Terminals | 660                      | 10    | 10| 2    | 3   | 9        | 45          | 20          | 250/85       | -55/100/-30 / 100 |
| SB-30155-00 | G     | Straight Terminals | 583                      | 16    | 10| 2.1  | 3   | 9        | 45          | 25          | 250/85       | -55/100/-30 / 100 |
| SB-30155-00 | Y     | Straight Terminals | 585                      | 8.3   | 10| 2.1  | 3   | 9        | 45          | 25          | 250/85       | -55/100/-30 / 100 |
| SB-30155-00 | D     | Straight Terminals | 584                      | 8.5   | 10| 2.2  | 3   | 9        | 45          | 25          | 250/85       | -55/100/-30 / 100 |

**Ultra Bright, Water Clear LED**

| Part Number | Color | Termination Options | I [Peak Wavelength (nm)] | Zr (Ω) | R | F [R] | V [V] | Min. Reverse | Viewing Angle | Max. Forward | Temperature (°C) |
|-------------|-------|---------------------|--------------------------|-------|---|------|-----|----------|-------------|-------------|--------------|----------------|
| SB-30205-00 | G     | Straight Terminals | 565                      | 35    | 10| 2.1  | 2.8 | 5       | 45          | 30          | -55/100       | -55/100       |
| SB-30205-00 | A     | Straight Terminals | 664                      | 200   | 10| 1.6  | 2.4 | 5       | 45          | 50          | -40/100       | -55/100       |
| SB-30205-00 | R     | Straight Terminals | 660                      | 110   | 10| 1.8  | 2.4 | 4       | 45          | 40          | -55/100       | -55/100       |

**Low Current, 2mA LED**

| Part Number | Color | Termination Options | I [Peak Wavelength (nm)] | Zr (Ω) | R | F [R] | V [V] | Min. Reverse | Viewing Angle | Max. Forward | Temperature (°C) |
|-------------|-------|---------------------|--------------------------|-------|---|------|-----|----------|-------------|-------------|--------------|----------------|
| SB-30205-00 | R     | Straight Terminals | 636                      | 18    | 2 | 1.8  | 2.2 | 5       | 50          | 7           | -55/100       | -45/100       |
| SB-30205-00 | Y     | Straight Terminals | 583                      | 16    | 2 | 1.9  | 2.7 | 5       | 50          | 7           | -55/100       | -45/100       |
| SB-30205-00 | G     | Straight Terminals | 585                      | 16    | 2 | 1.9  | 2.7 | 5       | 50          | 7           | -55/100       | -45/100       |

**Color Codes:**
- R: Red
- G: Green
- Y: Yellow
- D: Orange
- A: Amber

**Part Number Ordering Code:**
- R: Red
- G: Green
- Y: Yellow
- D: Orange
- A: Amber

Dialight Corporation • 1551 State Route 34 • Farmingdale, NJ 07727 • TEL: (732) 919-3191 • FAX: (732) 751-5779 • www.dialight.com

---

34
Appendix C. Microcontroller Code

//-------------------------------------------------------------------------------
// SeniorDesign.c
//-------------------------------------------------------------------------------

#include <c8051f340.h> // SFR declarations

//-----------------------------------------------------------------------------
// 16-bit SFR Definitions for 'F34x
//-------------------------------------------------------------------------------
sfr16 TMR2RL = 0xca; // Timer2 reload value
sfr16 TMR2 = 0xcc; // Timer2 counter
sfr16 ADC0 = 0xbd;

//-----------------------------------------------------------------------------
// Global Constants
//-------------------------------------------------------------------------------
#define SYSCLK 12000000 / 8 // SYSCLK frequency in Hz
#define BLINK_RATE 10 // Timer2 Interrupts per second
#define FIRST_ON 30 // Minutes heating up on first run
#define TIME_ON 13 // Minutes heating on other runs
#define TIME_OFF 48 // Minutes cooling on other runs

int SEC = 0;
int FIRST = 1;
int FAIL = 0;
int HEAT = 1;

sbit LED1 = P2^2; // LED='1' means ON
sbit LED2 = P2^3; // LED='1' means ON

//-----------------------------------------------------------------------------
// Function Prototypes
//-------------------------------------------------------------------------------

void OSCILLATOR_Init (void);
void PORT_Init (void);
void ADC0_Init(void);
void Timer2_Init (int counts);
void Timer2_ISR (void);
void main (void)
{
    PCA0MD &= ~0x40;  // WDTE = 0 (clear watchdog timer
    // enable)

    OSCILLATOR_Init ();  // Initialize system clock
    PORT_Init ();  // Initialize crossbar and GPIO
    ADC0_Init();  // Initialize ACDC0

    Timer2_Init (SYSCLK / 12);  // Init Timer2 to generate
    // interrupts at a 10Hz rate.

    EA = 1;  // Enable global interrupts

    LED1=1;
    LED2=1;
    P3MDOUT = 0x50;  // Turn on yellow LED

    ADC0CN |= 0x10;

    while (1) {}  // Spin forever
}

// Initialization Subroutines
//--

void OSCILLATOR_Init (void) { OSCICN = 0x80;  // Configure internal oscillator for
    // its lowest frequency
}

void PORT_Init (void) {
    // This function configures the crossbar and GPIO ports.

}
XBR0 = 0x00;  // No digital peripherals selected
XBR1 = 0x40;  // Enable crossbar and weak pull-ups
P2MDOUT = 0x0C;  // Enable LED as a push-pull output
P1MDIN = 0xFB;  // Set P1.2 to analog
P1SKIP = 0x02;  // Skip P1.2 with the crossbar

void ADC0_Init (void)
{
    ADC0CN = 0x40;  // ADC0 disabled, normal tracking,
    // conversion triggered on TMR2 overflow

    AMX0P = 0x14;  // ADC0 positive input = P1.2
    AMX0N = 0x1F;  // ADC0 negative input = GND
    // i.e., single ended mode

    ADC0CF = ((SYSCLK/3000000)-1)<<3;  // set sar clock to 3 MHz

    ADC0CF |= 0x00;  // right-justify results

    EIE1 |= 0x08;  // enable ADC0 conversion complete int.

    AD0EN = 1;  // enable ADC0
}

//-----------------------------------------------------------------------------
// Timer2_Init
//-----------------------------------------------------------------------------
void Timer2_Init (int counts)
{
    TMR2CN = 0x00;  // Stop Timer2; Clear TF2;
    // Use SYSCLK/12 as timebase
    CKCON &= ~0x60;  // Timer2 clocked based on T2XCLK;

    TMR2RL = -counts;  // Init reload values
    TMR2 = 0xffff;  // Set to reload immediately
    ET2 = 1;  // Enable Timer2 interrupts
    TR2 = 1;  // Start Timer2
}

//-----------------------------------------------------------------------------
// Interrupt Service Routines
//-----------------------------------------------------------------------------

//-----------------------------------------------------------------------------
// Timer2_ISR
//-----------------------------------------------------------------------------
void Timer2_ISR (void) interrupt 5
{
    TF2H = 0;  // Clear Timer2 interrupt flag
    SEC++;     
    if(FAIL=1){
        if(FIRST==0&&LED1==1&&SEC==TIME_ON*127)
            P3MDOUT = 0x48;  // Green LED on
            LED1 = 0;       // LED1 off
            LED2 = 0;       // LED2 off
            SEC = 0;        // Reset counter
        }
        if(FIRST==0&&LED1==0&&SEC==TIME_OFF*127)
            P3MDOUT = 0x50;  // Yellow LED on
            LED1 = 1;
            LED2 = 1;
            SEC = 0;
    }
    if(FIRST==1&&SEC==FIRST_ON*127)
            P3MDOUT = 0x48;  // Green LED on
            LED1 = 0;
            LED2 = 0;
            SEC = 0;
            FIRST = 0;
    }
}

void ADC0_ISR (void) interrupt 10
{
    static unsigned long voltage = 0;

    AD0INT = 0;

    voltage += ADC0;

    if(voltage<10||voltage>1013){
        FAIL = 1;
        P3MDOUT |= 0x20;  // Red LED on
    }
    else{
        FAIL = 0;
        P3MDOUT &= ~0x20;  // Red LED off
    }
}
if(FAIL == 0){
    if(HEAT == 1){
        if(voltage <= 222){ // If Max Temp Reached
            P3MDOUT |= 0x08; // Green LED on
            P3MDOUT &= ~0x10; // Yellow LED off
            LED1 = 0; // LED1 off
            LED2 = 0; // LED2 off
            HEAT = 0; // Start cooling
        }
    }
    else{ // If Cooling Down
        if(voltage >= 368){ // If Min Temp Reached
            P3MDOUT |= 0x50; // Yellow LED on
            P3MDOUT &= ~0x0C; // Green LED off
            LED1 = 1; // LED1 on
            LED2 = 1; // LED2 on
            HEAT = 1; // Start heating
        }
    }
}

voltage = 0;
ADC0CN |= 0x10;

//-----------------------------------------------------------------------------
// End Of File
//-----------------------------------------------------------------------------