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ECE 388

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**Results**:

Although each criteria of the UAT was met, the results of the demonstration were still interesting, as there were still obstacles to a perfect session.

The ten tests conducted during the demo were the same ten outlined in the UAT: 6.1 through 6.6 and 6.7a through 6.7d. They consisted of the ten main functions of the climate control and room occupancy system as a whole, with corresponding electrical measurements where applicable. All of the tests (save for 6.1), required direct user input; the tests were conducted and interpreted according to the UAT Scope, so some leeway was given when necessary, and some tests were not conducted. The UAT Scope states that the temperature of the system can be controlled with the UI (that being the up and down buttons on the system board), the room occupancy count is a rough estimate, and a light will shine indicating an occupancy threshold. Out of scope measurements and modifications for the project were the adjustment of temperature outside the given range (that being 10°C and 30°C), changing the humidity of the closed environment, modifying the voltage regulator in any way, and ensuring perfect room occupancy count (a much more robust and expensive system would be required for perfect accuracy).

Test 6.1: “Voltage and current input is 12V, 1A while outputs are 5V, 200mA.” This test was conducted with a multimeter, and the result of the test was that the input from the DC jack was 12V, 1A (as per the DC jack specifications), and the output from the VRM was 5V, 200mA. An incorrect value here could cause the microcontroller or other devices to malfunction or sustain damage, and cannot be changed by the user, as per the UAT Scope.

Test 6.2: “Desk lamp is provided with a maximum of 363mA when the relay is activated.” This was the first test that required user input. When any occupancy is reached, the desk lamp would turn on. This would mean that two wall sockets would be required for the demonstration, but thankfully, even when the relay isn’t switching to a device, it will still give an audible click. This meant that the desk lamp did not have to be connected to the system. When the occupancy count reached one, the relay for the lamp clicked, indicating the lamp would shine if it were connected. Because the lamp was not connected during the demonstration, current was not measured. However, further testing indicates that the current supplied to the lamp was 363mA. This test is also related to tests 6.7a-6.7d.

Test 6.3: “Heater is provided with a maximum of 1.55A on the low setting, 2.27A on the high setting.” This required the user to increase the set temperature to a setting above the current temperature. At this point, the heater, already set to either high or low, would run until the desired temperature is met. This was controlled by the relay again, so it was feasible to have the heater disconnected from the system and listen for the click, but the heater was important for other, more general tests. Because of this, the heater was indeed used and measured during the demo. The current supplied on low was 1.55A, and when switched to high, 2.27A was supplied. This test is also related to test 6.5.

Test 6.4: “MOSFET triggers the fan load with logic signal. (High for on, Low for off). Fans are provided with at most 250mA.” This required the user to decrease the set temperature to a setting below the current temperature. As described by the expected results of the UAT Test Cases, the two fans were controlled by a MOSFET instead of a relay. The specification for one fan is that it would draw 250mA, but as two were used, the current supplied to the two fans should be 500mA. When the fans were activated, the current draw of the two combined was 500mA, measured with a multimeter. This test is also related to test 6.6.

Test 6.5: “The UI will instantly update the set temperature value accordingly to the number of presses from the user. The heating relay will activate and power on the personal heater (Defaulted to the low setting). The relay will deactivate once the set temperature is matched with the currently read temperature.” This test focused on the user directly interfacing the system, and ensuring that the temperature is increased by the correct amount. It required correct interfacing between the button, microcontroller, and display, and kept in mind the set temperature’s given upper bound of 30°C. Given a button press, the set temperature increased by one, and subsequent presses would do the same, indicating proper incrementation. This was backed up with the system’s interfacing with the heater, which indeed turned on when the set temperature exceeded the room temperature, and turned off when the set temperature met or fell below the room temperature.

Test 6.6: “The UI will instantly update the set temperature value accordingly to the number of presses from the user. The cooling fan will be activated and will terminate when the currently measured temperature matches the set value.” This test was very similar to test 6.5, in that it ensured proper interfacing with the UI, but this time the down button was tested, and in a similar way. It once again kept in the set temperatures given bounds, this time the lower bound of 10°C was considered. On a button press, the set temperature decreased by one, and subsequent presses would continue to decrement the setting according to the amount of presses. This was backed up by the system’s interfacing with the two fans, which indeed turned on when the set temperature fell below the room temperature, and turned off when the set temperature met or exceeded the set temperature.

Test 6.7a: “IR sensors will trigger, indicating entrance. Light relay will activate and power the desk lamp.” This test focused on the proper functioning of the IR sensors, and the relationship between the sensors, the light, and the display. For the purposes of the demonstration, the humidity reading was replaced with the room count. The reason for this is because the four measurements that are possible (current temperature, set temperature, humidity, and room count) cannot all be displayed on-screen at once; there is not enough space on the display for all four values. Because of the size of the test environment, hands were waved in the desired direction to simulate an entity entering or exiting; toward the center of the room indicated entrance, away from the center indicated exit. In this case, an entrance was simulated, and the sensors detected this, incremented the count, and activated the relay (if the lamp was connected, it would turn on at this point).

Test 6.7b: “IR sensors will trigger. MAX LED is enabled.” When an excess of entities enters the environment, the LED on the project board labelled “MAX LED” would shine, indicating this excess. For the demonstration, the maximum of entities was three, as it would be an easy value to reach. Of course, this value could be easily reprogrammed. As this test follows 6.7a, the procedure was similar, except instead of simulating just one entity, the goal was to simulate three or more. After three entities were simulated, counted by the display and by the tester, MAX LED indeed lit up, indicating such excess.

Test 6.7c: “IR sensors will trigger. MAX LED is disabled.” When the count of entities in the environment is reduced below the threshold, the previously lit MAX LED would subsequently shut off. This test was conducted in the same way as Test 6.7b, except it simulated entities leaving the environment, rather than entering, and implies the success of 6.7b. After 6.7 was tested and confirmed to be functional, the exit of the entities were simulated, decrementing the count accordingly. When the count fell below the threshold, MAX LED turned off.

Test 6.7d: “Light relay is disabled. Desk Lamp will turn off.” This test is similar to that of 6.7a, except instead of simulating the first entity entering the environment, this test simulated the last entity leaving the environment. In this test, the final exit should trigger the lamp to shut off. The lamp was not connected to the system, so the proper deactivation of the relay was considered instead. The exits of the entities were simulated such that there would be zero in the environment, and the relay shut off, indicating that the lamp would also had it been connected to the system.

With the results of each test case considered, there were still some minor faults regarding an error-free operation of the product. One issue that occurred was the proper updating of the display to reflect the measurements and settings to be shown. Occasionally, the LCD would display gibberish (sometimes mixed in with the measurements) when any of the three values were updated, requiring a system reset. This was also possible on reset, requiring subsequent system resets until the LCD displayed correctly. While the board had a reset button, mitigating this issue somewhat, it was determined to be a slight error in the code that interfaced the microcontroller with the display, and could be eliminated with a longer delay when updating values or on system reset.

The second issue was regarding the PIR array, a decision changed from exit and entrance doors very close to the demonstration day. Because of the way the array is set up, the order in which they are tripped will determine if the entity is entering or exiting the environment. However, if only one sensor of the two is tripped, unintended functions occurred. If the first (ie. closest to the door) sensor was tripped first, the count will increase regardless of whether or not the second (ie. closest to the center) sensor is tripped. This is partly considered in the main control loop, but only such that tripping both of the sensors (ie. fully entering or fully exiting) will change the count according to the order. This could be fixed in code by checking for both sensors activating. For instance, if only one is tripped within a given time, the count will neither increment nor decrement. As it is now, there is no function of the system to check for this, and in these two cases, the system would essentially have to guess what to do.

The third issue was regarding the accuracy of the temperature readings from the Adafruit DHT22. Although it is more precise than the DHT11, there is still some degree of inaccuracy that must be considered. Although the humidity of the system was not tested (again, this test fell out of favor because displaying the occupancy count would be more helpful for the demo), this too would also have some inaccuracy. The temperature reading is good for -40-80°C, with ±0.5°C of accuracy. This means that if another sensor measured the same place as the DHT22, it could vary by a full 1° at the very worst case. During the testing of the heater and fans, another temperature sensor, provided by the instructor, was used to ensure that the heater and fans were functioning properly, and it uncovered that the system was reporting values that contradicted the secondary sensor by more than the degree of accuracy; in some cases, the two measurements varied by up to 5°, a much larger discrepancy than advertised. Granted, the secondary sensor used also has its own degree of accuracy, which was not provided by the instructor. However, it is unlikely it has ±4.5°C of potential inaccuracy, meaning the worst cases measured should still have been closer. More research could be done using other sensor models, and comparing them all against the project’s DHT22. At the time, the temperature could be held against readings from the ATMega328p, although it has a very high degree of inaccuracy, ±10°C; this means that the 328p can only detect major issues with DHT22 interfacing.

**Conclusion**

Everything that was done this semester culminated in the demonstrations of the final product for the climate control and room occupancy system. It was held against the ten UAT Test Cases for the general functionality of the product as a whole, and although there were a couple of small issues that were encountered during the demo, the session as a whole went quite well. The first six tests that were conducted had to do with the general function of the product, ensuring the product worked in general. These six tests entailed the functionality of all the sensors and actuators of the project, as well as the input and output voltages of the voltage regulator.

The sensors and actuators tested in this section were the two buttons, the DHT22, the PIR array, the desk lamp, the heater, and the two cooling fans. The testing of the sensors and actuators meant that related processing had to be tested, as well. The related processing saw focus during the testing of the buttons (and therefore, the DHT22) and the PIR sensors, the latter of which got their own battery of tests. The tests for the PIR array were the correct function of all possible scenarios: entities entering and exiting, as well as interaction with the occupancy threshold; if the threshold is met, the MAX LED will shine, indicating this threshold. When entities exit the environment such that the amount falls below the threshold, the LED will turn off, and when there all entities exit, the lamp will shut off.

However, three minor problems were encountered during the demo session. The first problem was the LCD would occasionally print gibberish, which could sometimes require multiple resets. The second problem was that the PIR array did not take in account entities that only tripped one sensor, which would have the unintended outcome of incrementing or decrementing the count depending on which one was tripped. The final problem was that the DHT22’s temperature reading did not always match the thermal probe that was used for testing the temperature readings. Although these issues are documented in the Postmortem in more detail, along with other issues the group faced, all of these issues could be remedied fairly easily, with extra delay in dealing with printing to the LCD and resetting the system when required, added code that takes in account of only one PIR sensor tripping, and the use of a second temperature sensor for better accuracy, respectively. All in all, this design project has been a very interesting and informative look at the world of designing a real product from scratch, and the development of said product from start to finish in the accelerated timeframe of only a couple of months.