Internet Enabled Multi-zone Thermostat

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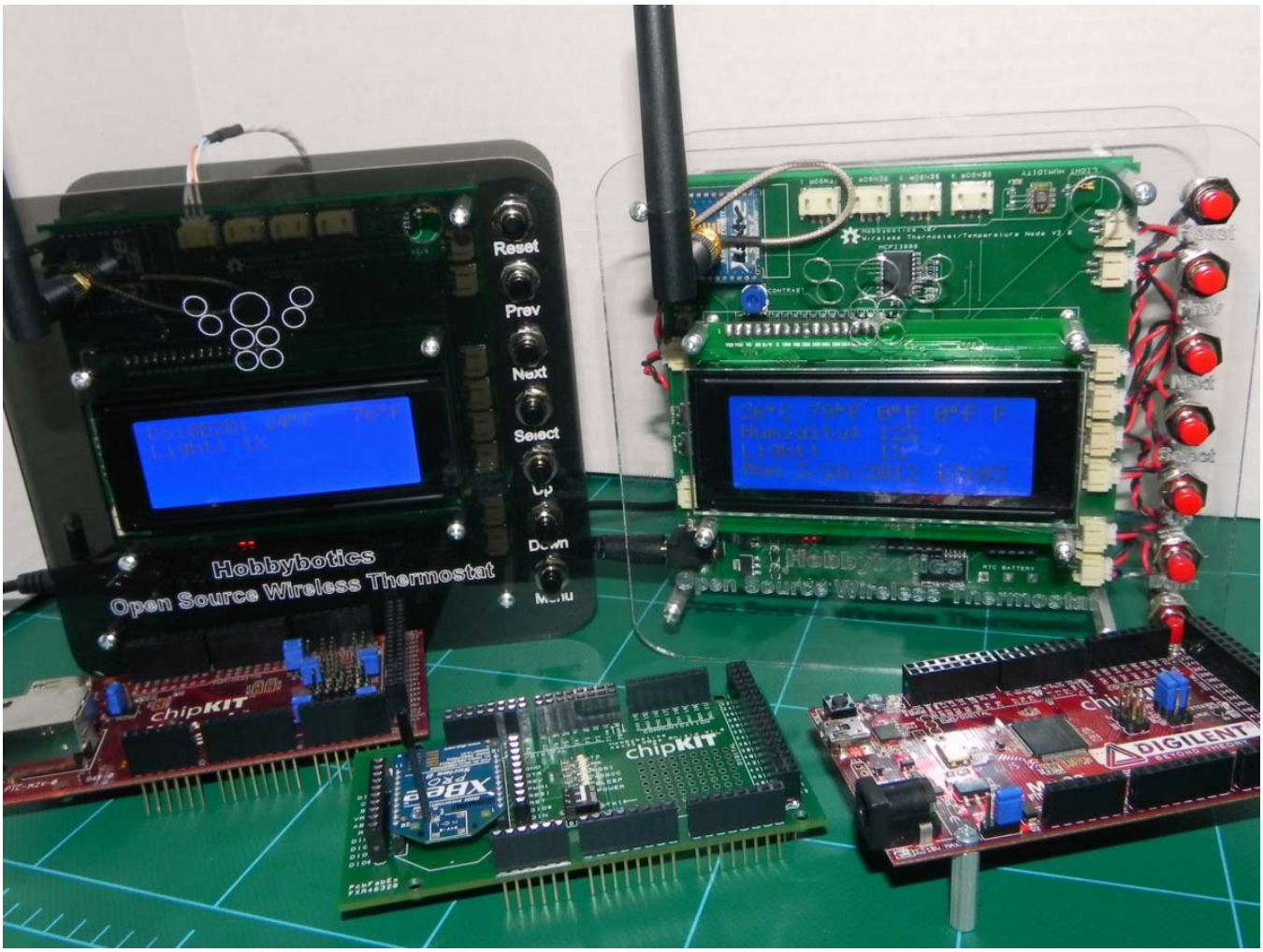
Project ID: 73934

Project URL

http://www.designspark.com/node/73934

A Multi-zone Internet enabled thermostat that can regulate the temperature in each room and be centrally monitored and controlled over the internet or locally through a wireless XBee network.



1. Abstract

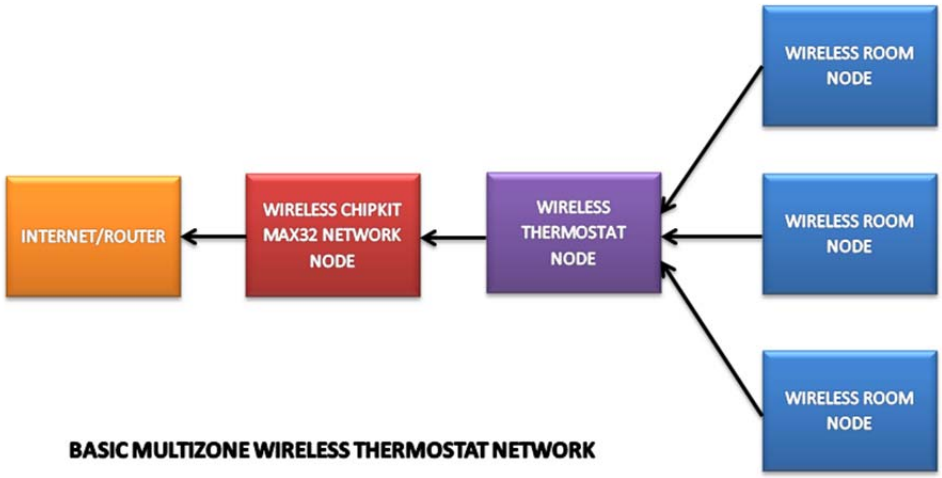
Heating, ventilation and cooling (HVAC) is the largest source of residential energy consumption. It takes a lot of energy to heat rooms in the summer and cool them in the winter. Energy Star estimates that 43% of the energy used in the average home is for heating and cooling rooms and that the annual energy bill for a typical single family home is approximately $2200 [1]. Most residential environments have a HVAC system that regulates the temperature based on a preset condition. The basic scheme is to apply heat when it is too cold, apply cool air when it is too hot and turn off the system when the temperature is just right. This basic HVAC system is highly inefficient and thus, we have programmable HVAC systems. A programmable HVAC system allows one to set parameters for what temperature to maintain and what time to change that set-point. This capability comes in handy for when you are away from home and do not need the entire house maintained at 69 degrees (F), for example. Inherent roadblocks too many programmable HVAC systems is the initial cost of ownership, annual cost savings (return for investment) and proper use. The aim of this project is to demonstrate how to use the chipKIT Max32 along with some cost effective "Do It Yourself (DIY) sensor technology to address the mentioned roadblocks to programmable HVAC systems. The overall goal is to demonstrate how a DIY Internet connected wireless thermostat system can be cost effectively developed in order to decrease the overall residential energy consumption for the United States and abroad.

2. Introduction

This project is broken out into three different designs with the first being a XBee shield for the chipKIT Max32, the second a wireless temperature board that contains a SHT15 Humidity Sensor, a TEMT6000 Light Sensor, a DS3234 Real Time Clock (RTC), two MCP23008 I2C Input/Output expanders, and connectors for a Secure Digital and MAX6675 Thermocouple breakout boards. The third design is an I2C controlled output board that has connections for four Solid State Relays (SSR) and four 5V @5A mechanical relays. Two wireless temperature control boards and two I2C output boards will be used for this project.

3. Communications

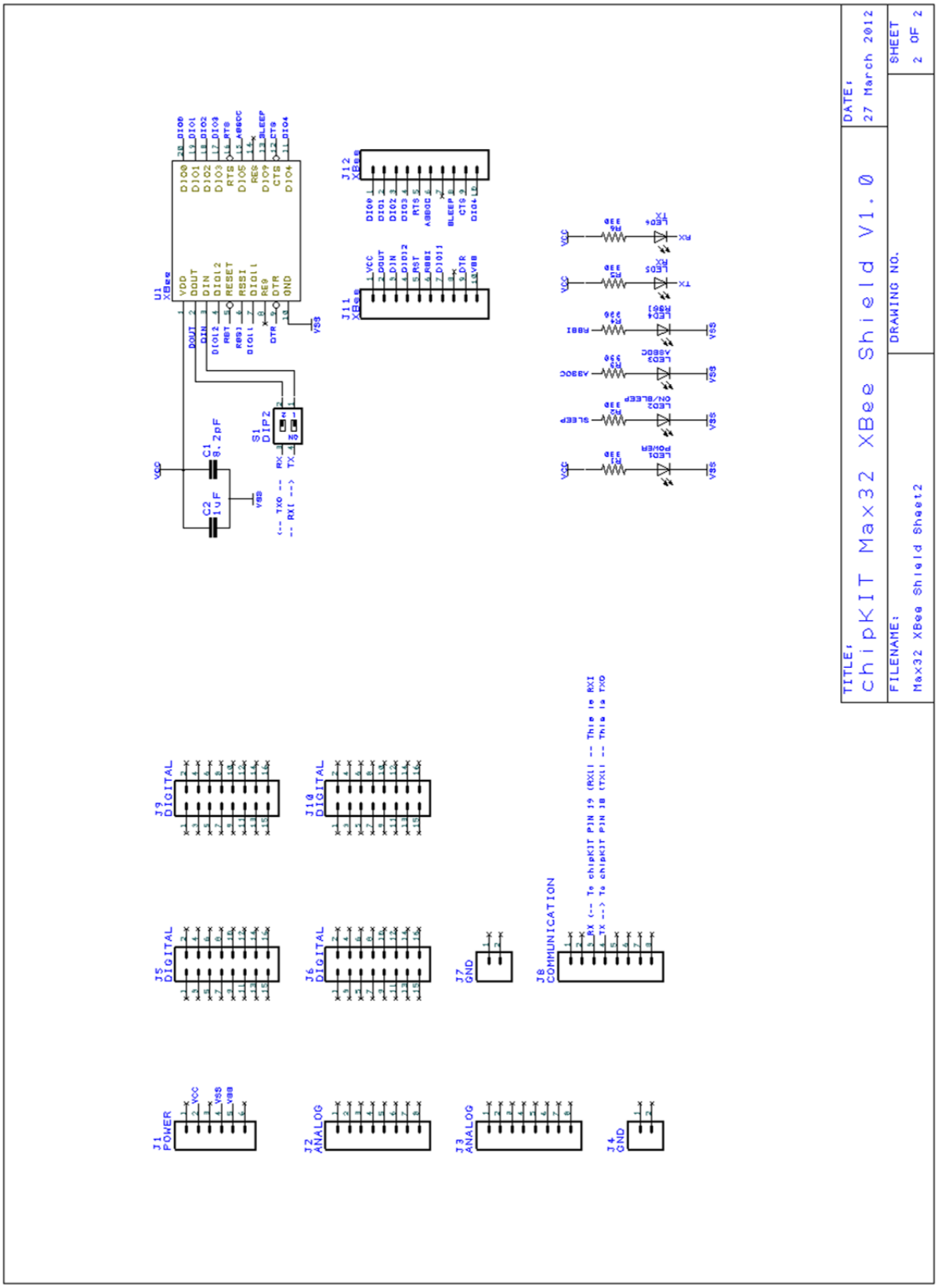
Here is a diagram the show a basic communication scheme for the wireless thermostat network.



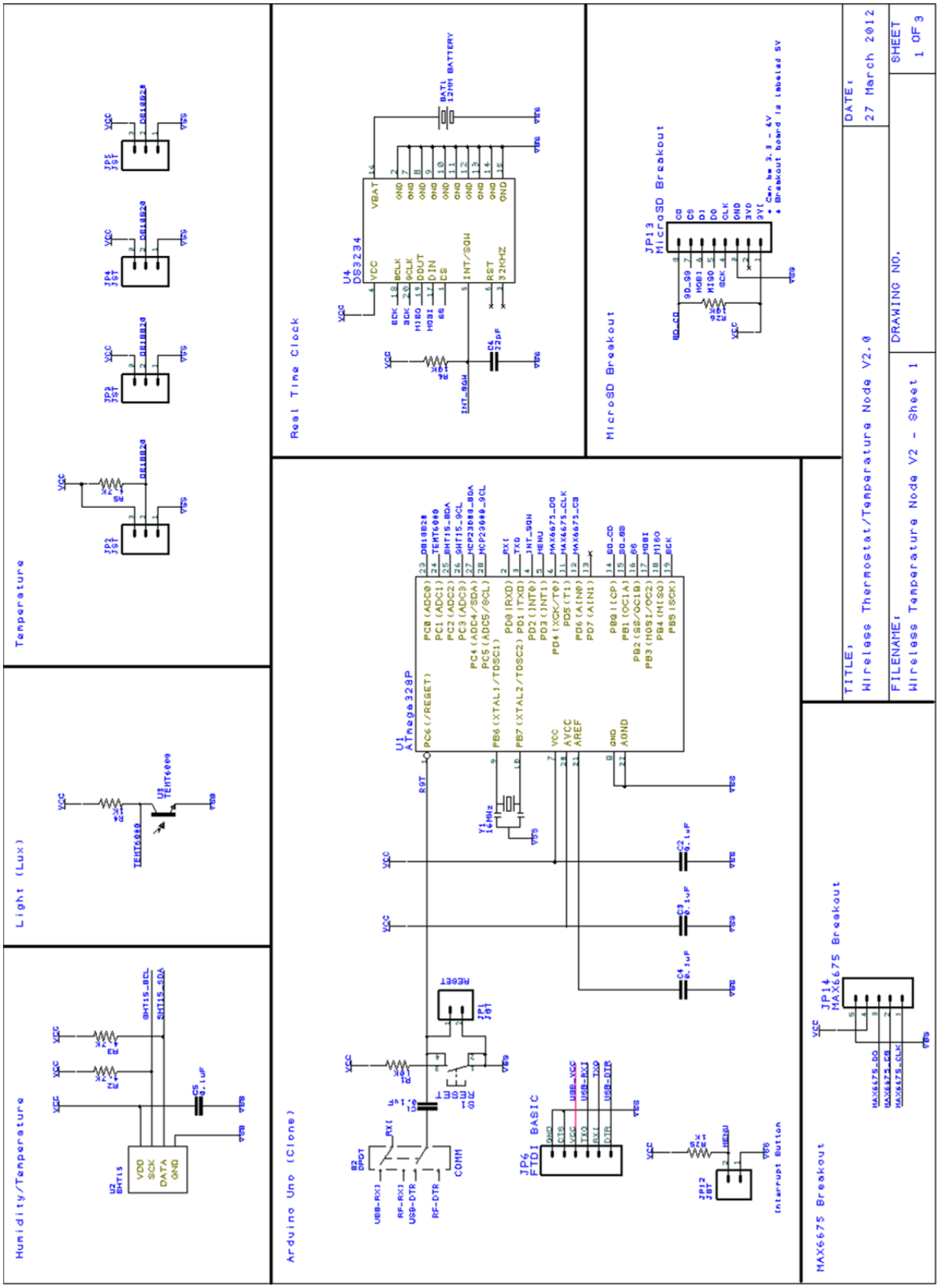
BASIC MULTIZONE WIRELESS THERMOSTAT NETWORK

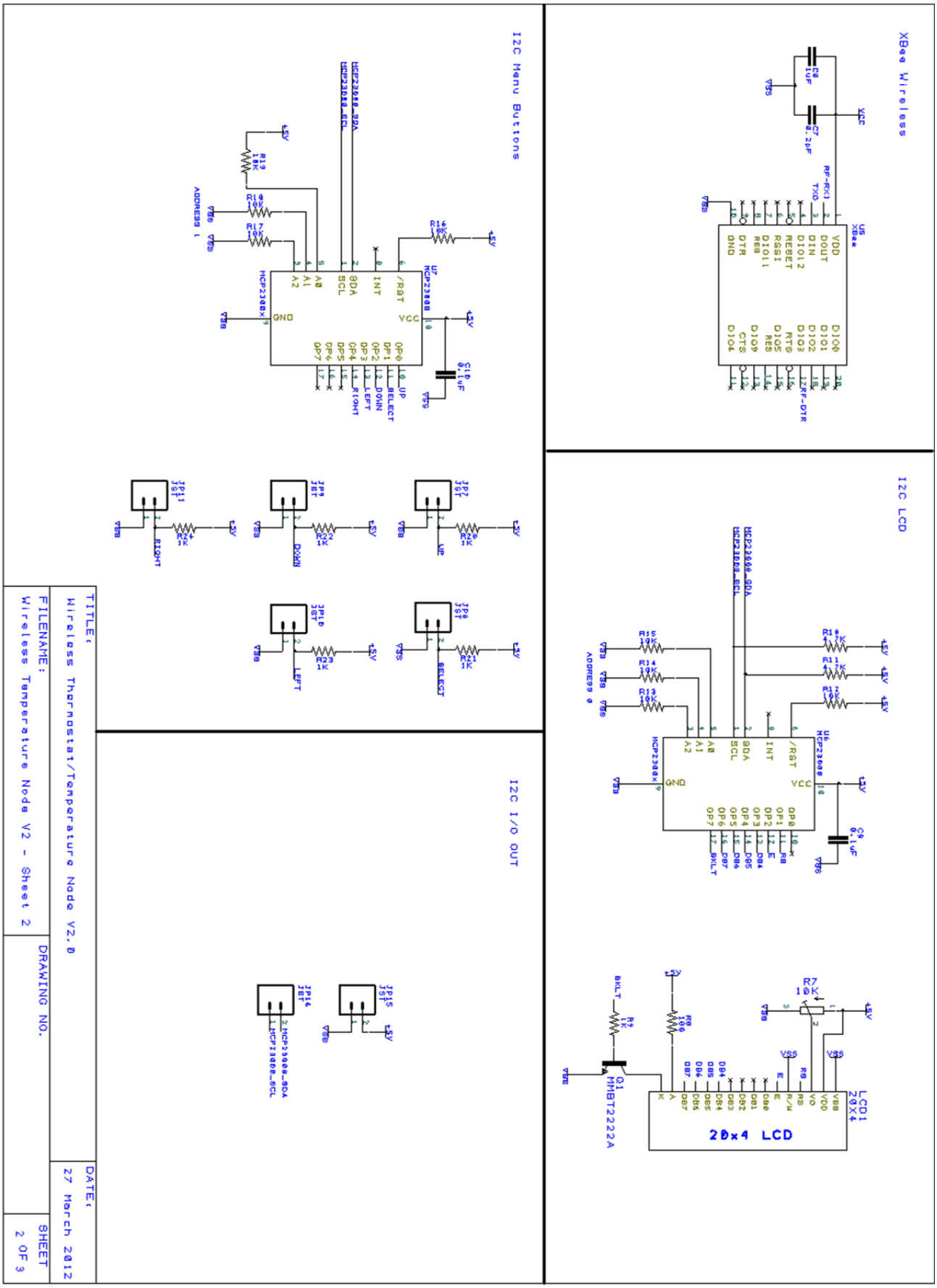
At the head of the setup is a router that provides internet access for the system. The first node is comprised of a chipKIT Max32, Max32 Ethernet Shield and XBee Shield (developed PCB). The second node is the Wireless Thermostat that is responsible for controlling the HVAC system and receiving data from the room nodes. The room nodes, with an output control board attached, can control a motorized damper to regulate the temperature in each room.

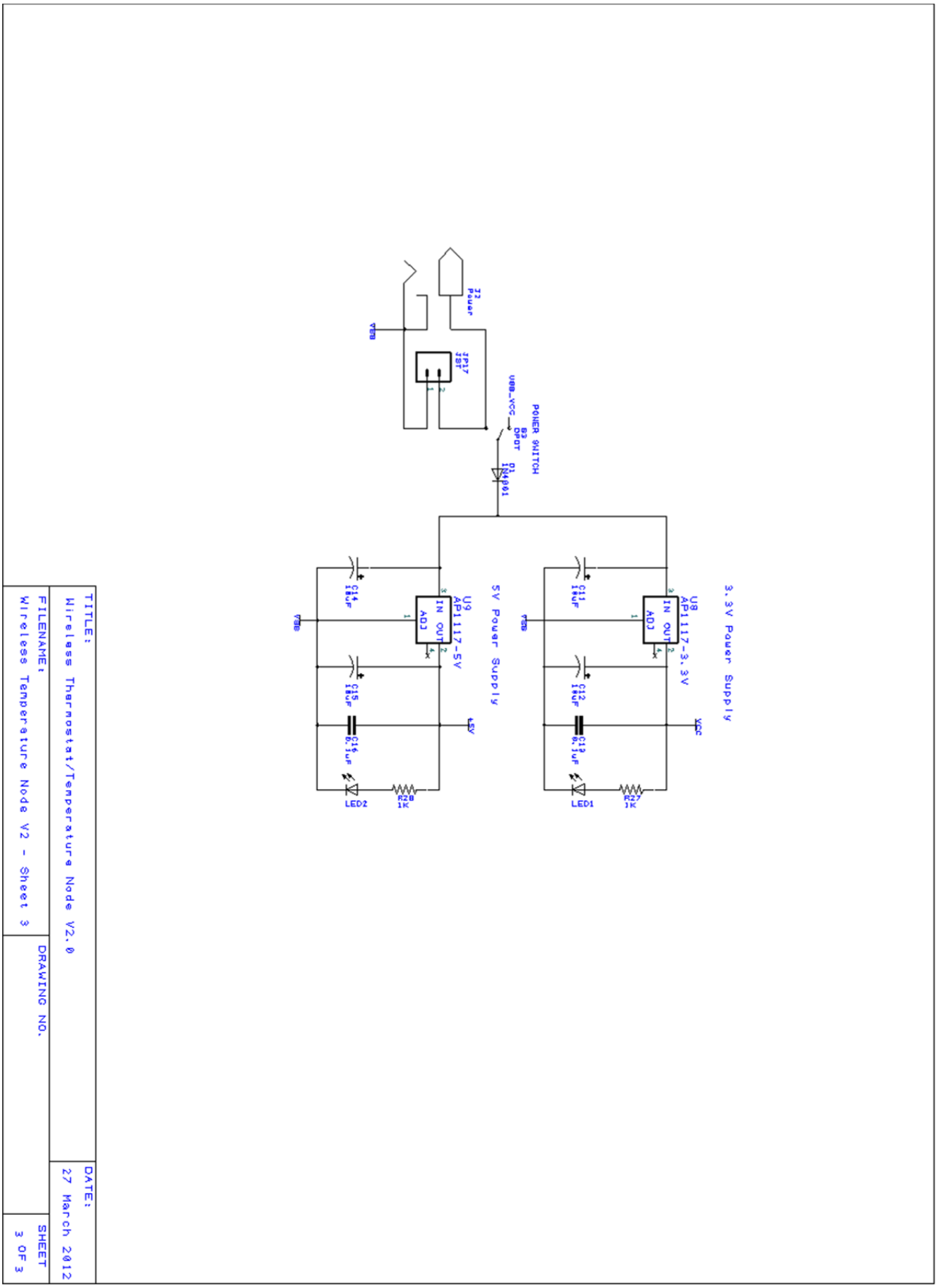
4. ChipKIT Max32 XBee Shield (Schematic)



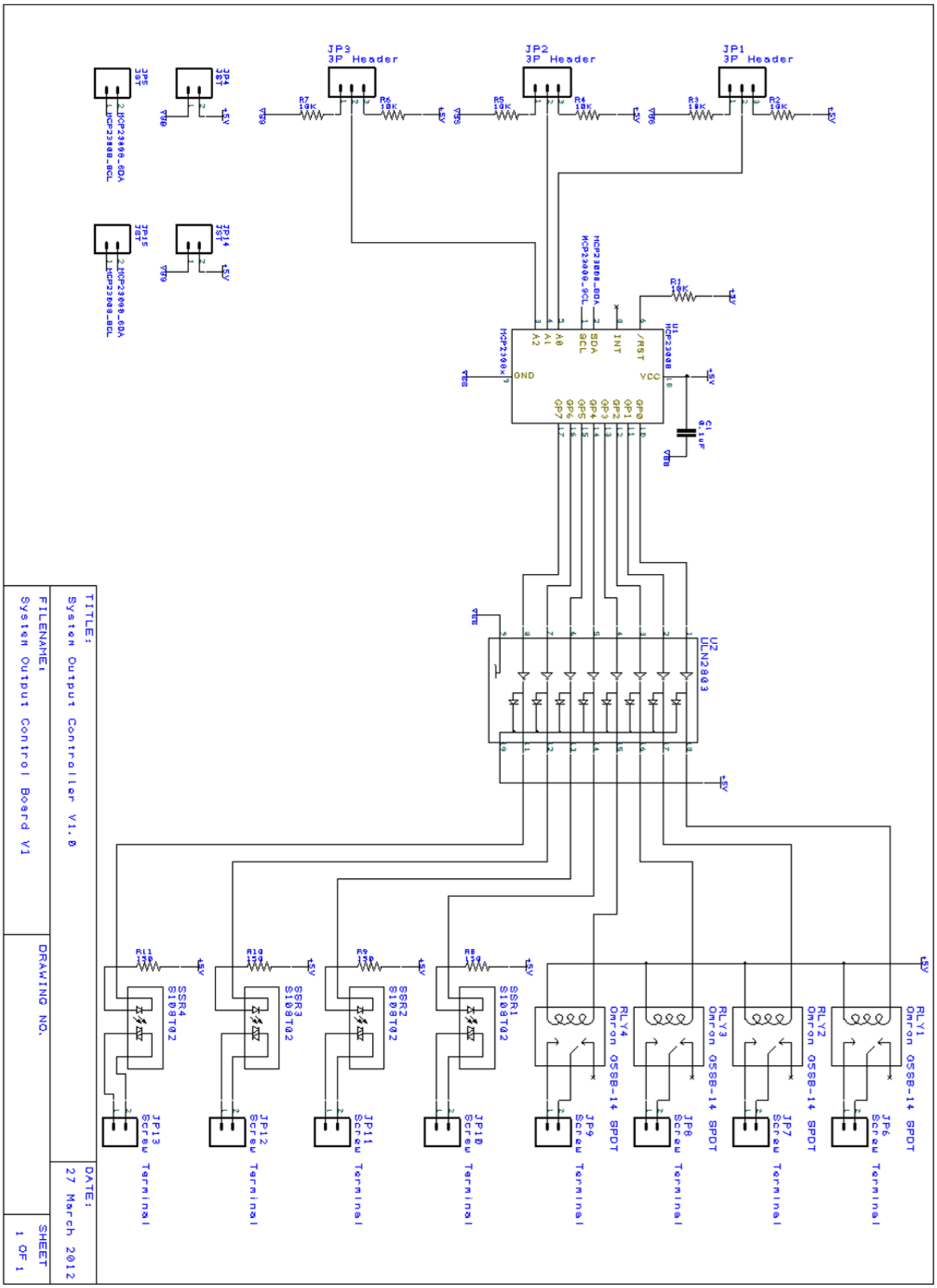
5. Wireless Thermostat/Temperature Node (Schematics)




XBee Wireless
I2C LCD
I2C Menu Buttons
I2C I/O OUT
20x4 LCD
TITLE:
Wireless Thermostat/Temperature Node V2.0
FILENAME:
Wireless Temperature Node V2 - Sheet 2
DRAWING NO.
DATE:
27 March 2012
SHEET
2 OF 3

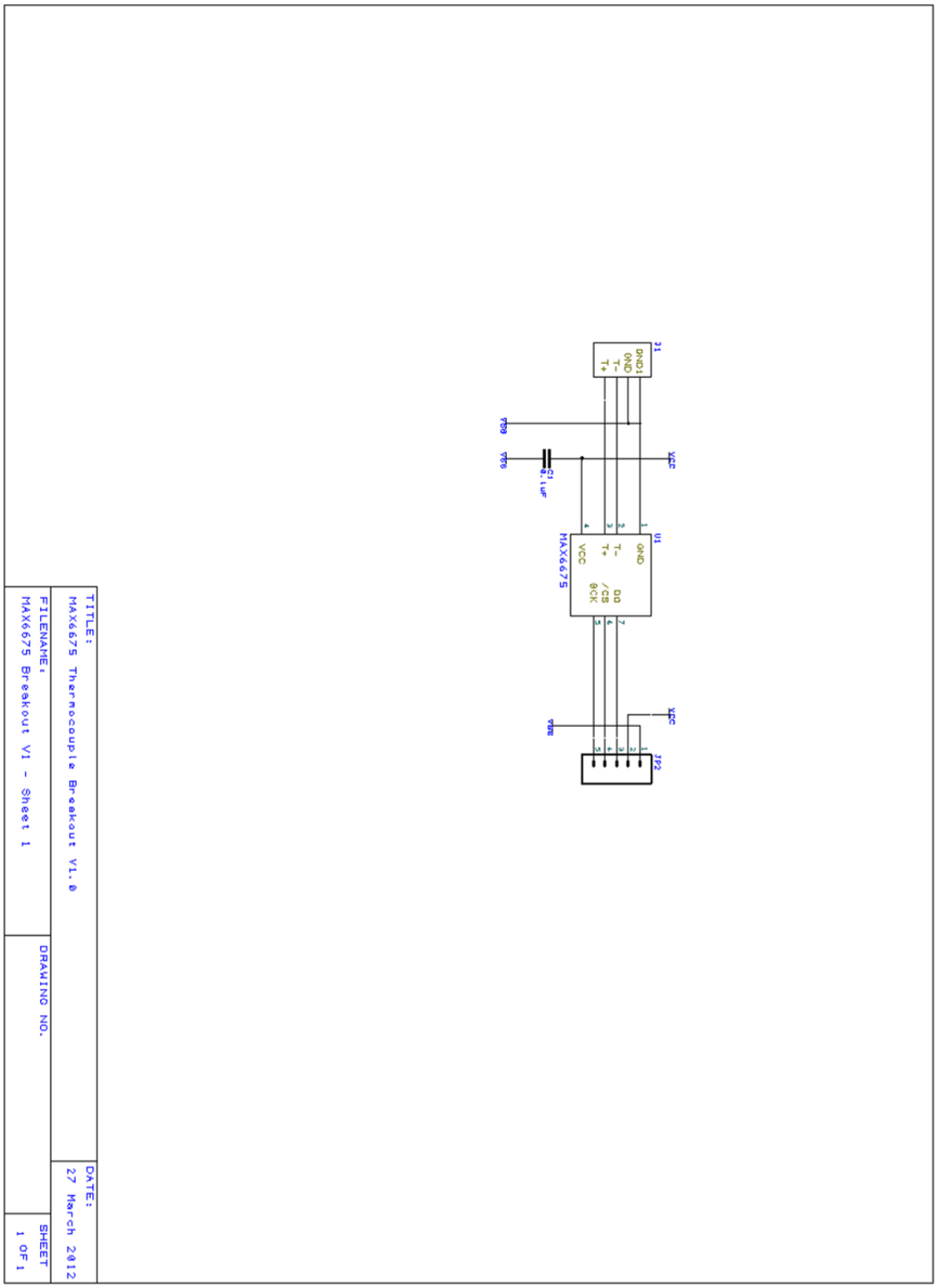

J2
Power
VBB
JP17
JSP
VBB_VCC
S3
DPDT
POWER SWITCH
D1
1N4001
C14
10uF
U9
AP1117-5V
IN OUT
ADJ
5V Power Supply
C15
10uF
C16
0.1uF
5V
R28
1K
LED2
C11
10uF
U8
AP1117-3.3V
3.3V Power Supply
C12
10uF
C13
0.1uF
VCC
R27
1K
LED1
TITLE:
Wireless Thermostat/Temperature Node V2.0
FILENAME:
Wireless Temperature Node V2 - Sheet 3
DRAWING NO.
DATE:
27 March 2012
SHEET
3 OF 3

6. System Output Controller (Schematic)



7. MAX6675 Thermocouple Breakout (Schematic)

The following board was created as an attachment for the Thermostat/Temperature board but, a PCB was not produced in time for this project. However, a prototype was created and tested. This board is not necessary for this project but, was developed to allow further applications.



8. Code Explanation (ChipKIT Max32)

The first sketch written for the Max32 (MPIDE) simply checks for sensor data received over the XBee connection and updates a web page. By default, the XBee Shield is connected to Serial Port 1 on the Max32. This keeps one from having to remove the XBee from the shield every time a sketch is uploaded. The default port can be disabled and another port selected by setting the dip switch on the shield.

The sample web server sketch is a modified version of the server sketch found in the Ethernet library for the ChipKIT Ethernet Shield. First, we set up two data structures for the sensor send *'txdata'* and receive data *'rxdata'*. The receive data structure contains variables to store sensor readings. The transmit data structure is used to send commands and a device ID to the remote nodes.

```
1.  struct RECEIVE_DATA_STRUCTURE{
2.    //put your variable definitions here for the data you want to receive
3.    //THIS MUST BE EXACTLY THE SAME ON THE OTHER ARDUINO
4.    int lightSensor;
5.    int humidity;
6.    int temperature;
7.    int heaterStatus;
8.    int acStatus;
9.    int fanStatus;
10.   int command;
11.   int device;
12. } rxdata;
13.
14. struct SEND_DATA_STRUCTURE{
15.   //put your variable definitions here for the data you want to receive
16.   //THIS MUST BE EXACTLY THE SAME ON THE OTHER ARDUINO
17.   int deviceID;
18.   int command;
19. } txda
```

Next, we setup an IP address for the Ethernet board and place that into our sketch. I simply plugged the Ethernet board into the router and allowed an address to automatically be assigned. You will need to log into your router to find out what this address is.

```
1.  // Enter a MAC address and IP address for your controller below.
2.  // A zero MAC address means that the chipKIT MAC is to be used
3.  byte mac[] = { 0x00, 0x00, 0x00, 0x00, 0x00, 0x00 };
4.
5.  //       !!MODIFY THIS!!
6.  // The IP address will be dependent on your local network:
7.  byte ip[] = { 192,168,0,159 };
```

Finally, we set up the serial ports, start the Ethernet client, and check for sensor data. This data will be posted to the serial port and web page.

```
// Initialize the Ethernet server library
// with the IP address and port you want to use
// (port 80 is default for HTTP):
Server server(80);

void setup()
{
  // start the Ethernet connection and the server:
  Ethernet.begin(mac, ip);

  //Ethernet.begin();  // this will use DHCP
  server.begin();

  // initialize serial
  Serial.begin(57600);
  Serial1.begin(57600);
}
```

```
void setup()
{
  // start the Ethernet connection and the server:
  Ethernet.begin(mac, ip);

  //Ethernet.begin();  // this will use DHCP
  server.begin();

  // initialize serial
  Serial.begin(57600);
  Serial1.begin(57600);
}

void loop()
{
  // Check for data on the XBee connected to serial port 1
  if (Serial1.available() >= 7)
  {
    // Check for the correct device ID
    rxdata.device = Serial1.read();

    // Get sensor data from port if correct
    if (rxdata.device == 1)
    {
      rxdata.lightSensor = Serial1.read();
      rxdata.humidity = Serial1.read();
      rxdata.temperature = Serial1.read();
      rxdata.heaterStatus = Serial1.read();
      rxdata.acStatus = Serial1.read();
      rxdata.fanStatus = Serial1.read();
    }
  }

  delay(1000);

  // Send it to the default serial port also
  Serial.print(rxdata.lightSensor);
```

```
38.   Serial.print(" ");
39.   Serial.print(rxdata.humidity);
40.   Serial.print(" ");
41.   Serial.print(rxdata.temperature);
42.   Serial.print(" ");
43.   Serial.print(rxdata.heaterStatus);
44.   Serial.print(" ");
45.   Serial.print(rxdata.acStatus);
46.   Serial.print(" ");
47.   Serial.println(rxdata.fanStatus);
48.
49.   delay(100);
50.
51.   // listen for incoming clients
52.   Client client = server.available();
53.
54.   if (client) {
55.
56.     // an http request ends with a blank line
57.     boolean currentLineIsBlank = true;
58.
59.     while (client.connected()) {
60.
61.       if (client.available()) {
62.
63.         char c = client.read();
64.
65.         // if you've gotten to the end of the line (received a newline
66.         // character) and the line is blank, the http request has ended,
67.         // so you can send a reply
68.         if (c == '\n' && currentLineIsBlank) {
69.
70.           // send a standard http response header
71.           client.println("HTTP/1.1 200 OK");
72.           client.println("Content-Type: text/html");
73.           client.println();
74.
75.           // output the value of each analog input pin
76.           for (int analogChannel = 0; analogChannel < 6; analogChannel++) {
77.
78.             client.print("analog input ");
79.             client.print(analogChannel);
80.             client.print(" is ");
81.             client.print(analogRead(analogChannel));
82.             client.println("<br />");
83.           }
84.
85.           client.println("<br />");
86.
87.           client.print("Thermostat Status: ");
88.           client.println("<br />");
89.           client.print(rxdata.device);
90.           client.print("  ");
91.           client.print(rxdata.lightSensor);
92.           client.print("  ");
93.           client.print(rxdata.humidity);
94.           client.print("  ");
95.           client.print(rxdata.temperature);
96.           client.print("  ");
97.           client.print(rxdata.heaterStatus);
98.           client.print("  ");
99.           client.print(rxdata.acStatus);
100.                  client.print("  ");
101.                  client.print(rxdata.fanStatus);
```

```
                client.println("<br />");
                break;
              }
              if (c == '\n') {
                // you're starting a new line
                currentLineIsBlank = true;
              }
              else if (c != '\r') {
                // you've gotten a character on the current line
                currentLineIsBlank = false;
              }
            }
          }
          // give the web browser time to receive the data
          delay(1);
          // close the connection:
          client.stop();
        }
      }
```

9. Code Explanation (Wireless Node)

The first sketch written for the Wireless Node (Arduino V1.0) simply sends Sensor data over a wireless network established with the XBee connected to the Max32.

As in the Max32 sketch, we first create the send and receive data types.

```
struct RECEIVE_DATA_STRUCTURE{
  //put your variable definitions here for the data you want to receive
  //THIS MUST BE EXACTLY THE SAME ON THE OTHER ARDUINO
  char deviceID;
  //int command;
} rxdata;

struct SEND_DATA_STRUCTURE{
  //put your variable definitions here for the data you want to receive
  //THIS MUST BE EXACTLY THE SAME ON THE OTHER ARDUINO
  int lightSensor;
  int humidity;
  int temperature;
  int heaterStatus;
  int acStatus;
  int fanStatus;
  int device;
} txdata;
```

Next, we set up the serial port, initialize the sensors and assign a device ID:

```
void setup()
{
```

```
3.    // Set device ID
4.    txdata.device = 1;
5.
6.    Serial.begin(57600);
7.
8.    // Setup LCD
9.    LCD.begin(20, 4);
10.
11.   // Initialize RTC
12.   INIT_DS3234();
13.
14.   // Initialize thermostat
15.   INIT_THERMOSTAT();
16.
17.   // Initialize menu buttons
18.   INIT_BUTTONS();
19. }
```

We will request temperature (Fahrenheit) and humidity from the SHT15 sensor, light level reading from the TEMT6000 light sensor and status of the fan, heat and AC relays.

```
1.  // Get sensor data and store in data structure
2.    txdata.lightSensor = LIGHT_SENSOR();
3.    txdata.humidity = SHT15_HUMIDITY();
4.    txdata.temperature = SHT15_FAHRENHEIT();
5.    txdata.heaterStatus = GET_THERMOSTAT_RELAY(thermostat, HEAT);
6.    txdata.acStatus = GET_THERMOSTAT_RELAY(thermostat, AC);
7.    txdata.fanStatus = GET_THERMOSTAT_RELAY(thermostat, FAN);
```

This data will be sent over the XBee network connection to the Max32 and posted to a webpage.

```
1.  // Line 0 - Print SHT15 temperature in celsius and fahrenheit
2.    LCD.setCursor(0, 0);
3.    LCD.print(SHT15_CELSIUS());
4.    LCD.print(degree);
5.    LCD.print("C");
6.
7.    LCD.setCursor(10, 0);
8.    LCD.print(txdata.temperature);
9.    LCD.print(degree);
10.   LCD.print("F");
11.
12.   // Line 1 - Print SHT humidity
13.   LCD.setCursor(0, 1);
14.   LCD.print("Humidity: ");
15.   LCD.print(txdata.humidity);
16.   LCD.print("%  ");
17.
18.   // Line 2 - Print TEMT6000 light level
19.   LCD.setCursor(0, 2);
20.   LCD.print("Light:");
21.   LCD.setCursor(10, 2);
22.   LCD.print(txdata.lightSensor);
23.   LCD.print("%  ");
24.
25.   // Line 3 - Print date and time
26.   LCD.setCursor(0, 3);
```

```
27.   LCD.print(DS3234(3));
28.
29.
30.   // Send sensor data over serial port
31.   Serial.write(txdata.device);
32.   Serial.write(txdata.lightSensor);
33.   Serial.write(txdata.humidity);
34.   Serial.write(txdata.temperature);
35.   Serial.write(txdata.heaterStatus);
36.   Serial.write(txdata.acStatus);
37.   Serial.write(txdata.fanStatus);
```

To test the above code, load the “WirelessNodeXBee1.ino” sketch onto a Wireless Thermostat/Temperature node. Be sure to set the serial switch on the board to RF in order to connect the serial port of the node to the XBee. Load the “ChipKITWebServer1.pde” sketch onto the Max32. Be sure to change the IP address to one compatible with your router. You will need an XBee Shield (developed as part of this project, a ChipKIT Max32 and a ChipKIT Ethernet Shield. Further details on this project can be found in the full write-up.