Temperature controller Module:

System objective:

System is designed to provide a temperature controlled functionality. The system shall provide the ability to reach a targeted temperature requested by a user interface. The system shall provide information for the user about the system state, the current temperature and the selected set temperature.

System architecture:

System is consisted of the following:

1. Atmega32 Microcontroller.
2. LM016 character LCD.
3. TC72 SPI to temperature convertor.
4. 4X3 Keypad.
5. PWM to voltage convertor module.
6. Calibration resistor.

System application behavior:

1. Welcome screen:

1. After power on, system shall display an animated welcome screen.
2. The welcome Screen shall display the word “WELCOME” on the Character LCD.
3. The welcome word shall move from right to left until the end of the screen.
4. The welcome word shall move from left to right until the other end of the screen.
5. The time of each movement step shall be 100ms.
6. Steps from 3 to 5 shall be repeated 3 times.
7. System shall then switch to IDLE screen with the 25 as a default set temperature.

2. IDLE screen:

1. IDLE screen consists of three sections, Set temperature, current temperature and system state.
2. Set temperature section shall be allocated on the left side of the screen from Row0 col0 to Row0 Col5.
3. Set temperature section shall be written on the form SET:XX where XX is the Set temperature value.

4. Set temperature value shall be changed based on a user entry from the 4X3 Keypad.
5. If Set temperature is less than 10, its value shall be written on the form 0X.
6. Current temperature section shall be allocated on the right side of the screen from Row0 Col10 to Row0 Col15.
7. Current temperature section shall be written on the form CRT:YY where YY is the current temperature value.
8. Current temperature shall be changed based on the current value read from the TC72 Temperature sensor.
9. System state section shall be allocated on the down left of the screen from row1 Col0 to row1 Col15.
10. System state section shall be written on the form STATE: SSSSS. Where SSSSS is equal to the system state.
11. System state shall vary from STANDBY, OPERATION, NORMAL and ERROR based on the current system state.

3. System states:

1. After power on, Systems state shall be STANDBY.
2. STANDBY state means system is not operational, no temperature reading and no Voltage module control (PWM output is 0).
3. Upon the click on the # button in Keypad, system shall move from STANDBY to OPERATIONAL.
4. In operational state, System shall read the current temperature periodically every 200ms.
5. In operational state, System shall drive PWM to voltage convertor based on the following equation:

   Vt = ((Set temperature – Current Temperature) / 100) * 10 if Set temperature > Current Temperature.

   Vt = 0 if Set temperature <= Current Temperature.

   Where V is the delivered voltage from the PWM to Voltage convertor.
6. In operational state, if Current temperature > Set temperature and (Current temperature – Set temperature) <= 5 system shall enter NORMAL state.
7. In operational state, if Current temperature < Set temperature and (Set temperature – Current temperature) <= 5 system shall enter NORMAL state.
8. In operational state, if Current temperature > Set temperature and (Current temperature – Set temperature) > 10 system shall enter Error state.

9. In operational state, if Set temperature > Current temperature and (Set temperature – Current temperature) > 5 for more than 3 minutes, system shall enter Error state.
10. In operational state, if # key is pressed, System shall enter STANDBY State.
11. In Normal state, Periodic temperature reading is exist with voltage V = 0.
12. In Error state, no temperature read and no PWM to voltage module control.
13. The only exit from Error state is to power off the system. Keypad shall not be functional.

4. Calibration Resistor:

1. Calibration resistor is used to define the percentage of average voltage to be delivered to the PWM to Voltage convertor.
2. Calibration resistor is a three terminal potentiometer formulate a voltage divider circuit. One terminal on VCC, other terminal on Ground and the middle terminal shall be read by the microcontroller.
3. The Calibration resistor voltage shall be read every 500ms in both Operational and normal states.

5. PWM to voltage convertor:

1. The PWM transfer voltage module LC-LM358-PWM2V converts the PWM digital signals into 0 to 10V analog signals.
2. The device shall be connected to the microcontroller only via PWM input.
3. The accepted PWM frequency is from 1KHZ to 3KHZ.
4. The value of the delivered PWM duty cycle is dependent on the targeted voltage and value of the calibration resistor voltage.
   Duty Cycle percentage = (((Vr * 2)/10) * Vt) / 10.
   Where Vr is the calibration resistor voltage, Vt is the target voltage as described in system states.

6. Temperature sensor:

1. TC72 is a temperature to SPI convertor.
2. Recommended system mode is the continues mode.
3. More information about the sensor constraints is located in its datasheets.

7. General constraints:

1. Refer to 4X3 phone keypad for keypad interface.
2. Refer to Chapter 12 in AVR mazidi for LM016 LCD interface.
3. LCD shall be used in 4 pin data mode.
4. All timing constraints shall be respected.
5. No delay loops is allowed for a time higher than 100us.
6. Code shall not have any unjustified MISRA violations.
7. Assume Jitter 10% of periodicity

```
_delay_us(10);
```