Application Brief

Designing a Thermal Monitor and Temperature Controller with TI's Programmable Logic Devices (TPLD)

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Application Description

Data centers and other enterprise applications consume a significant amount of power due to the complex infrastructure of the system. In order to minimize the potential of overheating and impacting system performance, data centers implement techniques to ensure reliable performance. One such technique is to measure the temperature of the system and respond accordingly to high temperatures. The temperature can be determined by using a system that converts temperature to voltage by using a temperature resistor or thermistor. After being converted, several signal handling measures can be implemented. This application brief shows how TI's programmable logic devices (TPLD) can be configured to control a cooling unit using the voltage from the temperature sensor, as shown in Figure 1. Compared to a discrete design, this solution integrates a pair of analog comparators and a PWM generator into a single chip. This specific design was created using TPLD1201, but any TPLD with a pair of analog comparators can be used. For more on temperature sensing, see Engineer's Guide to Temperature Sensing .

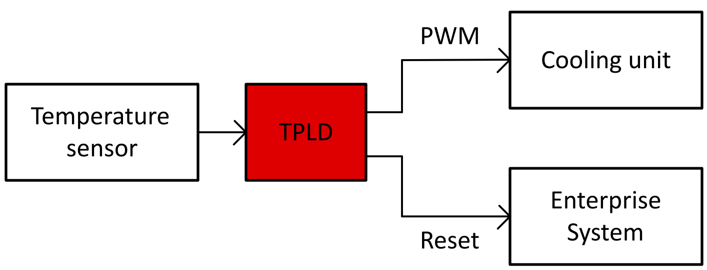

Figure 1. Simplified Block Diagram for Thermal Controller

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Solution Description

For this programmable logic design, the thermal voltage generated from the temperature sensor is compared to a programmable reference voltage utilizing an analog comparator in order to turn on a fan at 50% duty cycle once the temperature is above 85°C. Another comparator in conjunction with a programmable reference voltage is used to reset the system and turn on the fan completely when the temperature exceeds 100°C.

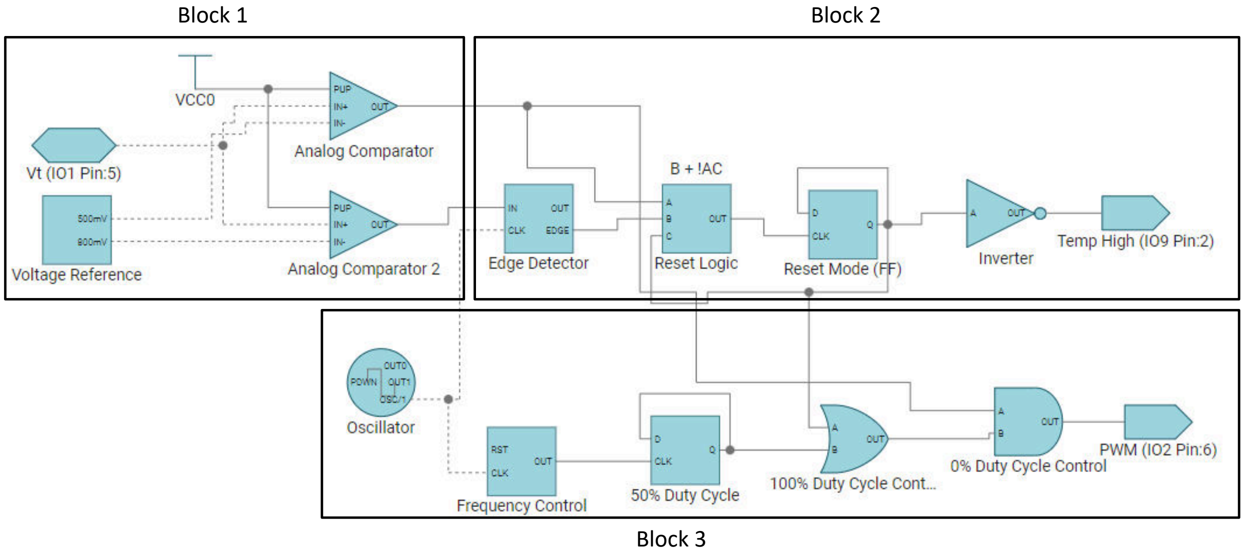

Figure 2. InterConnect Studio (ICS) Configuration

Figure 2 shows the entire solution using TI's Interconnect Studio. Block 1 is comprised of the analog comparators used to monitor the voltage outputs of the temperature sensors. The analog comparators compare the Vt input to the configurable voltage reference. In this example, we used 500mV to correspond to 85°C and 800mV to 100°C. These values are configurable and can be changed to match your system's needs. See below in the section "*Design Calculations"* for how we calculated our values in the system.

Block 2 detects when the temperature has exceeded a safe level and generates a signal that can be used to turn off an external system until the temperature falls. The delay block is used as a rising edge detector, which then sends the signal through a 3-input look up table denoted as reset logic, here is a screen grab of that table. The logic controls the clock of a flip-flop with an inverter output which drives the temp high output. Figure 3 shows the appropriate look-up table.

C B A	Custom 3 Input Boolean Function Table
0 0 0	☐
0 0 1	☐
0 1 0	☑
0 1 1	☑
1 0 0	☑
1 0 1	☐
1 1 0	☑
1 1 1	☑

Figure 3. Reset Logic Lookup Table Logic

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Block 3 controls a PWM signal for a cooling element such as a fan. The frequency control counter combined with the flip-flop divides the oscillator to produce a 1kHz signal to interface with common cooling elements. By setting the counters control data to 12, the counter pulses once every 12 oscillator cycles, which effectively divides the clock frequency by 12. The flip-flop further divides it by 2 giving a final frequency of 1.04kHz. The flip-flop is also used to create a 50% duty cycle and a series of logic element are used to control when the PWM is held high or low. The settings of the oscillator and counter from InterConnect Studio are shown in Figure 4 and can be configured to generate a signal with a different frequency.

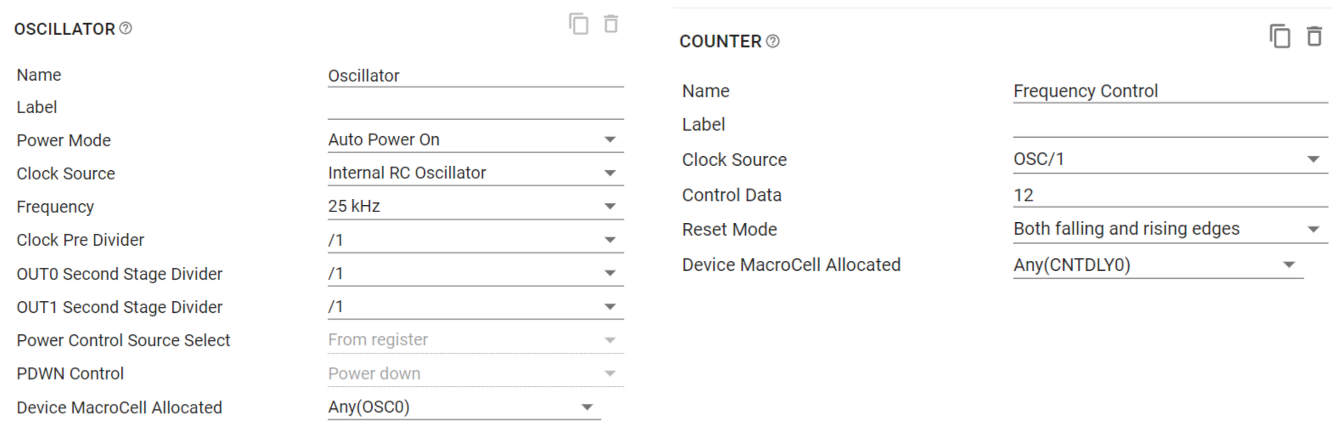

Figure 4. Oscillator and Counter Settings

Design Calculations

In our design, we used a thermistor resistor divider as shown in Figure 5.

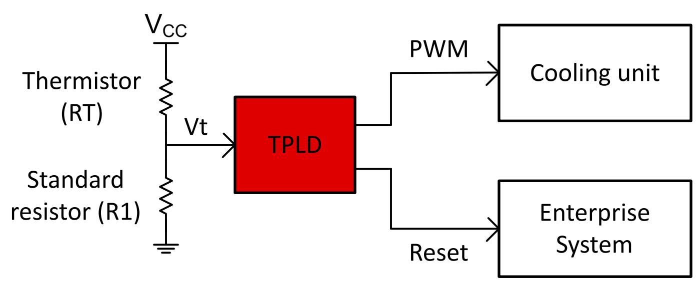

Figure 5. Thermistor Input Block Diagram

We calculated the value of the standard resistor using the following formula.

Vt = Vcc * (R1/(R1+RT))

At 80°C, the value of the thermistor is 1.6 k-ohms, which gives us the equation:

0.5 = 3.3 *(R1)/(R1+1.6 k-ohms)
R1 = 286 ohms

We can then calculate the voltage reference corresponding to 100°C using the formula below:

Vt = Vcc * (R1/(R1+RT))
Vt = 3.3 * (286 ohms) / (286 ohms + 900 ohms)) = 0.8V

Of course, other methods of temperature sensing can be used, such as an analog temperature sensor.

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Simulation

When the input voltage rises to 0.5V, which corresponds to 85°C Celsius in this design, the PWM turns on with a 50% duty cycle. Once the voltage exceeds 0.8V, which corresponds to 100°C, the PWM then generates a 100% duty cycle and the system is held in reset until the input voltage falls below 0.5V. This behavior is shown in the ICS simulation shown in Figure 6.

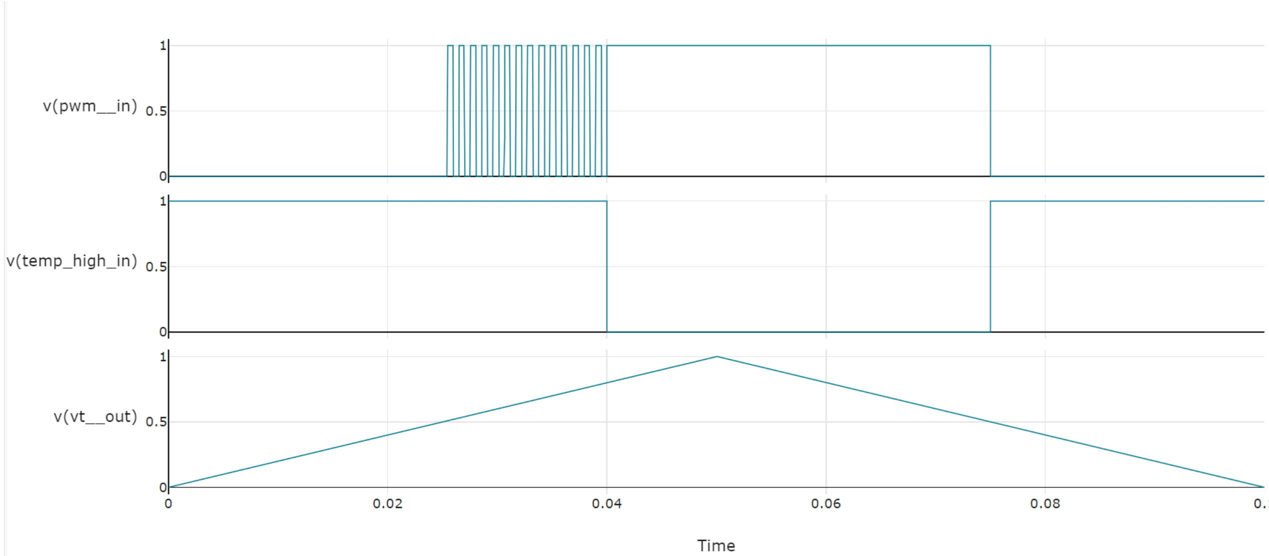

Figure 6. ICS Simulation

Design Considerations

- TPLD1201 can typically drive up to 50mA. Depending on the cooling system, this may not be sufficient. A load switch may be used if the cooling element requires more power.
- If the cooling element operates at a frequency different than 1kHz, Block 3 can be configured to produce other PWM frequencies up to the maximum frequency of the oscillator.
- The TPLD maximum operating temperature is 150°C, so it cannot be operated in an environment with a higher ambient temperature.
- The thermistor used in this design was the NTCG103JF103FT1. Different thermistors have different response curves that must be taken into account in a design.
- This configuration was designed to be operated at 3.3V. Operating at other voltages may require recalculating the resistance values used.

For more information on TPLD, visit the TPLD1201 product page.

Need additional assistance? Ask our engineers a question on the TI E2E™ Logic Support Forum.

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