DC/DC Power Supply
Module Five

Smart Fan Temperature Controller

Application Report

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2023

Contents

Abstract

On October 2022 I finished the design of the module. In electronics, components life expectancy is determined among other things at the temperature which they operate. The main function of this board is to maintain a temperature inside an enclosure that let electronics components function at its optimum level despite the load of the supply or external temperature factors.

Along this document you will find all the decisions made on the design in order to make it as robust as possible.

What is a Smart Fan Temperature Controller?

Using a DC Fan, a MCU (Microcontroller Unit) and temperature sensors, depending on the sensed temperature, the fan rpm (revolutions per minute) is adjusted so the heat extracted inside an enclosure is controlled. Figure 1 shows a simplified view of the module operation. The table shown is programmed inside microcontroller software, containing the temperature values to use.

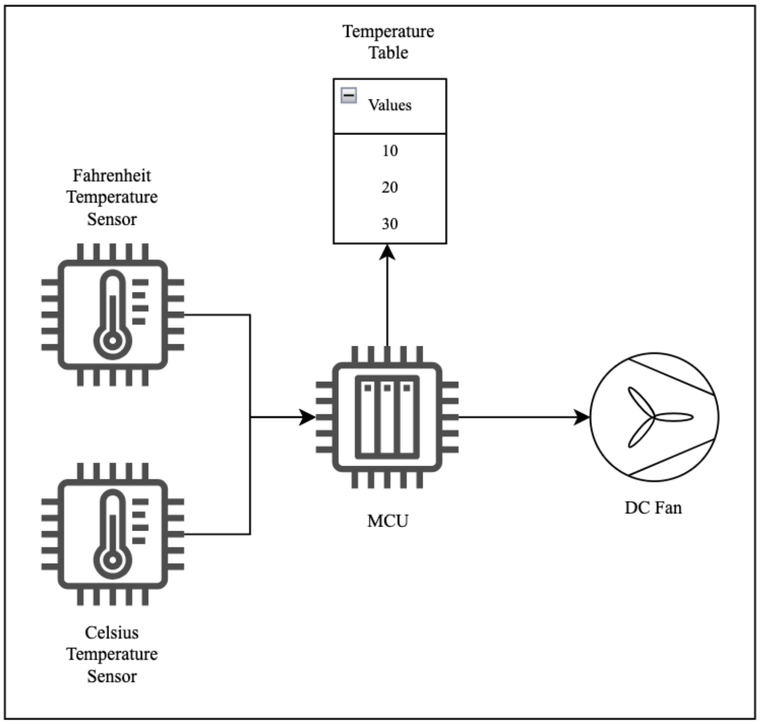

Figure 1 Module Operation

Module Characteristics

Voltage input of the circuit is 12V.

F1 is a very fast acting fuse [1] to protect the circuit from overcurrent. I choose one with a 1A of current rating.

IC1 is a P-Mosfet (FDS6679) [2] used to protect the module of reverse polarity. This mosfet can tolerate up to -13A of current (I_D), has a drain-source voltage rating up to -30V (V_{DSS}) and a gate-source voltage of ±25V (V_{GSS}).

D1 is a unidirectional tvs diode (SA12A-B) [3]. If a transient voltage occurs (because surge protector failed and IC1 eventually got damaged) the rest of the circuit is protected. I choose a unidirectional one because VIN is always positive.

Let's focus on the DC Fan. I decide to use a Delta QFR0812SH-CX13 [4] that among it features includes a speed sensor (tachometer) and PWM control. When I first had the design in mind, my requirements were: knowing at any time if the fan was spinning, how fast, and also, I wanted a low-noise solution.
Using the tach signal we can know at any time if the fan is spinning or not and how fast by counting the pulses of the sensor, and by using PWM we achieve efficiency and good acoustics. The fan can be programmed to not spin all the time or run at certain speed depending on the temperature.
Taking into account fan datasheet, I decided to use for FG Signal (tachometer) a resistance R5 of 4.7KΩ considering that VIN = 12V and $I_{C\,MAX}$ = 0.005A. With R5 value we have I_C = VIN / R5 = 12V / 4700Ω = 0.0025A.
Datasheet also specifies that the preferred operating point for PWM signal control is 25KHz. The MCU I decided to use is the ATmega328 [5] inside an Arduino Nano board. To generate this signal, we have to lower the clock speed of the MCU to 8Mhz. This means that it will take twice the time to execute instructions as when is configured to the default clock speed (16MHz).
PB1 pin (PCINT1/OC1A) in the MCU (D9 pin on Arduino Nano) is the output from the Timer/Counter1, also the output pin for the PWM mode timer function. To output 25KHz on it, the timer needs to be reset at 320 (8.000.000 / 25000), so we have 320 PWM values to control the fan speed.

With the purpose of powering the Arduino board either from usb port or VIN pin in a safe way, I've included a header J2. If the header is without the shunt, the board can be powered by usb and by VIN pin with the shunt on the header. IC2 supplies a regulated +10V to the board and also to voltage reference IC3.

In the same way, J3 header with the shunt, lets AREF pin be powered using an external voltage reference or use the default on the board without it. IC3 supplies a +2.5V reference to AREF pin, so we can achieve 0.002V (2.5V / 1024) on each of the 1024 steps available ($1024 = 2^{10}$) with 10 the resolution of the analog to digital converter of the Arduino nano.

Let’s talk now about temperature sensors. They are powered with +5V using the voltage regulator of the Arduino board. I use one Celsius [6] and one Fahrenheit [7], but the design supports any of the same type too. With this approach I can verify if they are working ok on real time and also, put them on different spots of the enclosure to measure the temperature.
I soldered a 200Ω resistor (1206) at output pin of both sensors to provide immunity to wiring capacitance. Then I cover all of the pins using uv liquid plastic glue to ensure that the leads of the sensors and the wires are at the same temperature as the surface.

In order to provide an easy way of showing faults on the board I’ve included a buzzer (LS1) [8] and two red led diodes. I programmed a fan test when board is powered on. If temperature sensors are unconnected or faulty, fan is not spinning or there is a problem with PWM/FG signal, an intermittent beep sound is executed and the corresponding led lights up in real time.

Conclusions

After testing the board, I consider the design offers a standard way of measure the temperature inside an enclosure. By using a DC Fan with PWM and tachometer, good acoustics and capabilities are achieved. Also, the way faults are managed offers an easy way to realize what is happening.

References

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[6] “LM35 Precision Centigrade Temperature Sensors” [Online]. Available: https://www.ti.com/lit/ds/symlink/lm35.pdf (Accessed: Dec. 22, 2023).

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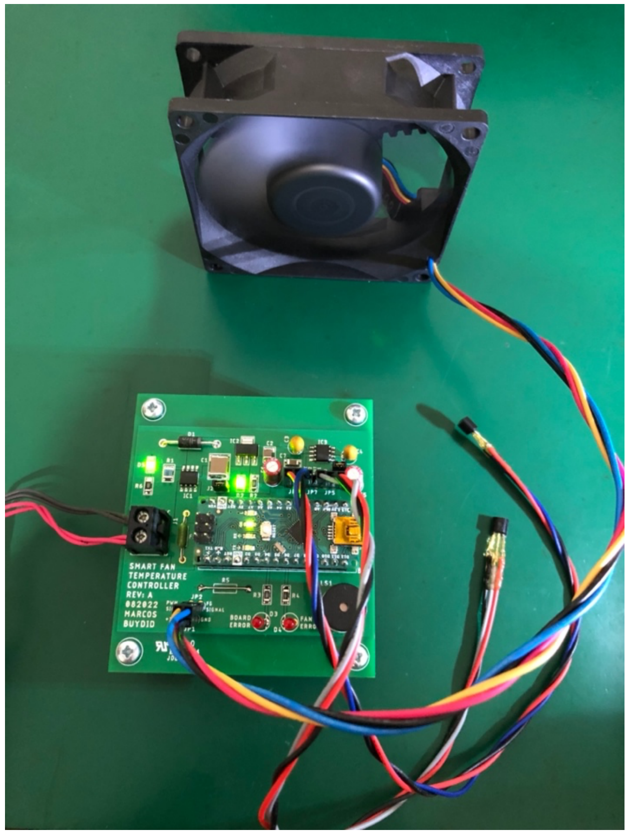
Annexes

Finish Assembly Photos



Module View From Above During Testing

Revision History

Date	Version	Changes
Dec-2023	1	First version