A Quiet Fan Controller

Speed varies with temperature

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Many modern radios and other electronic devices rely on muffin fans for cooling. These can be loud and annoying. Some run continuously, while others cycle on and off, either when needed or just on transmit. In some radios, the fan cycling results in a small frequency shift as the oscillator is heated and cooled.

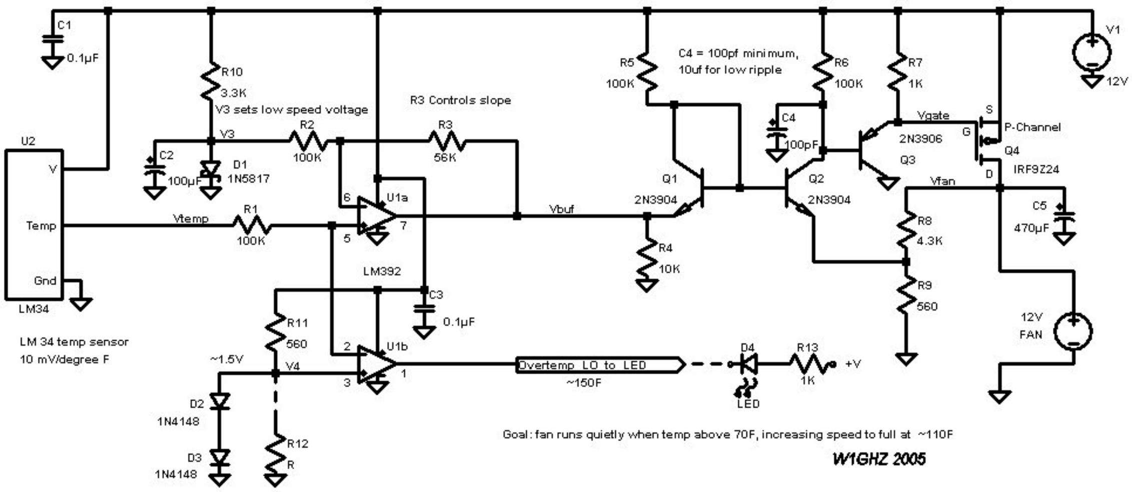
Wouldn't it be preferable to have a fan with a variable speed, responding to cooling needs? I've thought so for a long time, but never got around to doing something about it. Recently, I decided it was time. I figured this was an obviously useful thing, so there would be lots of circuits available on the web. NOPE! The only things I could find were microprocessor circuits, many of them relying on fancy fans with internal tachometers – none of those in my junkbox. Also, the microprocessor controls the speed by turning the fan on and off rapidly; some of the notes suggested that the results are audible.

Most muffin fans use DC brushless motors, so the speed is easily controlled by varying the motor voltage. 12-volt fans are convenient and readily available. Also, there are a number of inexpensive temperature-sensing ICs available. What we need is a simple circuit to vary the fan voltage in proportion to temperature – basically, an amplifier. A couple of opamps should do the job.

I sketched out some circuits and simulated them with the free **SwitcherCAD III** software from www.linear.com. None of them worked satisfactorily, so I called the opamp guru, Byron, N1EKV. He agreed that it sounded simple and would look into it. He soon called back to say it wasn't as simple as it sounded, because of some choices I had made: to keep one end of the temperature sensor and one end of the fan grounded, and to drive it with a power FET for minimum voltage drop at full speed. The result is that the sensor is referenced to ground, but the FET is referenced to the positive voltage. The final complication is that there is a huge gain in the circuit due to the transconductance of the FET, about 2.5 Siemens (in tube terms, this is 2,500,000 μmhos – a typical tube is 5000) or more. To make things worse, the FET is operating in a non-linear region, and having non-linear elements inside a feedback loop is never a good idea.

I went back to engineering basics: find a circuit to steal. One of the microprocessor fan controls[1] used an interesting circuit to drive a FET and shift the reference from ground to high side. The circuit, in the area of Q1 and Q2 in the schematic, looks like the Widlar current mirror used in many integrated circuits. I added this circuit plus the PNP emitter follower, Q3, and fiddled with the resistances to get it going. Then I consulted Byron again and added capacitors C4 and C5 to stabilize things.

Temperature-proportional Fan Speed Controller



Computer simulations are only as good as the models, and don't always fully model reality, so I built up a breadboard on a piece of perfboard. It actually works – and it definitely oscillates without C4!

Now it felt safe to make a printed-circuit board, to make it reproducible and robust enough for portable equipment – perfboard wonders seem to fall apart bouncing around in the back of the truck. Since opamps come in pairs and quads, I tried to think of something to do with the other half. The best use I could come up with is an over-temperature alert, but that really requires a comparator rather than an opamp. But there is one IC available with one of each, the LM392.

The comparator uses the output of the same temperature sensor to provide an alert at some higher temperature. The output goes low at the desired temperature to turn on whatever: an LED, a sound, a relay to shut down the amplifier, or a jolt to the operator's chair. The noisemaker from a defunct smoke alarm might be interesting, but a blinking LED seems adequate to remind me not to talk so much.

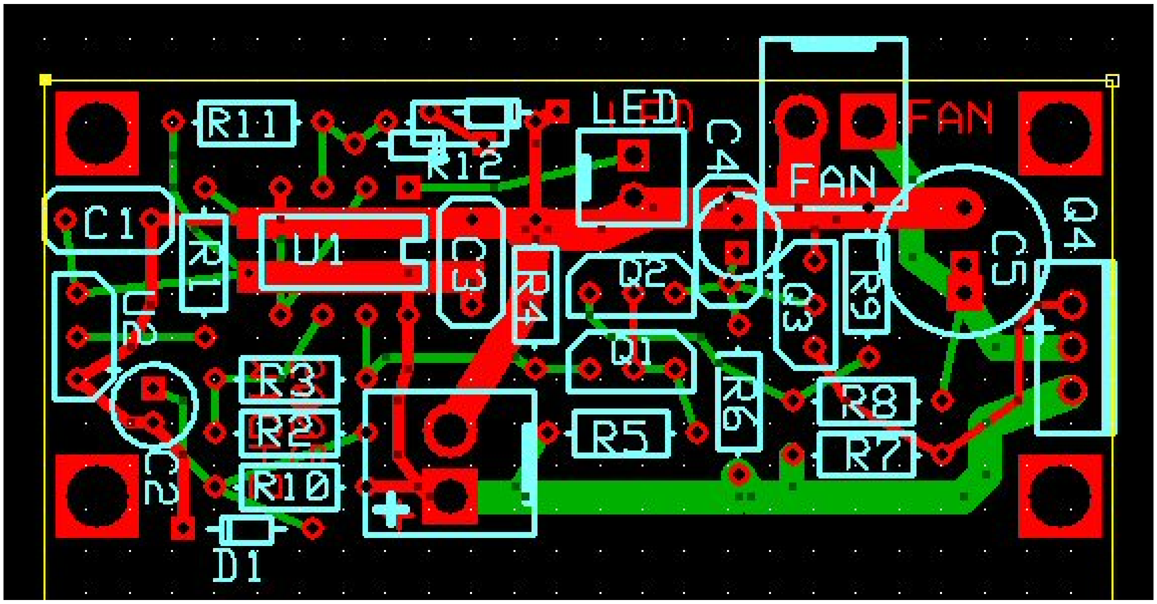


Figure 2

I used the free software from ExpressPCB (www.expresspcb.com) to layout the board shown in Figure 2 and placed a Miniboard order: three boards in four days for $59. Four days later, the boards arrived, I put one together and sparked it up. After I added one resistor that somehow was left out of the layout (Figure 2 includes the correction), it works fine. The fan purrs away at room temperature and speeds up as the temperature sensor is heated up. Figure 3 is a photo of the completed controller, with the LM34 temperature sensor at the left edge of the board, not yet attached to a heat source. It could also be soldered to the other side of the board, if the intent were to mount this board on the heat sink.

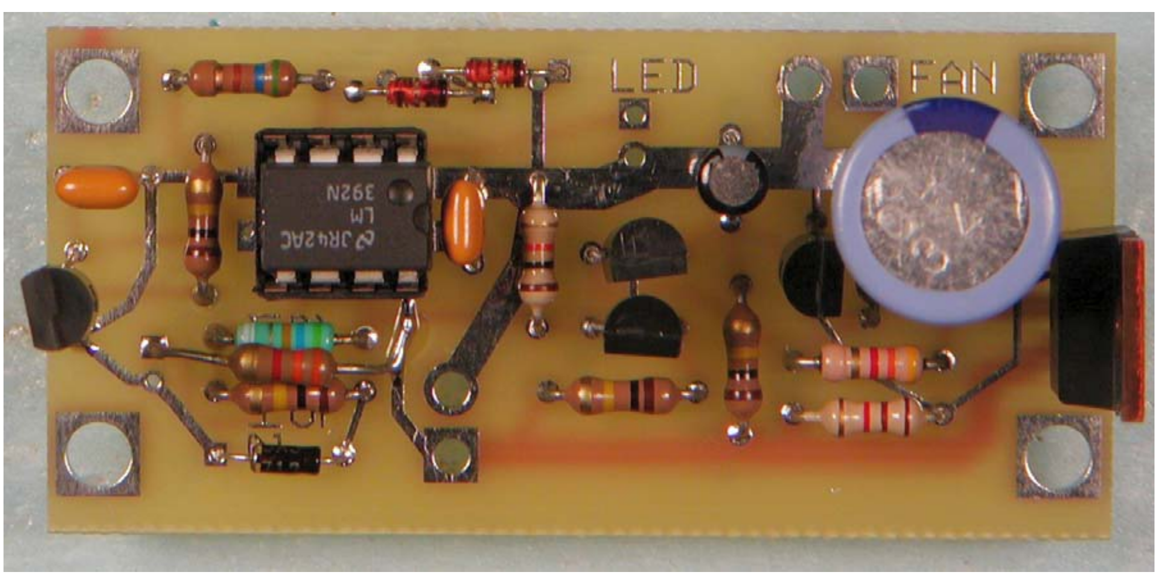


Figure 3

With the resistor values in the schematic, the fan gets about 9.5 volts at room temperature and gets up to full speed with full voltage at about 105°F. We will use Fahrenheit since the LM34 temperature sensor output is in Fahrenheit: 10mV per degree F, so the output at 70°F is 700 mV and at 105°F is 1.05 Volts. The slow speed is set by voltage V3, controlled by resistor R10; decreasing R10 increases the current through Schottky diode D1, which increases the voltage drop of the diode and increases V3. The temperature at which the fan reaches full speed is controlled by resistor R3; increasing R3 makes the fan reach full speed at a lower temperature. Note that we can monitor the temperature directly by measuring voltage Vtemp at the LM34 output, as 10mV per degree F.

The over-temperature setting for the comparator is similarly set by voltage V4, the voltage drop through silicon diodes D2 and D3. Decreasing resistor R11 increases the current through the diodes, increasing the voltage drop and thus raising the temperature setting. With the value shown for R11, V4 is about 1.50 volts, so the over-temperature alarm is at about 150°F. If a much different temperature setting is desired, R12 could be used instead of the diodes, but the temperature setting would vary with the supply voltage.

The temperature sensor U2, the LM34, should be in contact with the heat sink or surface being cooled by the fan. Either attach the flat side of U2 directly to the heat sink with Super Glue (cyanoacrylate), or use a dab of heat sink compound and clamp it on. A heat sink takes some time to heat and cool, so the fan will not change speed instantaneously, but will speed up as the heat sink heats. More important, it will continue running at higher speed until it brings the heat sink temperature down, gracefully slowing down as things cool. U2 need not be mounted on the printed circuit board, but may be mounted remotely, on the heat sink; twist the wires together, and consider adding ferrite beads if there is a lot of RF floating around.

Of course, controlling fan speed won't do much good if there isn't adequate cooling with the fan running at full speed. If you are adding a fan, size, placement, and airflow are important. For cooling a heat sink, *impingement cooling*, with the air blasting directly into the fins (like a Pentium cooling fan), is much more effective than ordinary *convection cooling*, where the airflow is just passing through the fins. If you are just cooling a cabinet or enclosure, sucking may be more effective than blowing. But any airflow is better than none at all.

1. ADM1028 data sheet, www.analog.com