TEMPERATURE CONTROLLED FAN USING OP-AMP COMPARATOR AND THERMISTOR

1. ABSTRACT

This project presents the design and simulation of a temperature-controlled fan using an operational amplifier configured as a comparator and an NTC thermistor as a temperature sensor. The circuit automatically switches ON a cooling fan when the ambient temperature exceeds a predefined threshold and switches it OFF when the temperature falls below this level. The entire system is designed and verified using LTspice simulation software. The proposed design is simple, cost-effective, and suitable for applications such as electronic equipment cooling and thermal protection systems.

2. INTRODUCTION

With the increasing use of electronic devices, effective thermal management has become essential to ensure reliability and longevity. Excessive heat can degrade performance and damage components. Manual control of cooling systems is inefficient and unreliable. Hence, an automatic temperature-controlled cooling mechanism is required.

This project implements an automatic fan control circuit using basic analog components without the need for a microcontroller. Temperature sensing is achieved using a thermistor, while decision-making is performed using an op-amp comparator.

3. OBJECTIVE OF THE PROJECT

The main objectives of this project are:

- To design a circuit that senses temperature variations
- To compare the sensed temperature with a preset reference
- To automatically control a fan based on temperature
- To verify the circuit operation using LTspice simulation

4. COMPONENTS USED

- Operational Amplifier (Op-Amp)
- NTC Thermistor (10kΩ, β = 3950)
- NPN Transistor (2N2222)
- Diode (1N4007)
- Resistors
- DC Power Supply (12V)
- Cooling Fan (represented as load in simulation)

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5. THEORY OF OPERATION

5.1 Thermistor

A thermistor is a temperature-sensitive resistor. In this project, an NTC (Negative Temperature Coefficient) thermistor is used, whose resistance decreases as temperature increases. The thermistor resistance is modeled using the equation:

$R(T) = R_{\square} \times \exp[\beta \times (1/T - 1/T_{\square})]$

where $R_{\square}$ is resistance at reference temperature $T_{\square}$.

5.2 Voltage Divider

The thermistor is connected with a fixed resistor to form a voltage divider. The output voltage (Vtemp) varies with temperature and represents the sensed temperature in voltage form.

5.3 Reference Voltage Generator

A fixed reference voltage (Vref) is generated using a resistor divider network. This voltage corresponds to the temperature threshold at which the fan should turn ON.

5.4 Op-Amp as Comparator

The op-amp is used in open-loop configuration as a comparator:

- Non-inverting terminal (+) receives Vtemp
- Inverting terminal (−) receives Vref

When Vtemp exceeds Vref, the op-amp output saturates HIGH; otherwise, it remains LOW.

5.5 Transistor Switching Stage

Since the op-amp cannot supply sufficient current to drive a fan directly, an NPN transistor (2N2222) is used as a switch. The op-amp output drives the base of the transistor through a resistor. When the base voltage exceeds approximately 0.7V, the transistor turns ON, allowing current to flow through the fan.

5.6 Flyback Diode

A diode is connected across the fan to protect the transistor from voltage spikes caused by the inductive nature of the fan when switching OFF.

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6. CIRCUIT DESCRIPTION

The circuit consists of a thermistor-based sensing stage, a reference voltage generator, an op-amp comparator, and a transistor-based switching stage. The op-amp compares the temperature-dependent voltage with a reference voltage and controls the transistor accordingly.

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7. SIMULATION SETUP IN LTspice

- Supply Voltage: 12V
- Temperature Sweep: 20°C to 80°C
- Step Size: 2°C
- Analysis Type: DC operating point with parameter sweep

The .step command is used to vary the temperature parameter and observe circuit behavior.

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8. SIMULATION RESULTS

The simulation results show that:

- Below the threshold temperature (~38°C), the comparator output remains LOW and the fan is OFF.
- Above the threshold temperature, the comparator output switches HIGH (~12V), turning the transistor ON and activating the fan.

The output graph clearly demonstrates a sharp transition, confirming correct comparator operation.

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9. ADVANTAGES

- Simple and economical design
- Automatic temperature control
- No microcontroller required
- Reliable and fast response

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10. APPLICATIONS

- CPU and computer cooling systems
- Power electronic circuits
- Battery thermal management
- Industrial temperature control

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11. FUTURE SCOPE

- Addition of hysteresis using positive feedback
- PWM-based speed control
- Microcontroller-based digital control
- Hardware implementation and testing

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12. CONCLUSION

The temperature-controlled fan circuit was successfully designed and simulated using LTspice. The use of an NTC thermistor and op-amp comparator provides an effective and reliable method for automatic temperature-based fan control. The simulation results validate the correctness of the design and demonstrate its suitability for practical thermal management applications.

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13. REFERENCES

1. Sedra & Smith, Microelectronic Circuits
2. LTspice Documentation
3. Datasheets of 2N2222 and 1N4007

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