# Application Brief

## Four-Speed Fan Control Using Simple Remote Diode Temperature Sensor

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The circuit shown in *Figure 1* controls the speed of a 12V DC fan using an LM88 Remote Diode Temperature Sensor (RDTS) IC. The LM88 is a dual remote diode temperature sensor with 3 digital comparators and has 3 open-drain outputs (O_SP0, O_SP1 and O_CRIT) that can be used as interrupts or to signal system shutdown. The digital comparators can be programmed independently to make a greater than or less than comparison. When programmed for a greater than comparison:

- O_SP0 and O_SP1 activate when the temperatures measured by D0 or D1 exceed the associated setpoints of T_SP0 or T_SP1.
- O_CRIT activates when the temperature measured by either D0 or D1 exceeds set point T_CRIT.

T_CRIT can be set at 1°C intervals from -40˚C to +125˚C. T_SP0 and T_SP1 can be set at 4°C intervals in the range of T_CRIT, ±100˚C.

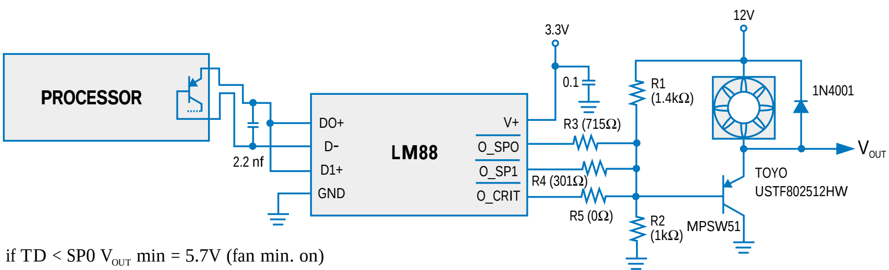
In the circuit shown in *Figure 1* the two D+ inputs have been wired in parallel to allow all three set points to be evaluated against a single temperature measurement. The hysteresis of each comparator is internally set to 1˚C, allowing the set point values to be placed very close together without any interaction. The three outputs of the LM88 are connected to resistors forming a crude 2-bit DAC. The output of this DAC is fed to a PNP emitter follower, controlling the voltage on the negative pin of the fan from 1.25V to 5.7V. The output voltage ($V_{OUT}$) decreases as the temperature reading increases, when SP0<SP1<CRIT.

The equations shown in *Figure 1* describe the behavior of $V_{OUT}$. The maximum speed of the fan is dependent on the minimum $V_{OUT}$. The minimum $V_{OUT}$ is dependent on the drain to source on resistance (Rds) of the O_CRIT output, the MPSW51's beta and base emitter voltage when R5 is set to 0Ω (as shown in *Figure 1*). The MPSW51 beta variation will introduce an error term that cannot be accounted for. Therefore, it is tempting to make the current through the resistors as high as possible. Increasing this current is a "Catch 22", because the minimum $V_{OUT}$ level will increase as the current increases, because of O_CRIT's Rds that is typical 100Ω and worst case .4V/3 mA = 133Ω. A compromise would be to set this current 10 times the MPSW51 base current.

O_SP0, O_SP1 and O_CRIT have a maximum voltage limit of 5V. This sets the ratio of R2/(R2+R1) = 5/12 = 0.41666.

The current through R1 and R2 should be set such that the base current of the MPSW51 is negligible. The current through the fan with (12 - 5.7) 6.3V is about 65 mA or so. That makes the base current about 65 mA/130 = 0.5 mA. Since the beta will vary slightly as the collector current changes, it's best to set the current through R1/R2 ten times greater than 0.5 mA. Therefore:

(R1+R2)= 12V/5 mA = 2400Ω
Since R2/(R2+R1)=5/12
R2= (5/12)*(2400)=1000Ω and R1=1400Ω




if TD < SP0 $V_{OUT}$ min = 5.7V (fan min. on)
if TD < SP1 $V_{OUT}$ in1 = ((Rp23/(R1+Rp23))12V)+0.7V=3.61V
if TD < CRIT $V_{OUT}$ int2 = ((Rp234/(R1+Rp234))12V)+0.7V= 2.28V
if TD > CRIT $V_{OUT}$ max = ((Rp2345/(R1+Rp2345))12V)+0.7V = 1.25V
where SP0<SP1<CRIT and TD=diode temperature, see text for values of Rp23, Rp234 and Rp2345.

*Figure 1. Low Cost Remote Diode Temperature Fan Speed Control*



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When the temperature of the diode is less than the SP0, SP1 and T_CRIT set points, all of the LM88's outputs will be deactivated. Therefore, $V_{OUT}$ will be set to approximately 5.7V. This will set the slowest speed of the fan.

The first intermediate fan speed will be set when only O_SP0 is activated. This happens when the temperature measured is greater than the SP0 set point but less than the SP1 and CRIT set points. For this case the following equations set $V_{OUT}$:

Rp23 = (R3+Rds)||R2 = 1/(1/(R3+Rds)+1/R2)

$V_{OUT}$ int1 = ((Rp23/(R1+Rp23))12V)+0.7V

Therefore, If Rds = 100Ω typical, then with R3 = 715Ω $V_{OUT}$ = 3.614V making the voltage across the fan equal to 12V - 3.614V = 8.386V.

The second intermediate speed of the fan will be set when both O_SP0 and O_SP1 are activated. This happens when the temperature measured is greater than both the SP0 and SP1 set points but less than the CRIT set point. For this case the following equations set $V_{OUT}$:

Rp234=(R3+Rds)||(R4+Rds)||R2 = 1/(1/(R3+Rds)+1/(R4+Rds)+1/R2)

$V_{OUT}$ int2 = ((Rp234/(R1+Rp234))12V)+0.7V. If R3 = 715Ω and Rds = 100Ω (typical) setting R4 to 301Ω will give a $V_{OUT}$ = 2.277V making the voltage across the fan equal to 12V-2.277V= 9.723V.

The fourth, and maximum, speed of the fan will be set when all three outputs O_CRIT, O_SP0 and O_SP1 are activated. This happens when the temperature measured is greater than all three set points. For this case the following equations set $V_{OUT}$:

Rp2345 = (R5+Rds)||(R4+Rds)||(R3+Rds)||R2 = 1/(1/(R5+Rds)+1/(R4+Rds)+1/(R3+Rds)+1/R2)

$V_{OUT}$ max = ((Rp2345/(R1+Rp2345))12V)+0.7V. If R3 = 715Ω, R4 = 301Ω and Rds = 100Ω (typical) setting R5 to 0Ω will give $V_{OUT}$ = 1.255V making the maximum voltage across the fan equal to 12V-1.255V=10.775V.

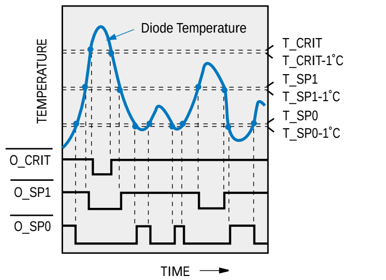


*Figure 2. Temperature Response Diagram Of The LM88's Outputs*

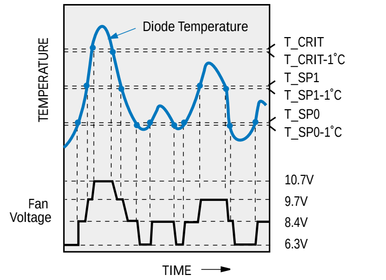


*Figure 3. Fan Voltage Temperature Response*

Using 1% resistor values measurements were made and the measured $V_{OUT}$ was within 3% of the calculated $V_{OUT}$ voltage.

*Figures 2* and *3* show the temperature response diagram of the LM88's outputs and the fan voltage. As the temperature increases the sequential activation of O_SP0 followed by O_SP1 and finally O_CRIT cause the voltage across the fan to increase.

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