National
Semiconductor

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LM27A
SOT-23, ±3˚C Accurate, 120˚C-150˚C Factory Preset Thermostat (LM27 in Die Form)

General Description

This datasheet applies to the LM27A, which is the die form of the LM27. The LM27 is available in the SOT23-5 package. Please refer to the LM27 datasheet for detailed specifications pertaining to the packaged part.

The LM27A is a precision, single digital-output, low-power thermostat comprised of an internal reference, DAC, temperature sensor and comparator. Utilizing factory programming, it can be manufactured with different trip points as well as different digital output functionality. The trip point (T_{OS}) can be preset at the factory to any temperature in the range of +120˚C to +150˚C in 1˚C increments. The LM27A has two digital output pads, one digital input (HYST) and one analog output (V_{TEMP}). One digitial output is an active-high, push-pull output and the other is an active-low, open-drain output. Either of the outputs (but not both) are available.

The LM27A is available in either an overtemperature shutdown or an undertemperature shutdown option. An LM27A with overtemperature shutdown is configured so that its thermostat outputs (OS and $\overline{OS}$) will go active when a rising temperature crosses the trip point and the hysteresis will apply to a falling temperature. The thermostat outputs of an LM27A with an undertemperature shutdown (US and $\overline{US}$) will trip on a falling temperature and hysteresis will apply on a rising temperature. For example, when the LM27A is preset as an overtemperature shutdown, the active-high output (OS) will go HIGH and the active-low output ($\overline{OS}$) will go LOW to indicate that the die temperature is over the internally preset T_{OS} . The outputs will reset to their normal states when the temperature goes below ($T_{OS}–T_{HYST}$). Similarly, when preprogrammed as an undertemperature shutdown the active-high output (US) will go HIGH and the active-low output ($\overline{US}$) will go LOW to indicate that the temperature is below T_{US} . The outputs will reset when the temperature is above ($T_{US}+T_{HYST}$). The typical hysteresis, T_{HYST}, can be set to 2˚C or 10˚C and is controlled by the state of the HYST pin. The V_{TEMP} analog output provides a voltage that is proportional to temperature and has a −10.7mV/˚C output slope.

Standard parts are available, see ordering information for details. For other part options, contact a National Semiconductor Distributor or Sales Representative for information on minimum-order qualification.

Applications

- Microprocessor Thermal Management
- Appliances
- Portable Battery Powered Systems
- Fan Control
- Industrial Process Control
- HVAC Systems
- Electronic System Protection

Features

- Internal comparator with pin selectable 2˚C or 10˚C hysteresis
- No external components required
- Open-drain or push-pull digital output; supports CMOS logic levels
- Internal temperature sensor with V_{TEMP} output pin
- V_{TEMP} output allows after-assembly system testing
- Internal voltage reference and DAC for trip-point setting
- Excellent power supply noise rejection

Key Specifications

Power Supply Voltage	2.7V to 5.5V
Power Supply Current	40µA(max) 15µA(typ)
Hysteresis Temperature	2˚C or 10˚C(typ)
Temperature Trip Point Accuracy	±3˚C (max)

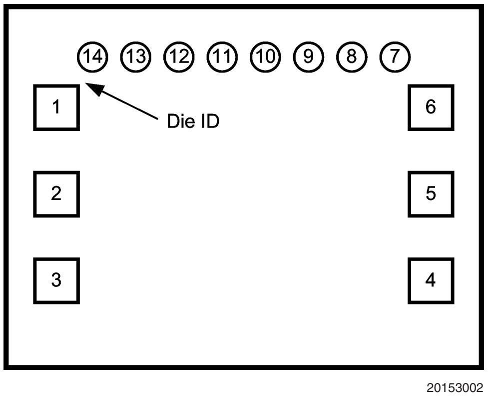
Ordering Information

For more detailed information on the suffix meaning see the part number template at the end of the Electrical Characteristics Section. Contact National Semiconductor for other set points and output options.

Order Number	NS Package Number	Trip Point Setting	Output Function	Transport Media
LM27-2PL MDA	Die form, no package	145˚C	Push-Pull (OS) Open-Drain ($\overline{OS}$)	400 units in waffle trays

Connection Diagram

LM27A
Bond Pad Layout



TOP VIEW
1130μm x 902μm

Bond Pad Mechanical Dimensions

Dimensions of bond pad coordinates are in micrometers.

Origin of coordinates: center of die.

X-Direction is in the longitudinal axis of the die.

Coordinates refer to center of Bond Pad.

Opening sizes for bond pads 1 through 6 are 85 μm x 85 μm.

Pin#	X	Y
1	−437 μm	+225 μm
2	−437 μm	0
3	−437 μm	−220 μm
4	+437 μm	−220 μm
5	+437 μm	+5 μm
6	+437 μm	+225 μm
BACK		

Pin Description

Pin Number	Pin Name	Function	Connection
1	HYST	Hysteresis control, digital input	GND for 10˚C or V⁺ for 2˚C
2 (Note 8)	OS	Overtemperature Shutdown push-pull active-high thermostat digital output	Controller interrupt, system or power supply shutdown
	US	Undertemperature Shutdown push-pull active-high thermostat digital output	System or power supply shutdown
3 (Note 8)	$\overline{OS}$	Overtemperature Shutdown open-drain active-low thermostat digital output	Controller interrupt, system or power supply shutdown; pull-up resistor ≥ 10kΩ
	$\overline{US}$	Undertemperature Shutdown open-drain active low thermostat digital output	System or power supply shutdown; pull-up resistor ≥ 10kΩ
4	V^+	Supply input	2.7V to 5.5V with a 0.1µF bypass capacitor. For PSRR information see *Section Titled NOISE CONSIDERATIONS*.
5	GND	Power supply ground	System ground
6	V_{TEMP}	Analog output voltage proportional to temperature	Leave floating or connect to a high impedance node.
7 - 14	NC		Do not connect
BACK	Backside		Can go to GND connection (Note: GND must be connected. The back is not a system ground connection).

Note: Only connect to one of the output pads, Pad 2 **or** Pad 3, not both. Either push-pull (Pad 2) or open-drain (Pad 3) can be used but they can not both be used on the same die.

Absolute Maximum Ratings (Note 1)

Input Voltage	6.0V
Input Current at any pin (Note 2)	5mA
Package Input Current(Note 2)	20mA
Storage Temperature	−65˚C to + 175˚C
ESD Susceptibility (Note 3)	
Human Body Model	2500V
Machine Model	250V

Operating Ratings(Note 1)

Specified Temperature Range	$\mathbf{T_{MIN} \le T_A \le T_{MAX}}$
LM27A	$-40˚C \le T_A \le +150˚C$
Positive Supply Voltage (V^+)	+2.7V to +5.5V
Maximum V_{OUT}	+5.5V

LM27A Electrical Characteristics

The following specifications apply for $V^+ = 2.7V_{DC}$ to $5.5V_{DC}$, and V_{TEMP} load current = 0μA unless otherwise specified. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX};** all other limits $T_A = T_J = 25˚C$ unless otherwise specified.

Symbol	Parameter	Conditions	Typical (Note 4)	LM27A Limits (Note 5)	Units (Limits)
Temperature Sensor					
	Trip Point Accuracy (Includes V_{REF}, DAC, Comparator Offset, and Temperature Sensitivity errors)	$+120˚C<T_A<+150˚C$		±3	˚C (max)
	Trip Point Hysteresis	HYST = GND	10		˚C
		HYST = V^+	2		˚C
	V_{TEMP} Output Temperature Sensitivity		−10.82		mV/˚C
	V_{TEMP} Temperature Sensitivity Error to Equation: $V_O = (-3.552x10^{-6}x(T-30)^2 + (-10.695x10^{-3}x(T-30)) + 1.8386V$	$-30˚C \le T_A \le 150˚C$, $2.7V \le V^+ \le 5.5V$		**±3**	˚C (max)
		$-55˚C \le T_A \le 150˚C$, $4.5V \le V^+ \le 5.5V$		**±3**	˚C (max)
		$T_A = 25˚C$		±2.5	˚C (max)
	V_{TEMP} Load Regulation	Source ≤ 1 μA	0.070		mV
		Sink ≤ 40 μA		**0.7**	mV (max)
	V_{TEMP} Line Regulation	$+2.7V \le V^+ \le +5.5V$, $-30˚C \le T_A \le +120˚C$	−0.2		mV/V
I_S	Supply Current		15	22 **40**	μA (max) μA (max)
Digital Output and Input					
$I_{OUT(“1”)}$	Logical “1” Output Leakage Current (Note 7)	$V^+ = +5.0V$	0.001	**1**	μA (max)
$V_{OUT(“0”)}$	Logical “0” Output Voltage	$I_{OUT} = +1.2mA$ and $V^+ \ge 2.7V$; $I_{OUT} = +3.2mA$ and $V^+ \ge 4.5V$; (Note 6)		**0.4**	V (max)
$V_{OUT(“1”)}$	Logical “1” Push-Pull Output Voltage	$I_{SOURCE} = 500μA$, $V^+ \ge 2.7V$		**0.8 x V^+**	V (min)
		$I_{SOURCE} = 800μA$, $V^+ \ge 4.5V$		**V^+ – 1.5**	V (min)
V_{IH}	HYST Input Logical ”1“ Threshold Voltage			**0.8 x V^+**	V (min)
V_{IL}	HYST Input Logical ”0“ Threshold Voltage			**0.2 x V^+**	V (max)

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

Note 2: When the input voltage (V_I) at any pin exceeds the power supply (V_I < GND or $V_I > V^+$), the current at that pin should be limited to 5mA. The 20mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5mA to four. Under normal operating conditions the maximum current that pins 2, 4 or 5 can handle is limited to 5mA each.

Note 3: The human body model is a 100pF capacitor discharge through a 1.5kΩ resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin.

Note 4: Typicals are at $T_J = T_A = 25^\circ C$ and represent most likely parametric norm.

Note 5: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 6: Care should be taken to include the effects of self heating when setting the maximum output load current. Self heating is not included in the trip point accuracy specification.

Note 7: The 1µA limit is based on a testing limitation and does not reflect the actual performance of the part. Expect to see a doubling of the current for every 15˚C increase in temperature. For example, the 1nA typical current at 25˚C would increase to 16nA at 85˚C.

Note 8: Only connect to one of the output pads, number 2 or number 3, not both. Either push-pull (Pad 2) or open-drain (Pad 3) can be used but they can not both be used on the same die.

Part Number Template

The series of digits labeled xyz in the part number LM27-xyz MDA, describe the set point value and the function of the output as follows:

The place holders xy describe the set point temperature as shown in the following table.

x (10x)	y (1x)	Temperature (˚C)
-	H	0
-	J	1
-	K	2
-	L	3
-	N	4
-	P	5
-	R	6

x (10x)	y (1x)	Temperature (˚C)
-	S	7
-	T	8
-	V	9
Z	-	12
1	-	13
2	-	14
3	-	15

The value of z describes the assignment/function of the output as shown in the following table:

Value of z	Digital Output Function
L	Overtemperature shutdown: active-high OS output or active-low $\overline{\text{OS}}$ output
N	Undertemperature shutdown: active-high US or active-low $\overline{\text{US}}$ output.

For example:

- The part number LM27-2SL MDA would have T_{OS} = 147˚C, and is programmed as an overtemperature shutdown output.
- The part number LM27-ZLN MDA would have T_{US} = 123˚C, and is programmed as an undertemperature shutdown output.

Active-high open-drain and active-low push-pull options are available, please contact National Semiconductor for more information.

Functional Description

Applications Hints

AFTER-ASSEMBLY PCB TESTING

The LM27A's V_{TEMP} output allows after-assembly PCB testing by following a simple test procedure. Simply measuring the V_{TEMP} output voltage will verify that the LM27A has been assembled properly and that its temperature sensing circuitry is functional. The V_{TEMP} output has very weak drive capability that can be overdriven by 1.5mA. Therefore, one can simply force the V_{TEMP} voltage to cause the digital output to change state, thereby verifying that the comparator and output circuitry function after assembly. Here is a sample test procedure that can be used to test a part that would have the part number LM27-2HJ MDA, which would have a 140˚C trip point.

1. Turn on V^+ and measure V_{TEMP}. Then calculate the temperature reading of the LM27A using the equation:

$$V_O = (-3.552\text{x}10^{-6}\text{x}(T-30)^2) + (-10.69576\text{x}10^{-3}\text{x}(T-30)) + 1.8386\text{V} \quad (1)$$

or

$$T = -1475.49 + \sqrt{2.2668 \times 10^6 + \frac{1.8386 - V_{TEMP}}{3.552 \times 10^{-6}}} \quad (2)$$

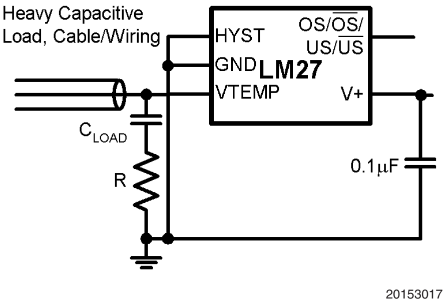
2. Verify that the temperature measured in step one is within (±3˚C + error of reference temperature sensor) of the ambient/board temperature. The ambient/board temperature (reference temperature) should be measured using an extremely accurate calibrated temperature sensor, which is in close proximity to and mounted on the same PCB as the LM27A perhaps even touching the GND lead of the LM27A if possible. The LM27A will sence the board temperature not the ambient temperature.
3.
   A. Observe that $\overline{\text{OS}}$ is high.
   B. Drive V_{TEMP} to ground.
   C. Observe that $\overline{\text{OS}}$ is now low.
   D. Release the V_{TEMP} pin.
   E. Observe that $\overline{\text{OS}}$ is now high.
4.
   A. Observe that $\overline{\text{OS}}$ is high.
   B. Drive V_{TEMP} voltage down gradually.
   C. When $\overline{\text{OS}}$ goes low, note the V_{TEMP} voltage.
   D. V_{TEMP}Trig = V_{TEMP} at $\overline{\text{OS}}$ trigger (HIGH->LOW)
   E. Calculate Ttrig using *Equation (2)*.
5.
   A. Gradually raise V_{TEMP} until $\overline{\text{OS}}$ goes HIGH. Note V_{TEMP}.
   B. Calculate T_{HYST} using *Equation (2)*.

V_{TEMP} LOADING

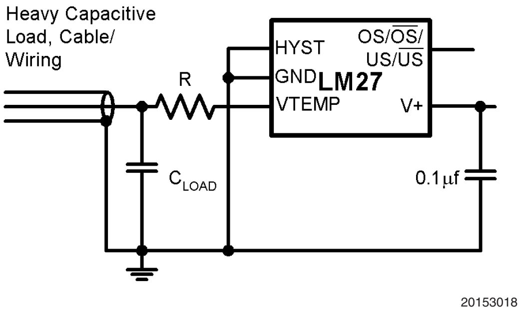
The V_{TEMP} output has very weak drive capability (1 µA source, 40 µA sink). So care should be taken when attaching circuitry to this pin. Capacitive loading may cause the V_{TEMP} output to oscillate. Simply adding a resistor in series as shown in *Figure 1* will prevent oscillations from occurring. To determine the value of the resistor follow the guidelines given in *Table 1*. The same value resistor will work for either placement of the resistor. If an additional capacitive load is placed directly on the LM27A output, rather than across C_{LOAD}, it should be at least a factor of 10 smaller than C_{LOAD}.

TABLE 1. Resistive compensation for capacitive loading of V_{TEMP}

C_{LOAD}	R (Ω)
≤100pF	0
1nF	8200
10nF	3000
100nF	1000
≥1µF	430



a) R in series with capacitor



b) R in series with signal path

FIGURE 1. Resistor placement for capacitive loading compensation of V_{TEMP}

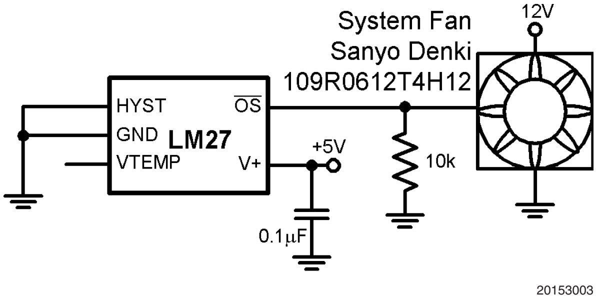
NOISE CONSIDERATIONS

The LM27A has excellent power supply noise rejection. Listed below is a variety of signals used to test the LM27A power supply rejection. False triggering of the output was not observed when these signals where coupled into the V+ pin of the LM27A.

- square wave 400kHz, 1Vp-p
- square wave 2kHz, 200mVp-p
- sine wave 100Hz to 1MHz, 200mVp-p

Testing was done while maintaining the temperature of the LM27A one degree centigrade way from the trip point with the output not activated.

Typical Applications



Note: The fan’s control pin has internal pull-up. The 10k pull-down sets a slow fan speed. When the output of the LM27A goes low, the fan will speed up.

FIGURE 2. Two Speed Fan Speed Control

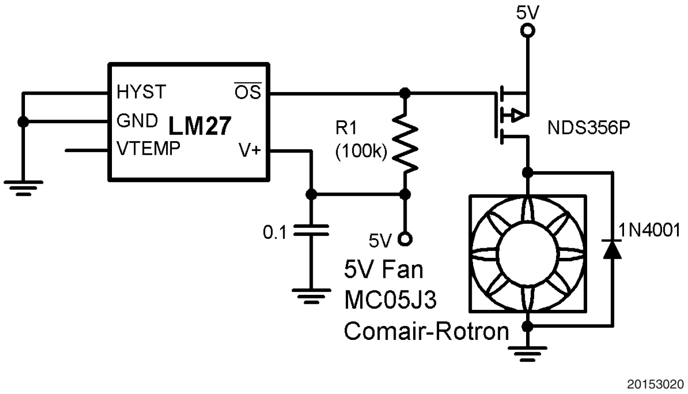


FIGURE 3. Fan High Side Drive

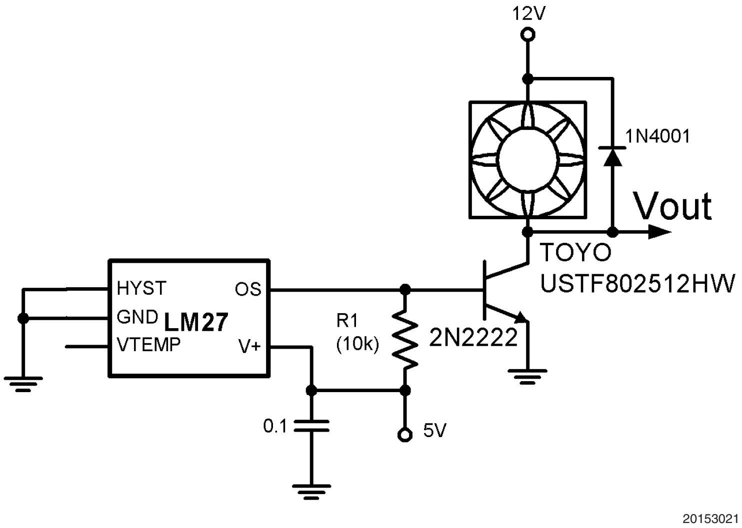


FIGURE 4. Fan Low Side Drive

Typical Applications (Continued)

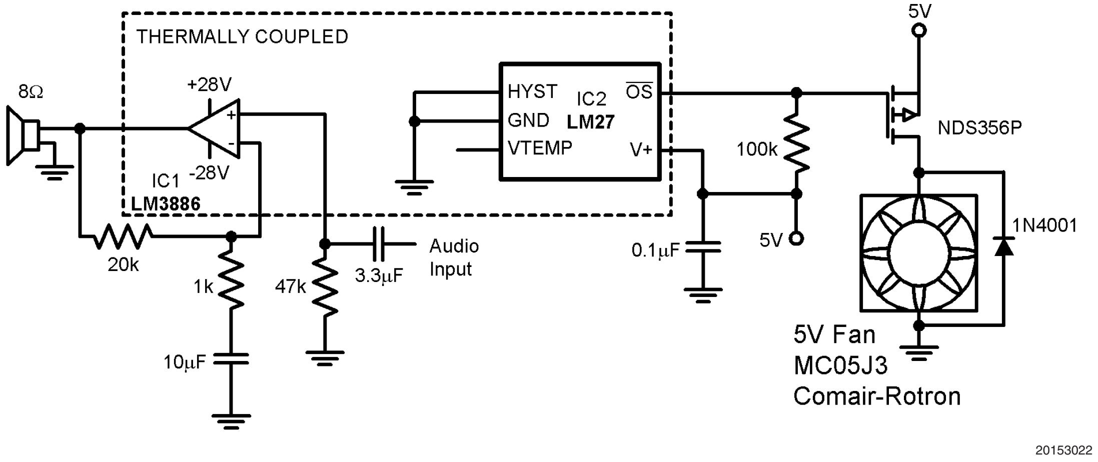


FIGURE 5. Audio Power Amplifier Thermal Protection

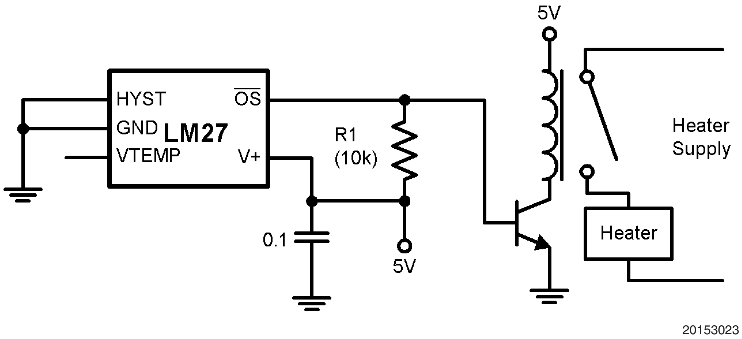
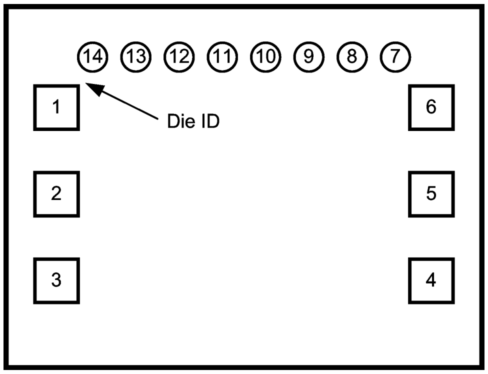


FIGURE 6. Simple Thermostat

Physical Dimensions inches (millimeters) unless otherwise noted



20153002

Order Number LM27-2PL MDA
Bare Die
TOP VIEW
1130µm x 902µm
For Bond Pad Mechanical Dimensions, see Connection Diagram Section

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