



# Fan-Failure Detector with Integrated Power Switch

**MAX6684**

## General Description

The MAX6684 is an integrated fan-failure detector that detects when a fan exhibits excessive underspeed or a locked rotor. This device is especially well suited for critical systems where no fan control, or simple on/off control is desired. The MAX6684 detects fan failure by evaluating fluctuations in current at the low side of the fan; no tachometer signal is necessary. The output of the device,  $\overline{\text{FAIL}}$ , is an active-low, open-drain alarm. The MAX6684 can also be used to switch the fan on or off, based on the state of a logic-level input,  $\overline{\text{OFF}}$ . This device can be used with fans rated at up to 24V and 250mA. The MAX6684 is available in an 8-pin SO package, and is specified for operation from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

## Features

- ◆ Dedicated Fan-Failure Detector
- ◆ Works with Ordinary 2-Wire Fans
- ◆ No Fan Tachometer Output Required
- ◆ No Software Development Required
- ◆ No Analog Circuit Design Required
- ◆ Logic-Level Fan Driver Control
- ◆ Works with Fans Rated Up to 24V/250mA

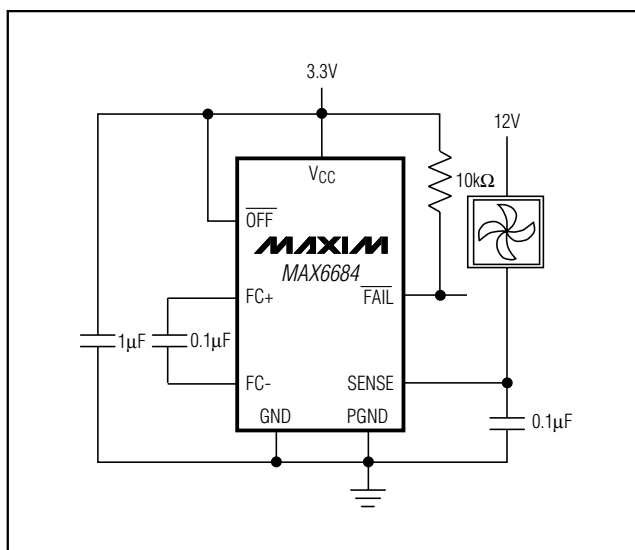
## Applications

Desktop PCs  
Notebooks  
Networking Equipment  
Telecommunications  
Industrial Applications

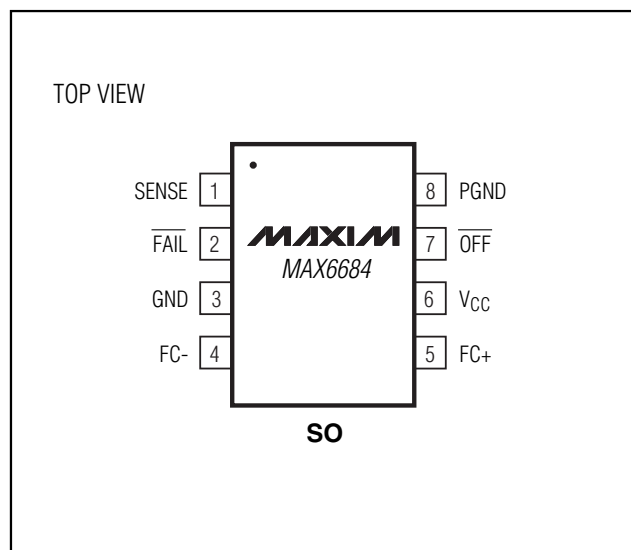
## Ordering Information

| PART       | TEMP RANGE                                     | PIN-PACKAGE |
|------------|------------------------------------------------|-------------|
| MAX6684ESA | $-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$ | 8 SO        |

## Typical Operating Circuit



## Pin Configuration



# Fan-Failure Detector with Integrated Power Switch

## ABSOLUTE MAXIMUM RATINGS

Voltages Referenced to GND, Unless Otherwise Noted

|                       |                                   |
|-----------------------|-----------------------------------|
| V <sub>CC</sub> ..... | -0.3V to +6.0V                    |
| FC+, FC- .....        | -0.3V to (V <sub>CC</sub> + 0.3V) |
| OFF, FAIL .....       | -0.3V to +6.0V                    |
| PGND .....            | -0.3V to +0.3V                    |
| SENSE to PGND .....   | -0.3V to +28.0V                   |
| SENSE Current .....   | 1400mA                            |

Continuous Power Dissipation (T<sub>A</sub> = +70°C)

|                                                |                 |
|------------------------------------------------|-----------------|
| 8-Pin SO (derate 5.9mW/°C above +70°C) .....   | 470mW           |
| Operating Temperature Range .....              | -40°C to +85°C  |
| Storage Temperature Range .....                | -65°C to +150°C |
| Junction Temperature .....                     | +150°C          |
| Soldering Temperature (vapor phase, 60s) ..... | +215°C          |
| Soldering Temperature (infrared, 15s) .....    | +220°C          |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(V<sub>CC</sub> = 3.0 to 5.5V,  $\overline{\text{OFF}}$  = V<sub>CC</sub>, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at V<sub>CC</sub> = 3.3V, T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                                      | SYMBOL              | CONDITIONS                    | MIN                   | TYP | MAX                   | UNITS |
|------------------------------------------------|---------------------|-------------------------------|-----------------------|-----|-----------------------|-------|
| Supply Voltage                                 | V <sub>CC</sub>     |                               | 3.0                   |     | 5.5                   | V     |
| Supply Current                                 | I <sub>CC</sub>     | I <sub>FAN</sub> = 300mA      |                       |     | 3.4                   | mA    |
| V <sub>CC</sub> Shutdown Supply Current        | I <sub>SHDN</sub>   | $\overline{\text{OFF}}$ = GND |                       |     | 10                    | μA    |
| SENSE-to-PGND Output Low Voltage               |                     | I <sub>FAN</sub> = 300mA      |                       | 0.3 | 0.66                  | V     |
| SENSE-to-PGND Output On-Resistance             | R <sub>DS(on)</sub> |                               |                       | 1   | 2.2                   | Ω     |
| SENSE Leakage Current                          |                     | V <sub>SENSE</sub> = 26V      |                       | 1   | 10                    | μA    |
| V <sub>FAIL</sub> Output Low Voltage           |                     | I <sub>FAIL</sub> = 3mA       |                       |     | 0.8                   | V     |
| V <sub>FAIL</sub> Output Leakage Current       |                     | V <sub>FAIL</sub> = 5.5V      |                       | 0.1 | 1                     | μA    |
| Average SENSE (Fan) Current                    |                     |                               | 50                    |     | 300                   | mA    |
| SENSE Current Shutdown                         |                     | V <sub>CC</sub> = 3V          | 600                   |     | 1200                  | mA    |
| Thermal Shutdown of SENSE                      |                     | 15°C hysteresis               |                       | 160 |                       | °C    |
| Fan-Current Fluctuation Frequency              |                     | No fault detected             | 25                    |     | 400                   | Hz    |
| V <sub>FAIL</sub> Output Delay After Fault     | t <sub>FD</sub>     |                               | 0.3                   | 1   | 2.0                   | s     |
| Minimum Fan-Current Fluctuation Level (Note 2) |                     | No fault detected             | 15                    | 35  | 60                    | mAp-p |
| $\overline{\text{OFF}}$ Input High Voltage     | V <sub>IH</sub>     |                               | 0.7 x V <sub>CC</sub> |     |                       | V     |
| $\overline{\text{OFF}}$ Input Low Voltage      | V <sub>IL</sub>     |                               |                       |     | 0.3 x V <sub>CC</sub> | V     |
| $\overline{\text{OFF}}$ Input Current          |                     |                               | -10                   | 0   | 1                     | μA    |

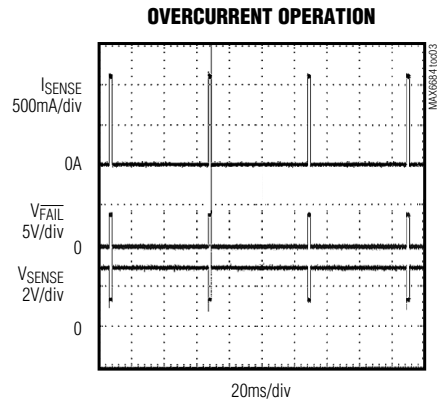
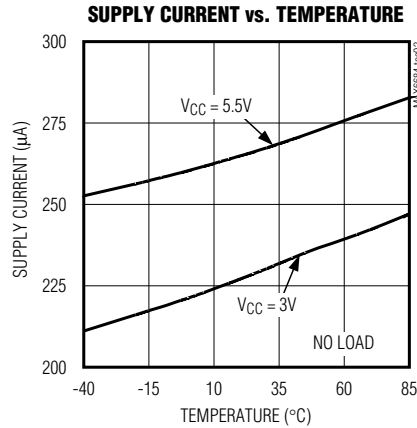
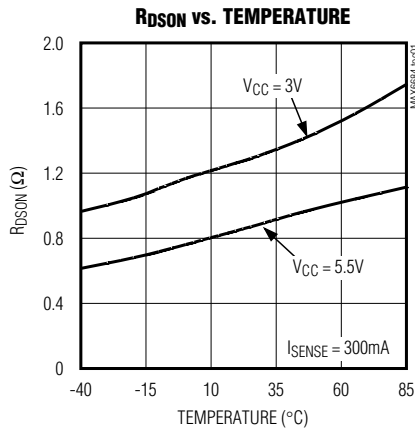
**Note 1:** Specifications to -40°C are guaranteed by design and not production tested.

**Note 2:** The MAX6684 is guaranteed to register a fault when the fan current fluctuates less than the minimum; it is guaranteed not to register a fault when the fan current is above the maximum.

# Fan-Failure Detector with Integrated Power Switch

## Typical Operating Characteristics

( $V_{CC} = 3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Description

| PIN | NAME              | FUNCTION                                                                                                                                                                            |
|-----|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | SENSE             | Positive Current-Sensing Terminal. Connect SENSE to low side of fan.                                                                                                                |
| 2   | $\overline{FAIL}$ | Active-Low, Open-Drain Fan-Failure Output                                                                                                                                           |
| 3   | GND               | Ground                                                                                                                                                                              |
| 4   | FC-               | Connect to 0.1 $\mu F$ capacitor for most locked-rotor detection applications. To detect minimum speed, select $C_F$ according to <i>Minimum Speed and Locked-Rotor Detection</i> . |
| 5   | FC+               | Connect to 0.1 $\mu F$ capacitor for most locked-rotor detection applications. To detect minimum speed, select $C_F$ according to <i>Minimum Speed and Locked-Rotor Detection</i> . |
| 6   | $V_{CC}$          | Supply Voltage Input. Bypass $V_{CC}$ to GND with a 1 $\mu F$ capacitor.                                                                                                            |
| 7   | $\overline{OFF}$  | Active-Low Fan-Control Input. Drive $\overline{OFF}$ high or leave floating to turn fan on. Drive $\overline{OFF}$ low to turn fan off.                                             |
| 8   | PGND              | Power Ground. Connect to GND.                                                                                                                                                       |

# Fan-Failure Detector with Integrated Power Switch

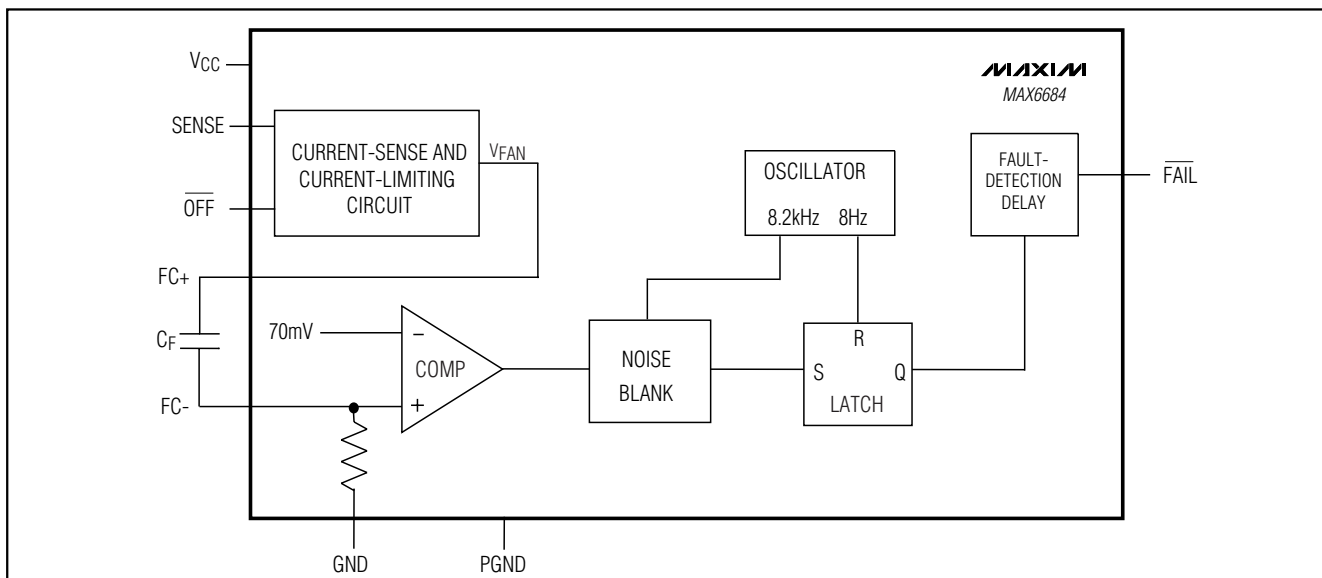


Figure 1. MAX6684 Functional Diagram

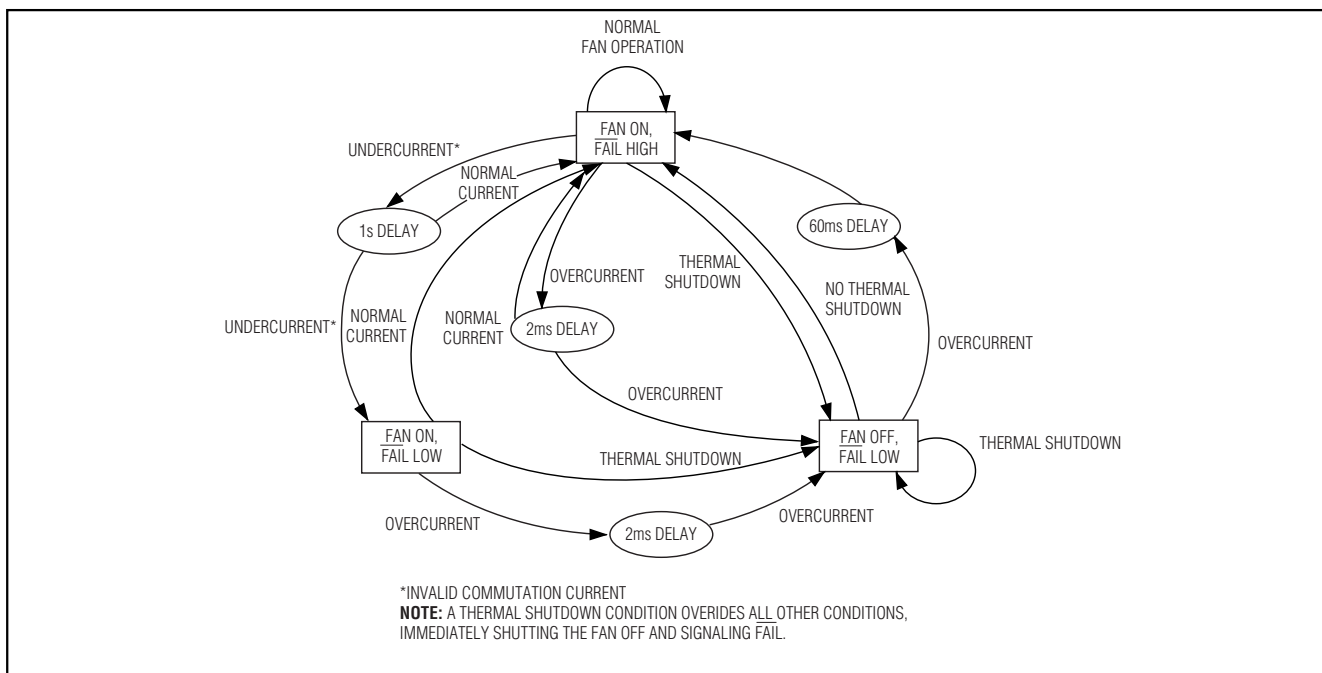


Figure 2. MAX6684 State Diagram

## Detailed Description

The MAX6684 detects fan failure in brushless DC fans. This device is especially well suited for critical systems where no fan control is desired. No software is necessary to control the MAX6684.

## Fan-Failure Detection

Fan failure is determined based on the fan current observed at SENSE. The current observed at SENSE is converted to a voltage,  $V_{FAN}$ , and highpass filtered by the capacitor,  $C_F$ , from  $FC+$  to  $FC-$  (Figure 1).

# Fan-Failure Detector with Integrated Power Switch

MAX6684

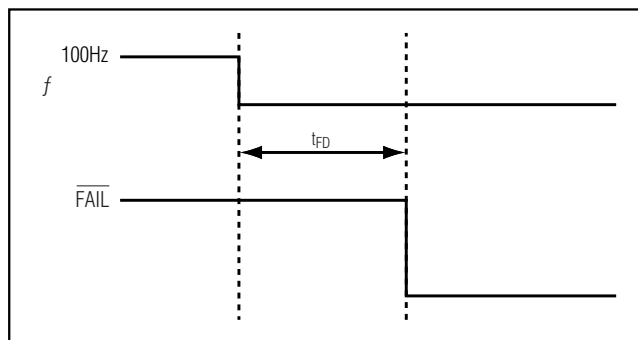


Figure 3. MAX6684 Commutation Fault Timing Diagram

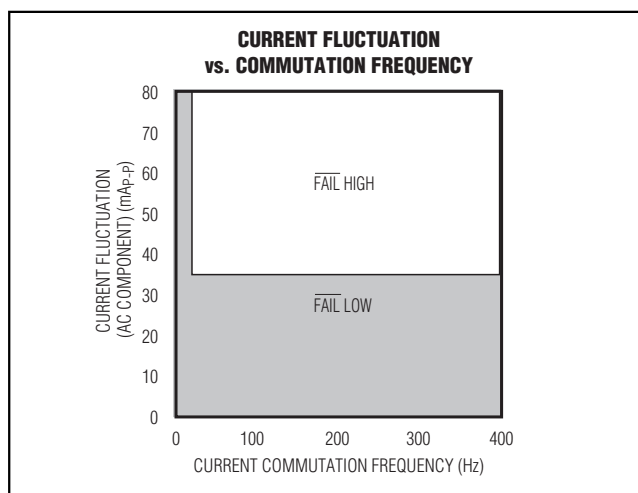


Figure 4. Current Fluctuation and Commutation Frequency Diagram

## Undercurrent (AC Component)

Fan failure is signaled if the AC component of  $I_{FAN}$  is less than 35mA<sub>p-p</sub> and remains out of specification for at least 1s (Figure 2). The fan remains powered during undercurrent failures.

## Minimum Speed and Locked-Rotor Detection

The MAX6684 asserts  $\overline{FAIL}$  if the fan-current fluctuation frequency is below 25Hz, which corresponds to a fan speed of approximately 700rpm. The fan remains powered during a locked rotor or an under-speed failure condition (Figures 3 and 4).

The MAX6684 can be designed to detect fan failure below intended speeds by varying the value of  $C_F$ . Because of the complexity of fan-current waveforms, the value of  $C_F$  has to be arrived at empirically and must be verified by bench testing. The guidelines of

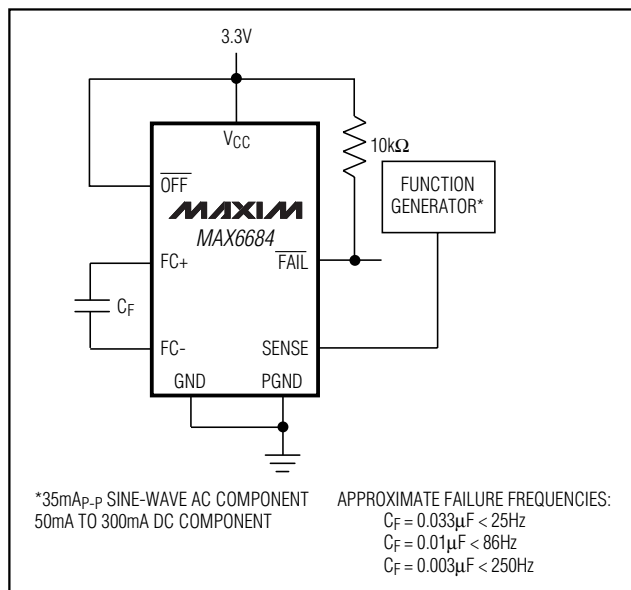


Figure 5. Test Circuit Demonstrates Failure Frequency as a Function of the Value of  $C_F$

Figure 5 are only appropriate for the test signals used and do not represent all possible fan waveforms. They are to illustrate the ability of the MAX6684 to discriminate failure due to low fan speed. As a rule, failure typically occurs when the amplitude measured at pin 4 of the MAX6684 drops below 70mV.

## Overcurrent Protection

If an overcurrent condition begins and continues for 2ms, fan failure is signaled for 60ms. During this 60ms period, the power to the fan is turned off. If the part does not enter thermal shutdown and the overcurrent condition continues, power to the fan is turned on every 62ms for 2ms (see Overcurrent Operation in *Typical Operating Characteristics*). Once the overcurrent condition is removed, the fan is powered continuously. A 0.1 $\mu F$  capacitor between SENSE and PGND prevents the internal DMOS switch from being damaged by back EMF current.

## Thermal Shutdown

A die temperature in excess of +160°C initiates thermal shutdown. In thermal shutdown, the MAX6684 shuts off the fan and the  $\overline{FAIL}$  output asserts. While in thermal shutdown, the MAX6684 monitors the die temperature. Once the die has cooled to below +145°C, the MAX6684 exits thermal shutdown and power is returned to the fan. A thermal shutdown fault condition has precedence over all other failure modes. While the MAX6684 die is over temperature, power is not cycled to the fan, as occurs during overcurrent failure.

# Fan-Failure Detector with Integrated Power Switch

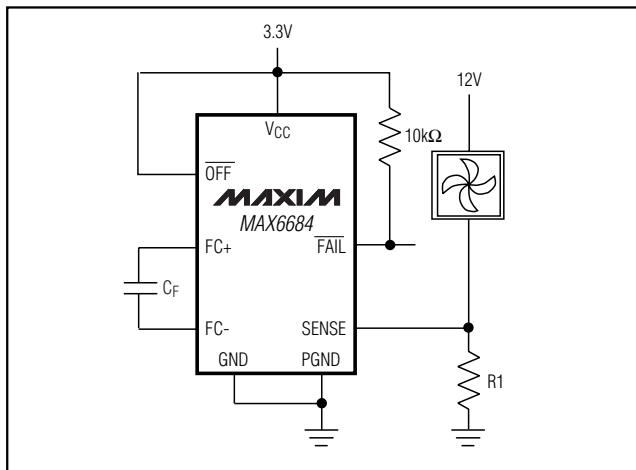


Figure 6. Increased Current Capability Using External Resistance

## FAIL Output

The  $\overline{\text{FAIL}}$  output is an active-low, open-drain alarm. Three fan-failure modes are possible (see the *Fan-Failure Detection* section).

## OFF

Drive  $\overline{\text{OFF}}$  low to turn off power to the fan. If  $\overline{\text{OFF}}$  is tied high or floating, the MAX6684 is enabled.

## Applications Information

### Fan Compatibility

This device can be used with fans that require operating voltages up to 24V and supply currents up to 250mA. See the *Fan-Failure Detection* section regarding fan-current waveform issues.

Figures 6 and 7 show two ways to increase the current capability of the MAX6684. In Figure 6, a parallel external resistance between SENSE and PGND is used to increase current capability. This method eliminates the fan-control functionality normally associated with the MAX6684  $\overline{\text{OFF}}$  pin. Select the external resistor, R1, such that approximately 100mA flows across the internal  $R_{\text{DS(on)}}$  of the MAX6684, which is typically 1Ω.

Figure 7 also shows how to use an external current-boost PNP bipolar transistor to increase the current capability of the MAX6684. This method preserves the fan-control functionality of the  $\overline{\text{OFF}}$  pin. A 6Ω  $R_{\text{BOOST}}$  allows approximately 100mA of the fan current to flow through the MAX6684.

The MAX6684 is not compatible with fans designed for use with external PWM fan controllers.

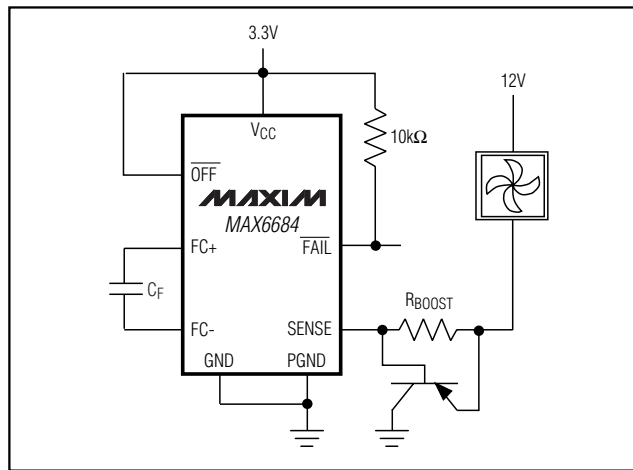


Figure 7. Increased Current Capability Using PNP Transistor

## Fan-Specific Concerns

Because fan-current waveforms can vary substantially from one given fan make or model to another, validate the performance of the MAX6684 with the intended fan. It is possible to encounter fans where the MAX6684 is limited to detecting locked-rotor conditions only, because of the nature of the fan-current waveform. In cases where fan-speed detection does not seem to be working properly (although locked-rotor detection is taking place), adding a 100μF capacitor across the fan may solve the problem.

When the MAX6684 is used with fans that include locked-rotor protection, the  $\overline{\text{FAIL}}$  output is active when the rotor locks, and toggles each time the locked-rotor protection built into the fan attempts a restart, over a timeframe typically measured in seconds. Toggling should be considered an indication of fan failure; conversely, a fan is functioning properly only when  $\overline{\text{FAIL}}$  is constantly inactive.

## Capacitor Selection

A ceramic or mylar capacitor,  $C_F$ , is required from FC- to FC+. The capacitor blocks the DC component of the signal, allowing the MAX6684 to monitor the AC current consumption of the fan. See the *Minimum Speed and Locked-Rotor Detection* section for more information.

## Power Supply and Bypassing

The effects of noise can be minimized by placing a 1μF ceramic bypass capacitor close to the device's supply pin.

# Fan-Failure Detector with Integrated Power Switch

## Chip Information

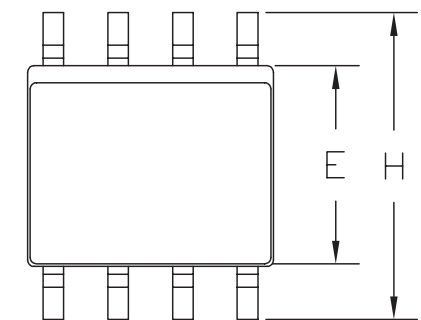
TRANSISTOR COUNT: 3993

PROCESS: BiCMOS

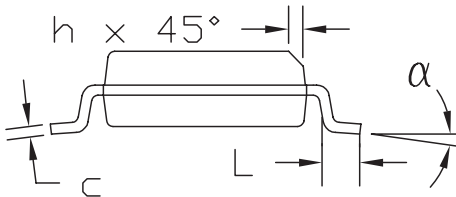
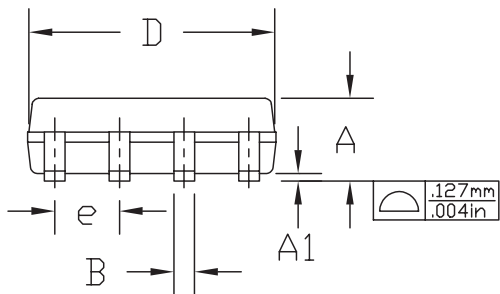
## Package Information

MAX6684

9LUCSP, 3x3.EPS



| DIM      | INCHES |       | MILLIMETERS |      |
|----------|--------|-------|-------------|------|
|          | MIN    | MAX   | MIN         | MAX  |
| A        | 0.053  | 0.069 | 1.35        | 1.75 |
| A1       | 0.004  | 0.010 | 0.10        | 0.25 |
| B        | 0.014  | 0.019 | 0.35        | 0.49 |
| C        | 0.007  | 0.010 | 0.19        | 0.25 |
| D        | 0.189  | 0.197 | 4.80        | 5.00 |
| e        | 0.050  | BSC   | 1.27        | BSC  |
| E        | 0.150  | 0.157 | 3.80        | 4.00 |
| H        | 0.228  | 0.244 | 5.80        | 6.20 |
| h        | 0.010  | 0.020 | 0.25        | 0.50 |
| L        | 0.016  | 0.050 | 0.40        | 1.27 |
| $\alpha$ | 0?     | 8?    | 0?          | 8?   |



- NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH.
  2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
  3. CONTROLLING DIMENSION: MILLIMETER
  4. MEETS JEDEC MS-012 AA.

| MAXIM                   |         |     |     |
|-------------------------|---------|-----|-----|
| PROPRIETARY INFORMATION |         |     |     |
| TITLE 8L SOIC OUTLINE   |         |     |     |
| APPROVAL                | DWG     | REV | 1/1 |
|                         | 21-0325 | A   |     |

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