



December 2003

# LM9076

## 150mA Ultra-Low Quiescent Current LDO Regulator with Delayed Reset Output

### General Description

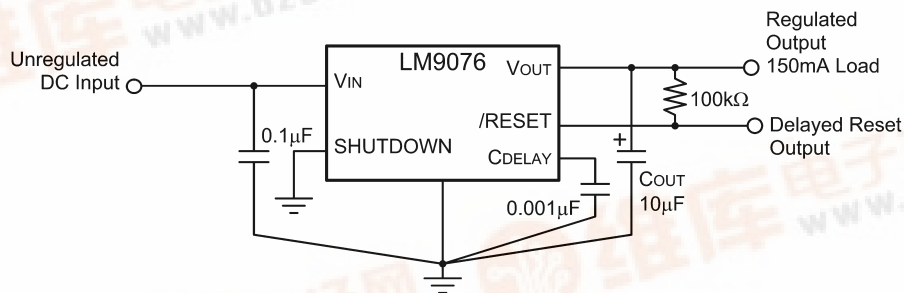
The LM9076 is a 5 Volt, +/-2%, 150mA logic controlled voltage regulator. The regulator features an active low delayed reset output flag which can be used to reset a micro-processor system at turn-ON and in the event that the regulator input voltage falls below a minimum value. An external capacitor programs a delay time interval before the reset output pin can return high.

Designed for automotive and industrial applications, the LM9076 contains a variety of protection features such as thermal shutdown, input transient protection and a wide operating temperature range. The LM9076 uses an PNP pass transistor which allows low drop-out voltage operation.

### Features

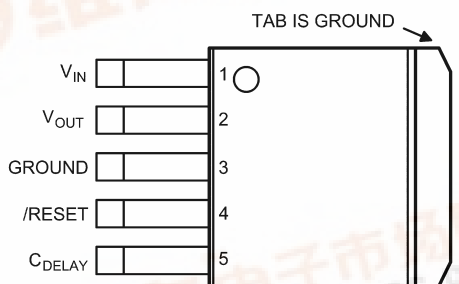
- Ultra Low Ground Pin Current, 25µA typical for 100µA load
- $V_{OUT}$  initial accuracy of +/-1%
- $V_{OUT}$  accurate to +/-2% over Load and Temperature Conditions
- Low Dropout Voltage, 200mV typical with 150mA load
- Low Off State Ground Pin current
- Delayed  $\overline{RESET}$  output pin for low  $V_{OUT}$  detection
- +70V/-50V Voltage Transients
- Operational  $V_{IN}$  up to +40V

### Typical Application

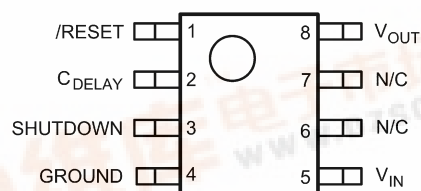


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### Package Outline



**Top View**  
Part Number LM9076S-5.0  
See NS TO-263 Package Number TS5



**Top View**  
Part Number LM9076BMA-5.0  
See NS SOIC Package Number M08A

LM9076 - 150mA Ultra-Low Quiescent Current LDO Regulator with Delayed Reset Output



**Absolute Maximum Ratings** (Note 1)

$V_{IN}(DC)$	-15V to +55V
$V_{IN}(+Transient)$ $t < 10ms$ , Duty Cycle $< 1\%$	+70V
$V_{IN}(-Transient)$ $t < 1ms$ , Duty Cycle $< 1\%$	-50V
SHUTDOWN Pin	-15V to +52V
$\overline{RESET}$ Pin	-0.3V to 20V
$C_{DELAY}$ Pin	-0.3V to $V_{OUT} + 0.3V$
Storage Temperature	-65°C to +150°C
Junction Temperature ( $T_J$ )	+175°C
ESD, HBM, per AEC - Q100 - 002	+/-2kV
ESD, MM, per AEC - Q100 - 003	+/-250V

**Operating Ratings** (Note 1)

$V_{IN}$ Pin	5.35V to 40V
$V_{SHUTDOWN}$ Pin	0V to 40V
Ambient Temperature	-40°C $< T_A < +125$ °C
Thermal Resistance TS5B (Note 6)	
$\theta_{ja}$	75°C/W
$\theta_{jc}$	2.9°C/W
Thermal Resistance M08A (Note 6)	
$\theta_{ja}$	156°C/W
$\theta_{jc}$	59°C/W

**Electrical Characteristics for LM9076–5.0**

The following specifications apply for  $V_{IN} = 14V$ ;  $V_{SHUTDOWN} = \text{Open}$ ;  $I_{LOAD} = 10mA$ ;  $T_A = +25$ °C;  $C_{OUT} = 10\mu F$ ,  $0.5\Omega < ESR < 4.0\Omega$ ; unless otherwise specified. **Bold Values indicate -40°C  $\leq T_A \leq 125$ °C. (Note 4, Note 5)**

Symbol	Parameter	Conditions	Min	Typ	Max	Units
<b>LM9076–5.0 REGULATOR CHARACTERISTICS</b>						
$V_{OUT}$	Output Voltage		4.95	5.00	5.05	V
		$1mA \leq I_{LOAD} \leq 150mA$	<b>4.90</b>	<b>5.00</b>	<b>5.10</b>	V
		$V_{IN} = 60V$ , $R_{LOAD} = 1K\Omega$ , $t \leq 40ms$	4.50	5.00	5.50	V
	Output Voltage Off	$V_{SHUTDOWN} \geq 2V$ , $R_{LOAD} = 1K\Omega$	–	40	250	mV
	Reverse Battery	$V_{IN} = -15V$ , $R_{LOAD} = 1K\Omega$	–	0	-300	mV
$\Delta V_{OUT}$	Line Regulation	$9.0V \leq V_{IN} \leq 16V$ , $I_{LOAD} = 10mA$	–	4	25	mV
		$16V \leq V_{IN} \leq 40V$ , $I_{LOAD} = 10mA$	–	17	25	mV
	Load Regulation	$1mA \leq I_{LOAD} \leq 150mA$	–	42	60	mV
$V_{DO}$	Dropout Voltage	$I_{LOAD} = 10mA$	–	30	50	mV
		$I_{LOAD} = 50mA$	–	80	–	mV
		$I_{LOAD} = 150mA$	–	150	250	mV
$I_{GND}$	Ground Pin Current	$9V \leq V_{IN} \leq 16V$ , $I_{LOAD} = 100\mu A$	–	25	35	$\mu A$
		$9V \leq V_{IN} \leq 40V$ , $I_{LOAD} = 10mA$	–	125	160	$\mu A$
		$9V \leq V_{IN} \leq 40V$ , $I_{LOAD} = 50mA$	–	0.6	–	mA
		$9V \leq V_{IN} \leq 16V$ , $I_{LOAD} = 150mA$	–	3.6	4.5	mA
	Ground Pin Current in Shut- down Mode	$9V \leq V_{IN} \leq 40V$ , $V_{SHUTDOWN} = 2V$	–	15	25	$\mu A$
$I_{SC}$	$V_{OUT}$ Short Circuit Current	$V_{IN} = 14V$ , $R_{LOAD} = 1\Omega$	200	400	750	mA
PSRR	Ripple Rejection	$V_{IN} = (14V_{DC}) + (1V_{RMS} @ 120Hz)$ $I_{LOAD} = 50mA$	50	60	–	dB
<b>RESET PIN CHARACTERISTICS</b>						
$V_{OR}$	Minimum $V_{IN}$ for valid $\overline{RESET}$ Status	(Note 3)	–	1.3	2.0	V

## Electrical Characteristics for LM9076–5.0 (Continued)

The following specifications apply for  $V_{IN} = 14V$ ;  $V_{SHUTDOWN} = \text{Open}$ ;  $I_{LOAD} = 10mA$ ;  $T_A = +25^\circ C$ ;  $C_{OUT} = 10\mu F$ ,  $0.5\Omega < ESR < 4.0\Omega$ ; unless otherwise specified. **Bold Values indicate  $-40^\circ C \leq T_A \leq 125^\circ C$ . (Note 4, Note 5)**

Symbol	Parameter	Conditions	Min	Typ	Max	Units
<b>RESET PIN CHARACTERISTICS</b>						
$V_{THR}$	$V_{OUT}$ Threshold for $\overline{\text{RESET}}$ Low	(Note 3)	0.83	0.89	0.94	X $V_{OUT}$ (Nom)
$V_{OH}$	$\overline{\text{RESET}}$ pin high voltage	External pull-up resistor to $V_{OUT} = 100k\Omega$	$V_{OUT} \times 0.90$	$V_{OUT} \times 0.99$	$V_{OUT}$	V
$V_{OL}$	$\overline{\text{RESET}}$ pin low voltage	$C_{DELAY} < 4.0V$ , $I_{SINK} = 250\mu A$	—	0.2	0.3	V
<b><math>C_{DELAY}</math> PIN CHARACTERISTICS</b>						
$I_{DELAY}$	$C_{DELAY}$ Charging Current	$V_{IN} = 14V$ , $V_{DELAY} = 0V$	-0.35	-0.42	-0.50	$\mu A$
$V_{OL}$	$C_{DELAY}$ pin low voltage	$V_{OUT} < 4.0V$ , $I_{SINK} = I_{DELAY}$	—	0.100	—	V
$t_{DELAY}$	Reset Delay Time	$V_{IN} = 14V$ , $C_{DELAY} = 0.001\mu F$ $V_{OUT}$ rising from 0V, $\Delta t$ from $V_{OUT} > V_{OR}$ to $\overline{\text{RESET}}$ pin HIGH	9.5	11.9	14.3	ms
<b>SHUTDOWN CONTROL LOGIC — LM9076BMA Only</b>						
$V_{IL(SD)}$	SHUTDOWN Input Low Threshold Voltage	$V_{SHUTDOWN}$ pin falling from 5.0V until $V_{out} > 4.5V$ ( $V_{out} = \text{On}$ )	1	1.5	—	V
$V_{IH(SD)}$	SHUTDOWN Input High Threshold Voltage	$V_{SHUTDOWN}$ pin rising from 0V until $V_{out} < 0.5V$ ( $V_{out} = \text{Off}$ )	—	1.5	2	V
$I_{IH(SD)}$	SHUTDOWN Pin High Bias Current	$V_{SHUTDOWN} = 40V$	—	35	—	$\mu A$
		$V_{SHUTDOWN} = 5V$	—	15	35	$\mu A$
		$V_{SHUTDOWN} = 2V$	—	6	10	$\mu A$
$I_{IL(SD)}$	SHUTDOWN Input Low Bias Current	$V_{SHUTDOWN} = 0V$	—	0	—	$\mu A$

**Note 1:** Absolute Maximum Ratings indicate the limits beyond which the device may cease to function, and/or damage to the device may occur.

**Note 2:** Operating Ratings indicate conditions for which the device is intended to be functional, but does not guarantee specific performance limits. For guaranteed specifications and conditions refer to the Electrical Characteristics

**Note 3:** Not Production tested, Guaranteed by Design. Minimum, Typical, and/or Maximum values are provided for informational purposes only.

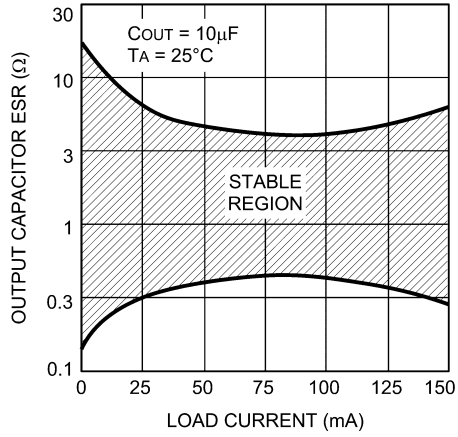
**Note 4:** Pulse testing used maintain constant junction temperature ( $T_J$ ).

**Note 5:** The regulated output voltage specification is not guaranteed for the entire range of  $V_{IN}$  and output loads. Device operational range is limited by the maximum junction temperature ( $T_J$ ). The junction temperature is influenced by the ambient temperature ( $T_A$ ), package selection, input voltage ( $V_{IN}$ ), and the output load current. When operating with maximum load currents the input voltage and/or ambient temperature will be limited. When operating with maximum input voltage the load current and/or the ambient temperature will be limited.

**Note 6:** Worst case (FREE AIR) per EIA/JESD51–3.

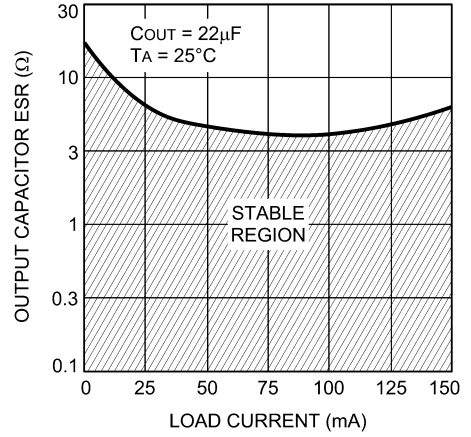
# Typical Performance Characteristics

Output Capacitor ESR



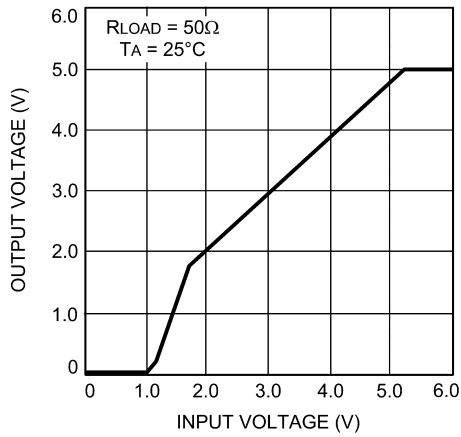
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Output Capacitor ESR



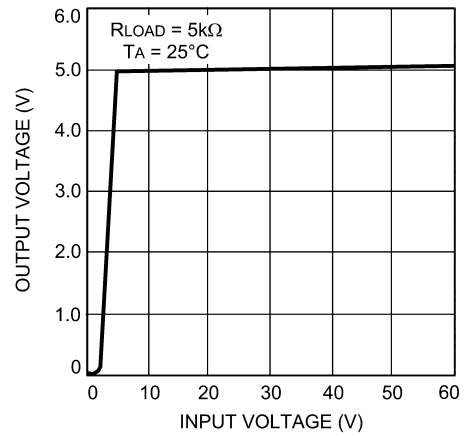
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Low Voltage Behavior



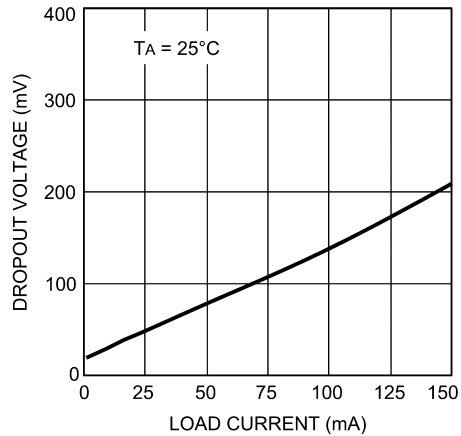
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High Voltage Behavior



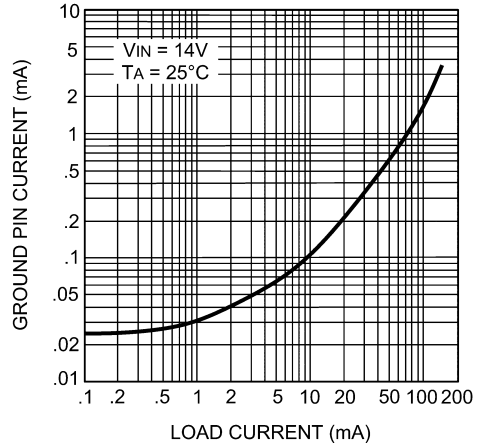
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Dropout Voltage



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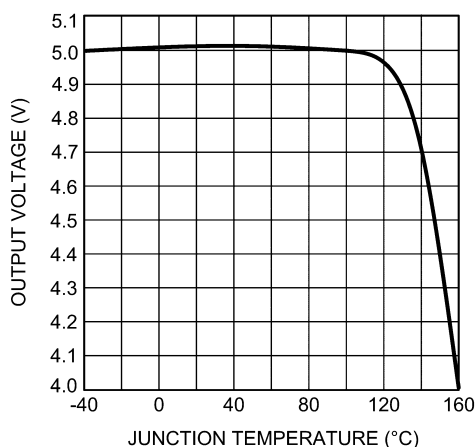
Ground Pin Current vs Load Current



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## Typical Performance Characteristics (Continued)

Output Voltage vs Junction Temperature



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## Application Information

### REGULATOR BASICS

This regulator is suitable for Automotive applications where continuous connection to the battery is required (refer to the Typical Application circuit).

The pass transistor of the regulator is an PNP device. A 10 $\mu$ F capacitor on the  $V_{OUT}$  pin will provide adequate performance in most circumstances. There is no maximum value for the regulator output bypass capacitance.

### INPUT CAPACITOR

The LM9076 requires a low source impedance to maintain regulator stability because portions of the internal bias circuitry are connected directly to  $V_{IN}$ . At a minimum, at 0.1 $\mu$ F ceramic capacitor should be placed between the LM9076  $V_{IN}$  and Ground pins, as close as is physically possible.

### OUTPUT CAPACITOR

An output capacitor is also required for stability. This capacitor must be placed between the LM9076  $V_{OUT}$  and Ground pins, as close as is physically possible, using traces that are not part of the main load current path.

The output capacitor must meet the requirements for minimum capacitance and also maintain the appropriate ESR value of the full operating ambient temperature range to assure stability. There is no maximum limit for the output capacitance value, as long as ESR is maintained. See the Typical Performance Characteristics curves for details.

Solid tantalum capacitors are recommended as they generally maintain capacitance and ESR ratings over a wide temperature range.

Ceramic capacitor types XR7 and X5R may be used if a series resistor is added to simulate the ESR requirement.

Aluminum electrolytic capacitors are not recommended, as they are subject to wide changes in capacitance and ESR values across temperature.

### DELAY CAPACITOR

The capacitor on the Delay pin must be a low leakage type since the charge current is minimal (500nA typical) and the pin must fully charge to 5V. Ceramic, Mylar, and polystyrene

capacitor types are generally recommended, although changes in capacitance values across temperature changes will have some effect on the delay timing.

### SHUTDOWN PIN

The basic On/Off control of the regulator is accomplished with the SHUTDOWN pin. By pulling the SHUTDOWN pin high the regulator output is switched Off. When the regulator is switched Off the load on the battery will be primarily due to the SHUTDOWN pin current.

When the SHUTDOWN pin is low, or left open, the regulator is switched On. When an unregulated supply, such as V BATTERY, is used to pull the SHUTDOWN pin high a series resistor in the range of 10K $\Omega$  to 50K $\Omega$  is recommended to provide reverse voltage transient protection of the SHUTDOWN pin. Adding a small capacitor (0.001 $\mu$ F typical) from the SHUTDOWN pin to Ground will add noise immunity to prevent accidental turn on due to noise on the supply line.

### RESET FLAG

Proper operation of the  $\overline{\text{RESET}}$  circuitry is not guaranteed for  $V_{IN}$  voltages of less than 2.0V. The  $\overline{\text{RESET}}$  pin will provide information on the status of the regulator  $V_{OUT}$  voltage level. Any condition that causes the  $V_{OUT}$  voltage to drop to typically 89% normal would cause the  $\overline{\text{RESET}}$  pin to go low. This will warn of a system Vcc supply that may cause abnormal operation.

Of course, when the regulator is switched Off in normal operation the  $\overline{\text{RESET}}$  pin will be low.

If the regulator is On, and then switched off, the  $\overline{\text{RESET}}$  flag will go low when the  $V_{OUT}$  voltage stored on the output capacitor has decayed adequately.

Excessive thermal dissipation of the device such that the Thermal Shutdown circuit is activated which then switches the regulator output Off, would cause the  $\overline{\text{RESET}}$  pin to go low.

The  $\overline{\text{RESET}}$  pin is an open collector output and requires an external pull-up resistor to  $V_{OUT}$ . The external pull-up resistor should be in the range of 10K $\Omega$  to 200K $\Omega$ .

## Application Information (Continued)

### RESET DELAY TIME

When the regulator output is switched On, or after recovery from brief  $V_{OUT}$  fault condition, the  $\overline{RESET}$  flag can be programmed to remain low for an additional delay time. This will give time for any system reference voltages, clock signals, etc., to stabilize before the micro-controller resumes normal operation.

This delay time is controlled by the capacitor value on the  $C_{DELAY}$  pin. During normal operation the  $C_{DELAY}$  capacitor is charged to near  $V_{OUT}$ . When a  $V_{OUT}$  fault causes the  $\overline{RESET}$  pin to go low, the  $C_{DELAY}$  capacitor is quickly discharged to ground. When the  $V_{OUT}$  fault is removed, and  $V_{OUT}$  returns to the normal operating value, the  $C_{DELAY}$  capacitor begins charging at a typical constant 0.420uA rate. When the voltage on the  $C_{DELAY}$  capacitor reaches the same potential as the  $V_{OUT}$  pin the  $\overline{RESET}$  pin will be allowed to return high.

The typical  $\overline{RESET}$  delay time can be calculated with the following formula:

$$t_{DELAY} = V_{OUT} \times (C_{DELAY} / I_{DELAY})$$

For a  $C_{DELAY}$  value of 0.001uF and a  $I_{DELAY}$  value of 0.475uA the typical  $\overline{RESET}$  delay time is:

$$t_{DELAY} = V_{OUT} \times (0.001\mu F / 0.475\mu A)$$

$$t_{DELAY} = 5.0V \times (0.001\mu F / 0.420\mu A) = 11.9ms$$

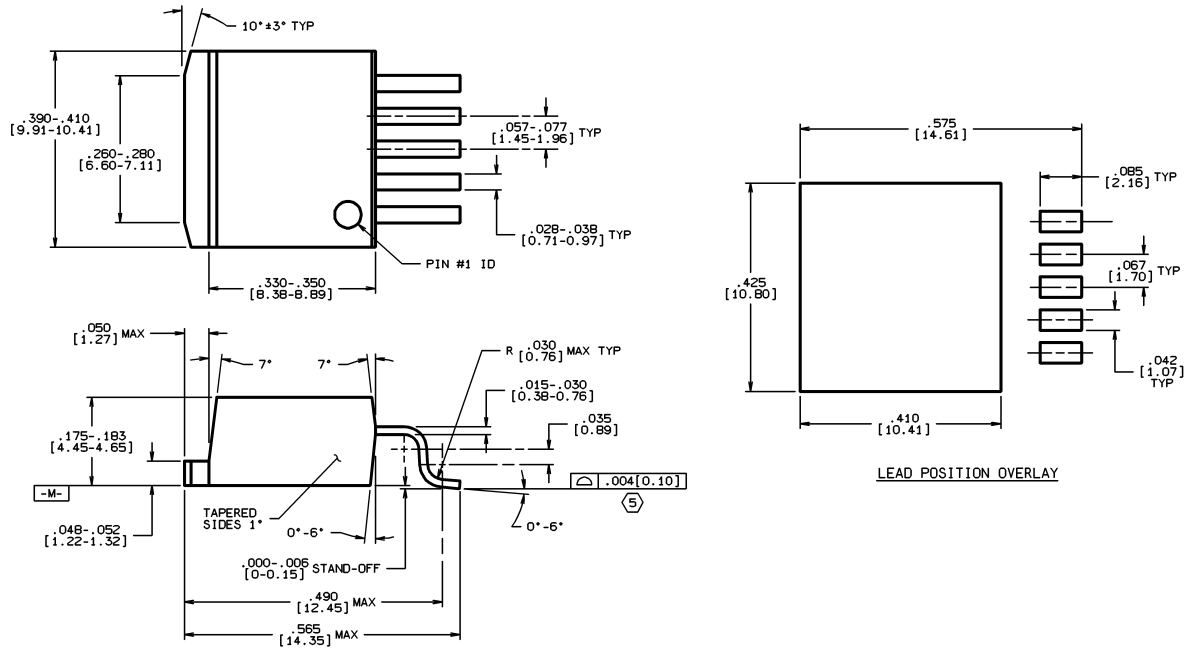
### THERMAL PROTECTION

Device operational range is limited by the maximum junction temperature ( $T_J$ ). The junction temperature is influenced by the ambient temperature ( $T_A$ ), package selection, input voltage ( $V_{IN}$ ), and the output load current. When operating with maximum load currents the input voltage and/or ambient temperature will be limited. When operating with maximum input voltage the load current and/or the ambient temperature will be limited.

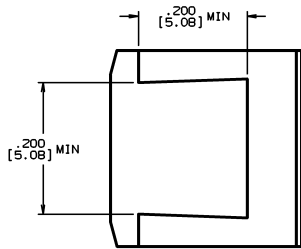
Even though the LM9076 is equipped with circuitry to protect itself from excessive thermal dissipation, it is not recommended that the LM9076 be operated at, or near, the maximum recommended die junction temperature ( $T_J$ ) as this may impair long term device reliability.

The thermal protection circuitry monitors the temperature at the die level. When the die temperature exceeds typically 160C the voltage regulator output will be switched off.

**Physical Dimensions** inches (millimeters) unless otherwise noted



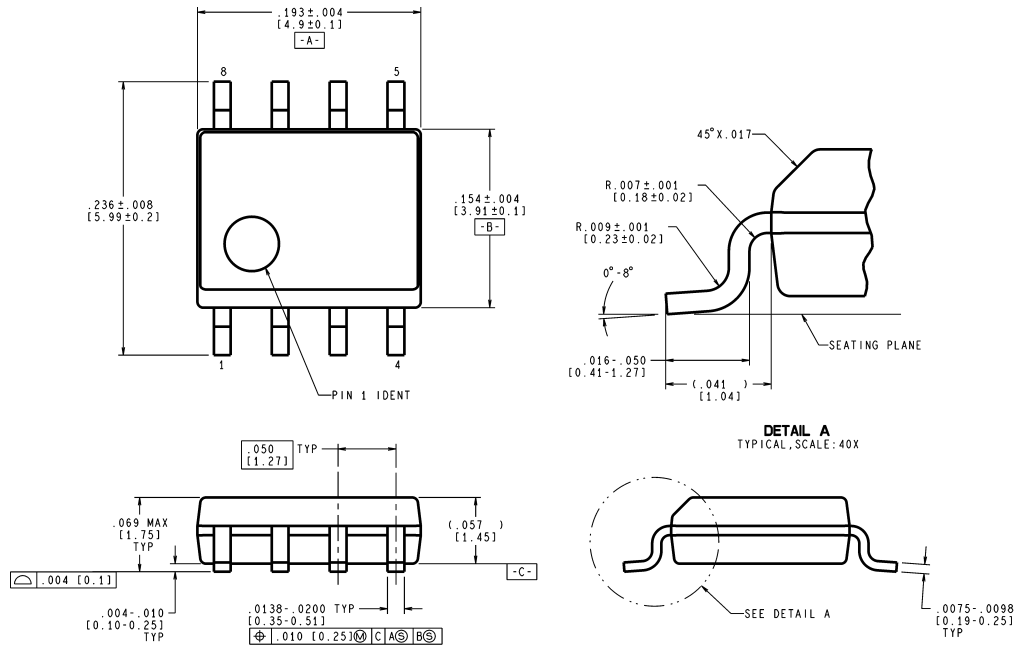
CONTROLLING DIMENSION: INCH



TS5B (Rev C)

**5-Lead**  
**Order Number LM9076S**  
**NS Package Number TS5B**

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



CONTROLLING DIMENSION IS INCH  
VALUES IN ( ) ARE MILLIMETERS

**8-Lead (0.150" Wide) Molded SO Package**  
**Order Number LM9076M**  
**NS Package Number M08A**

M08A (Rev J)

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