November 12, 2007

National Semiconductor

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

General Description

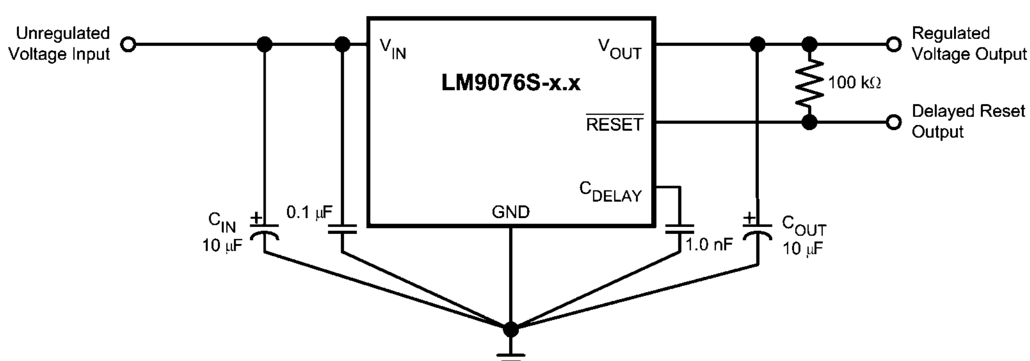
The LM9076 is a ±3%, 150 mA logic controlled voltage regulator. The regulator features an active low delayed reset output flag which can be used to reset a microprocessor system at turn-ON and in the event that the regulator output voltage falls below a minimum value. An external capacitor programs a 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.

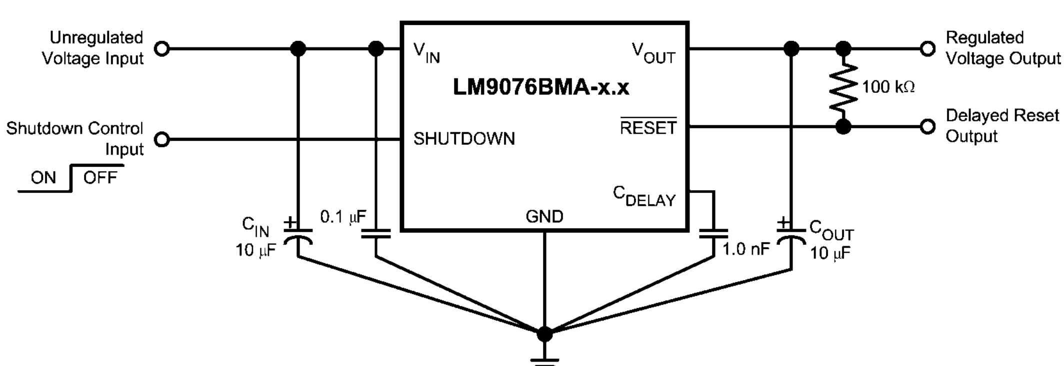
Features

- Available with 5.0V or 3.3V output voltage
- Ultra Low Ground Pin Current, 25 µA typical for 100 µA load
- V_{OUT} initial accuracy of ±1.5%
- V_{OUT} accurate to ±3% over Load and Temperature Conditions
- Low Dropout Voltage, 200 mV typical with 150 mA load
- Low Off State Ground Pin current for LM9076BMA
- Delayed $\overline{RESET}$ output pin for low V_{OUT} detection
- +70V/-50V Voltage Transients
- Operational V_{IN} up to +40V

Typical Applications

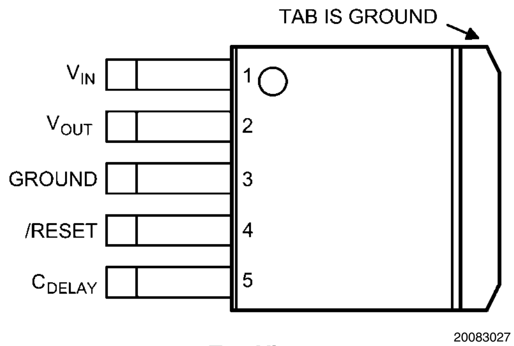


LM9076S-x.x in 5 lead TO-263 package

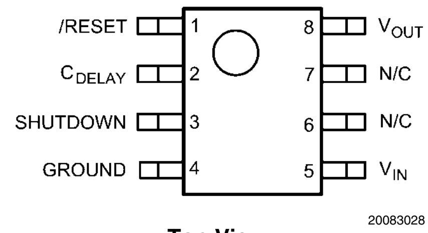


LM9076BMA-x.x in 8 lead SO package

Connection Diagrams



Top View
Part Numbers LM9076S-3.3 and LM9076S-5.0
See NS TO-263 Package Number TS5



Top View
Part Numbers LM9076BMA-3.3 and LM9076BMA-5.0
See NS SOIC Package Number M08A

Ordering Information

Output Voltage	Package Type	Order Number	Package Marking	Shipped As
3.3	TO-263–5	LM9076S-3.3	LM9076S-3.3	Rail of 45
		LM9076SX-3.3	LM9076S-3.3	Tape and Reel of 500
	SO-8	LM9076BMA-3.3	9076B MA3.3	Rail of 95
		LM9076BMAX-3.3	9076B MA3.3	Tape and Reel of 2500
5.0	TO-263–5	LM9076S-5.0	LM9076S-5.0	Rail of 45
		LM9076SX-5.0	LM9076S-5.0	Tape and Reel of 500
	SO-8	LM9076BMA-5.0	9076BMA5.0	Rail of 95
		LM9076BMAX-5.0	9076BMA5.0	Tape and Reel of 2500

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)	+175C
ESD, HBM, per AEC - Q100 - 002	+/-2 kV
ESD, MM, per AEC - Q100 - 003	+/-250V

Operating Ratings (Note 1)

V_{IN} Pin	5.35V to 40V
$V_{SHUTDOWN}$ Pin	0V to 40V
Junction Temperature	$-40°C < T_J < +125°C$
Thermal Resistance TS5B (Note 6)	
θja	75°C/W
θjc	2.9°C/W
Thermal Resistance M08A (Note 6)	
θja	156°C/W
θjc	59°C/W

Electrical Characteristics for LM9076–3.3

The following specifications apply for V_{IN} = 14V; I_{LOAD} = 10 mA; T_J = +25C; C_{OUT} = 10 µF, 0.5Ω < ESR < 4.0Ω; unless otherwise specified. **Bold values indicate –40°C ≤ T_J ≤ +125°C**.(Notes 5, 4) Minimum and Maximum limits are guaranteed through test, design or statistical correlation.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
LM9076–3.3 REGULATOR CHARACTERISTICS						
V_{OUT}	Output Voltage		3.251	3.30	3.349	V
		–20°C ≤ T_J ≤ 85°C 1 mA ≤ I_{LOAD} ≤ 150 mA	3.234	3.30	3.366	V
		1mA ≤ I_{LOAD} ≤ 150 mA	**3.201**	**3.30**	**3.399**	V
		V_{IN} = 60V, R_{LOAD} = 1 kΩ, t ≤ 40ms	2.970	3.30	3.630	V
	Output Voltage Off LM9076 BMA only	$V_{SHUTDOWN}$ ≥ 2V, R_{LOAD} = 1 kΩ	–	0	250	mV
	Reverse Battery	V_{IN} = -15V, R_{LOAD} = 1 kΩ	–300	0	–	mV
ΔV_{OUT}	Line Regulation	9.0V ≤ V_{IN} ≤ 16V, I_{LOAD} = 10 mA	–	4	25	mV
		16V ≤ V_{IN} ≤ 40V, I_{LOAD} = 10 mA	–	17	35	mV
	Load Regulation	1 mA ≤ I_{LOAD} ≤ 150 mA	–	42	60	mV
V_{DO}	Dropout Voltage	I_{LOAD} = 10 mA	–	30	50	mV
		I_{LOAD} = 50 mA	–	80	–	mV
		I_{LOAD} = 150 mA	–	150	250	mV
I_{GND}	Ground Pin Current	9V ≤ V_{IN} ≤ 16V, I_{LOAD} = 100 uA	–	25	45	µA
		9V ≤ V_{IN} ≤ 40V, I_{LOAD} = 10 mA	–	125	160	µA
		9V ≤ V_{IN} ≤ 40V, I_{LOAD} = 50 mA	–	0.6	–	mA
		9V ≤ V_{IN} ≤ 16V, I_{LOAD} = 150 mA	–	3.6	4.5	mA
I_{SC}	V_{OUT} Short Circuit Current	V_{IN} = 14V, R_{LOAD} = 1Ω	200	400	750	mA

Symbol	Parameter	Conditions	Min	Typ	Max	Units
PSRR	Ripple Rejection	V_{IN} = (14V_{DC}) + (1V_{RMS} @ 120Hz) I_{LOAD} = 50 mA	50	60	–	dB
$\overline{\text{RESET}}$ PIN CHARACTERISTICS						
V_{OR}	Minimum V_{IN} for valid $\overline{\text{RESET}}$ Status	(Note 3)	–	1.3	2.0	V
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} = 100 kΩ	V_{OUT} X 0.90	V_{OUT} X 0.99	V_{OUT}	V
V_{OL}	$\overline{\text{RESET}}$ pin low voltage	C_{DELAY} < 4.0V, I_{SINK} = 250 µA	–	0.2	0.3	V
C_{DELAY} PIN CHARACTERISTICS						
I_{DELAY}	C_{DELAY} Charging Current	V_{IN} = 14V, V_{DELAY} = 0V	-0.70	-0.42	-0.25	uA
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 uF V_{OUT} rising from 0V, Δt from V_{OUT} > V_{OR} to $\overline{\text{RESET}}$ pin HIGH	4.7	7.8	13.2	ms

Electrical Characteristics for LM9076–5.0

The following specifications apply for V_{IN}= 14V; $V_{SHUTDOWN}$ = Open; I_{LOAD} = 10 mA; T_J = +25°C; C_{OUT} = 10 µF, 0.5Ω < ESR < 4.0Ω; unless otherwise specified. **Bold Values indicate –40°C ≤ T_J ≤ 125°C**. (Note 4), (Note 5) Minimum and Maximum limits are guaranteed through test, design, or statistical correlation.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
LM9076–5.0 REGULATOR CHARACTERISTICS						
V_{OUT}	Output Voltage		4.925	5.00	5.075	V
		–20°C ≤ T_J ≤ 85°C 1 mA ≤ I_{LOAD} ≤ 150 mA	4.900	5.00	5.100	V
		1 mA ≤ I_{LOAD} ≤ 150 mA	**4.850**	**5.00**	**5.150**	V
		V_{IN} = 60V, R_{LOAD} = 1 kΩ, t ≤ 40ms	4.500	5.00	5.500	V
	Output Voltage Off LM9076 BMA only	$V_{SHUTDOWN}$ ≥ 2V, R_{LOAD} = 1 kΩ	–	0	250	mV
	Reverse Battery	V_{IN} = -15V, R_{LOAD} = 1 kΩ	–300	0	–	mV
ΔV_{OUT}	Line Regulation	9.0V ≤ V_{IN} ≤ 16V, I_{LOAD} = 10 mA	–	4	25	mV
		16V ≤ V_{IN} ≤ 40V, I_{LOAD} = 10 mA	–	17	35	mV
	Load Regulation	1 mA ≤ I_{LOAD} ≤ 150 mA	–	42	60	mV
V_{DO}	Dropout Voltage	I_{LOAD} = 10 mA	–	30	50	mV
		I_{LOAD} = 50 mA	–	80	–	mV
		I_{LOAD} = 150 mA	–	150	250	mV
I_{GND}	Ground Pin Current	9V ≤ V_{IN} ≤ 16V, I_{LOAD} = 100 uA	–	25	45	µA
		9V ≤ V_{IN} ≤ 40V, I_{LOAD} = 10 mA	–	125	160	µA
		9V ≤ V_{IN} ≤ 40V, I_{LOAD} = 50 mA	–	0.6	–	mA
		9V ≤ V_{IN} ≤ 16V, I_{LOAD} = 150 mA	–	3.6	4.5	mA
	Ground Pin Current in Shutdown Mode	9V ≤ V_{IN} ≤ 40V, $V_{SHUTDOWN}$ = 2V	–	15	25	µA
I_{SC}	V_{OUT} Short Circuit Current	V_{IN} = 14V, R_{LOAD} = 1Ω	200	400	750	mA
PSRR	Ripple Rejection	V_{IN} = (14V_{DC}) + (1V_{RMS} @ 120Hz) I_{LOAD} = 50 mA	50	60	–	dB
$\overline{RESET}$ PIN CHARACTERISTICS						
V_{OR}	Minimum V_{IN} for valid $\overline{RESET}$ Status	(Note 3)	–	1.3	2.0	V
V_{THR}	V_{OUT} Threshold for $\overline{RESET}$ Low	(Note 3)	0.83	0.89	0.94	X V_{OUT} (Nom)
V_{OH}	$\overline{RESET}$ pin high voltage	External pull-up resistor to V_{OUT} = 100 kΩ	V_{OUT} X 0.90	V_{OUT} X 0.99	V_{OUT}	V
V_{OL}	$\overline{RESET}$ pin low voltage	C_{DELAY} < 4.0V, I_{SINK} = 250 µA	–	0.2	0.3	V
C_{DELAY} PIN CHARACTERISTICS						

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{DELAY}	C_{DELAY} Charging Current	V_{IN} = 14V, V_{DELAY} = 0V	-0.70	-0.42	-0.25	uA
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 uF V_{OUT} rising from 0V, Δt from $V_{OUT} > V_{OR}$ to $\overline{RESET}$ pin HIGH	7.1	11.9	20.0	ms
SHUTDOWN CONTROL LOGIC — LM9076BMA-5.0 Only						
$V_{IL(SD)}$	SHUTDOWN Pin Low Threshold Voltage	$V_{SHUTDOWN}$ pin falling from 5.0V until V_{OUT} >4.5V (V_{OUT} = On)	1	1.5	–	V
$V_{IH(SD)}$	SHUTDOWN Pin High Threshold Voltage	$V_{SHUTDOWN}$ pin rising from 0V until V_{OUT} < 0.5V (V_{OUT} = Off)	–	1.5	2	V
$I_{IH(SD)}$	SHUTDOWN Pin High Bias Current	$V_{SHUTDOWN}$ = 40V	–	35	–	μA
		$V_{SHUTDOWN}$ = 5V	–	15	35	μA
		$V_{SHUTDOWN}$ = 2V	–	6	10	μA
$I_{IL(SD)}$	SHUTDOWN Pin Low Bias Current	$V_{SHUTDOWN}$ = 0V	–	0	–	μA

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.

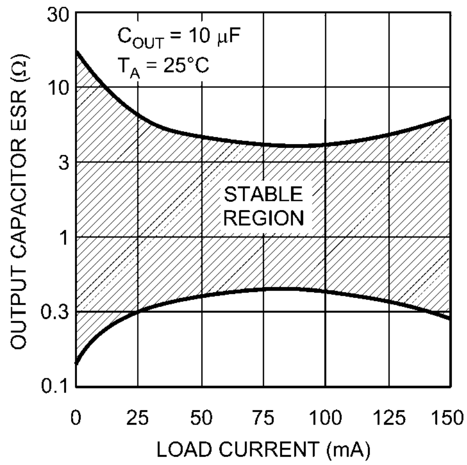
Note 4: Pulse testing used maintain constant junction temperature (T_J).

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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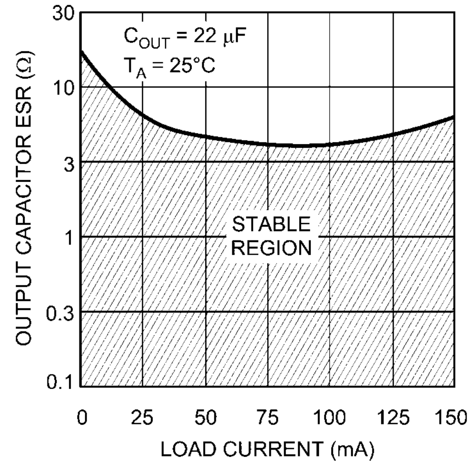
Output Capacitor ESR



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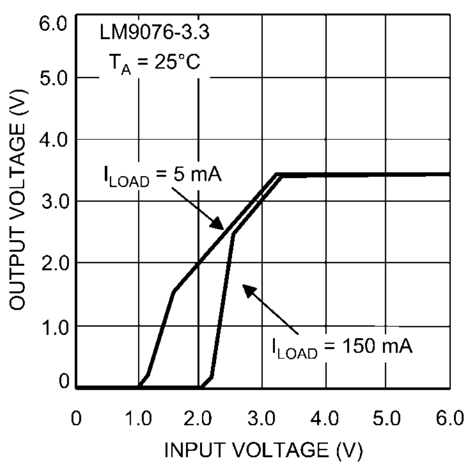
Output Voltage vs Low Input Voltage



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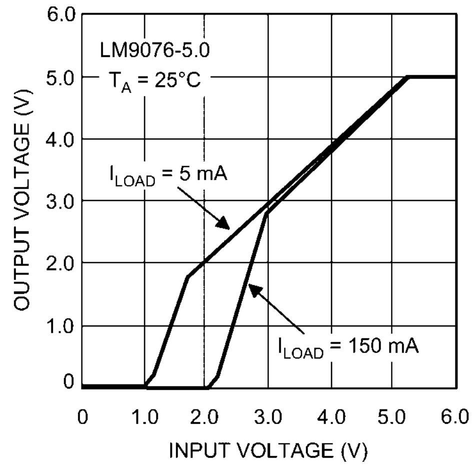
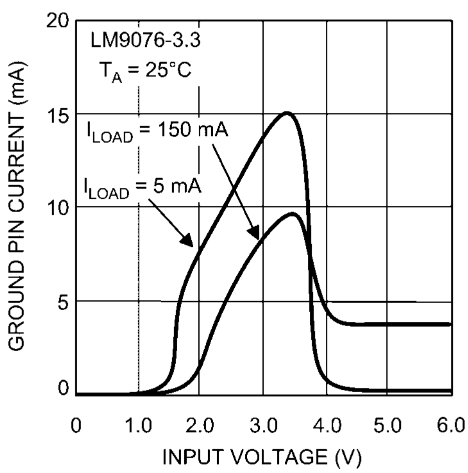
Output Voltage vs Low Input Voltage



20083034

Ground Pin Current vs Low Input Voltage



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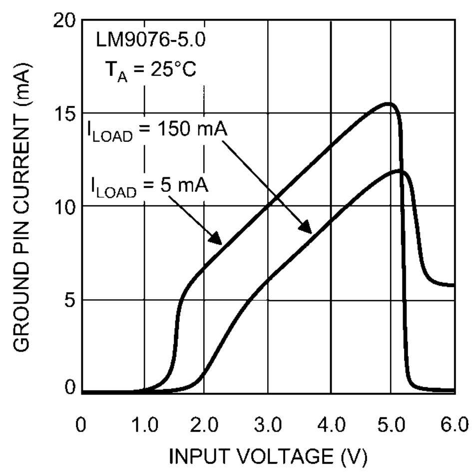
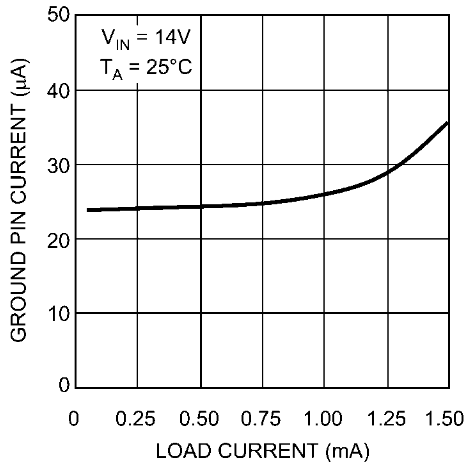
Ground Pin Current vs Low Input Voltage



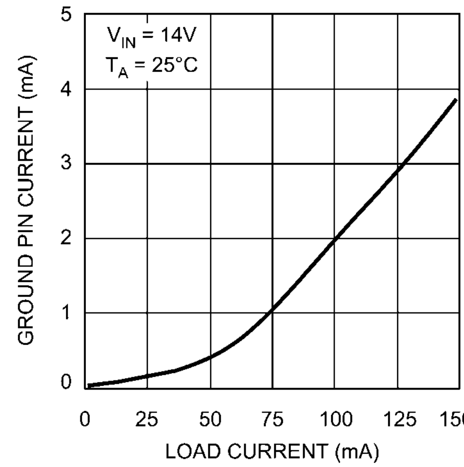
20083036

Ground Pin Current vs Load Current



20083037

Ground Pin Current vs Load Current



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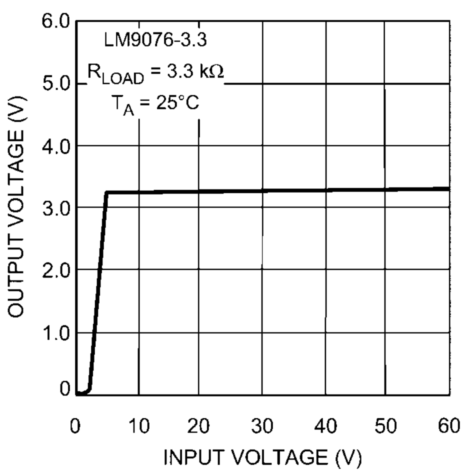
Output Voltage vs Input Voltage



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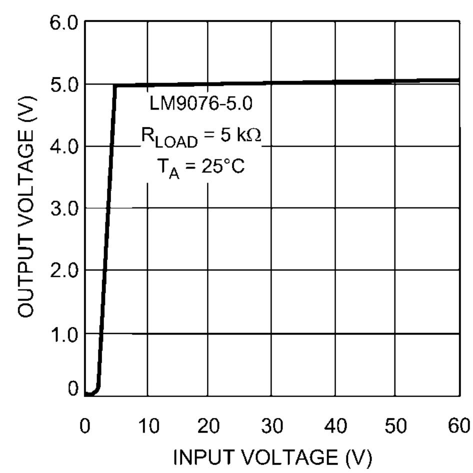
Output Voltage vs Input Voltage



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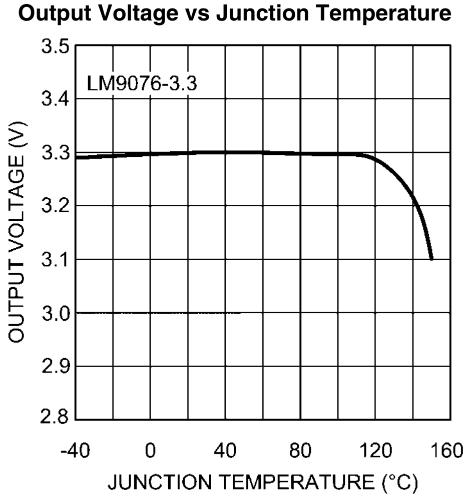
Output Voltage vs Junction Temperature



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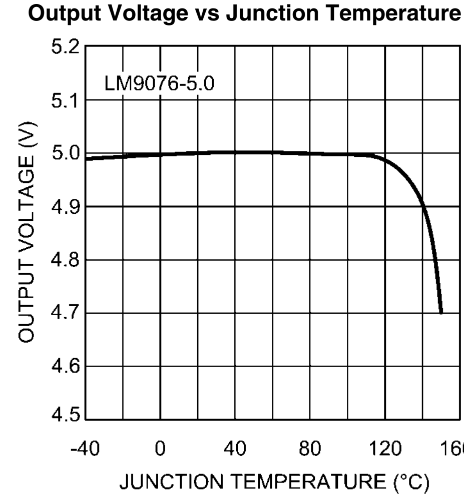
Output Voltage vs Junction Temperature



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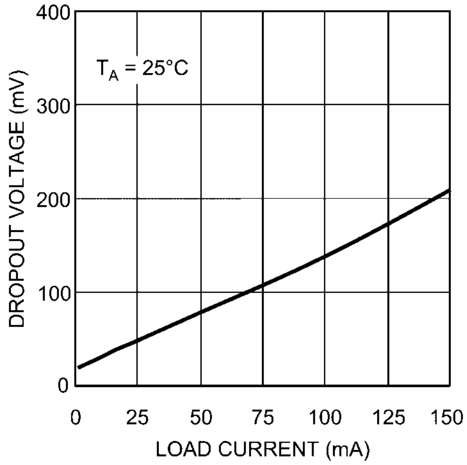
Dropout Voltage vs Load Current



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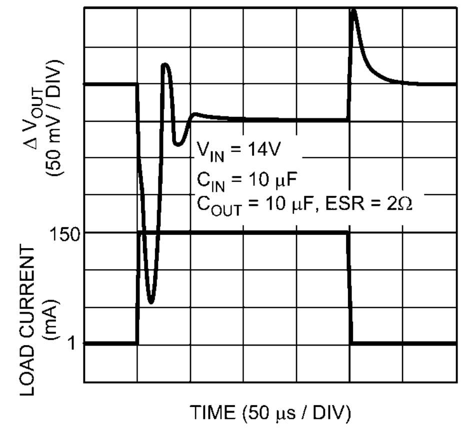
Load Transient Response



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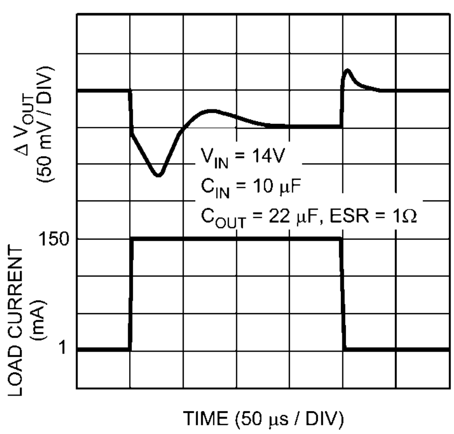
Load Transient Response



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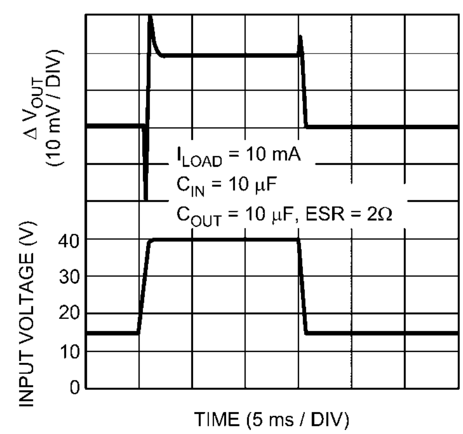
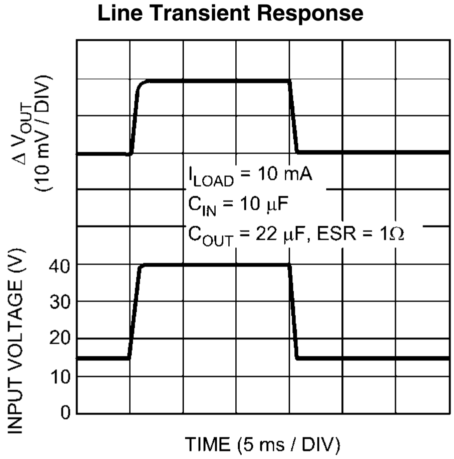
Line Transient Response



20083046

Line Transient Response



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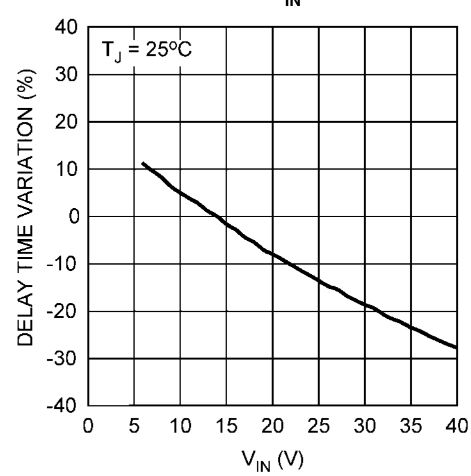
Delayed Reset Time vs Vin Normalized to V_{IN} = 14V



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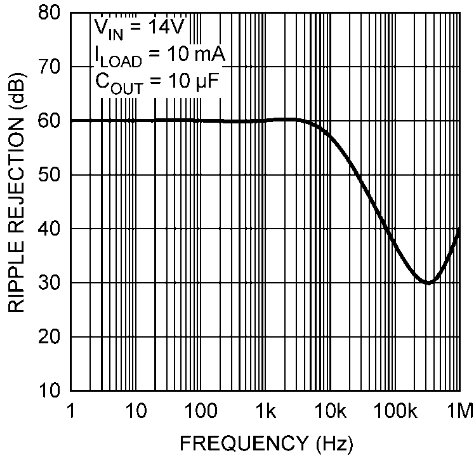
Ripple Rejection



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Application Information

REGULATOR BASICS

The LM9076 regulator is suitable for Automotive and Industrial applications where continuous connection to a battery supply is required (refer to the Typical Application circuit).

The pass element of the regulator is a PNP device which requires an output bypass capacitor for stability. The minimum bypass capacitance for the output is 10 µF (refer to ESR limitations). A 22 µF, or larger, output bypass capacitor is recommended for typical applications

INPUT CAPACITOR

The LM9076 requires a low source impedance to maintain regulator stability because critical portions of the internal bias circuitry are connected to directly to V_{IN}. In general, a 10 µF electrolytic capacitor, located within two inches of the LM9076, is adequate for a majority of applications. Additionally, and at a minimum, a 0.1 µF ceramic capacitor should be located between the LM9076 V_{IN} and Ground pin, and as close as is physically possible to the LM9076 itself .

OUTPUT CAPACITOR

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

The output capacitor must meet the requirements for minimum capacitance and also maintain the appropriate ESR value across the entire operating ambient temperature range. There is no limit to the maximum output capacitance as long as ESR is maintained.

The minimum bypass capacitance for the output is 10 µF (refer to ESR limitations). A 22 µF, or larger, output bypass capacitor is recommended for typical applications.

Solid tantalums capacitors are recommended as they generally maintain capacitance and ESR ratings over a wide temperature range. Ceramic capacitor types XR7 and XR5 may be used if a series resistor is added to simulate the minimum ESR requirement. See *Figure 1*.

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

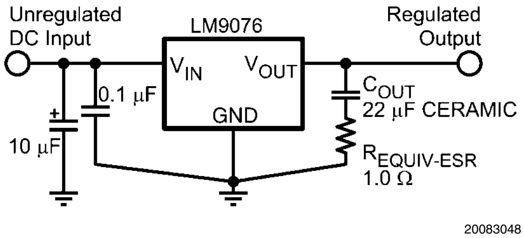


FIGURE 1. Using Low ESR Capacitors

DELAY CAPACITOR

The capacitor on the Delay pin must be a low leakage type since the charge current is minimal (420 nA typical) and the pin must fully charge to V_{OUT}. 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.

Any leakage of the I_{DELAY} current, be it through the delay capacitor or any other path, will extend the delay time, possibly to the point that the Reset pin output does not go high.

SHUTDOWN PIN - LM9076BMA ONLY

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 10KΩ to 50KΩ is recommended to provide reverse voltage transient protection of the SHUTDOWN pin. Adding a small capacitor (0.001uF typical) from the SHUTDOWN pin to Ground will add noise immunity to prevent accidental turn on due to noise on the supply line.

$\overline{\text{RESET}}$ FLAG

The $\overline{\text{RESET}}$ pin is an open collector output which requires an external pull-up resistor to develop the reset signal. The external pull-up resistor should be in the range of 10 kΩ to 200 kΩ.

At V_{IN} values of less than typically 2V the $\overline{\text{RESET}}$ pin voltage will be high. For V_{IN} values between typically 2V and approximately $V_{OUT} + V_{BE}$ the $\overline{\text{RESET}}$ pin voltage will be low. For V_{IN} values greater than approximately $V_{OUT} + V_{BE}$ the $\overline{\text{RESET}}$ pin voltage will be dependent on the status of the V_{OUT} pin voltage and the Delayed Reset circuitry. The value of V_{BE} is typically 600 mV at 25°C and will decrease approximately 2 mV for every 1°C increase in the junction temperature. During normal operation the $\overline{\text{RESET}}$ pin voltage will be high .

Any load condition that causes the V_{OUT} pin voltage to drop below typically 89% of normal will activate the Delayed Reset circuit and the $\overline{\text{RESET}}$ pin will go low for the duration of the delay time.

Any line condition that causes V_{IN} pin voltage to drop below typically $V_{OUT} + V_{BE}$ will cause the $\overline{\text{RESET}}$ pin to go low without activating the Delayed Reset circuitry.

Excessive thermal dissipation will raise the junction temperature and could activate the Thermal Shutdown circuitry which, in turn, will cause the $\overline{\text{RESET}}$ pin to go low.

For the LM9076BMA devices, pulling the SHUTDOWN pin high will turn off the output which, in turn, will cause the $\overline{\text{RESET}}$ pin to go low once the V_{OUT} voltage has decayed to a value that is less than typically 89% of normal. See *Figure 2*.

$\overline{\text{RESET}}$ DELAY TIME

When the regulator output is switched On, or after recovery from brief V_{OUT} fault condition, the $\overline{\text{RESET}}$ flag can be 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 $\overline{\text{RESET}}$ 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 0.420 uA rate. When the voltage on the C_{DELAY} capacitor reaches the same potential as the V_{OUT} pin the $\overline{\text{RESET}}$ pin will be allowed to return high.

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

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

For the LM9076–3.3 with a C_{DELAY} value of 0.001 uF and a I_{DELAY} value of 0.420 uA the typical $\overline{RESET}$ delay time is:

$$t_{DELAY} = 3.3V \times (0.001\ uF / 0.420\ uA) = 7.8\ ms$$

For the LM9076–5.0 with a C_{DELAY} value of 0.001 uF and a I_{DELAY} value of 0.420 uA the typical $\overline{RESET}$ delay time is:

$$t_{DELAY} = 5.0V \times (0.001uF / 0.420uA) = 11.9\ ms$$

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 circuity monitors the temperature at the die level. When the die temperature exceeds typically 160°C the voltage regulator output will be switched off.

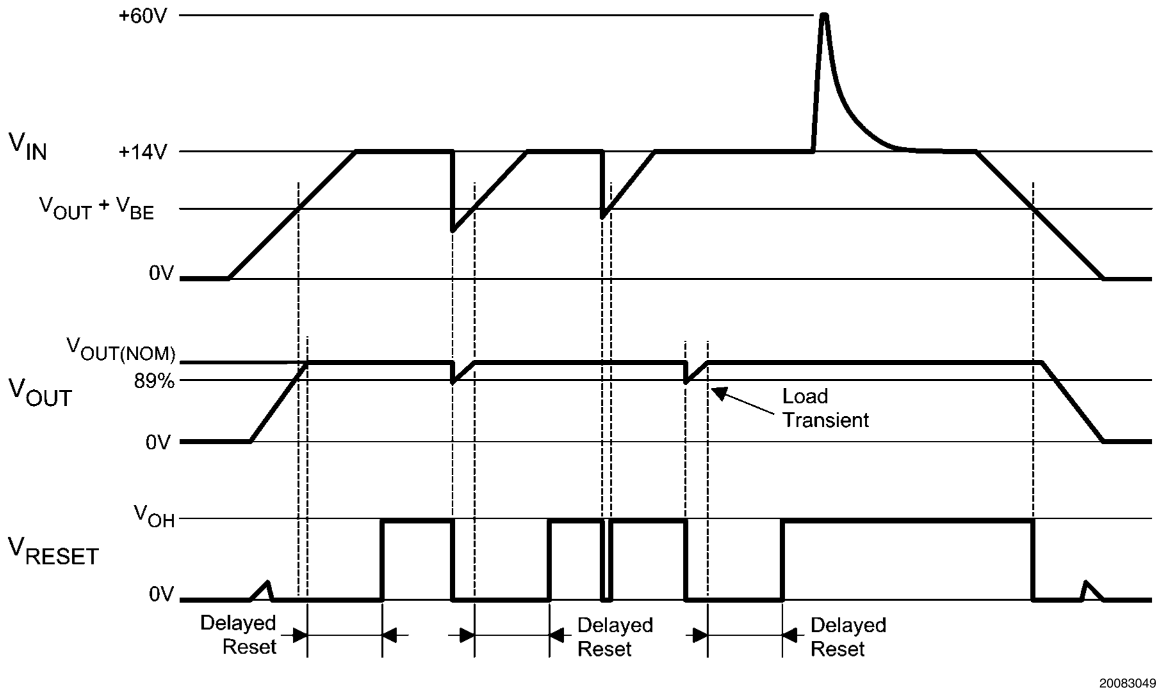
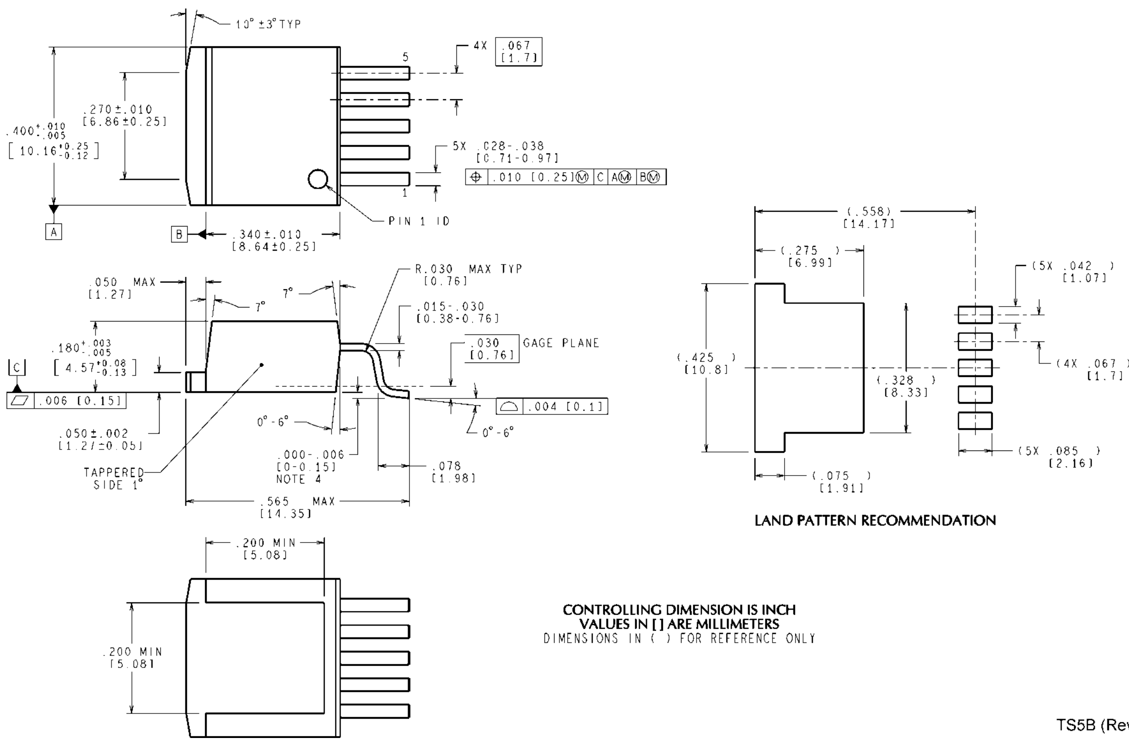


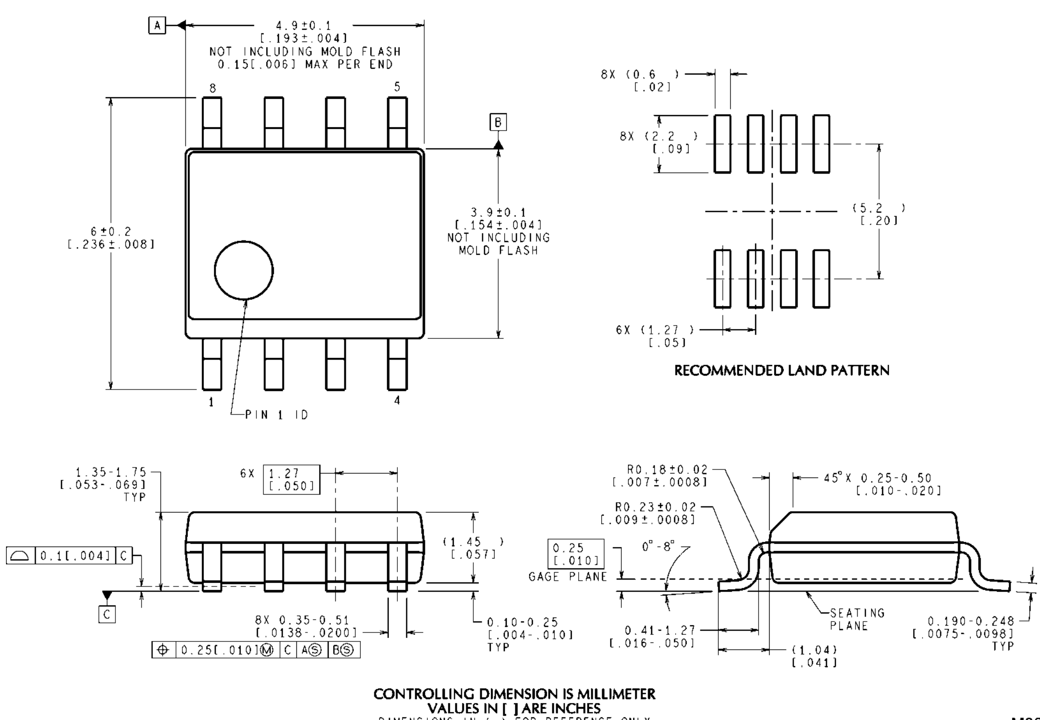
FIGURE 2. Typical $\overline{Reset}$ Pin Operational Waveforms

Physical Dimensions inches (millimeters) unless otherwise noted



TS5B (Rev D)

5-Lead TO-263
NS Package Number TS5B



M08A (Rev L)

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

Notes

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