National Semiconductor

July 2005

LM2936
Ultra-Low Quiescent Current LDO Voltage Regulator

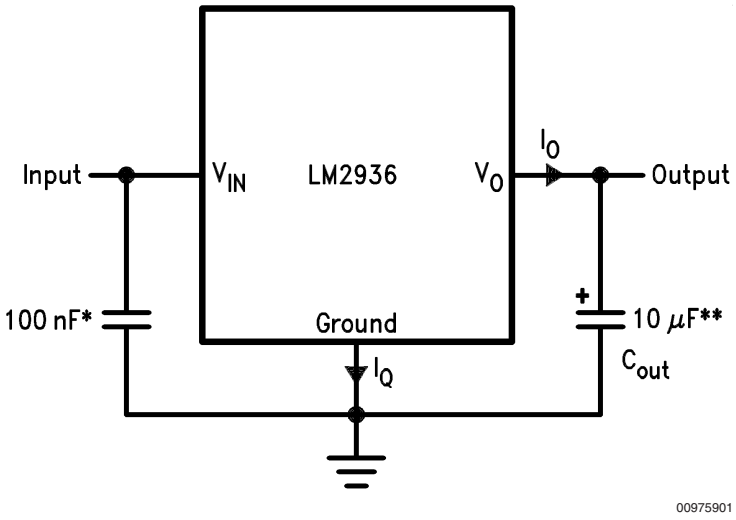
General Description

The LM2936 ultra-low quiescent current regulator features low dropout voltage and low current in the standby mode. With less than 15 µA quiescent current at a 100 µA load, the LM2936 is ideally suited for automotive and other battery operated systems. The LM2936 retains all of the features that are common to low dropout regulators including a low dropout PNP pass device, short circuit protection, reverse battery protection, and thermal shutdown. The LM2936 has a 40V maximum operating voltage limit, a –40˚C to +125˚C operating temperature range, and ±3% output voltage tolerance over the entire output current, input voltage, and temperature range. The LM2936 is available in a TO-92 package, SO-8 and SOT–23 surface mount packages, and a TO-252 surface mount power package.

Features

- Ultra low quiescent current ($I_Q \leq 15$ µA for $I_O = 100$ µA)
- Fixed 3.0V, 3.3V or 5.0V with 50 mA output
- ±2% Initial output tolerance
- ±3% Output tolerance over line, load, and temperature
- Dropout voltage typically 200 mV @ $I_O = 50$ mA
- Reverse battery protection
- –50V reverse transient protection
- Internal short circuit current limit
- Internal thermal shutdown protection
- 40V operating voltage limit
- 60V operating voltage limit for LM2936HV
- Shutdown Pin available with LM2936BM package

Typical Application



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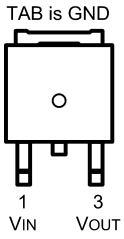
* Required if regulator is located more than 2" from power supply filter capacitor.

** Required for stability. See Electrical Characteristics for required values. Must be rated over intended operating temperature range. Effective series resistance (ESR) is critical, see curve. Locate capacitor as close as possible to the regulator output and ground pins. Capacitance may be increased without bound.

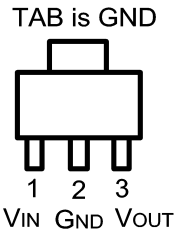
Connection Diagrams

TO-252



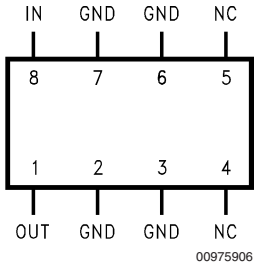
Top View
LM2936DT
See NS Package Number TD03B

SOT-223



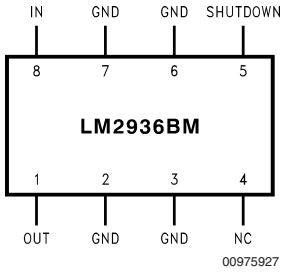
Top View
LM2936MP
See NS Package Number MP04A

8-Pin SO (M)



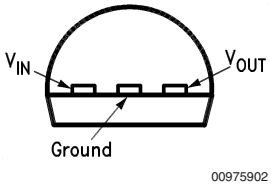
Top View
LM2936M and LM2936HVMA
See NS Package Number M08A

8-Pin SO (M)



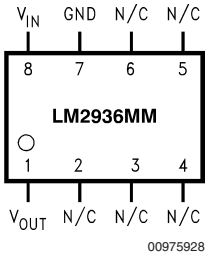
Top View
LM2936BM and LM2936HVBMA
See NS Package Number M08A

TO-92



Bottom View
LM2936Z
See NS Package Number Z03A

8-Pin Mini SOIC (MM)



Top View
LM2936MM
See NS Package Number MUA08A

Ordering Information

Output Voltage	High Voltage	Shutdown Pin	Order	Package Type	Package Drawing	Transport Media
	-	Yes	LM2936BM-3.0	8-Lead SOIC	M08A	Rail
	-	Yes	LM2936BMX-3.0	8-Lead SOIC	M08A	Tape/Reel
	-	-	LM2936DT-3.0	TO-252	TD03B	Rail
	-	-	LM2936DTX-3.0	TO-252	TD03B	Tape/Reel
	Yes	Yes	LM2936HVBMA-3.0	8-Lead SOIC	M08A	Rail
	Yes	Yes	LM2936HVBMAX-3.0	8-Lead SOIC	M08A	Tape/Reel
3.00V	-	-	LM2936M-3.0	8-Lead SOIC	M08A	Rail
	-	-	LM2936MX-3.0	8-Lead SOIC	M08A	Tape/Reel
	-	-	LM2936MP-3.0	SOT-223	MP04A	Tape/Reel
	-	-	LM2936MPX-3.0	SOT-223	MP04A	Tape/Reel
	-	-	LM2936MM-3.0	8-Lead Mini SOIC	MUA08A	Rail
	-	-	LM2936MMX-3.0	8-Lead Mini SOIC	MUA08A	Tape/Reel
	-	-	LM2936Z-3.0	TO-92	Z03A	Box
	-	Yes	LM2936BM-3.3	8-Lead SOIC	M08A	Rail
	-	Yes	LM2936BMX-3.3	8-Lead SOIC	M08A	Tape/Reel
	-	-	LM2936DT-3.3	TO-252	TD03B	Rail
	-	-	LM2936DTX-3.3	TO-252	TD03B	Tape/Reel
	Yes	Yes	LM2936HVBMA-3.3	8-Lead SOIC	M08A	Rail
	Yes	Yes	LM2936HVBMAX-3.3	8-Lead SOIC	M08A	Tape/Reel
3.30V	-	-	LM2936M-3.0	8-Lead SOIC	M08A	Rail
	-	-	LM2936MX-3.3	8-Lead SOIC	M08A	Tape/Reel
	-	-	LM2936MP-3.3	SOT-223	MP04A	Tape/Reel
	-	-	LM2936MPX-3.3	SOT-223	MP04A	Tape/Reel
	-	-	LM2936MM-3.3	8-Lead Mini- SOIC	MUA08A	Rail
	-	-	LM2936MMX-3.3	8-Lead Mini- SOIC	MUA08A	Tape/Reel
	-	-	LM2936Z-3.3	TO-92	Z03A	Box
	-	Yes	LM2936BM-5.0	8-Lead SOIC	M08A	Rail
	-	Yes	LM2936BMX-5.0	8-Lead SOIC	M08A	Tape/Reel
	-	-	LM2936DT-5.0	TO-252	TD03B	Rail
	-	-	LM2936DTX-5.0	TO-252	TD03B	Tape/Reel
	Yes	Yes	LM2936HVBMA-5.0	8-Lead SOIC	M08A	Rail
	Yes	Yes	LM2936HVBMAX-5.0	8-Lead SOIC	M08A	Tape/Reel
	Yes	-	LM2936HVMA-5.0	8-Lead SOIC	M08A	Rail
5.00V	Yes	-	LM2936HVMAX-5.0	8-Lead SOIC	M08A	Tape/Reel
	-		LM2936M-5.0	8-Lead SOIC	M08A	Rail
	-	-	LM2936MX-5.0	8-Lead SOIC	M08A	Tape/Reel
	-	-	LM2936MP-5.0	SOT-223	MP04A	Tape/Reel
	-	-	LM2936MPX-5.0	SOT-223	MP04A	Tape/Reel
	-	-	LM2936MM-5.0	8-Lead Mini-SOIC	MUA08A	Rail
	-	-	LM2936MMX-5.0	8-Lead Mini-SOIC	MUA08A	Tape/Reel
	-	-	LM2936Z-5.0	TO-92	Z03A	Box

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Voltage (Survival)	+60V, –50V
ESD Susceptibility (Note 2)	2000V
Power Dissipation (Note 3)	Internally limited
Junction Temperature (T_{Jmax})	150˚C
Storage Temperature Range	–65˚C to +150˚C
Lead Temperature (Soldering, 10 sec.)	260˚C

Operating Ratings

Operating Temperature Range	–40˚C to +125˚C
Maximum Operating Input Voltage - LM2936	+40V
Maximum Operating Input Voltage - LM2936HV only	+60V
Maximum Shutdown Pin Voltage - LM2936BM only	0V to 40V
TO-92 (Z03A) θ_{JA}	195˚C/W
MSO-8 (MUA08A) θ_{JA}	200˚C/W
SO-8 (M08A) θ_{JA}	140˚C/W
SO-8 (M08A) θ_{JC}	45˚C/W
TO-252 (TD03B) θ_{JA}	136˚C/W
TO-252 (TD03B) θ_{JC}	6˚C/W
SOT-223 (MP04A) θ_{JA}	149˚C/W
SOT-223 (MP04A) θ_{JC}	36˚C/W

Electrical Characteristics for LM2936–3.0

V_{IN} = 14V, I_O = 10 mA, T_J = 25˚C, unless otherwise specified. **Boldface** limits apply over entire operating temperature range

Parameter	Conditions	Min (Note 5)	Typical (Note 4)	Max (Note 5)	Units
LM2936HV–3.0 Only					
Output Voltage	5.5V ≤ V_{IN} ≤ 48V, 100 µA ≤ I_O ≤ 50 mA (Note 6)	**2.910**	**3.000**	**3.090**	V
Line Regulation	6V ≤ V_{IN} ≤ 60V, I_O = 1mA		10	30	mV
All LM2936–3.0					
Output Voltage		2.940	3.000	3.060	V
	4.0V ≤ V_{IN} ≤ 26V, 100 µA ≤ I_O ≤ 50 mA (Note 6)	**2.910**	**3.000**	**3.090**	
Quiescent Current	I_O = 100 µA, 8V ≤ V_{IN} ≤ 24V		15	20	µA
	I_O = 10 mA, 8V ≤ V_{IN} ≤ 24V		0.20	0.50	mA
	I_O = 50 mA, 8V ≤ V_{IN} ≤ 24V		1.5	2.5	mA
Line Regulation	9V ≤ V_{IN} ≤ 16V		5	10	mV
	6V ≤ V_{IN} ≤ 40V, I_O = 1 mA		10	30	
Load Regulation	100 µA ≤ I_O ≤ 5 mA		10	30	mV
	5 mA ≤ I_O ≤ 50 mA		10	30	
Dropout Voltage	I_O = 100 µA		0.05	0.10	V
	I_O = 50 mA		0.20	0.40	V
Short Circuit Current	V_O = 0V	65	120	250	mA
Output Impedance	I_O = 30 mAdc and 10 mArms, $_f$ = 1000 Hz		450		mΩ
Output Noise Voltage	10 Hz–100 kHz		500		µV
Long Term Stability			20		mV/1000 Hr
Ripple Rejection	V_{ripple} = 1V_{rms}, $_{fripple}$ = 120 Hz	–40	–60		dB
Reverse Polarity Transient Input Voltage	R_L = 500Ω, T = 1 ms	–50	–80		V
Output Voltage with Reverse Polarity Input	V_{IN} = –15V, R_L = 500Ω		0.00	–0.30	V
Maximum Line Transient	R_L = 500Ω, V_O ≤ 3.30V, T = 40ms	60			V

Electrical Characteristics for LM2936–3.0 (Continued)

V_{IN} = 14V, I_O = 10 mA, T_J = 25˚C, unless otherwise specified. **Boldface** limits apply over entire operating temperature range

Parameter	Conditions	Min (Note 5)	Typical (Note 4)	Max (Note 5)	Units
Output Bypass Capacitance (C_{OUT}) ESR	C_{OUT} = 22µF 0.1mA ≤ I_{OUT} ≤ 50mA	0.3		8	Ω
Shutdown Input – LM2936BM–3.0 Only					
Output Voltage, V_{OUT}	Output Off, V_{SD}=2.4V, R_{LOAD} = 500Ω		0	0.010	V
Shutdown High Threshold Voltage, V_{IH}	Output Off, R_{LOAD} = 500Ω	2.00	1.1		V
Shutdown Low Threshold Voltage, V_{IL}	Output On, R_{LOAD} = 500Ω		1.1	0.60	V
Shutdown High Current, I_{IH}	Output Off, V_{SD} = 2.4V, R_{LOAD} = 500Ω		12		µA
Quiescent Current	Output Off, V_{SD} = 2.4V, R_{LOAD} = 500Ω Includes I_{IH} Current		30		µA

Electrical Characteristics for LM2936–3.3

V_{IN} = 14V, I_O = 10 mA, T_J = 25˚C, unless otherwise specified. **Boldface** limits apply over entire operating temperature range

Parameter	Conditions	Min (Note 5)	Typical (Note 4)	Max (Note 5)	Units
LM2936HV–3.3 Only					
Output Voltage	5.5V ≤ V_{IN} ≤ 48V, 100 µA ≤ I_O ≤ 50 mA (Note 6)	**3.201**	**3.300**	**3.399**	V
Line Regulation	6V ≤ V_{IN} ≤ 60V, I_O = 1mA		10	30	mV
All LM2936–3.3					
Output Voltage		3.234	3.300	3.366	V
	4.0V ≤ V_{IN} ≤ 26V, 100 µA ≤ I_O ≤ 50 mA (Note 6)	**3.201**	**3.300**	**3.399**	
Quiescent Current	I_O = 100 µA, 8V ≤ V_{IN} ≤ 24V		15	20	µA
	I_O = 10 mA, 8V ≤ V_{IN} ≤ 24V		0.20	0.50	mA
	I_O = 50 mA, 8V ≤ V_{IN} ≤ 24V		1.5	2.5	mA
Line Regulation	9V ≤ V_{IN} ≤ 16V		5	10	mV
	6V ≤ V_{IN} ≤ 40V, I_O = 1 mA		10	30	
Load Regulation	100 µA ≤ I_O ≤ 5 mA		10	30	mV
	5 mA ≤ I_O ≤ 50 mA		10	30	
Dropout Voltage	I_O = 100 µA		0.05	0.10	V
	I_O = 50 mA		0.20	0.40	V
Short Circuit Current	V_O = 0V	65	120	250	mA
Output Impedance	I_O = 30 mAdc and 10 mArms, $_f$ = 1000 Hz		450		mΩ
Output Noise Voltage	10 Hz–100 kHz		500		µV
Long Term Stability			20		mV/1000 Hr
Ripple Rejection	V_{ripple} = 1V_{rms}, $_{fripple}$ = 120 Hz	–40	–60		dB
Reverse Polarity Transient Input Voltage	R_L = 500Ω, T = 1 ms	–50	–80		V
Output Voltage with Reverse Polarity Input	V_{IN} = –15V, R_L = 500Ω		0.00	–0.30	V
Maximum Line Transient	R_L = 500Ω, V_O ≤ 3.63V, T = 40ms	60			V

Electrical Characteristics for LM2936–3.3 (Continued)

V_{IN} = 14V, I_O = 10 mA, T_J = 25˚C, unless otherwise specified. **Boldface** limits apply over entire operating temperature range

Parameter	Conditions	Min (Note 5)	Typical (Note 4)	Max (Note 5)	Units
Output Bypass Capacitance (C_{OUT}) ESR	C_{OUT} = 22µF 0.1mA ≤ I_{OUT} ≤ 50mA	0.3		8	Ω
Shutdown Input – LM2936BM–3.3 Only					
Output Voltage, V_{OUT}	Output Off, V_{SD}=2.4V, R_{LOAD} = 500Ω		0	0.010	V
Shutdown High Threshold Voltage, V_{IH}	Output Off, R_{LOAD} = 500Ω	2.00	1.1		V
Shutdown Low Threshold Voltage, V_{IL}	Output On, R_{LOAD} = 500Ω		1.1	0.60	V
Shutdown High Current, I_{IH}	Output Off, V_{SD} = 2.4V, R_{LOAD} = 500Ω		12		µA
Quiescent Current	Output Off, V_{SD} = 2.4V, R_{LOAD} = 500Ω Includes I_{IH} Current		30		µA

Electrical Characteristics for LM2936–5.0

V_{IN} = 14V, I_O = 10 mA, T_J = 25˚C, unless otherwise specified. **Boldface** limits apply over entire operating temperature range

Parameter	Conditions	Min (Note 5)	Typical (Note 4)	Max (Note 5)	Units
LM2936HV–5.0 Only					
Output Voltage	5.5V ≤ V_{IN} ≤ 48V, 100 µA ≤ I_O ≤ 50 mA (Note 6)	**4.85**	**5.00**	**5.15**	V
Line Regulation	6V ≤ V_{IN} ≤ 60V, I_O = 1mA		15	35	mV
All LM2936–5.0					
Output Voltage		4.90	5.00	5.10	V
	5.5V ≤ V_{IN} ≤ 26V, 100 µA ≤ I_O ≤ 50 mA (Note 6)	**4.85**	**5.00**	**5.15**	
Quiescent Current	I_O = 100 µA, 8V ≤ V_{IN} ≤ 24V		9	15	µA
	I_O = 10 mA, 8V ≤ V_{IN} ≤ 24V		0.20	0.50	mA
	I_O = 50 mA, 8V ≤ V_{IN} ≤ 24V		1.5	2.5	mA
Line Regulation	9V ≤ V_{IN} ≤ 16V		5	10	mV
	6V ≤ V_{IN} ≤ 40V, I_O = 1 mA		10	30	
Load Regulation	100 µA ≤ I_O ≤ 5 mA		10	30	mV
	5 mA ≤ I_O ≤ 50 mA		10	30	
Dropout Voltage	I_O = 100 µA		0.05	0.10	V
	I_O = 50 mA		0.20	0.40	V
Short Circuit Current	V_O = 0V	65	120	250	mA
Output Impedance	I_O = 30 mAdc and 10 mArms, $_f$ = 1000 Hz		450		mΩ
Output Noise Voltage	10 Hz–100 kHz		500		µV
Long Term Stability			20		mV/1000 Hr
Ripple Rejection	V_{ripple} = 1V_{rms}, fripple = 120 Hz	–40	–60		dB
Reverse Polarity Transient Input Voltage	R_L = 500Ω, T = 1 ms	–50	–80		V
Output Voltage with Reverse Polarity Input	V_{IN} = –15V, R_L = 500Ω		0.00	–0.30	V
Maximum Line Transient	R_L = 500Ω, V_O ≤ 5.5V, T = 40ms	60			V

Electrical Characteristics for LM2936–5.0 (Continued)

V_{IN} = 14V, I_O = 10 mA, T_J = 25˚C, unless otherwise specified. **Boldface** limits apply over entire operating temperature range

Parameter	Conditions	Min (Note 5)	Typical (Note 4)	Max (Note 5)	Units
Output Bypass Capacitance (C_{OUT}) ESR	C_{OUT} = 10µF 0.1mA ≤ I_{OUT} ≤ 50mA	0.3		8	Ω
Shutdown Input – LM2936BM–5.0 Only					
Output Voltage, V_{OUT}	Output Off, V_{SD}=2.4V, R_{LOAD} = 500Ω		0	0.010	V
Shutdown High Threshold Voltage, V_{IH}	Output Off, R_{LOAD} = 500Ω	2.00	1.1		V
Shutdown Low Threshold Voltage, V_{IL}	Output On, R_{LOAD} = 500Ω		1.1	0.60	V
Shutdown High Current, I_{IH}	Output Off, V_{SD} = 2.4V, R_{LOAD} = 500Ω		12		µA
Quiescent Current	Output Off, V_{SD} = 2.4V, R_{LOAD} = 500Ω Includes I_{IH} Current		30		µA

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its specified operating ratings.

Note 2: Human body model, 100 pF discharge through a 1.5 kΩ resistor.

Note 3: The maximum power dissipation is a function of T_{Jmax}, θ_{JA}, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{Jmax} - T_A)/\theta_{JA}$. If this dissipation is exceeded, the die temperature will rise above 150˚C and the LM2936 will go into thermal shutdown.

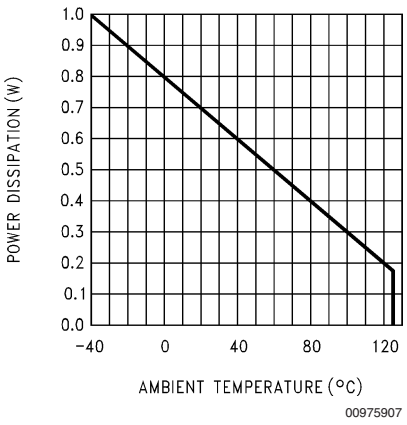
Note 4: Typicals are at 25˚C (unless otherwise specified) and represent the most likely parametric norm.

Note 5: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Note 6: To ensure constant junction temperature, pulse testing is used.

Typical Performance Characteristics

Maximum Power Dissipation (TO-92)



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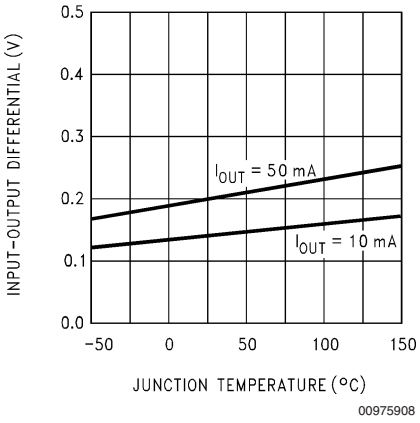
Dropout Voltage



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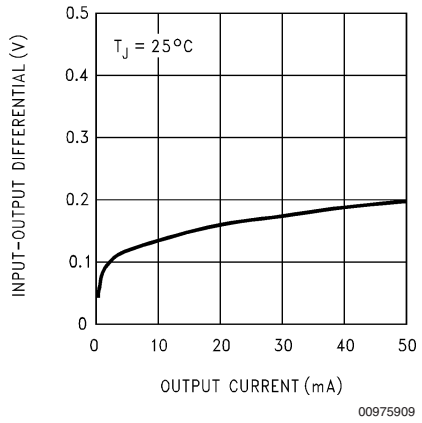
Typical Performance Characteristics (Continued)

Dropout Voltage



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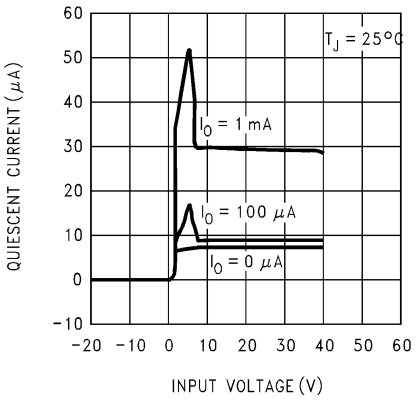
Quiescent Current



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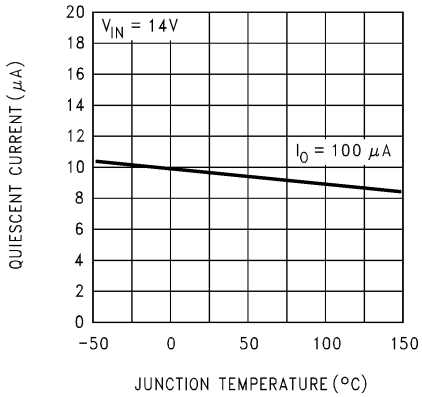
Quiescent Current



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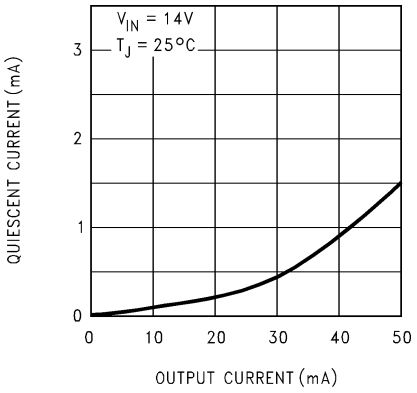
Quiescent Current



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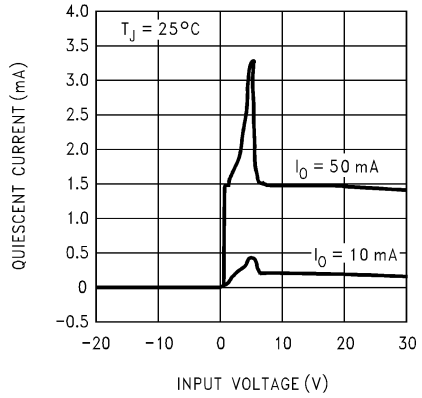
Quiescent Current



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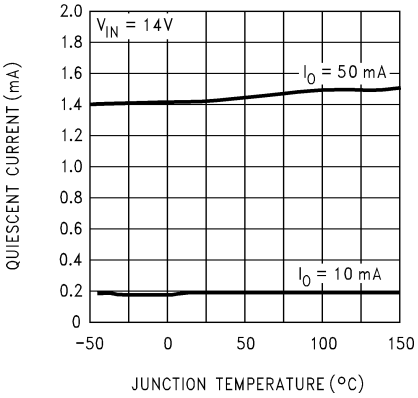
Quiescent Current



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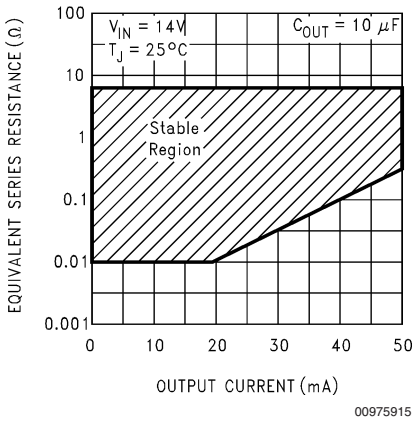
Typical Performance Characteristics (Continued)

LM2936–5.0 C_{OUT} ESR



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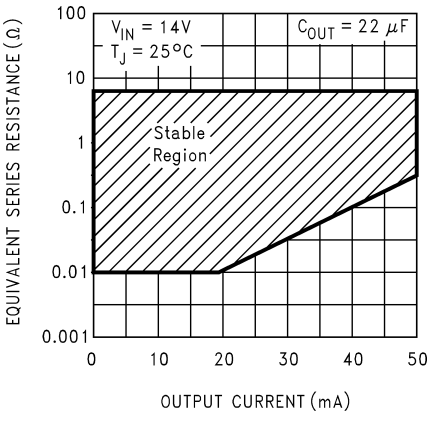
LM2936–3.0 C_{OUT} ESR



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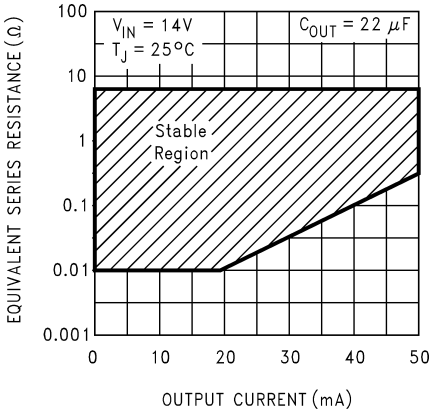
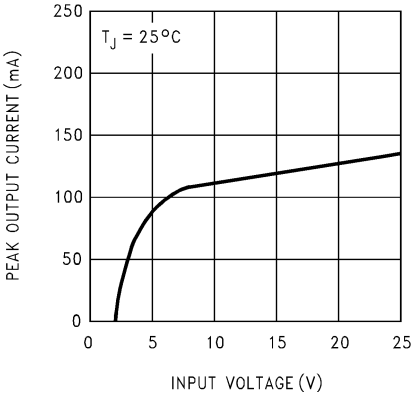
LM2936–3.3 C_{OUT} ESR



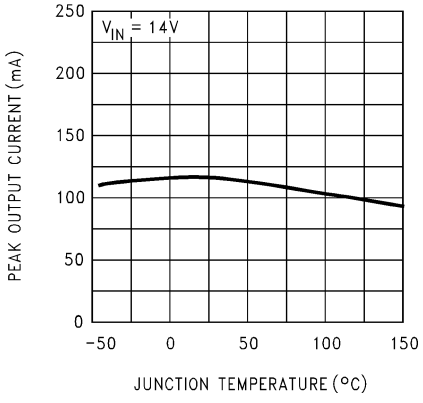
00975930

Peak Output Current



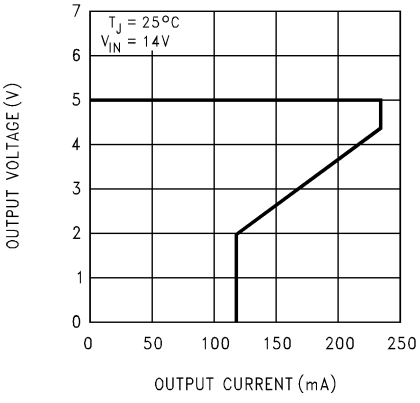
00975916

Peak Output Current



00975917

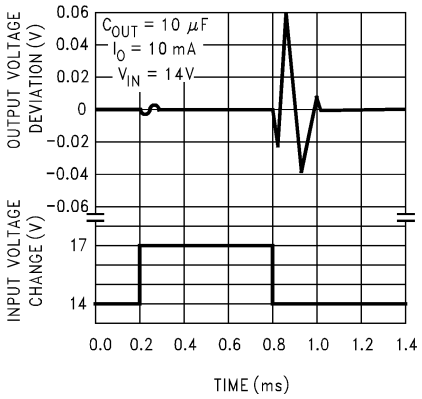
LM2936–5.0 Current Limit



00975918

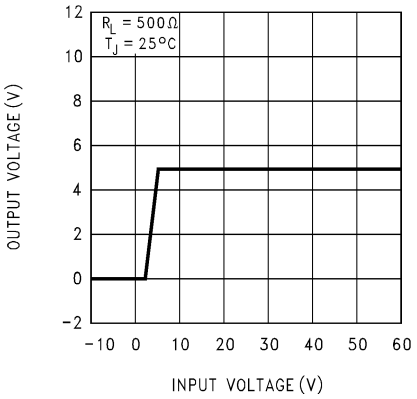
Typical Performance Characteristics (Continued)

LM2936–5.0 Line Transient Response



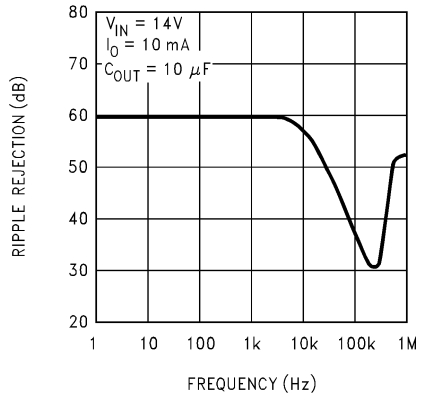
00975919

LM2936–5.0 Output at Voltage Extremes



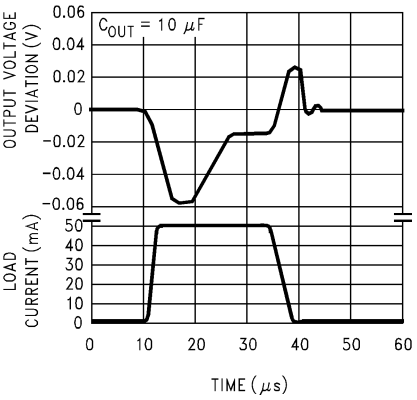
00975920

LM2936–5.0 Ripple Rejection



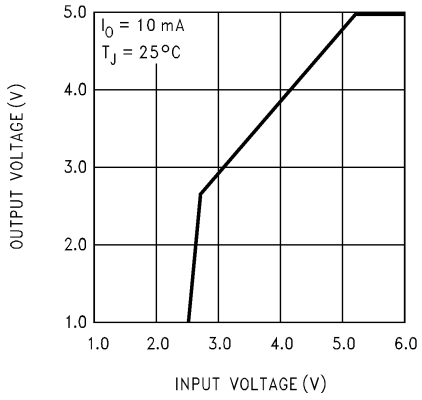
00975921

LM2936–5.0 Load Transient Response



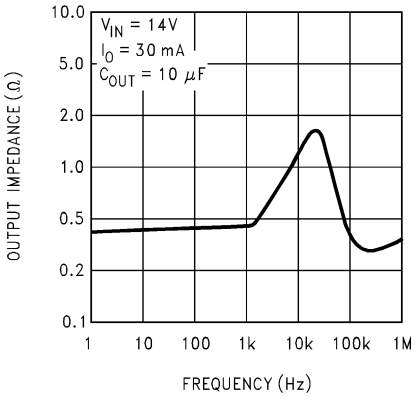
00975922

LM2936–5.0 Low Voltage Behavior



00975923

LM2936–5.0 Output Impedance



00975924

Applications Information

Unlike other PNP low dropout regulators, the LM2936 remains fully operational to 40V. Owing to power dissipation characteristics of the available packages, full output current cannot be guaranteed for all combinations of ambient temperature and input voltage. As an example, consider an LM2936Z–5.0 operating at 25˚C ambient. Using the formula for maximum allowable power dissipation given in (Note 3) , we find that P_{Dmax} = 641 mW at 25˚C. Including the small contribution of the quiescent current to total power dissipation the maximum input voltage (while still delivering 50 mA output current) is 17.3V. The LM2936Z–5.0 will go into thermal shutdown if it attempts to deliver full output current with an input voltage of more than 17.3V. Similarly, at 40V input and 25˚C ambient the LM2936Z–5.0 can deliver 18 mA maximum.

Under conditions of higher ambient temperatures, the voltage and current calculated in the previous examples will drop. For instance, at the maximum ambient of 125˚C the LM2936Z–5.0 can only dissipate 128 mW, limiting the input voltage to 7.34V for a 50 mA load, or 3.5 mA output current for a 40V input.

The junction to ambient thermal resistance θ_{JA} rating has two distinct components: the junction to case thermal resistance rating θ_{JC}; and the case to ambient thermal resistance rating θ_{CA}. The relationship is defined as: $\theta_{JA} = \theta_{JC} + \theta_{CA}$.

For the SO-8 and TO-252 surface mount packages the θ_{JA} rating can be improved by using the copper mounting pads on the printed circuit board as a thermal conductive path to extract heat from the package.

On the SO-8 package the four ground pins are thermally connected to the backside of the die. Adding approximately 0.04 square inches of 2 oz. copper pad area to these four pins will improve the θ_{JA} rating to approximately 110˚C/W. If this extra pad are is placed directly beneath the package there should not be any impact on board density.

On the TO-252 package the ground tab is thermally connected to the backside of the die. Adding 1 square inch of 2 oz. copper pad area directly under the ground tab will improve the θ_{JA} rating to approximately 50˚C/W.

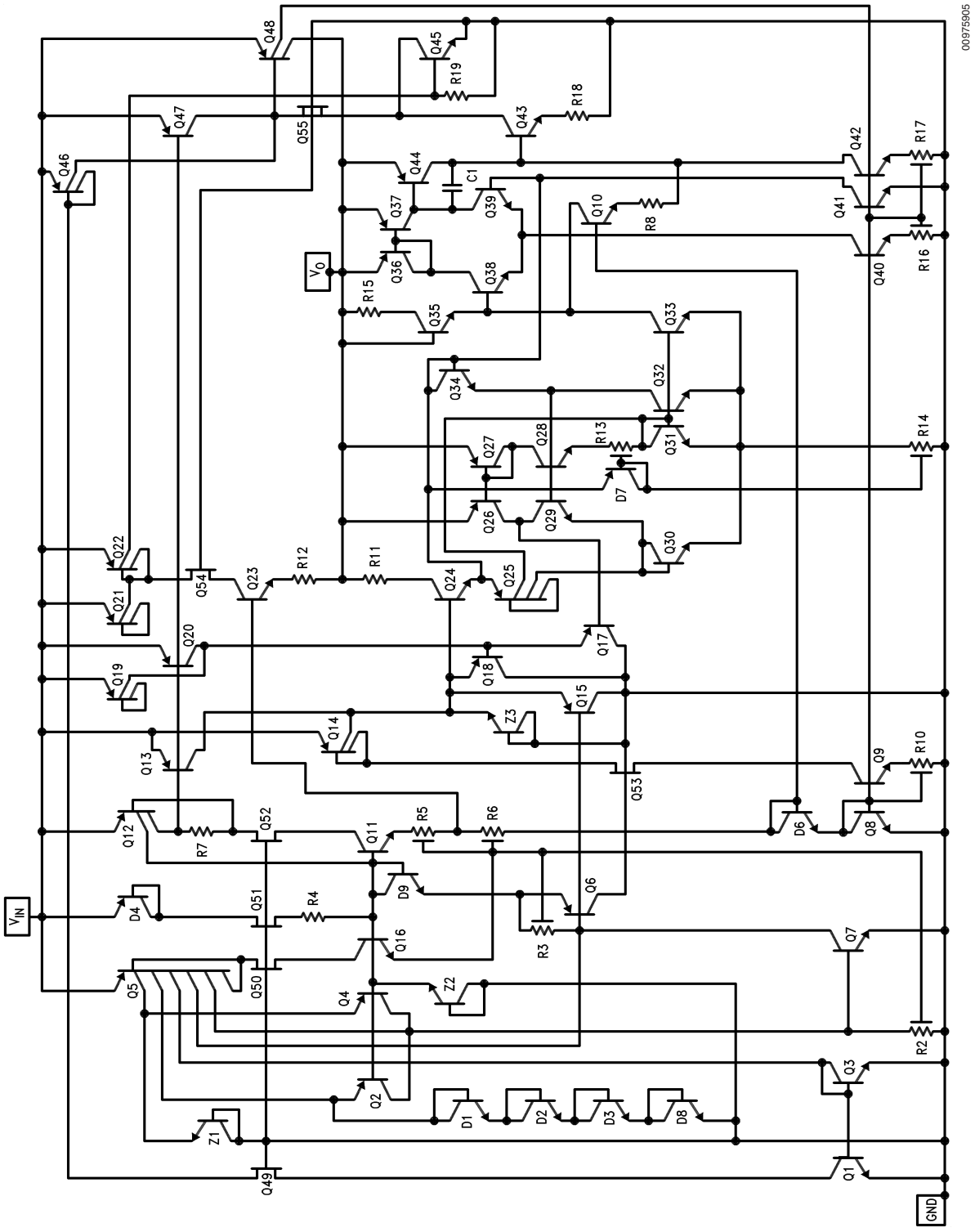
While the LM2936 has an internally set thermal shutdown point of typically 160˚C, this is intended as a safety feature only. Continuous operation near the thermal shutdown temperature should be avoided as it may have a negative affect on the life of the device.

While the LM2936 maintains regulation to 60V, it will not withstand a short circuit above 40V because of safe operating area limitations in the internal PNP pass device. Above 60V the LM2936 will break down with catastrophic effects on the regulator and possibly the load as well. Do not use this device in a design where the input operating voltage may exceed 40V, or where transients are likely to exceed 60V.

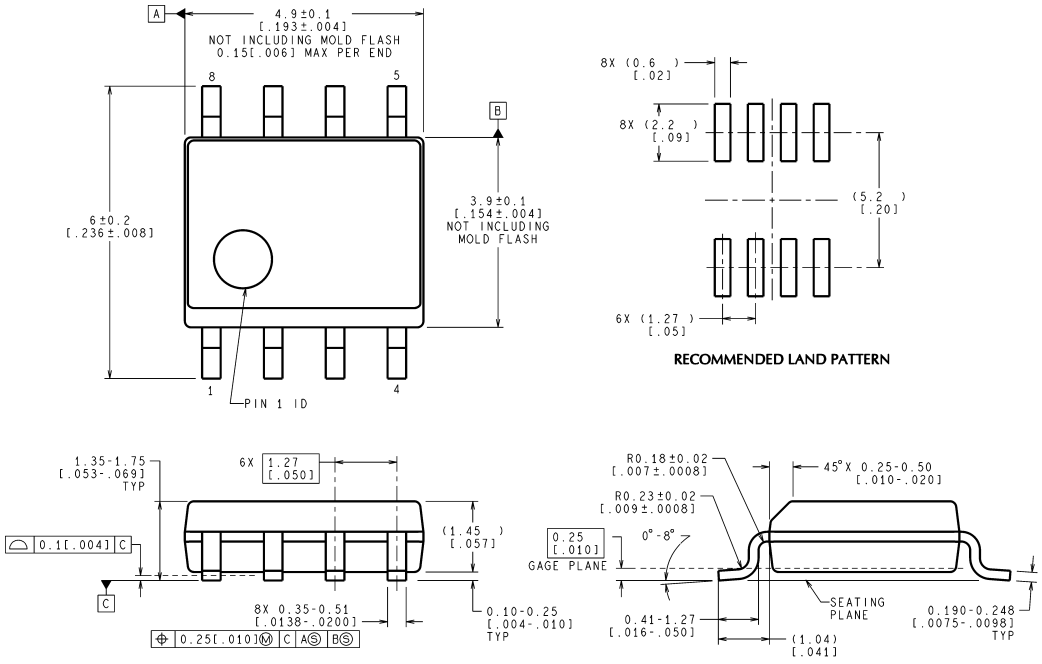
SHUTDOWN PIN

The LM2936BM has a pin for shutting down the regulator output. Applying a Logic Level High (>2.0V) to the Shutdown pin will cause the output to turn off. Leaving the Shutdown pin open, connecting it to Ground, or applying a Logic Level Low (<0.6V) will allow the regulator output to turn on.

Equivalent Schematic Diagram



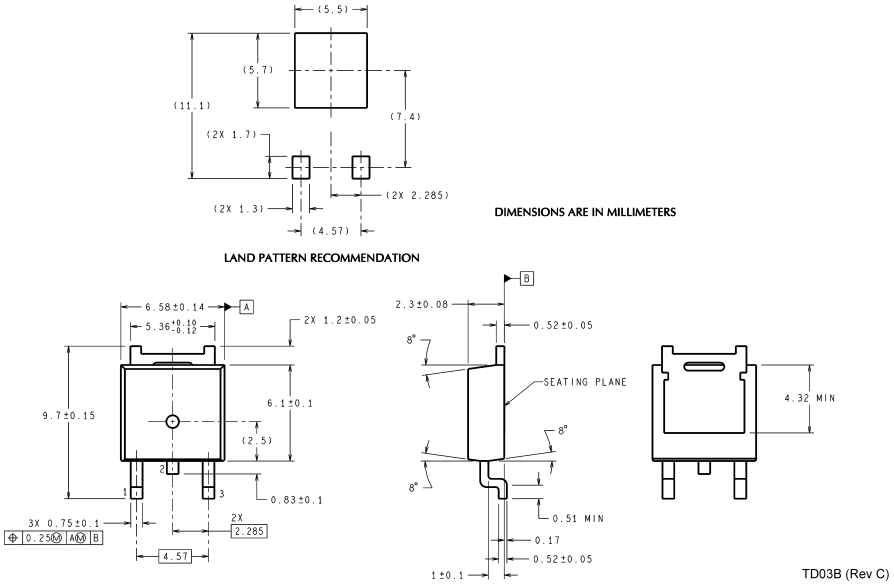
Physical Dimensions inches (millimeters) unless otherwise noted



CONTROLLING DIMENSION IS MILLIMETER
VALUES IN [ ] ARE INCHES
DIMENSIONS IN ( ) FOR REFERENCE ONLY

M08A (Rev K)

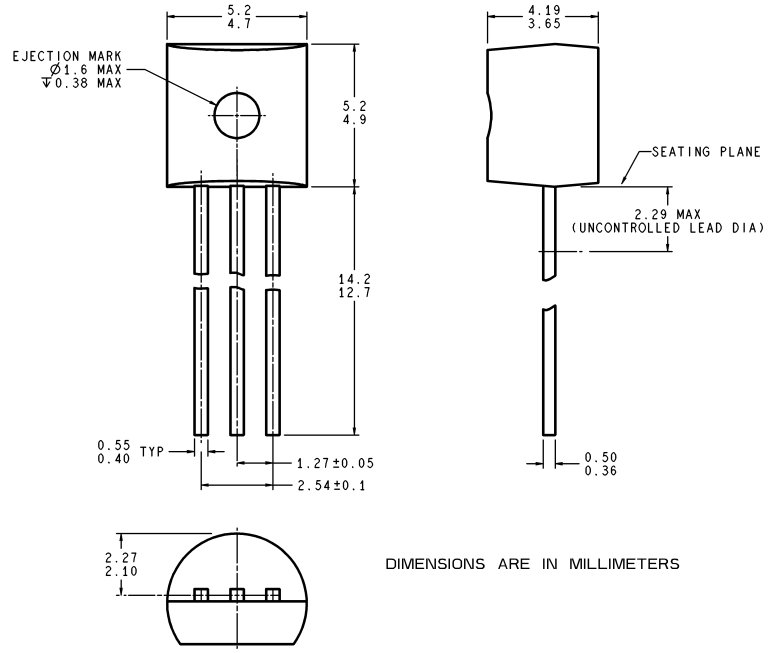
8-Lead Small Outline Molded Package (M)
NS Package Number M08A



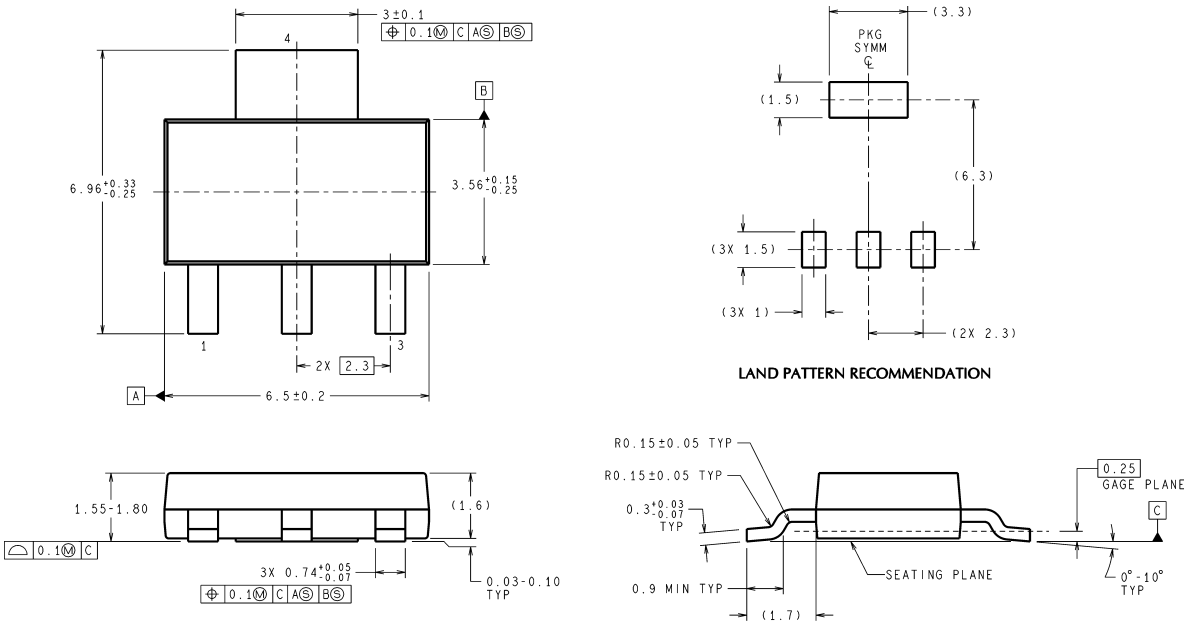
TD03B (Rev C)

TO-252 Package (DT)
NS Package Number TD03B

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

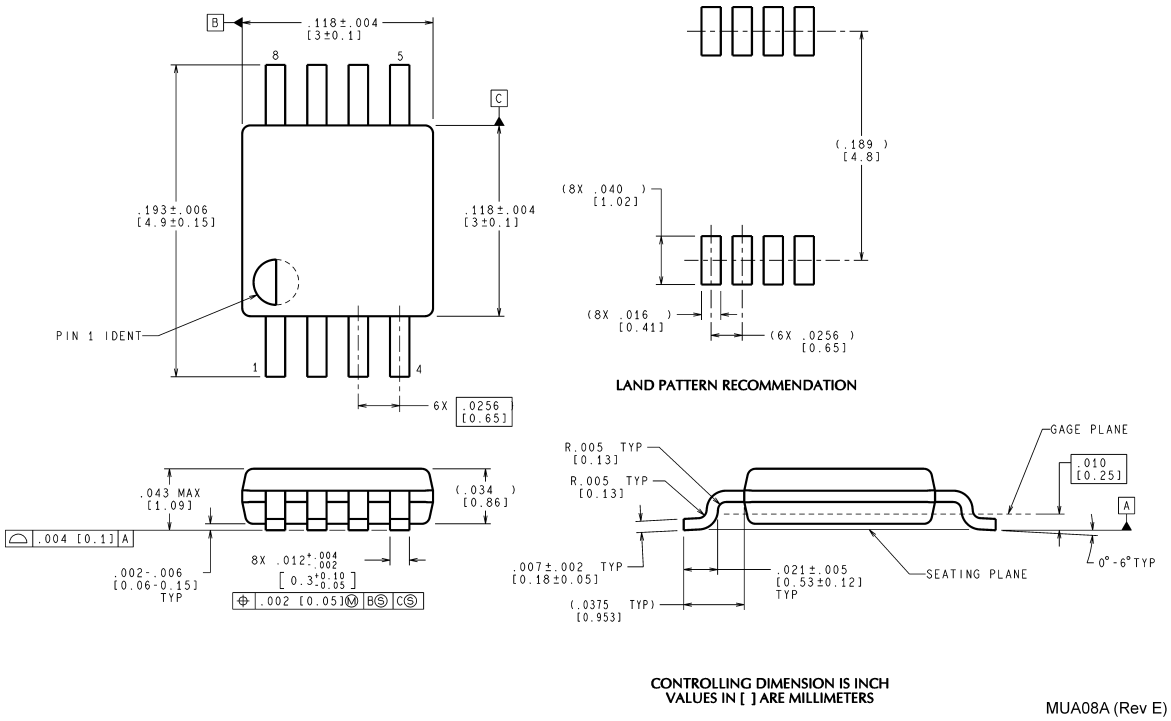


3-Lead TO-92 Plastic Package (Z)
NS Package Number Z03A



SOT-223 Package (MP)
NS Package Number MP04A

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



8-Lead Mini SOIC package (MM)
NS Package Number MUA08A

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