LM3350

LM3350 Switched Capacitor Voltage Converter

National Semiconductor

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Switched Capacitor Voltage Converter

General Description

The LM3350 is a CMOS charge-pump voltage converter which efficiently provides a 3.3V to 5V step-up, or 5V to 3.3V step-down. The LM3350 uses four small, low cost capacitors to provide the voltage conversion. It eliminates the cost, size and radiated EMI related to inductor based circuits, or the power loss of a linear regulator. Operating power conversion efficiency greater than 90% provides ideal performance for battery powered portable systems.

The architecture provides a fixed voltage conversion ratio of 3/2 or 2/3. Thus it can be used for other DC-DC conversions as well.

Features

- Conversion of 3.3V to 5V, or 5V to 3.3V
- 4.2Ω typical step-up output impedance
- 1.8Ω typical step-down output impedance
- 90% typical power conversion efficiency at 50 mA
- 800 kHz switch frequency allows use of very small, inexpensive capacitors.
- No inductor required
- 250 nA typical shutdown current
- Small Mini SO-8 package

Applications

- Any mixed 5V and 3.3V system
- Laptop computers and PDAs
- Handheld instrumentation
- PCMCIA cards

Basic Operating Circuits

Step-Up Converter

10000201

Step-Down Converter

10000202

Connection Diagram

Mini SO8 Package

```
        ┌───────┐
Cap1+ ──┤1     8├── Enable
Cap1- ──┤2     7├── V_high
Cap2+ ──┤3     6├── GND
Cap2- ──┤4     5├── V_low
        └───────┘
```

Top View   10000203
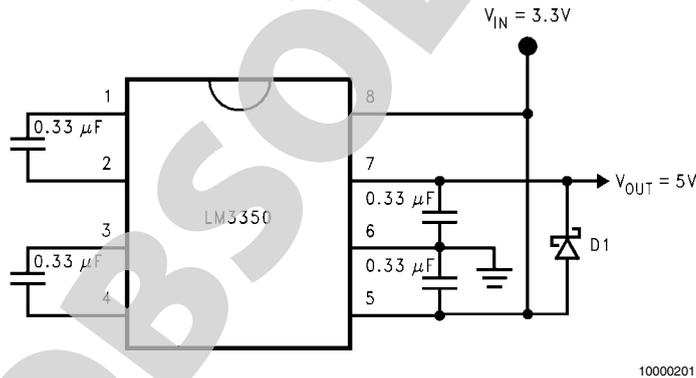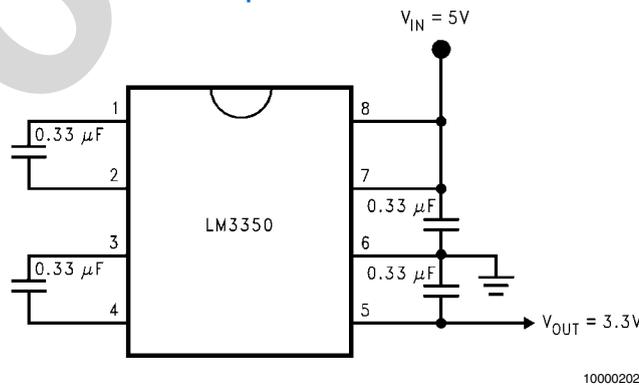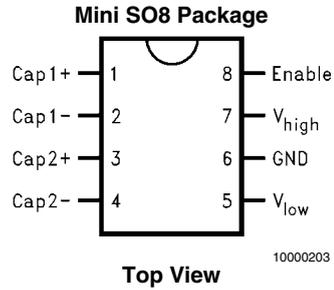
Ordering Information

Order Number	Package Type	NSC Package Drawing	Package Marking	Supplied As
LM3350MMX	Mini SO-8	MUA08A	S00A	3500k Units on Tape and Reel
LM3350MM	Mini SO-8	MUA08A	S00A	1000 Units on Tape and Reel

Pin Descriptions

Pin	Name	Function
1	Cap1+	Positive terminal for the first charge pump capacitor.
2	Cap1−	Negative terminal for the first charge pump capacitor.
3	Cap2+	Positive terminal for the second charge pump capacitor.
4	Cap2−	Negative terminal for the second charge pump capacitor.
5	V_{low}	In Step-Up mode, this will be the input terminal. In Step-Down mode, this will be the output terminal.
6	Gnd	Ground
7	V_{high}	In Step-Down mode, this will be the input terminal. In Step-Up mode, this will be the output terminal.
8	Enable	Active high CMOS logic level Enable Input. Connect to Voltage Input terminal to enable the IC. Connect to Ground (Pin 6) to disable.

Absolute Maximum Ratings (Note 1)

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

Maximum Input Voltage, Step-Down	5.5V
Maximum Input Voltage, Step-Up	3.65V
Power Dissipation (P_D) (T_A=25°C, (Note 2))	500 mW
θ_{ja} (Note 2)	250°C/W
Tj Max (Note 2)	150°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 secs)	260°C
ESD Susceptibility (Note 3)	2kV

Not short circuit protected.

Operating Conditions (Note 1)

Ambient Temperature Range	−40°C to + 85°C

Electrical Characteristics
3/2 Step-Up Voltage Converter

Specifications in standard type face are for T_j = 25°C, and those with **boldface type** apply over **full operating temperature range**. Unless otherwise specified, V_{in} = 3.3V, V_{Enable} = 3.3V, I_{load} = 50 mA.

Symbol	Parameter	Conditions	Typ (Note 4)	Limits (Note 5)	Units
$V_{out_{NL}}$	Output Voltage at No Load	C1, C2, C_{in} and C_{out}: 0.33µF, esr ≤ 0.33 Ω at 1MHz. I_{load} = 0 A	5.0		V
$V_{out_{FL}}$	Output Voltage at 50 mA	C1, C2, C_{in} and C_{out}: 0.33µF, esr ≤ 0.33 Ω at 1MHz. I_{load} = 50 mA	4.7		V
V_{in}	Input Supply Voltage Range		3.3	**2.5** **3.65**	V V(Min) V(Max)
I_{Q1}	Quiescent Current	Shutdown Mode, V_{Enable} = 0V, I_{load}=0 A; Current into pin V_{low}	0.025	**3**	µA µA(Max)
I_{Q2}	Quiescent Current	Normal Mode, I_{load} = 0A; Current into pin V_{low}	3.75	**5**	mA mA(Max)
Z_{out}	Output Source Impedance	I_{load} = 50 mA	4.2	**6.25**	Ω Ω (Max)
f_{SW}	Switching Frequency	(Note 6)	800	**500** **1100**	kHz kHz(Min) kHz(Max)
V_{Enable}	Enable Threshold Voltage		1.7	**1.0** **2.5**	V V(Min) V(Max)
I_{Enable}	Leakage Current	Current into ENABLE pin; ENABLE = 5V and all other pins at ground	0.025	**1**	µA µA(Max)
P_n	Power Efficiency		90		%

Electrical Characteristics
2/3 Step-Down Voltage Converter

Specifications in standard type face are for $T_j = 25°C$, and those with **boldface type** apply over **full operating temperature range**. Unless otherwise specified, $V_{high} = 5V$, $V_{Enable} = 5V$, $I_{load} = 50$ mA.

Symbol	Parameter	Conditions	Typ (*Note 4*)	Limits (*Note 5*)	Units
$V_{out_{NL}}$	Output Voltage at No Load	C1, C2, C_{in} and C_{out}: 0.33μF, esr ≤ 0.33 Ω at 1MHz. $I_{load} = 0$ A	3.3		V
$V_{out_{FL}}$	Output Voltage at 50 mA	C1, C2, C_{in} and C_{out}: 0.33 μF, esr ≤ 0.33Ω at 1MHz. $I_{load} = 50$ mA	3.2		V
V_{in}	Input Supply Voltage Range		5		V
				2.2	V(Min)
				5.5	V(Max)
I_{Q1}	Quiescent Current	Shutdown Mode, $V_{Enable} = 0V$, $I_{load} = 0$ A; Current into pin V_{high}	0.25		μA
				3	μA(Max)
I_{Q2}	Quiescent Current	Normal Mode, $I_{load} = 0A$; Current into pin V_{high}	2.5		mA
				3.3	mA(Max)
Z_{out}	Output Source Impedance	$I_{load} = 50$ mA	1.8		Ω
				3	Ω (Max)
f_{SW}	Switching Frequency	(*Note 6*)	800		kHz
				500	kHz(Min)
				1100	kHz(Max)
V_{Enable}	Enable Threshold Voltage		1.7		V
				1.0	V(Min)
				2.5	V(Max)
I_{Enable}	Leakage Current	Current into ENABLE pin; ENABLE = 5V and all other pins at ground	0.025		μA
				1	μA(Max)
$P_η$	Power Efficiency		90		%

Note 1: Absolute maximum ratings indicate limits beyond which damage to the device may occur. Operating ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see 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: For operation at elevated temperatures, LM3350 must be derated based on package thermal resistance of $θ_{ja}$ and T_j max, $T_j = T_A + θ_{ja}P_D$.

Note 3: The human body model is a 100 pF capacitor discharged through a 1.5 kW resistor into each pin.

Note 4: Typical numbers are at 25°C and represent the most likely parametric norm.

Note 5: Limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate National's Averaging Outgoing Quality Level (AOQL).

Note 6: The internal oscillator runs at 1.6 MHz, the output switches operate at one half of the oscillator frequency, $f_{OSC} = 2f_{SW}$.

Typical Performance Characteristics

V_{out} vs I_{load} (Step-Up)
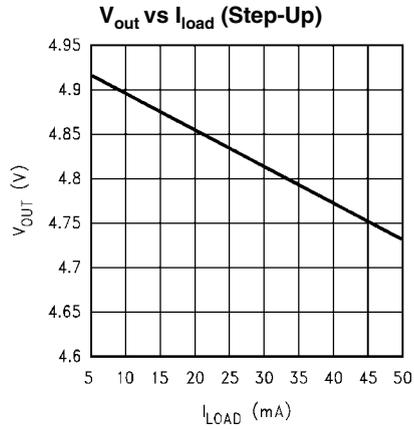
10000204
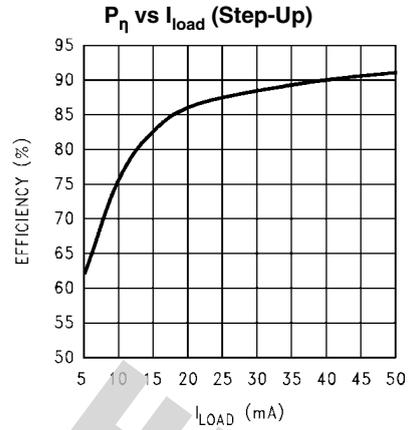
P_η vs I_{load} (Step-Up)

10000206

Output Source Impedance vs Temperature (Step-Up)
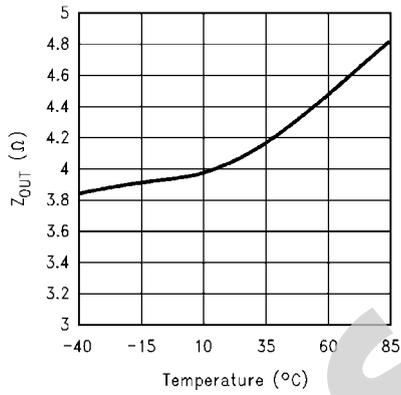
10000209

V_{out} vs I_{load} (Step-Down)

10000205

P_η vs I_{load} (Step-Down)
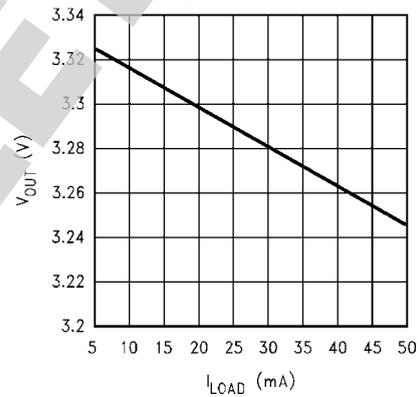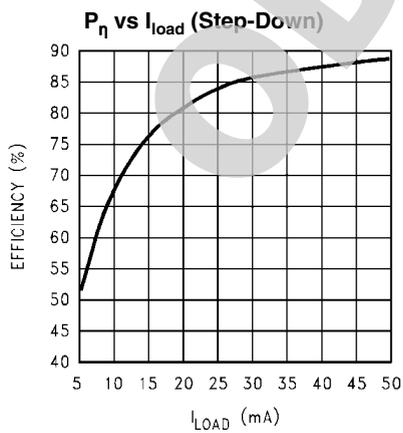
10000207

Output Source Impedance vs Temperature (Step-Down)
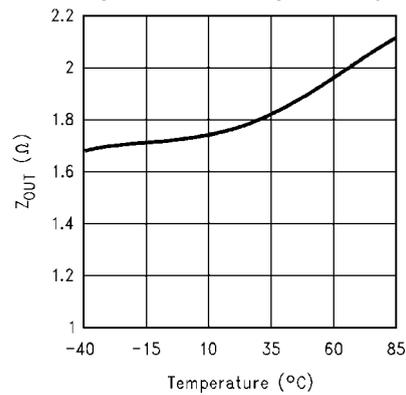
10000208

Switching Frequency vs Temperature
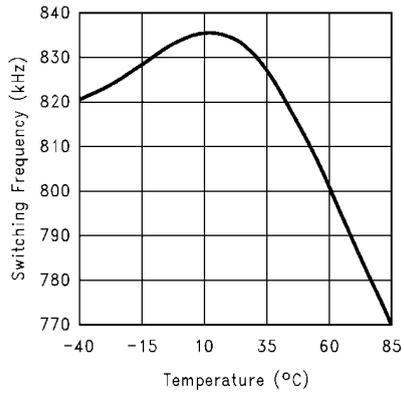
10000210

Detailed Operation

OPERATING PRINCIPLE

The LM3350 is a charge-pump voltage converter that provides a voltage conversion ratio of 3/2 in step-up mode and a conversion ratio of 2/3 in the step-down mode. Thus it can be used in the step-down mode to provide a 3.3V output from a regulated 5V input or in the step-up mode to provide a 5V output from a regulated 3.3V input. Other values of input voltages can be used as long as they are within the limits.

The LM3350 contains an array of CMOS switches which are operated in a certain sequence to provide the step-up or step-down of the input supply. An internal RC oscillator provides the timing signals.

Energy transfer and storage are provided by four inexpensive ceramic capacitors. The selection of these capacitors is explained in the Capacitor Selection section under Application Information.

STEP-UP APPLICATIONS NEED AN EXTRA DIODE

The LM3350 is biased from pin V_{high}. Thus for step-up applications, an external Schottky diode (D1) is needed to supply power to V_{high} during startup (See *Figure 2*). Note that during shutdown, this diode will provide a DC path from V_{in} to V_{out}. The load may therefore continue to draw current from the input voltage source. This Schottky diode is not required for step-down applications (See *Figure 3*).

SHUTDOWN MODE

When ENABLE is a logic low (ground), the LM3350 enters a low power shutdown mode. In this mode, all circuitry is disabled and therefore, all switching action stops. During shutdown, the current consumption drops to 250 nA (typical). When ENABLE is a logic high, (i.e. 3.3V for step-up mode and 5.0V for step-down mode), the LM3350 returns to normal operation.

Application Information

CAPACITOR SELECTION

The LM3350 requires four capacitors: an input bypass capacitor (connected between V_{in} and ground), an output hold capacitor (connected between V_{out} and ground), and two sampling capacitors (C1 and C2 in Figures 2, 3). 0.33 µF (±20%) ceramic chip type capacitors are recommended for all four capacitors. The usable operating frequency should be greater than 5 MHz for all capacitors.

The input bypass capacitor (C_{in}) is the least critical. Its value should be at least that of the sampling capacitors.

While the recommended sampling capacitor values are 0.33 µF, other values may be selected. Values other than 0.33 µF affect maximum output current rating and efficiency. *Figure 1* shows typical output impedance (Z_{out}) versus capacitor value.

The output hold capacitor value determines the output ripple. Increasing the value of the hold capacitor decreases the rip-

ple. The value of this capacitor (C_{out}) can be calculated (approximately) based on the output ripple (ΔV_{out}) requirements from:

$$C_{OUT} = \frac{I_{LOAD}}{\Delta V_{OUT}\, f_O}$$

where I_{load} is the load current and f_O is the oscillator frequency.

In order to ensure superior performance over the entire operating temperature range, capacitors made of X7R dielectric material are suggested. However, capacitors made of other dielectric materials that still meet the ±20% specification over the entire temperature range can also be used.
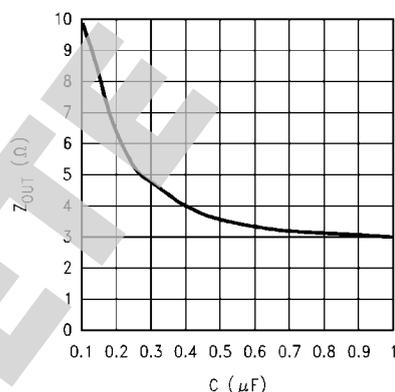
10000211

A. Step-Up Mode

10000212
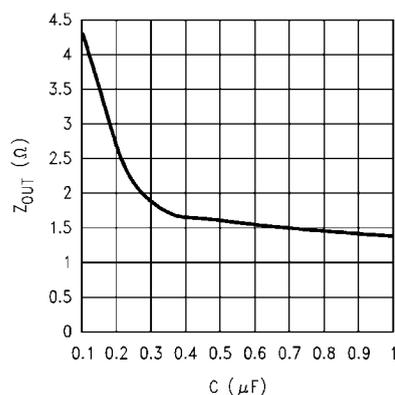
B. Step-Down Mode

FIGURE 1. Z_{out} vs. C

PRECAUTIONS

The LM3350 is not short circuit protected.

Typical Application Circuits
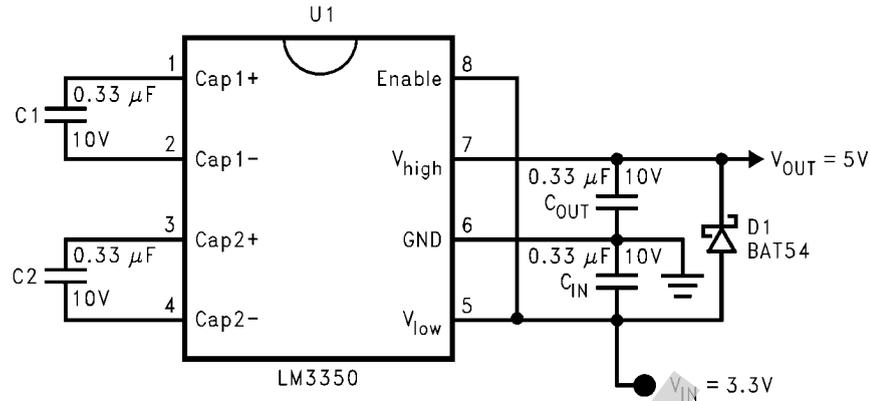
FIGURE 2. Step-Up Converter
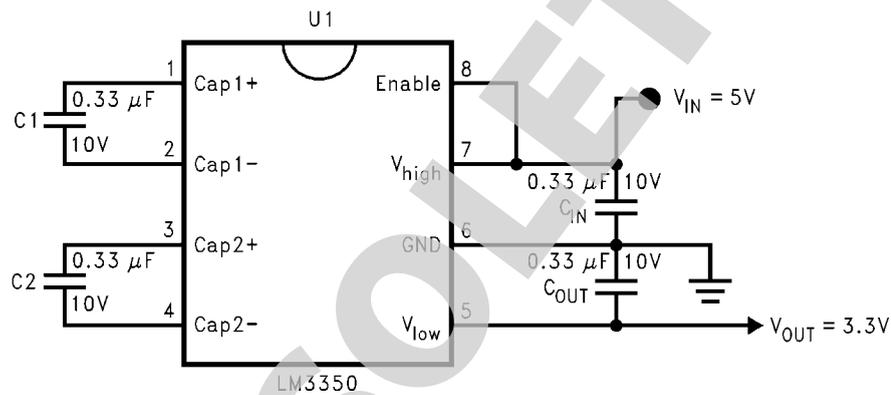
FIGURE 3. Step-Down Converter

Layout Information

LAYOUT CONSIDERATIONS

The LM3350's high switching frequency (800 kHz) makes a good layout important. *Figure 4* illustrates a typical layout. It is important to keep the distance short between the four capacitors and the IC. Wide traces and grounding are also recommended. These steps will minimize trace inductance and high frequency ringing. Of the four capacitors, C_{high} and C_{low} have the highest value of di/dt. It is therefore most important to keep them close to the IC. The ground lead that C_{high} and C_{low} share should also be kept wide and short.

The location of the diode (D1) used in the step-up configuration is not critical. This diode is only used during the initial turn on of the IC. D1 is not needed in step-down applications.
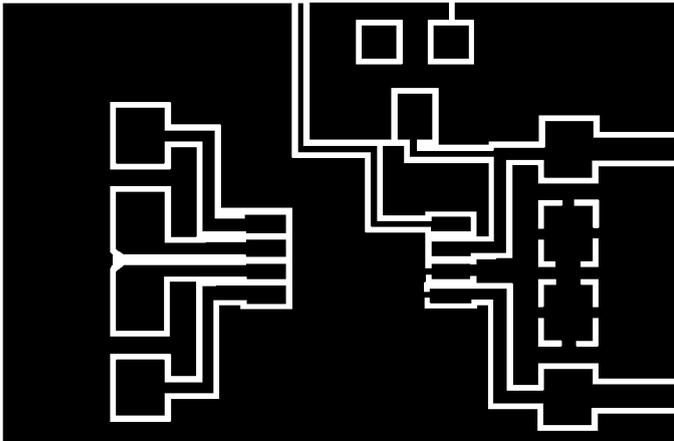
A. Copper side (5X)

10000215
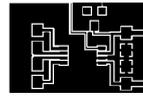
10000216

B. Actual Size of the Layout

10000217
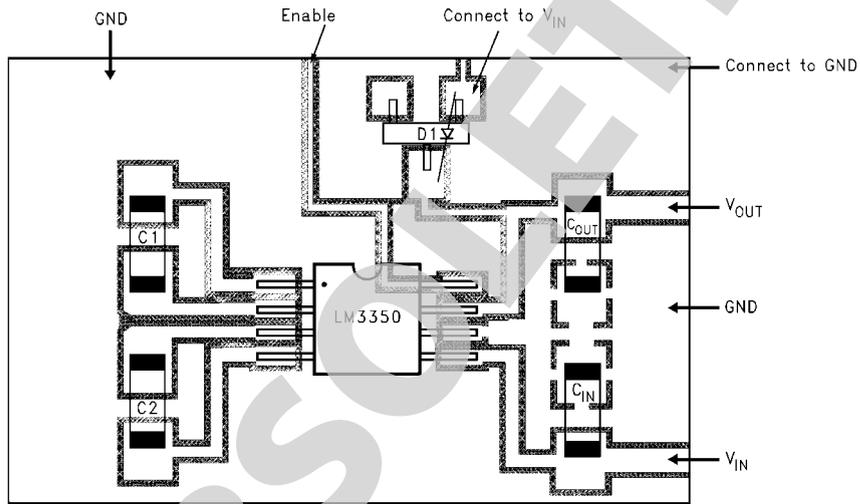
C. Copper side with Component Locations (5X)

FIGURE 4. Typical Layout

Physical Dimensions inches (millimeters) unless otherwise noted

.118±.004
[3±0.1]
NOT INCLUDING MOLD FLASH
.006[0.15] MAX PER END

.193±.006
[4.9±0.15]

.118±.004
[3±0.1]
NOT INCLUDING
MOLD FLASH

PIN 1 IDENT

6X .0256
[0.65]

(.189)
[4.8]

(8X .040)
[1.02]

(8X .016)
[0.41]

(6X .0256)
[0.65]

RECOMMENDED LAND PATTERN

.043 MAX
[1.09]

(.034)
[0.86]

.004 [0.1] A

.002-.006
[0.06-0.15]
TYP

8X .012 +.004/-.002
[0.3 +0.10/-0.05]

.002 [0.05] M B S C S

R.005 TYP
[0.13]

R.005 TYP
[0.13]

.007±.002 TYP
[0.18±0.05]

(.0375 TYP)
[0.953]

.021± .005
[0.53±0.12]
TYP

GAGE PLANE

.010
[0.25]

A

SEATING PLANE

0°-6° TYP

CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MUA08A (Rev F)

8-Lead Mini SO (MM)
Order Number LM3350MMX or LM3350MM
NS Package Number MUA08A

Notes

OBSOLETE

Notes

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Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Applications & Markets	www.national.com/solutions
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