



DMOS

400mA Low-Dropout Regulator

FEATURES

- **CAP-FREE DMOS TOPOLOGY:**
Ultra Low Dropout Voltage:
250mV typ at 400mA
Output Capacitor *not* Required for Stability
- **UP TO 500mA PEAK, TYPICAL**
- **FAST TRANSIENT RESPONSE**
- **VERY LOW NOISE: 28µVrms**
- **HIGH ACCURACY: ±1.5% max**
- **HIGH EFFICIENCY:**
 $I_{GND} = 850\mu A$ at $I_{OUT} = 400mA$
Not Enabled: $I_{GND} = 0.01\mu A$
- **2.5V, 2.85V, 3.0V, 3.3V, AND 5.0V OUTPUT VERSIONS**
- **OTHER OUTPUT VOLTAGES AVAILABLE UPON REQUEST**
- **FOLDBACK CURRENT LIMIT**
- **THERMAL PROTECTION**
- **SMALL SURFACE-MOUNT PACKAGES:**
SOT23-5 and MSOP-8

APPLICATIONS

- **PORTABLE COMMUNICATION DEVICES**
- **BATTERY-POWERED EQUIPMENT**
- **PERSONAL DIGITAL ASSISTANTS**
- **MODEMS**
- **BAR-CODE SCANNERS**
- **BACKUP POWER SUPPLIES**

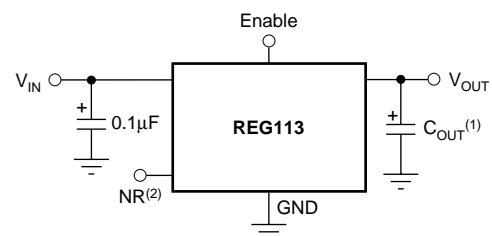
DESCRIPTION

The REG113 is a family of low-noise, low-dropout linear regulators with low ground pin current. Its new DMOS topology provides significant improvement over previous designs, including low-dropout voltage (only 250mV typ at full load), and better transient performance. In addition, no output capacitor is required for stability, unlike conventional low-dropout regulators that are difficult to compensate and require expensive low ESR capacitors greater than 1µF.

Typical ground pin current is only 850µA (at $I_{OUT} = 400mA$) and drops to 10nA when not enabled. Unlike regulators with PNP pass devices, quiescent current remains relatively constant over load variations and under dropout conditions.

The REG113 has very low output noise (typically 28µVrms for $V_{OUT} = 3.3V$ with $C_{NR} = 0.01\mu F$), making it ideal for use in portable communications equipment. Accuracy is maintained over temperature, line, and load variations. Key parameters are tested over the specified temperature range (–40°C to +85°C).

The REG113 is well protected—internal circuitry provides a current limit which protects the load from damage, furthermore, thermal protection circuitry keeps the chip from being damaged by excessive temperature. The REG113 is available in SOT23-5 and MSOP-8 packages.



NOTES: (1) Optional. (2) NR = Noise Reduction.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

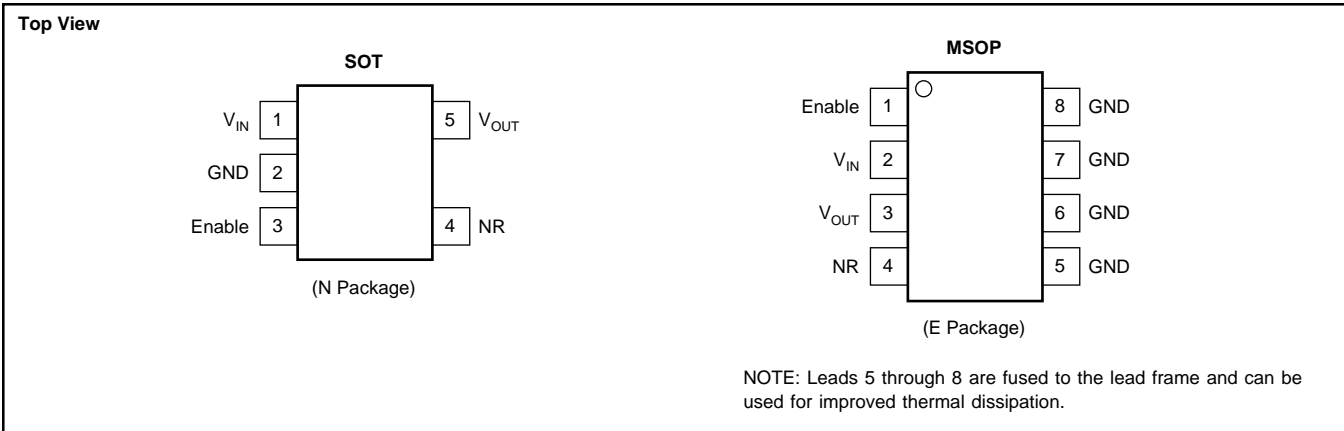
PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR ⁽¹⁾	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
5V Output						
REG113	SOT23-5	DBV	-40°C to +85°C	R13B	REG113NA-5/250	Tape and Reel, 250
"	"	"	"	"	REG113NA-5/3K	Tape and Reel, 3000
REG113	MSOP-8	DGK	-40°C to +85°C	R13B	REG113EA-5/250	Tape and Reel, 250
"	"	"	"	"	REG113EA-5/2K5	Tape and Reel, 2500
3.3V Output						
REG113	SOT23-5	DBV	-40°C to +85°C	R13C	REG113NA-3.3/250	Tape and Reel, 250
"	"	"	"	"	REG113NA-3.33K	Tape and Reel, 3000
REG113	MSOP-8	DGK	-40°C to +85°C	R13C	REG113EA-3.3/250	Tape and Reel, 250
"	"	"	"	"	REG113EA-3.3/2K5	Tape and Reel, 2500
3V Output						
REG113	SOT23-5	DBV	-40°C to +85°C	R13D	REG113NA-3/250	Tape and Reel, 250
"	"	"	"	"	REG113NA-3/3K	Tape and Reel, 3000
REG113	MSOP-8	DGK	-40°C to +85°C	R13D	REG113EA-3/250	Tape and Reel, 250
"	"	"	"	"	REG113EA-3/2K5	Tape and Reel, 2500
2.85V Output						
REG113	SOT23-5	DBV	-40°C to +85°C	R13N	REG113NA-2.85/250	Tape and Reel, 250
"	"	"	"	"	REG113NA-2.85/3K	Tape and Reel, 3000
REG113	MSOP-8	DGK	-40°C to +85°C	R13N	REG113EA-2.85/250	Tape and Reel, 250
"	"	"	"	"	REG113EA-2.85/2K5	Tape and Reel, 2500
2.5V Output						
REG113	SOT23-5	DBV	-40°C to +85°C	R13G	REG113NA-2.5/250	Tape and Reel, 250
"	"	"	"	"	REG113NA-2.5/3K	Tape and Reel, 3000
REG113	MSOP-8	DGK	-40°C to +85°C	R13G	REG113EA-2.5/250	Tape and Reel, 250
"	"	"	"	"	REG113EA-2.5/2K5	Tape and Reel, 2500

NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

Many custom output voltage versions, from 2.5V to 5.1V in 50mV increments, are available upon request. Minimum order quantities apply. Contact factory for details.

PIN CONFIGURATIONS



ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Supply Input Voltage, V_{IN}	-0.3V to 12V
Enable Input	-0.3V to V_{IN}
Output Short-Circuit Duration	Indefinite
Operating Temperature Range (T_J)	-55°C to +125°C
Storage Temperature Range (T_A)	-65°C to +150°C
Lead Temperature (soldering, 3s)	+240°C

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability.



ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ELECTRICAL CHARACTERISTICS

Boldface limits apply over the specified temperature range, $T_J = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$.

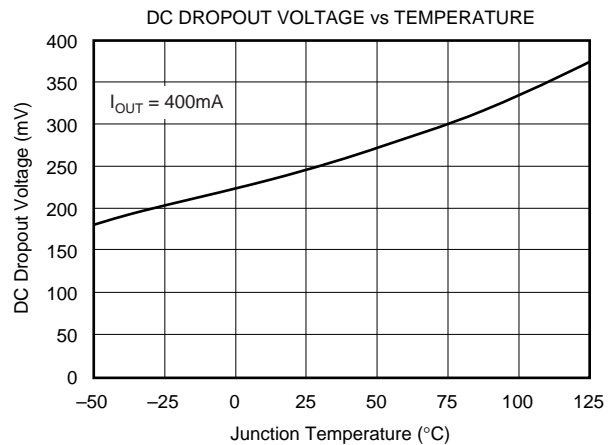
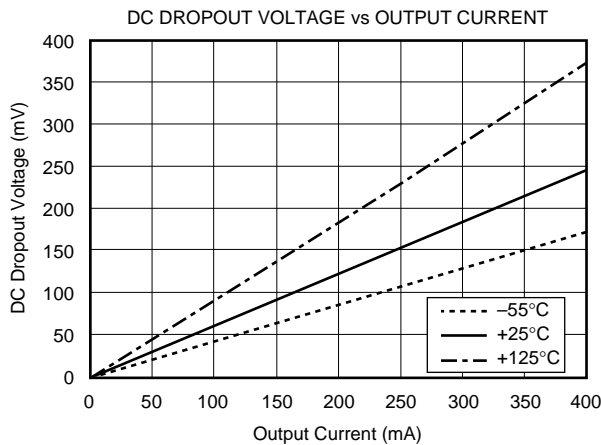
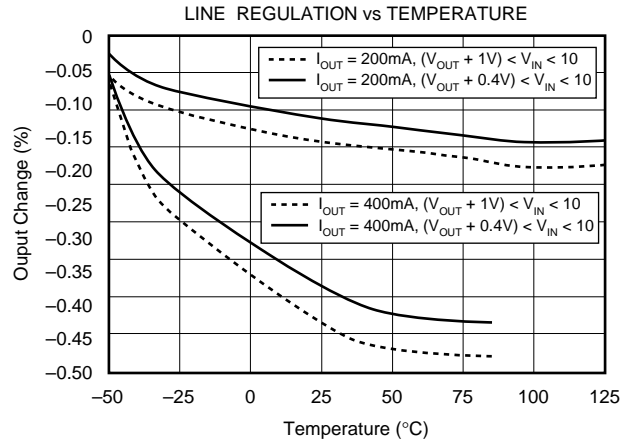
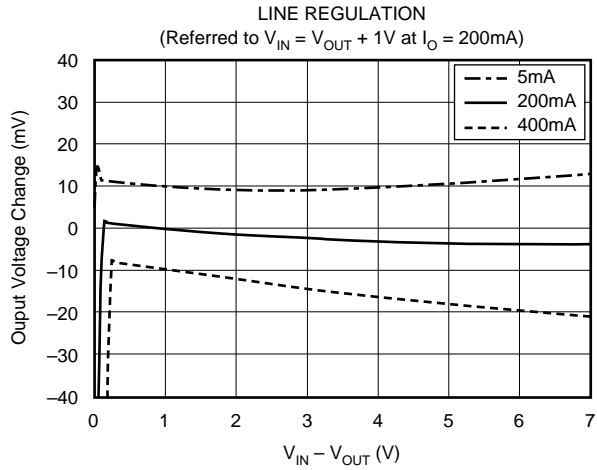
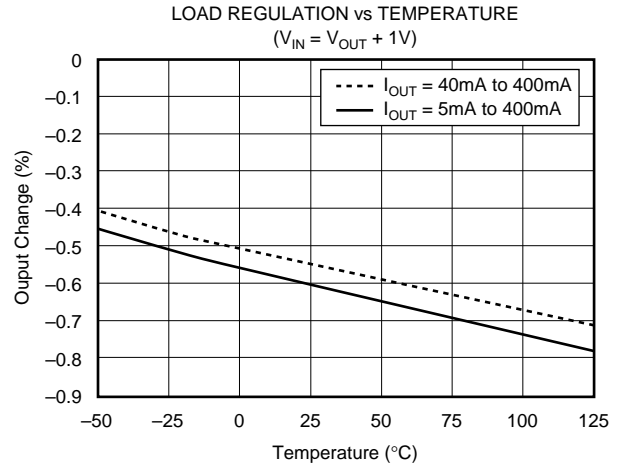
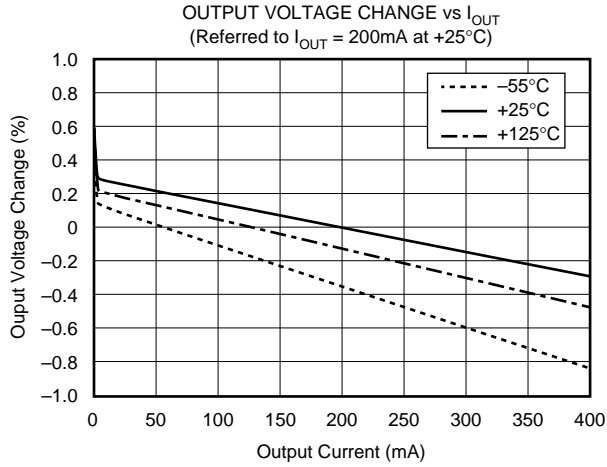
At $T_J = +25^{\circ}\text{C}$, $V_{IN} = V_{OUT} + 1\text{V}$, $V_{ENABLE} = 1.8\text{V}$, $I_{OUT} = 5\text{mA}$, $C_{NR} = 0.01\mu\text{F}$, and $C_{OUT} = 0.1\mu\text{F}^{(1)}$, unless otherwise noted.

PARAMETER	CONDITION	REG113NA REG113EA			UNITS
		MIN	TYP	MAX	
OUTPUT VOLTAGE					
Output Voltage Range	V_{OUT}		2.5		V
REG113-2.5			2.85		V
REG113-2.85			3.0		V
REG113-3			3.3		V
REG113-3.3			5.0		V
REG113-5			± 0.5	± 1.5	%
Accuracy				± 2.3	%
Over Temperature vs Temperature	dV_{OUT}/dT		50	± 2.3	ppm/ $^{\circ}\text{C}$
vs Line and Load		$I_{OUT} = 5\text{mA to } 400\text{mA}$, $V_{IN} = (V_{OUT} + 0.4\text{V})$ to 10V	± 1	± 2.3	%
Over Temperature		$I_{OUT} = 5\text{mA to } 400\text{mA}$, $V_{IN} = (V_{OUT} + 0.6\text{V})$ to 10V		± 3.0	%
DC DROPOUT VOLTAGE⁽²⁾	V_{DROP}				
For all models		$I_{OUT} = 5\text{mA}$	4	10	mV
Over Temperature		$I_{OUT} = 400\text{mA}$	250	325	mV
		$I_{OUT} = 400\text{mA}$		410	mV
VOLTAGE NOISE					
$f = 10\text{Hz to } 100\text{kHz}$	V_n				
Without C_{NR}		$C_{NR} = 0$, $C_{OUT} = 0$	$23\mu\text{Vrms/V} \cdot V_{OUT}$		μVrms
With C_{NR}		$C_{NR} = 0.01\mu\text{F}$, $C_{OUT} = 10\mu\text{F}$	$7\mu\text{Vrms/V} \cdot V_{OUT}$		μVrms
OUTPUT CURRENT					
Current Limit ⁽³⁾	I_{CL}		425	500	575
Over Temperature					600
Short-Circuit Current Limit	I_{SC}			200	
RIPPLE REJECTION					
$f = 120\text{Hz}$				65	dB
ENABLE CONTROL					
V_{ENABLE} HIGH (output enabled)	V_{ENABLE}		1.8		V_{IN}
V_{ENABLE} LOW (output disabled)			-0.2		0.5
I_{ENABLE} HIGH (output enabled)	I_{ENABLE}	$V_{ENABLE} = 1.8\text{V to } V_{IN}$, $V_{IN} = 1.8\text{V to } 6.5^{(4)}$		1	100
I_{ENABLE} LOW (output disabled)		$V_{ENABLE} = 0\text{V to } 0.5\text{V}$		2	100
Output Disable Time		$C_{OUT} = 1.0\mu\text{F}$, $R_{LOAD} = 13\Omega$		50	μs
Output Enable Softstart Time		$C_{OUT} = 1.0\mu\text{F}$, $R_{LOAD} = 13\Omega$		1.5	ms
THERMAL SHUTDOWN					
Junction Temperature				160	$^{\circ}\text{C}$
Shutdown				140	$^{\circ}\text{C}$
Reset from Shutdown					
GROUND PIN CURRENT					
Ground Pin Current	I_{GND}	$I_{OUT} = 5\text{mA}$		400	μA
		$I_{OUT} = 400\text{mA}$		850	μA
Enable Pin LOW		$V_{ENABLE} \leq 0.5\text{V}$		0.01	0.2
INPUT VOLTAGE					
Operating Input Voltage Range ⁽⁵⁾	V_{IN}		1.8		10
Specified Input Voltage Range		$V_{IN} > 1.8\text{V}$	$V_{OUT} + 0.4$		10
Over Temperature		$V_{IN} > 1.8\text{V}$	$V_{OUT} + 0.6$		10
TEMPERATURE RANGE					
Specified Range	T_J		-40		$^{\circ}\text{C}$
Operating Range	T_J		-55		$^{\circ}\text{C}$
Storage Range	T_A		-65		$^{\circ}\text{C}$
Thermal Resistance					
SOT23-5 Surface-Mount	θ_{JA}	Junction-to-Ambient		200	$^{\circ}\text{C/W}$
MSOP-8 Surface-Mount	θ_{JC}	Junction-to-Case		35 ⁽⁶⁾	$^{\circ}\text{C/W}$
	θ_{JA}	Junction-to-Ambient		160 ⁽⁶⁾	$^{\circ}\text{C/W}$

NOTES: (1) The REG113 does not require a minimum output capacitor for stability. However, transient response can be improved with proper capacitor selection. (2) Dropout voltage is defined as the input voltage minus the output voltage that produces a 2% change in the output voltage from the value at $V_{IN} = V_{OUT} + 1\text{V}$ at fixed load. (3) Current limit is the output current that produces a 10% change in output voltage from $V_{IN} = V_{OUT} + 1\text{V}$ and $I_{OUT} = 5\text{mA}$. (4) For $V_{ENABLE} > 6.5\text{V}$, see typical characteristic I_{ENABLE} vs V_{ENABLE} . (5) The REG113 no longer regulates when $V_{IN} < V_{OUT} + V_{DROP(MAX)}$. In dropout, the impedance from V_{IN} to V_{OUT} is typically less than 1Ω at $T_J = +25^{\circ}\text{C}$. (6) See Figure 7.

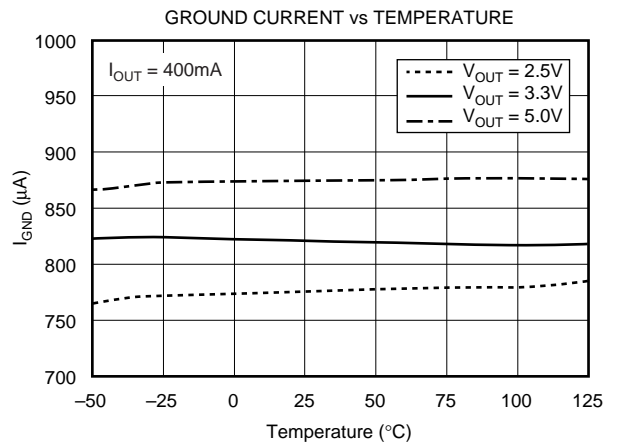
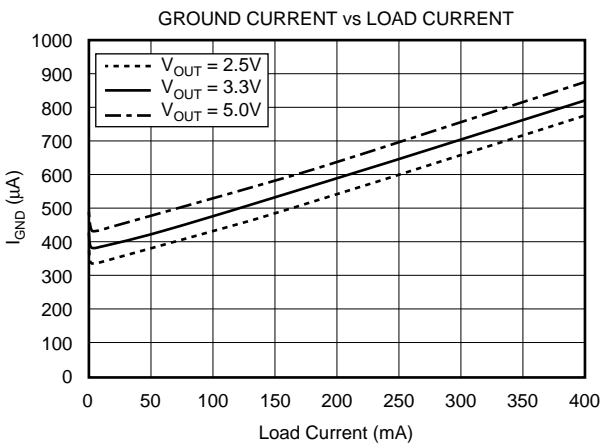
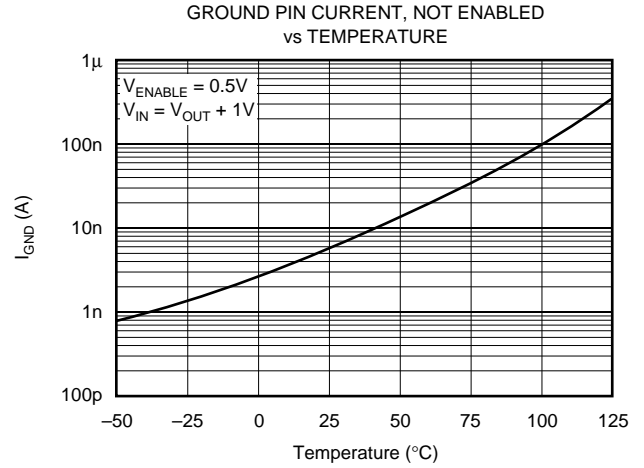
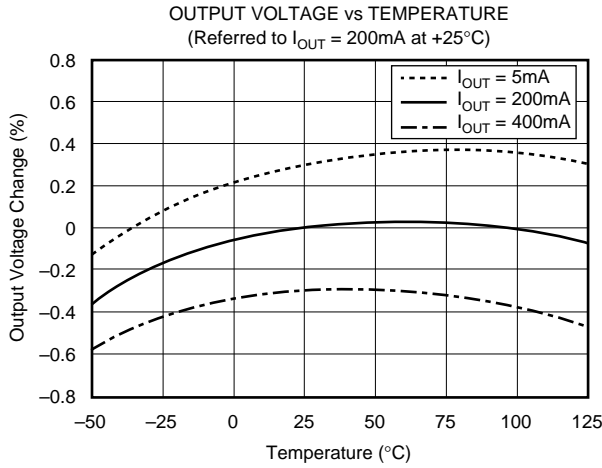
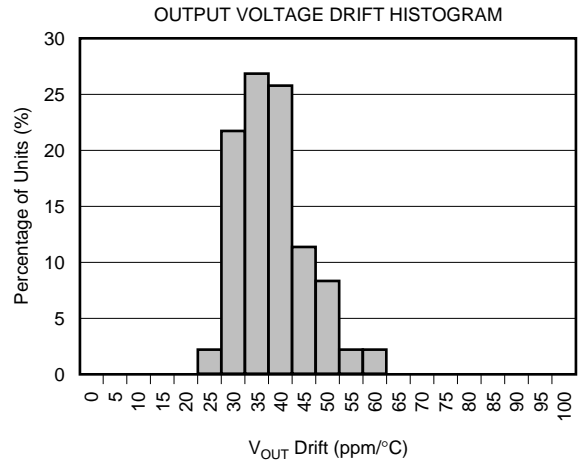
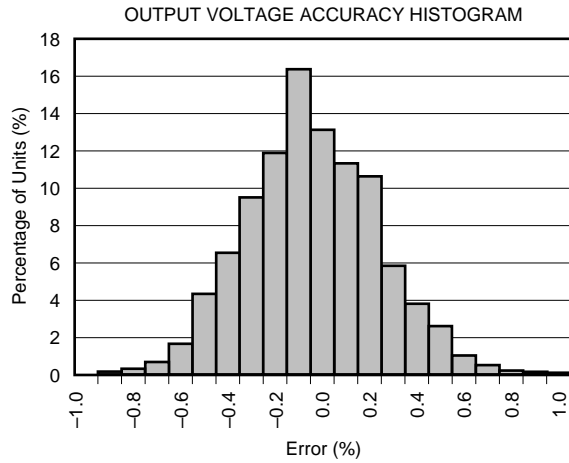
TYPICAL CHARACTERISTICS

For all models, at $T_J = +25^\circ\text{C}$ and $V_{\text{ENABLE}} = 1.8\text{V}$, unless otherwise noted.



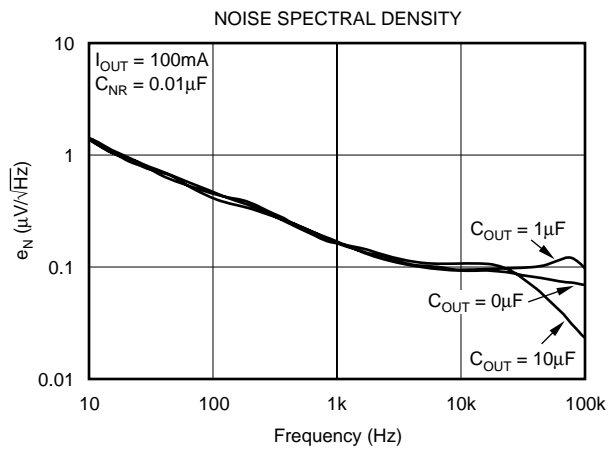
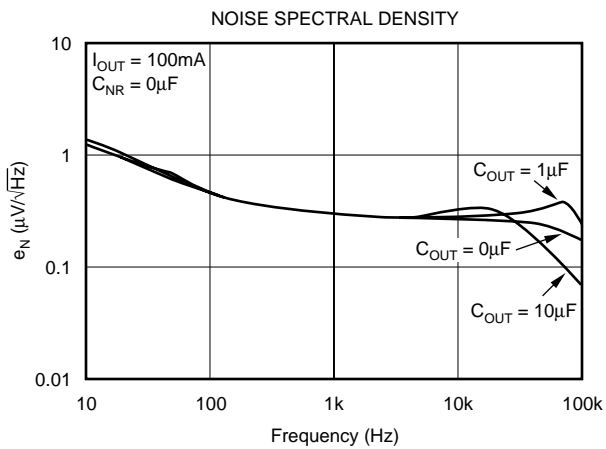
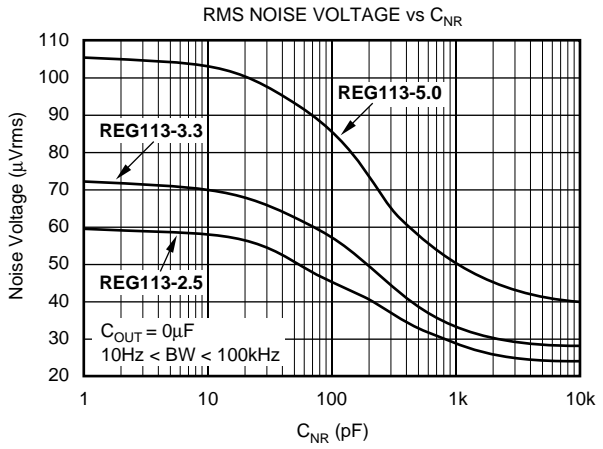
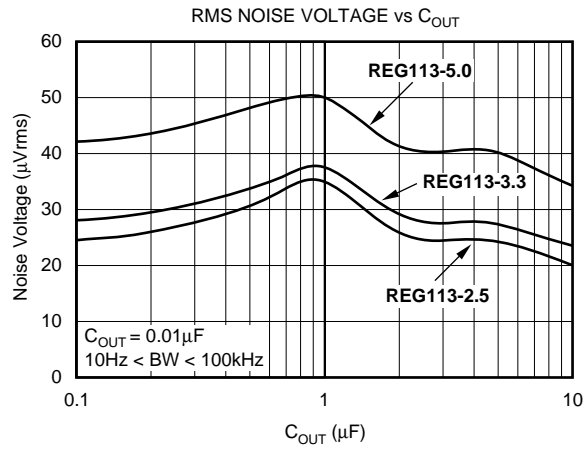
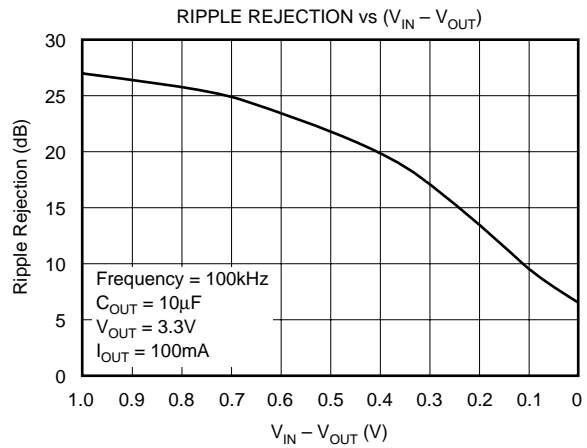
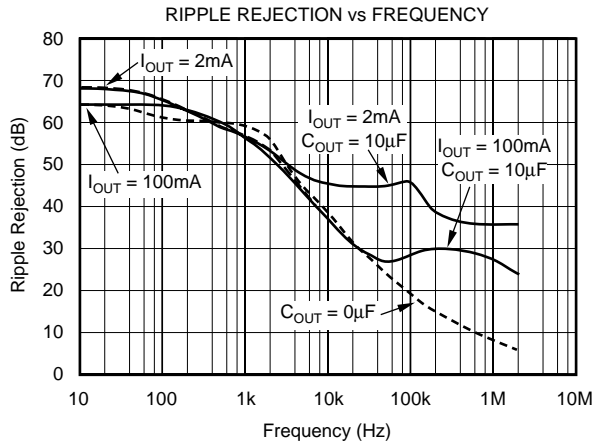
TYPICAL CHARACTERISTICS (Cont.)

For all models, at $T_J = +25^\circ\text{C}$ and $V_{\text{ENABLE}} = 1.8\text{V}$, unless otherwise noted.



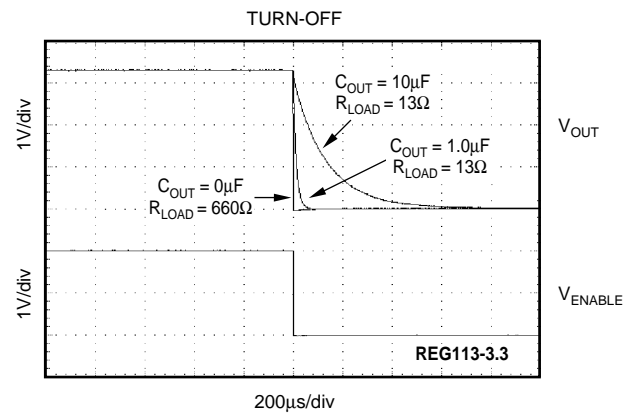
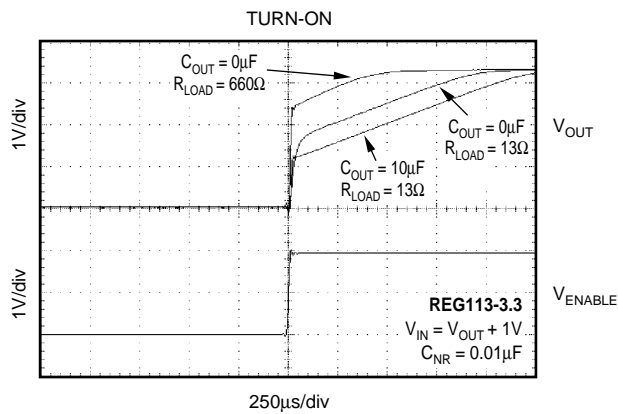
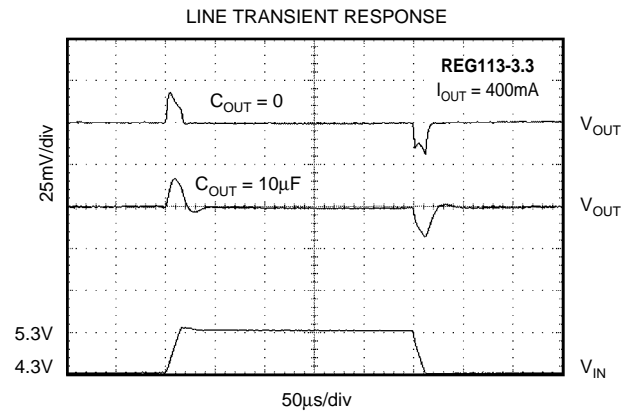
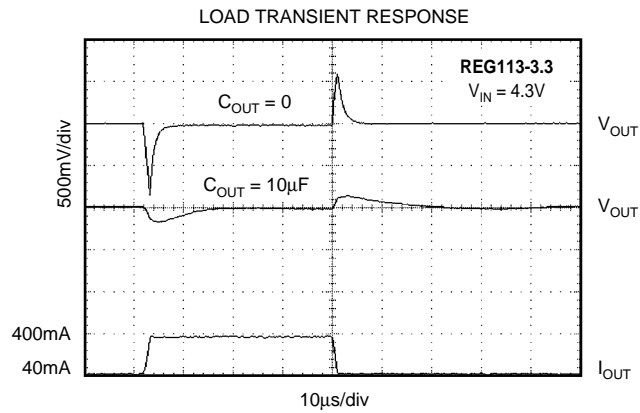
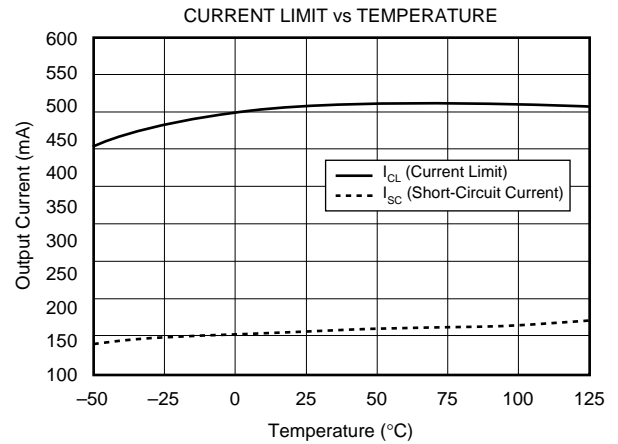
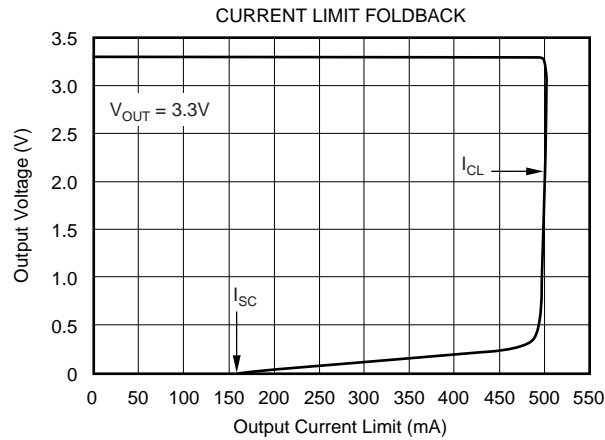
TYPICAL CHARACTERISTICS (Cont.)

For all models, at $T_J = +25^\circ\text{C}$ and $V_{\text{ENABLE}} = 1.8\text{V}$, unless otherwise noted.



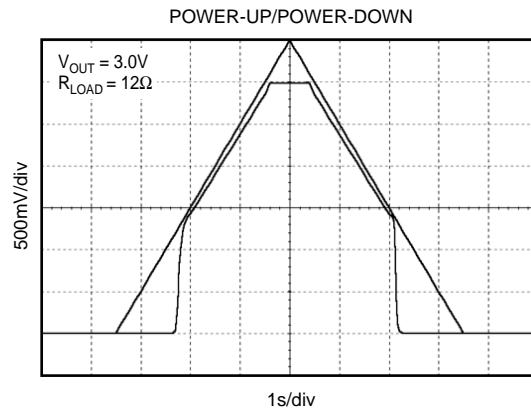
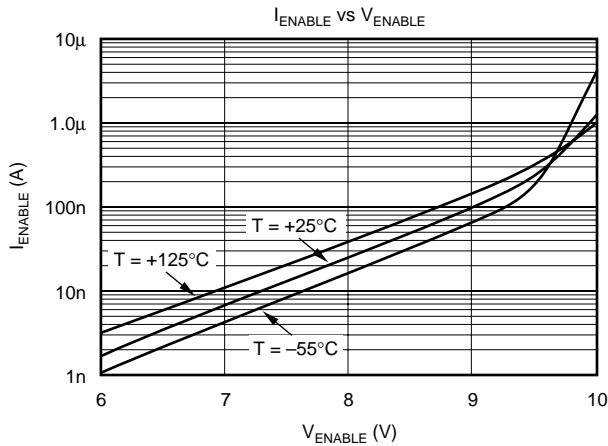
TYPICAL CHARACTERISTICS (Cont.)

For all models, at $T_J = +25^\circ\text{C}$ and $V_{\text{ENABLE}} = 1.8\text{V}$, unless otherwise noted.



TYPICAL CHARACTERISTICS (Cont.)

For all models, at $T_J = +25^\circ\text{C}$ and $V_{\text{ENABLE}} = 1.8\text{V}$, unless otherwise noted.



BASIC OPERATION

The REG113 series of LDO (low dropout) linear regulators offers a wide selection of fixed output voltage versions and an adjustable output version. The REG113 belongs to a family of new generation LDO regulators that use a DMOS pass transistor to achieve ultra low-dropout performance and freedom from output capacitor constraints. Ground pin current remains under 1mA over all line, load, and temperature conditions. All versions have thermal and over-current protection, including foldback current limit.

The REG113 does not require an output capacitor for regulator stability and is stable over most output currents and with almost any value and type of output capacitor up to 10 μF or more. For applications where the regulator output current drops below several milliamps, stability can be enhanced by adding a 1kW to 2kW load resistor, using capacitance values smaller than 10 μF , or keeping the effective series resistance greater than 0.05 Ω including the capacitor ESR and parasitic resistance in printed circuit board traces, solder joints, and sockets.

Although an input capacitor is not required, it is a good standard analog design practice to connect a 0.1 μF low ESR capacitor across the input supply voltage; this is recommended to counteract reactive input sources and improve ripple rejection by reducing input voltage ripple. Figure 1 shows the basic circuit connections for the fixed voltage models.

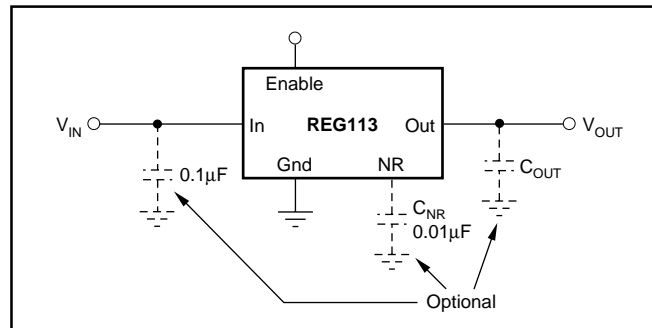


FIGURE 1. Fixed Voltage Nominal Circuit for the REG113.

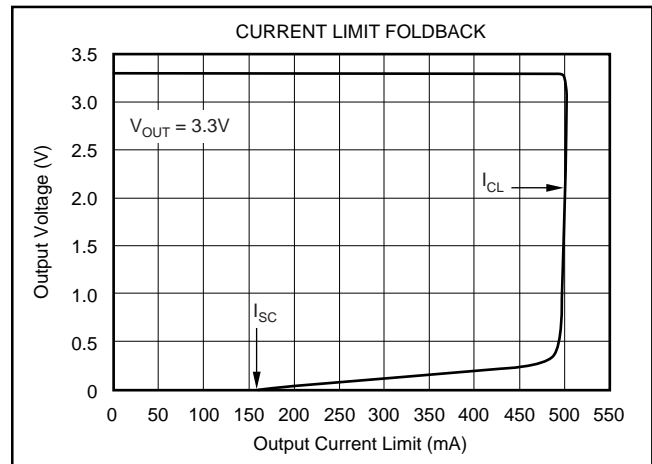


FIGURE 2. Foldback Current Limit of the REG113-3.3 at 25 $^\circ\text{C}$.

INTERNAL CURRENT LIMIT

The REG113 internal current limit has a typical value of 500mA. A foldback feature limits the short-circuit current to a typical short-circuit value of 200mA. A curve of V_{OUT} versus I_{OUT} is given in Figure 2, and in the Typical Characteristics section.

ENABLE

The Enable pin is active high and compatible with standard TTL-CMOS levels. Inputs below 0.5V (max) turn the regulator off and all circuitry is disabled. Under this condition, ground pin current drops to approximately 10nA. When not used, the Enable pin can be connected to V_{IN} .

OUTPUT NOISE

A precision bandgap reference is used to generate the internal reference voltage, V_{REF} . This reference is the dominant noise source within the REG113 and generates approximately $29\mu\text{Vrms}$ in the 10Hz to 100kHz bandwidth at the reference output. The regulator control loop gains up the reference noise, so that the noise voltage of the regulator is approximately given by:

$$V_N = 29\mu\text{Vrms} \frac{R_1 + R_2}{R_2} = 29\mu\text{Vrms} \cdot \frac{V_{OUT}}{V_{REF}} \quad (1)$$

Since the value of V_{REF} is 1.26V, this relationship reduces to:

$$V_N = 23 \frac{\mu\text{Vrms}}{\text{V}} \cdot V_{OUT} \quad (2)$$

Connecting a capacitor, C_{NR} , from the Noise Reduction (NR) pin to ground (as shown in Figure 3) forms a low-pass filter for the voltage reference. For $C_{NR} = 10\text{nF}$, the total noise in the 10Hz to 100kHz bandwidth is reduced by approximately a factor of 2.8 for $V_{OUT} = 3.3\text{V}$. This noise reduction effect is shown in Figure 4, and as *RMS Noise Voltage vs C_{NR}* in the Typical Characteristics section.

Noise can be further reduced by carefully choosing an output capacitor, C_{OUT} . Best overall noise performance is achieved with very low ($< 0.22\mu\text{F}$) or very high ($> 2.2\mu\text{F}$) values of C_{OUT} (see the *RMS Noise Voltage vs C_{OUT}* typical characteristic).

The REG113 uses an internal charge pump to develop an internal supply voltage sufficient to drive the gate of the DMOS pass element above V_{IN} . The charge-pump switching noise (nominal switching frequency = 2MHz) is not measurable at the output of the regulator over most values of I_{OUT} and C_{OUT} .

DROPOUT VOLTAGE

The REG113 uses an N-channel DMOS as the pass element. When $(V_{IN} - V_{OUT})$ is less than the dropout voltage ($V_{DROPOUT}$), the DMOS pass device behaves like a resistor; therefore, for low values of $(V_{IN} - V_{OUT})$, the regulator input-to-output resistance is the $R_{DS(ON)}$ of the DMOS pass element (typically 600mW). For static (DC) loads, the REG113 will

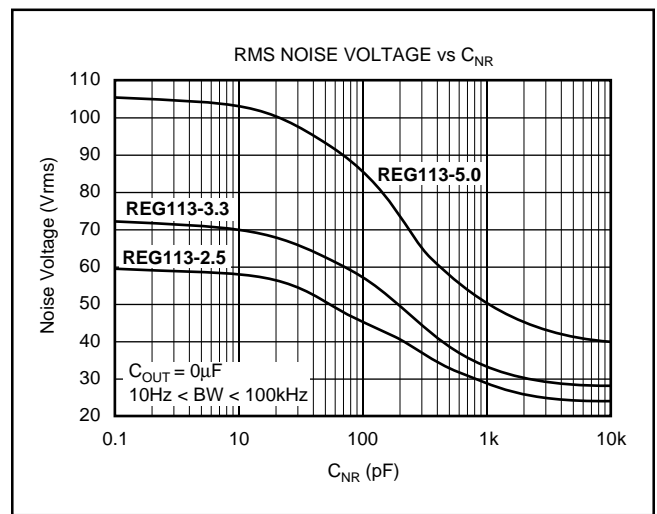


FIGURE 4. Output Noise versus Noise Reduction Capacitor.

typically maintain regulation down to a $(V_{IN} - V_{OUT})$ voltage drop of 250mV at full rated output current. In Figure 5, the bottom line (DC dropout) shows the minimum V_{IN} to V_{OUT} voltage drop required to prevent dropout under DC load conditions.

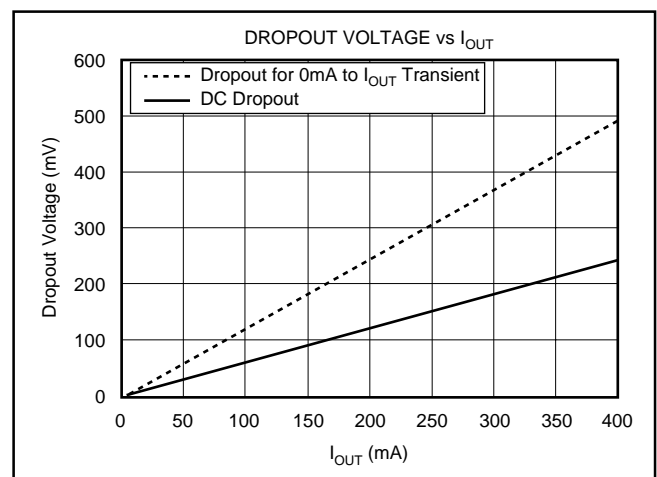


FIGURE 5. Transient and DC Dropout.

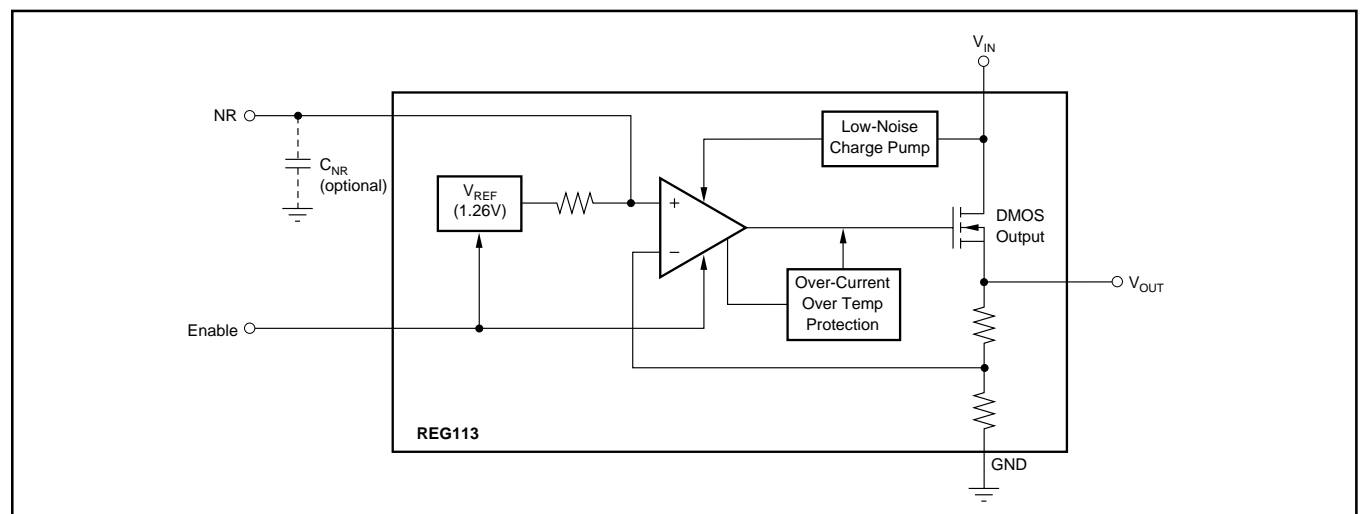


FIGURE 3. Block Diagram.

For large step changes in load current, the REG113 requires a larger voltage drop across it to avoid degraded transient response. The boundary of this transient dropout region is shown as the top line in Figure 5. Values of V_{IN} to V_{OUT} voltage drop above this line insure normal transient response.

In the transient dropout region between DC and Transient, transient response recovery time increases. The time required to recover from a load transient is a function of both the magnitude and rate of the step change in load current and the available headroom V_{IN} to V_{OUT} voltage drop. Under worst-case conditions (full-scale load change with $(V_{IN} - V_{OUT})$ voltage drop close to DC dropout levels), the REG113 can take several hundred microseconds to re-enter the specified window of regulation.

TRANSIENT RESPONSE

The REG113 response to transient line and load conditions improves at lower output voltages. The addition of a capacitor (nominal value $0.47\mu\text{F}$) from the output pin to ground may improve the transient response. In the adjustable version, the addition of a capacitor, C_{FB} (nominal value 10nF), from the output to the adjust pin also improves the transient response.

THERMAL PROTECTION

Power dissipated within the REG113 can cause the junction temperature to rise, however, the REG113 has thermal shutdown circuitry that protects the regulator from damage. The thermal protection circuitry disables the output when the junction temperature reaches approximately 160°C , allowing the device to cool. When the junction temperature cools to approximately 140°C , the output circuitry is again enabled. Depending on various conditions, the thermal protection circuit can cycle on and off. This limits the dissipation of the regulator, but can have an undesirable effect on the load.

Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heat sink. For reliable operation, junction temperature should be limited to 125°C , maximum. To estimate the margin of safety in a complete design (including heat sink), increase the ambient temperature until the thermal protection is triggered. Use worst-case loads and signal conditions. For good reliability, thermal protection should trigger more than 35°C above the maximum expected ambient condition of the application. This produces a worst-case junction temperature of 125°C at the highest expected ambient temperature and worst-case load.

The internal protection circuitry of the REG113 is designed to protect against overload conditions and is not intended to replace proper heat sinking. Continuously running the REG113 into thermal shutdown will degrade reliability.

POWER DISSIPATION

The REG113 is available in two different package configurations. The ability to remove heat from the die is different for each package type and, therefore, presents different considerations in the printed circuit-board layout. On the MSOP-8 package, leads 5 through 8 are fused to the lead frame and may be used to improve the thermal performance of the package. The PCB area around the device that is free of other components moves the heat from the device to the ambient air. Although it is difficult or impossible to quantify all of the variables in a thermal design of this type, performance data for several simplified configurations are shown in Figure 6. In all cases the PCB copper area is bare copper, free of solder resist mask, and not solder plated. All examples are for 1-ounce copper and in the case of the MSOP-8, the copper area is connected to fused leads 5 to 8. See Figure 7 for thermal resistance for varying areas of copper. Using heavier copper can increase the effectiveness in removing the heat from the device. In those examples where there is copper on both sides of the PCB, no connection has been provided between the two sides. The addition of plated through holes will improve the heat sink effectiveness.

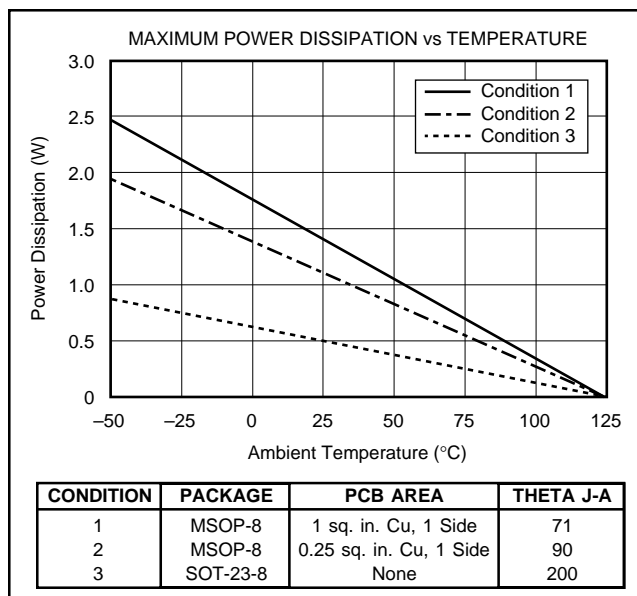


FIGURE 6. Maximum Power Dissipation versus Ambient Temperature for the Various Packages and PCB Heat Sink Configurations.

Power dissipation depends on input voltage, load conditions, and duty cycle and is equal to the product of the average output current times the voltage across the output element (V_{IN} to V_{OUT} voltage drop):

$$P_D = (V_{IN} - V_{OUT}) \cdot I_{OUT} \quad (3)$$

Power dissipation can be minimized by using the lowest possible input voltage necessary to assure the required output voltage.

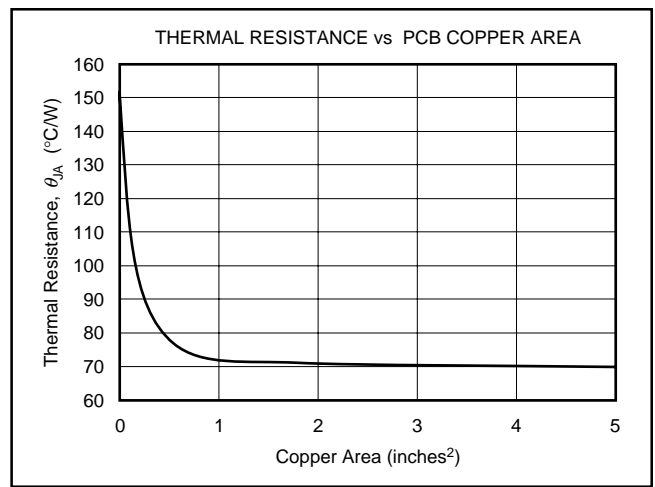
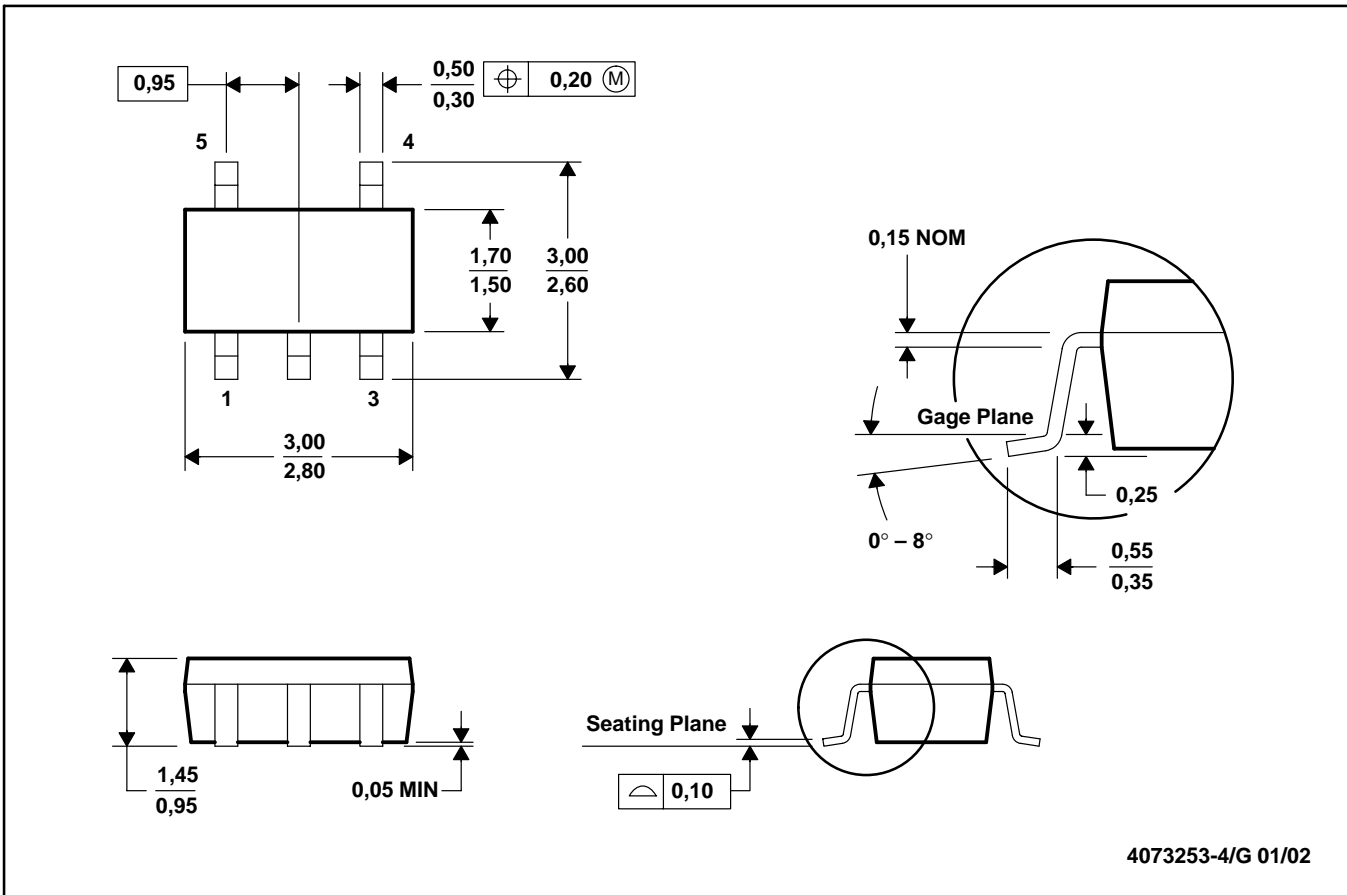
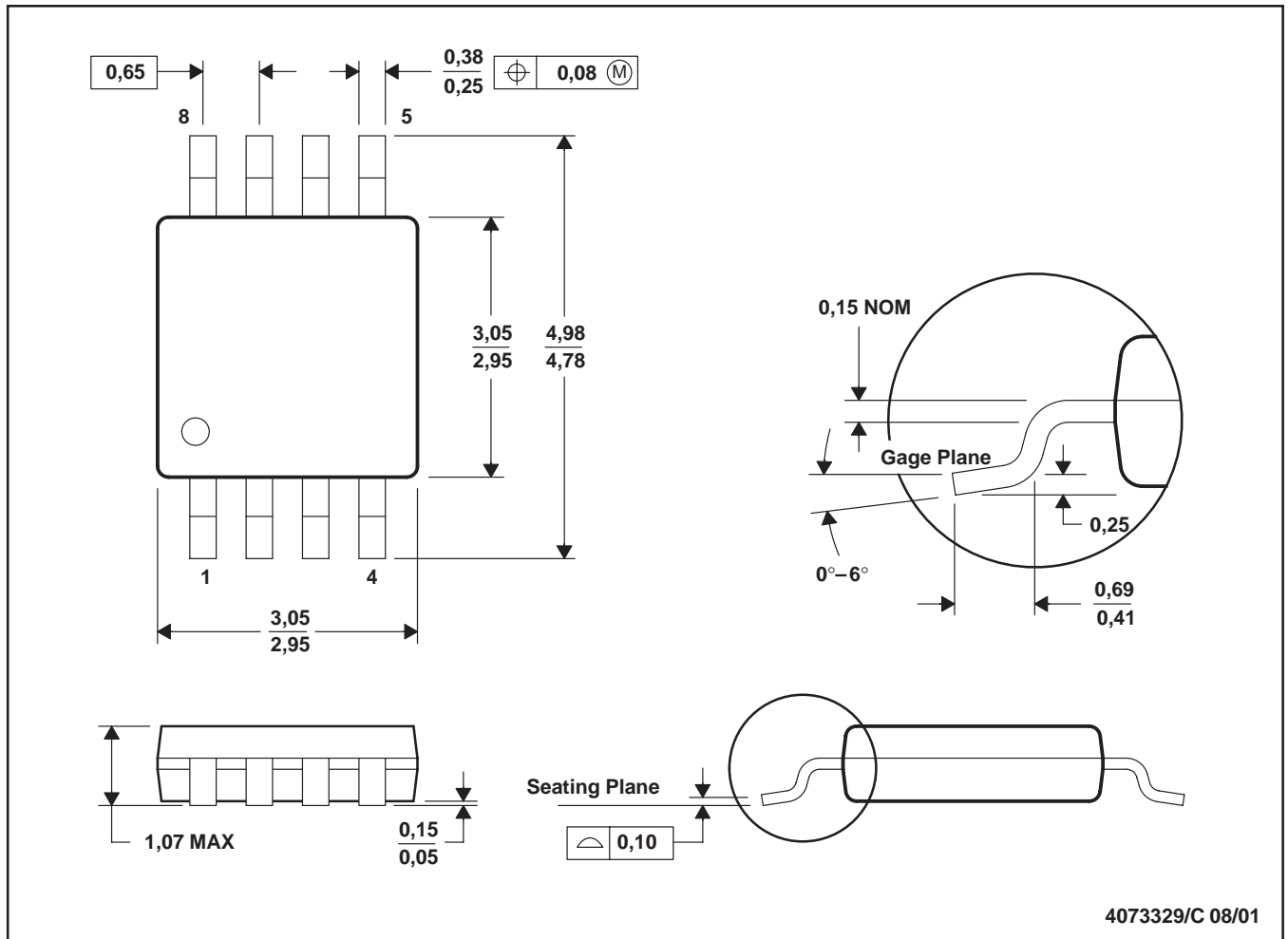


FIGURE 7. Thermal Resistance versus PCB Area for the MSOP-8.



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion.
 D. Falls within JEDEC MO-178



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion.
 D. Falls within JEDEC MO-187

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265