![Microchip logo]

MIC5528

High Performance 500 mA LDO in Thin and Extra Thin DFN Packages

Features

- Input Voltage Range: 2.5V to 5.5V
- Fixed Output Voltages Down to 1.0V
- ±2% Room Temperature Accuracy
- Low Quiescent Current 38 µA
- Stable with 2.2 µF Ceramic Output Capacitors
- Low Dropout Voltage 260 mV @ 500 mA
- Auto-Discharge and Internal Enable Pull-Down
- Thermal Shutdown and Current-Limit Protection
- 6-Pin 1.2 mm × 1.2 mm Extra Thin DFN Package
- 6-Pin 1.2 mm × 1.2 mm Thin DFN Package

Applications

- Portable Communication Equipment
- DSC, GPS, PMP, and PDAs
- Portable Medical Devices
- 5V POL Applications

General Description

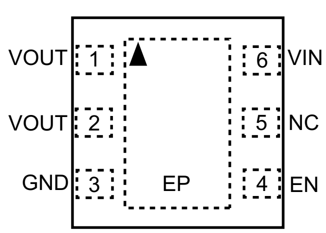
The MIC5528 is a low-power, µCap, low dropout regulator designed for optimal performance in a very small footprint. It is capable of sourcing up to 500 mA of output current while only drawing 38 µA of operating current. This high performance LDO is a µCap design in a thermally enhanced 1.2 mm × 1.2 mm extra thin (0.4 mm height) DFN package. It operates with small ceramic output capacitor for stability, thereby reducing required board space.

Ideal for battery-operated applications, the MIC5528 offers ±2% accuracy, extremely low dropout voltage (260 mV @ 500 mA), and can regulate output voltages down to 1.0V. Equipped with a TTL logic-compatible enable pin, the MIC5528 can be put into a zero-off-mode current state, drawing no current when disabled.

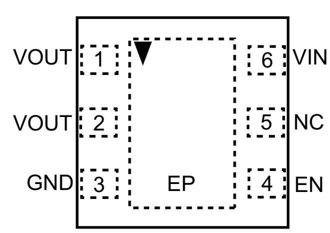
The MIC5528 is a µCap design, operating with very small ceramic output capacitors for stability, reducing required board space and component cost for space-critical applications. The MIC5528 has an operating junction temperature range of –40°C to 125°C.

Package Types

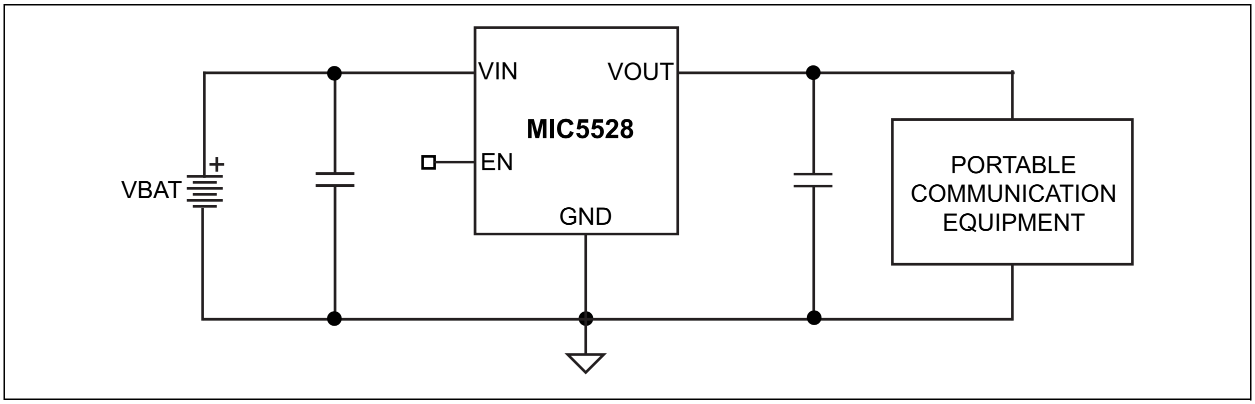
MIC5528
6-Lead Thin DFN (MT)
(Top View)



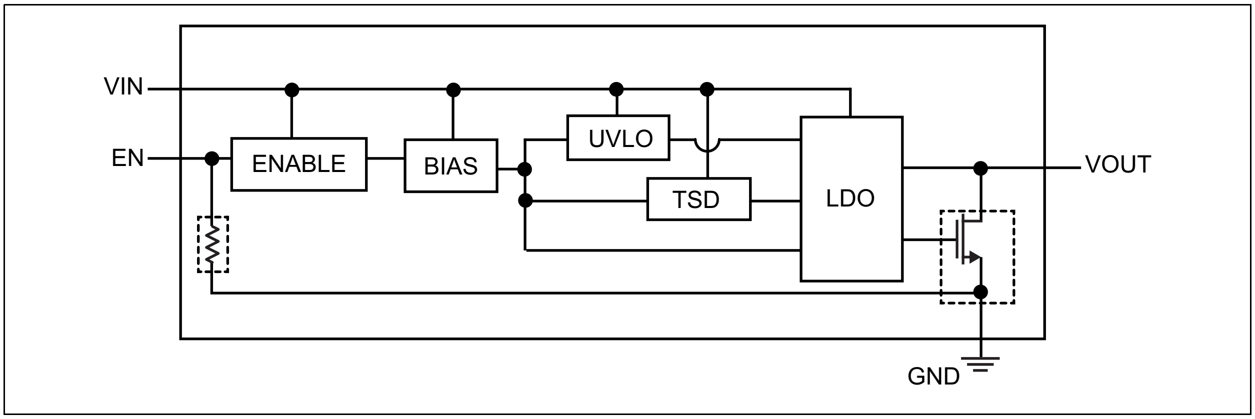
MIC5528
6-Lead Extra Thin DFN (MX)
(Top View)



Typical Application Circuit



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}) .... –0.3V to +6V
Enable Voltage (V_{EN}) .... –0.3V to V_{IN}
Power Dissipation (P_D) .... Internally Limited, Note 1
ESD Rating (Note 2) .... 3 kV

Operating Ratings ‡

Supply Voltage (V_{IN}) .... +2.5V to +5.5V
Enable Voltage (V_{EN}) .... 0V to V_{IN}

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

‡ **Notice:** The device is not guaranteed to function outside its operating ratings.

Note 1: The maximum allowable power dissipation of any T_A (ambient temperature) is $P_{D(max)} = (T_{J(max)} - T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.

2: Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5 kΩ in series with 100 pF.

TABLE 1-1: ELECTRICAL CHARACTERISTICS

Electrical Characteristics: $V_{IN} = V_{EN} = V_{OUT} + 1V$; $C_{IN} = C_{OUT} = 2.2\ \mu F$; $I_{OUT} = 100\ \mu A$; $T_J = +25°C$, **bold** values indicate –40°C to +85°C, unless noted. Note 1

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy	—	–2.0	±1	+2.0	%	Variation from nominal V_{OUT}
		–3.0	—	**+3.0**		Variation from nominal V_{OUT}; –40°C to +85°C
Line Regulation	—	—	0.02	**0.3**	%/V	$V_{IN} = V_{OUT} + 1V$ to 5.5V; $I_{OUT} = 100\ \mu A$
Load Regulation (Note 2)	—	—	14	65	mV	$I_{OUT} = 100\ \mu A$ to 500 mA
Dropout Voltage (Note 3)	V_{DO}	—	80	**180**	mV	$I_{OUT} = 150$ mA
		—	260	**500**		$I_{OUT} = 500$ mA
Ground Pin Current (Note 4)	I_{GND}	—	38	**55**	µA	$I_{OUT} = 0$ mA
		—	42	**65**		$I_{OUT} = 500$ mA
Ground Pin Current in Shutdown	I_{SHDN}	—	0.05	1	µA	$V_{EN} = 0V$
Ripple Rejection	PSRR	—	70	—	dB	f = 100 Hz, $I_{OUT} = 100$ mA
		—	60	—		f = 1 kHz, $I_{OUT} = 100$ mA
Current Limit	I_{LIM}	**525**	800	—	mA	$V_{OUT} = 0V$
Output Voltage Noise	—	—	175	—	μV_{RMS}	f =10 Hz to 100 kHz
Auto-Discharge NFET Resistance	—	—	25	—	Ω	$V_{EN} = 0V$; $V_{IN} = 3.6V$; $I_{OUT} = -3$ mA
Enable Input						
Enable Pull-Down Resistor	—	—	4	—	MΩ	—
Enable Input Voltage	V_{EN}	—	—	**0.2**	V	Logic low
		1.2	—	—		Logic high

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: $V_{IN} = V_{EN} = V_{OUT} + 1V$; $C_{IN} = C_{OUT} = 2.2\ \mu F$; $I_{OUT} = 100\ \mu A$; $T_J = +25°C$, **bold** values indicate –40°C to +85°C, unless noted. Note 1

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Enable Input Current	I_{EN}	—	0.01	1	µA	$V_{EN} = 0V$
		—	1.4	2		$V_{EN} = 5.5V$
Turn-On Time	t_{ON}	—	50	**125**	µs	$I_{OUT} = 150\ mA$

Note 1: Specification for packaged product only.

2: Regulation is measured at constant junction temperature using low duty cycle pulse testing. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

3: Dropout voltage is defined as the input-to-output differential at which the output voltage drops 2% below its nominal value measured at 1V differential. For outputs below 2.5V, dropout voltage is the input-to-output differential with the minimum input voltage 2.5V.

4: Ground pin current is the regulator quiescent current. The total current drawn from the supply is the sum of the load current plus the ground pin current.

TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Storage Temperature Range	T_S	–65	—	+150	°C	—
Maximum Junction Temperature Range	T_J	–40	—	+150	°C	—
Junction Operating Temperature Range	T_J	–40	—	+125	°C	—
Lead Temperature	—	—	—	+260	°C	Soldering, 10s
Package Thermal Resistances						
Thermal Resistance 6-Lead Extra Thin DFN	θ_{JA}	—	173	—	°C/W	—

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., T_A, T_J, θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +125°C rating. Sustained junction temperatures above +125°C can impact the device reliability.

2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

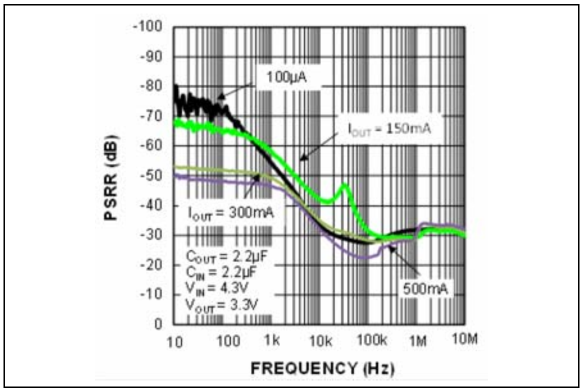


FIGURE 2-1: *Power Supply Rejection Ratio.*

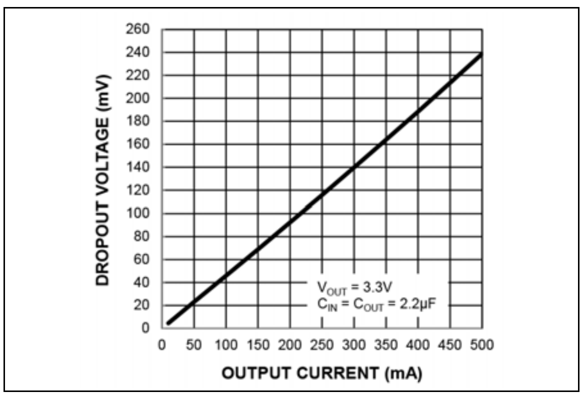


FIGURE 2-2: *Dropout Voltage vs. Output Current.*

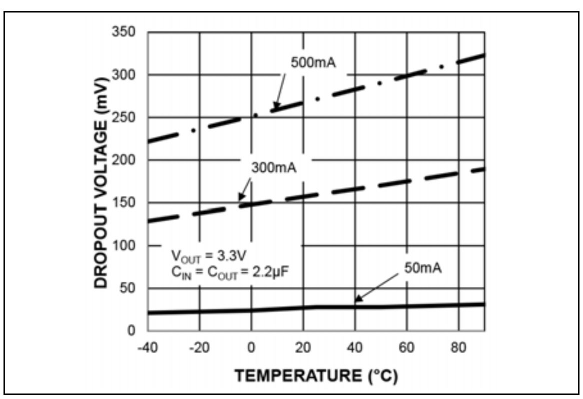


FIGURE 2-3: *Dropout Voltage vs. Temperature.*

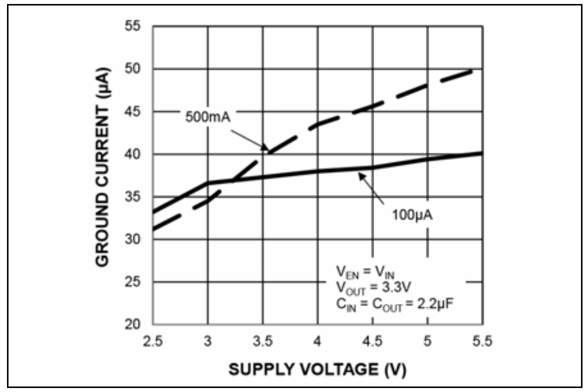


FIGURE 2-4: *Ground Current vs. Supply Voltage.*

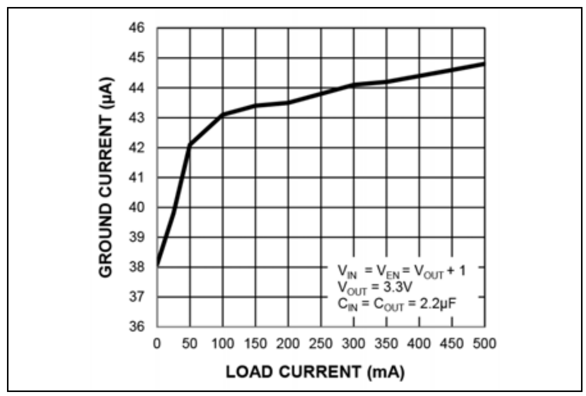


FIGURE 2-5: *Ground Current vs. Load Current.*

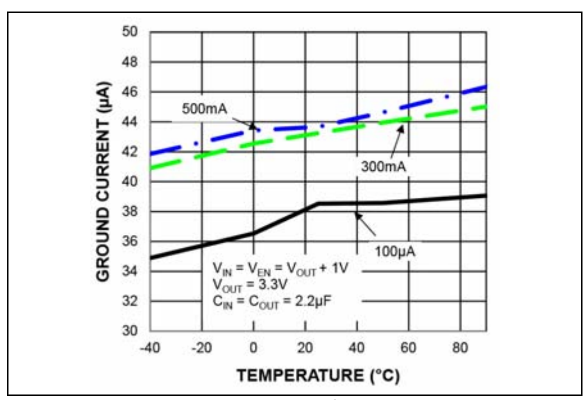


FIGURE 2-6: *Ground Current vs. Temperature.*

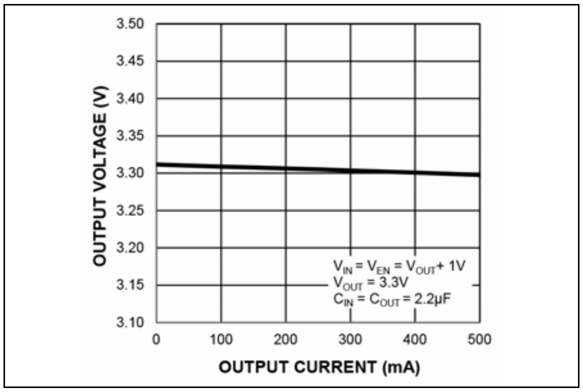


FIGURE 2-7: *Output Voltage vs. Output Current.*

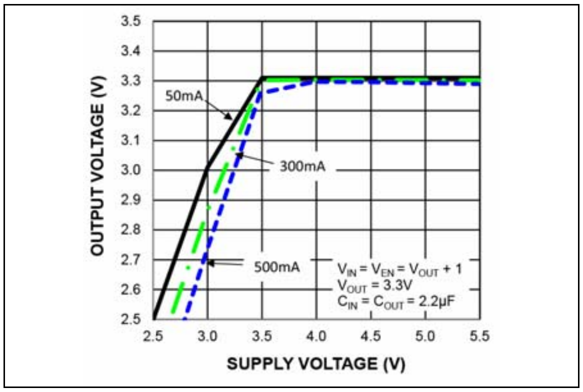


FIGURE 2-8: *Output Voltage vs. Supply Voltage.*

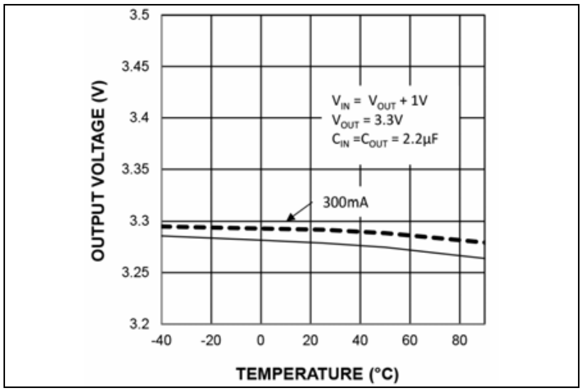


FIGURE 2-9: *Output Voltage vs. Temperature.*

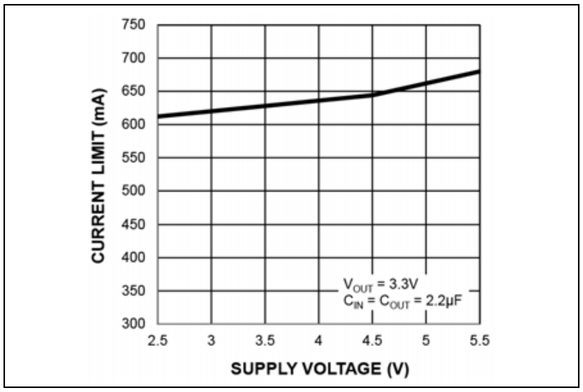


FIGURE 2-10: *Current Limit vs. Supply Voltage.*

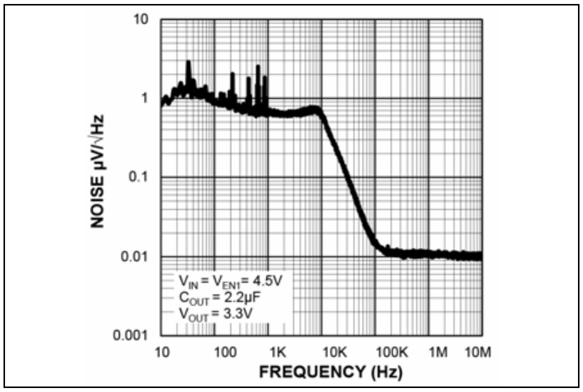


FIGURE 2-11: *Output Noise Spectral Density (MIC5528-3.3YMT).*

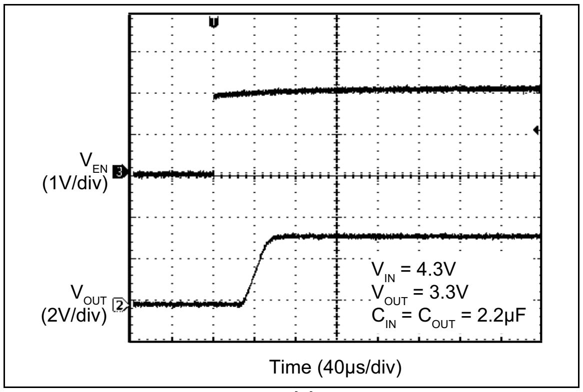


FIGURE 2-12: *Enable Turn-On.*

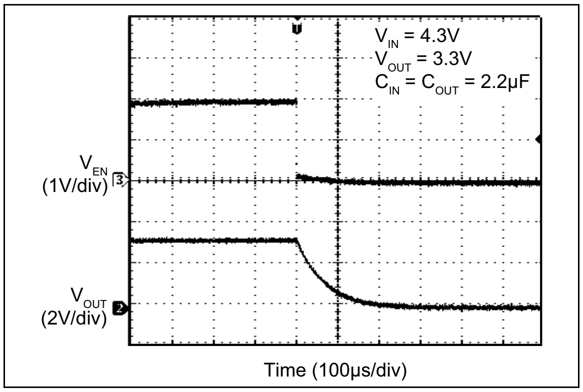


FIGURE 2-13: *Auto-Discharge (No Load).*

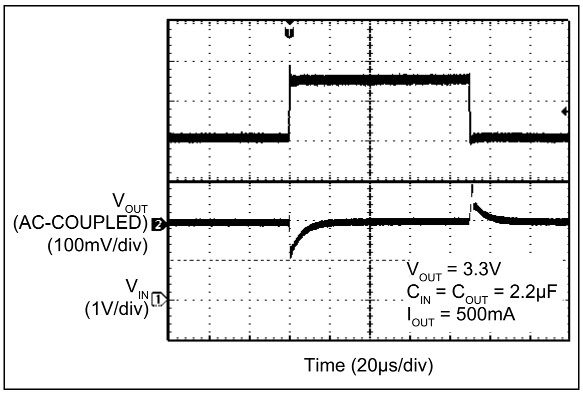


FIGURE 2-14: *Line Transient.*

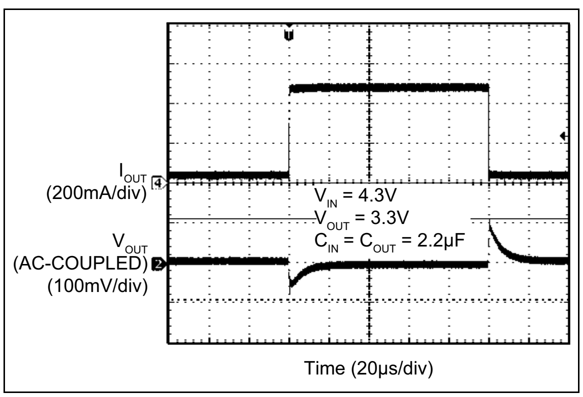


FIGURE 2-15: *Load Transient.*

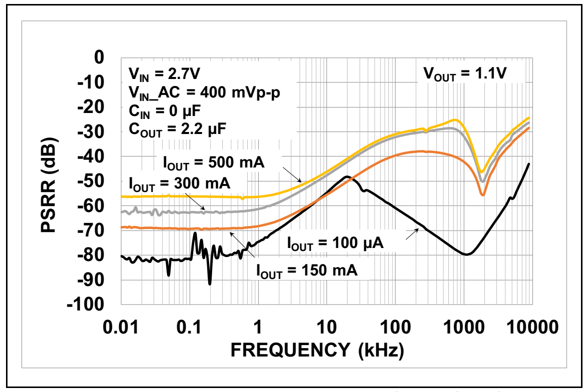


FIGURE 2-16: *Power Supply Rejection Ratio.*

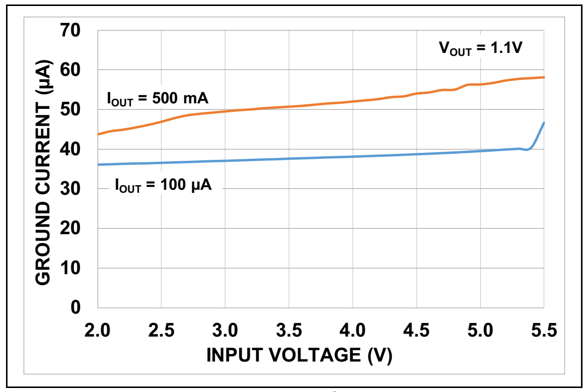


FIGURE 2-17: *Ground Current vs. Input Voltage.*

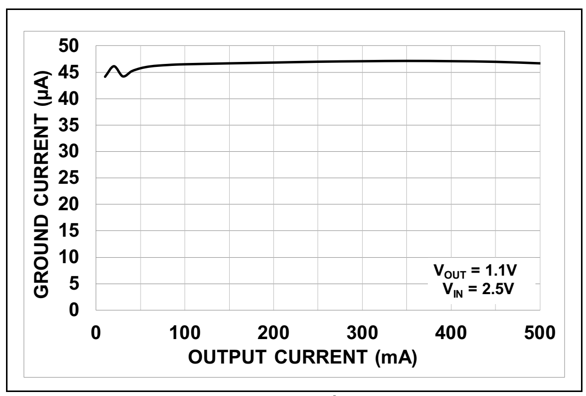


FIGURE 2-18: *Ground Current vs. Output Current.*

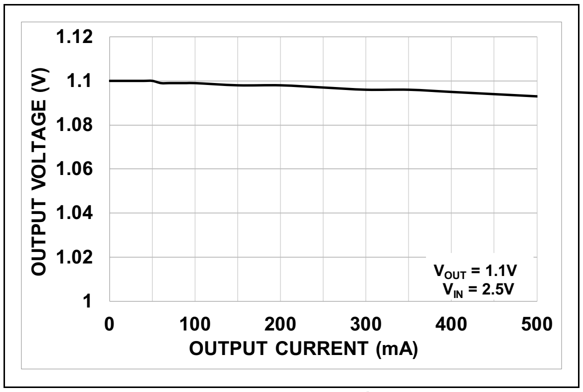


FIGURE 2-19: Output Voltage vs. Output Current.

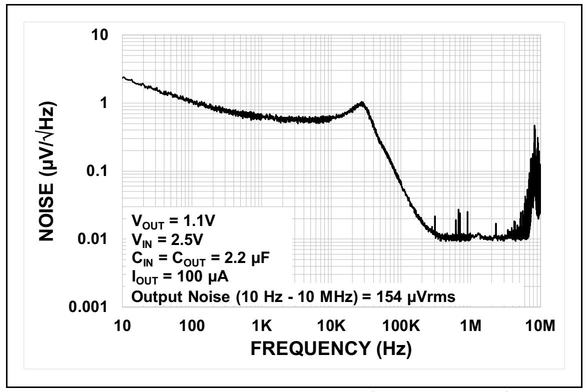


FIGURE 2-22: Output Noise Spectral Density.

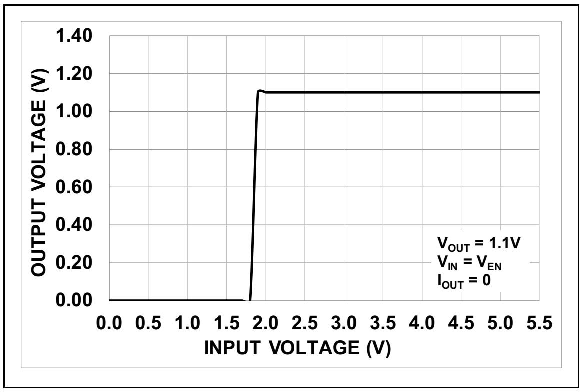


FIGURE 2-20: Output Voltage vs. Input Voltage.

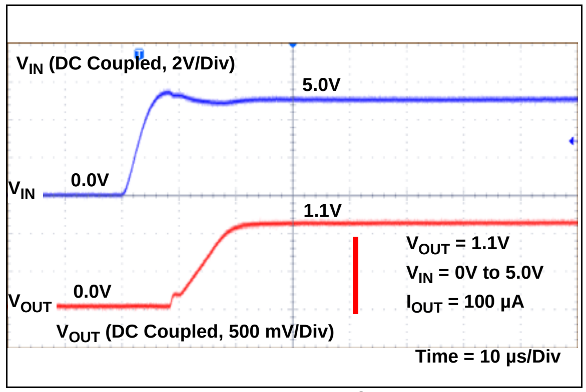


FIGURE 2-23: Start-Up from V_{IN}.

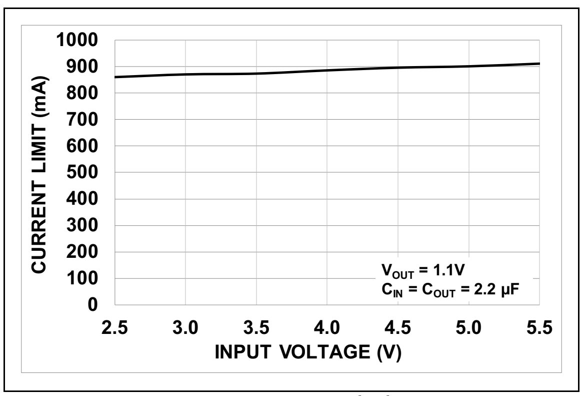


FIGURE 2-21: Current Limit vs. Input Voltage.

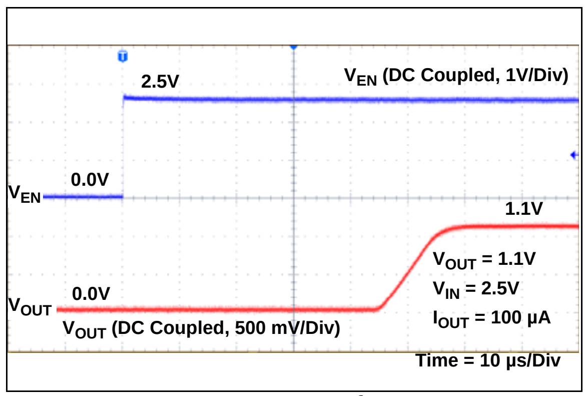


FIGURE 2-24: Start-Up from ENABLE.

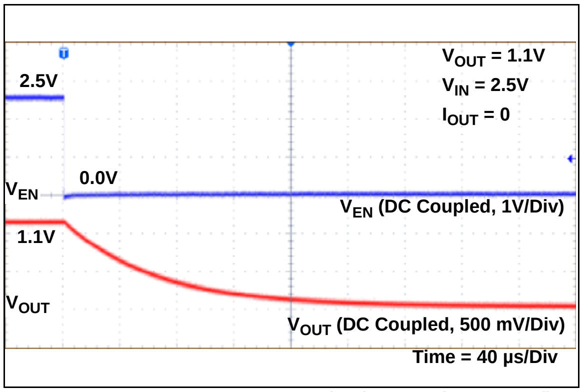


FIGURE 2-25: *Auto-Discharge (No Load).*

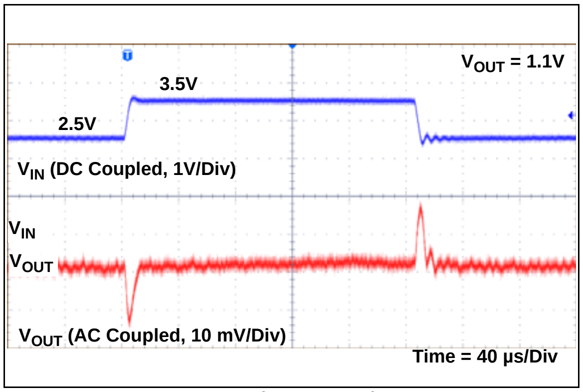


FIGURE 2-26: *Line Transient.*

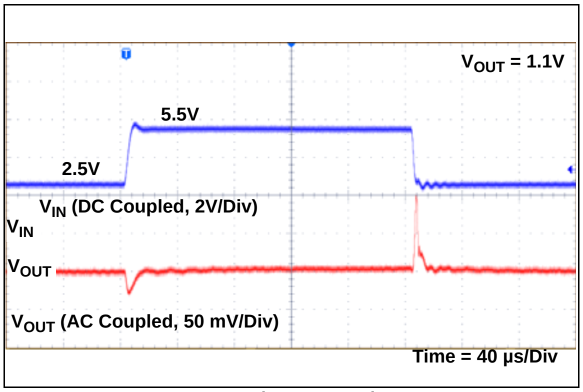


FIGURE 2-27: *Line Transient.*

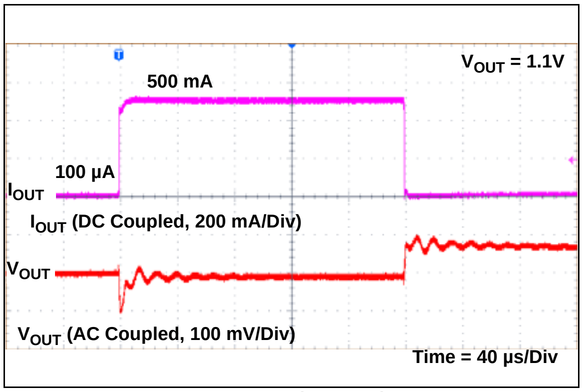


FIGURE 2-28: *Load Transient.*

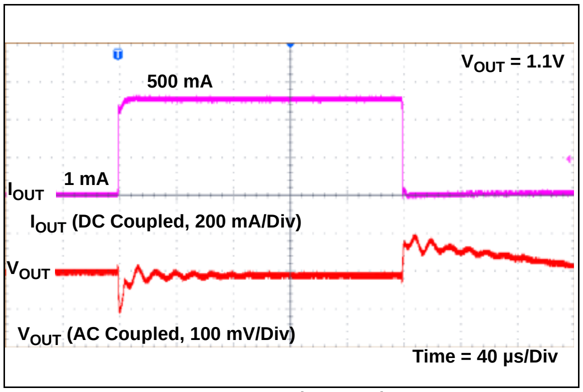


FIGURE 2-29: *Load Transient.*

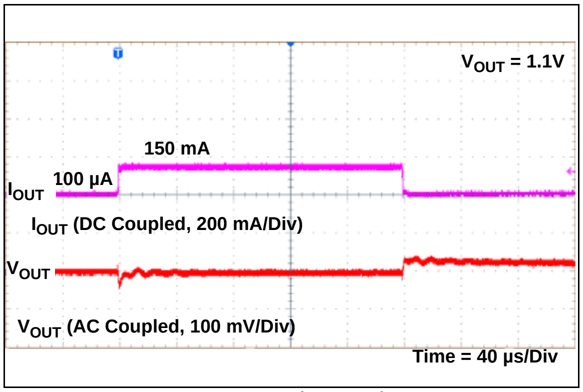


FIGURE 2-30: *Load Transient.*

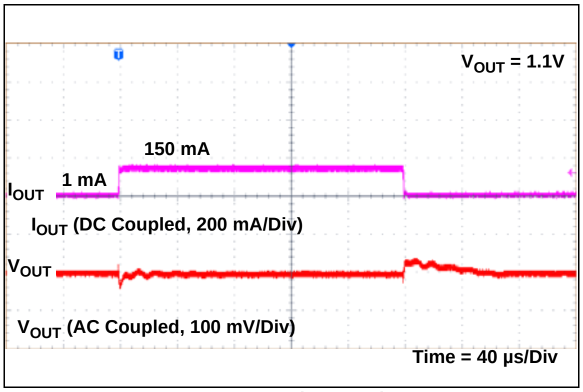


FIGURE 2-31: *Load Transient.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number	Pin Name	Description
1, 2	VOUT	Output Voltage. When disabled, the MIC5528 switches in an internal 25Ω load to discharge the external capacitors.
3	GND	Ground.
4	EN	Enable Input: Active-High. High = ON; Low = OFF. The MIC5528 has an internal pull-down and this pin can be left floating.
5	NC	No Connection.
6	VIN	Supply input.
EP	ePad	Exposed Heatsink Pad. Connect to GND for best thermal performance.

4.0 APPLICATION INFORMATION

The MIC5528 is a high performance, low power 500 mA LDO. The MIC5528 includes an auto-discharge circuit that is switched on when the regulator is disabled through the enable pin. The MIC5528 also offers an internal pull-down resistor on the enable pin to ensure the output is disabled if the control signal is tri-stated. The MIC5528 regulator is fully protected from damage due to fault conditions, offering linear current-limiting and thermal shutdown.

4.1 Input Capacitor

The MIC5528 is a high performance, high bandwidth device. An input capacitor of 2.2 µF is required from the input to ground to provide stability. Low-ESR ceramic capacitors provide optimal performance at a minimum of space. Additional high frequency capacitors, such as small-valued NPO dielectric-type capacitors, help filter out high frequency noise and are good practice in any RF-based circuit. X5R or X7R dielectrics are recommended for the input capacitor. Y5V dielectrics lose most of their capacitance over temperature and are therefore, not recommended.

4.2 Output Capacitor

The MIC5528 requires an output capacitor of 2.2 µF or greater to maintain stability. The design is optimized for use with low-ESR ceramic chip capacitors. High-ESR capacitors are not recommended because they may cause high frequency oscillation. The output capacitor can be increased, but performance has been optimized for a 2.2 µF ceramic output capacitor and does not improve significantly with larger capacitance.

X7R/X5R dielectric-type ceramic capacitors are recommended because of their temperature performance. X7R-type capacitors change capacitance by 15% over their operating temperature range and are the most stable type of ceramic capacitors. Z5U and Y5V dielectric capacitors change value by as much as 50% and 60%, respectively, over their operating temperature ranges. To use a ceramic chip capacitor with Y5V dielectric, the value must be much higher than an X7R ceramic capacitor to ensure the same minimum capacitance over the equivalent operating temperature range.

4.3 No-Load Stability

Unlike many other voltage regulators, the MIC5528 remains stable and in regulation with no load. This is especially important in CMOS RAM keep-alive applications.

4.4 Enable/Shutdown

The MIC5528 comes with an active-high enable pin that allows the regulator to be disabled. Forcing the enable pin low disables the regulator and sends it into an off mode current state drawing virtually zero current. When disabled the MIC5528 switches an internal 25Ω load on the regulator output to discharge the external capacitor.

Forcing the enable pin high enables the output voltage. The MIC5528 has an internal pull-down resistor on the enable pin to disable the output when the enable pin is floating.

4.5 Thermal Considerations

The MIC5528 is designed to provide 500 mA of continuous current in a very small package. Maximum ambient operating temperature can be calculated based on the output current and the voltage drop across the part. For example, if the input voltage is 3.6V, the output voltage is 3.3V, and the output current is 500 mA. The actual power dissipation of the regulator circuit can be determined using Equation 4-1:

EQUATION 4-1:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_{GND}$$

Because this device is CMOS and the ground current is typically <100 µA over the load range, the power dissipation contributed by the ground current is <1% and can be ignored Equation 4-2:

EQUATION 4-2:

$$P_D = (3.6V - 3.3V) \times 500mA = 0.150W$$

To determine the maximum ambient operating temperature of the package, use the junction-to-ambient thermal resistance of the device Equation 4-3:

EQUATION 4-3:

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

Where:

$T_{J(MAX)}$ = 125°C, the maximum junction temperature of the die.

θ_{JA} = Thermal resistance of 173°C/W for the XTDFN.

Substituting P_D for $P_{D(MAX)}$ and solving for the ambient operating temperature will give the maximum operating conditions for the regulator circuit. The junction-to-ambient thermal resistance for the minimum footprint is 173°C/W.

The maximum power dissipation must not be exceeded for proper operation.

For example, when operating the MIC5528-3.3YMX at an input voltage of 3.6V and a 500 mA load with a minimum footprint layout, the maximum ambient operating temperature T_A can be determined as in Equation 4-4:

EQUATION 4-4:

$$0.15W = (125°C - T_A)/(173°C/W)$$

$$T_A = 99°C$$

Therefore, the maximum ambient operating temperature allowed in a thermally enhanced 1.2 mm × 1.2 mm XTDFN package is 99°C. For a full discussion of heat sinking and thermal effects on voltage regulators, refer to the “Regulator Thermals” section of Microchip’s Designing with Low-Dropout Voltage Regulators handbook.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

6-Lead TDFN*	Example
▲ XX	▲ CF

6-Lead XTDFN*	Example
▼ XX	▼ CF

Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.
	●, ▲, ▼	Pin one index is identified by a dot, delta up, or delta down (triangle mark).

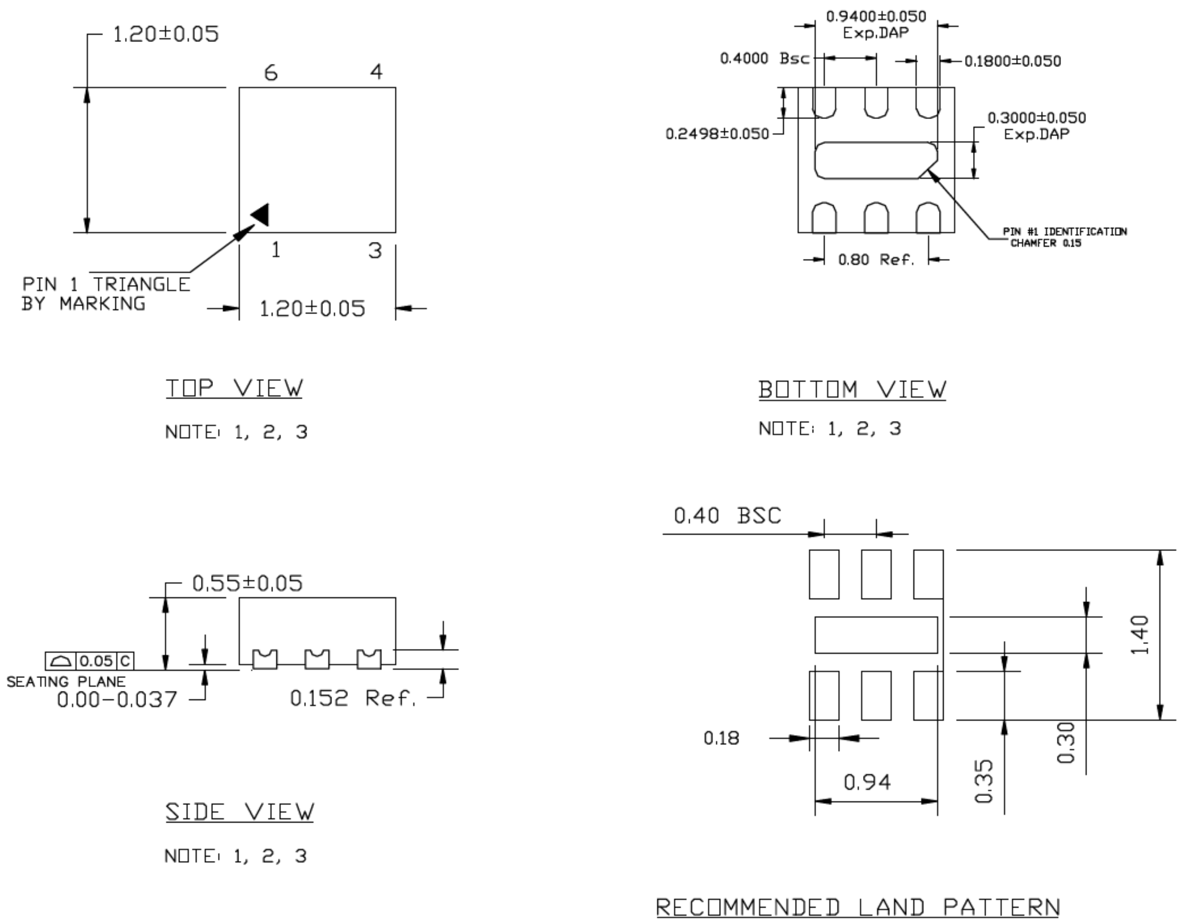
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

Underbar (_) and/or Overbar (‾) symbol may not be to scale.

6-Lead Thin DFN 1.2 mm x 1.2 mm Package Outline and Recommended Land Pattern

TITLE
6 LEAD TDFN 1.2x1.2mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	TDFN1212-6LD-PL-1	UNIT	MM



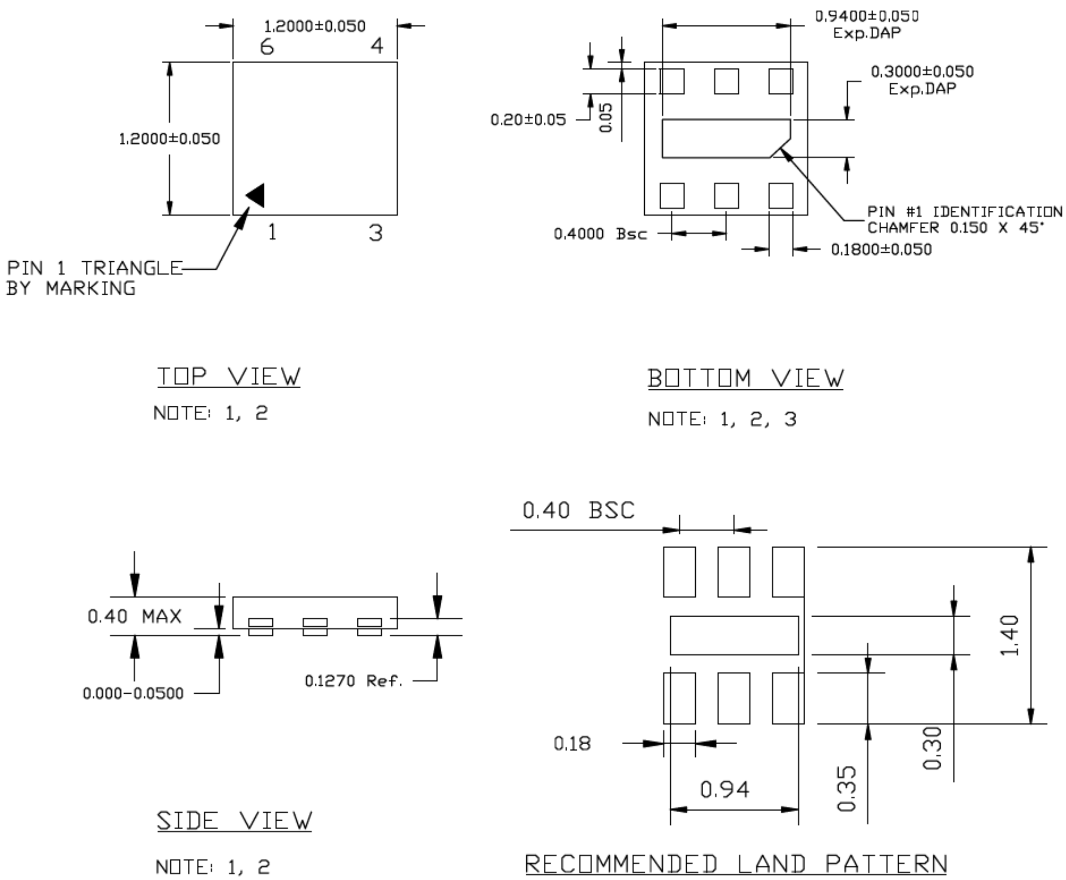
NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging.

6-Lead Extra Thin DFN 1.2 mm x 1.2 mm Package Outline and Recommended Land Pattern

TITLE
6 LEAD XTDFN 1.2x1.2mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	XTDFN1212-6LD-PL-1	**UNIT**	MM
Lead Frame	NiPdAu	**Lead Finish**	NiPdAu



NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. LEAD AND EPAD CORNER MAXIMUM RADIUS 0.075MM

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging.

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (March 2018)

- Converted Micrel document MIC5528 to Microchip data sheet DS20005982A.
- Minor text changes throughout.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

Device	**-X.X**	**X**	**XX**	**-XX**
Part No.	Output Voltage	Junction Temp. Range	Package	Media Type

Device:	MIC5528:	High Performance Single 500 mA µCap LDO in Thin and Extra Thin DFN Packages, Featuring Auto Discharge & Internal Enable Pull-Down
Output Voltage:	1.1 =	1.1V (MX Package only)
	2.8 =	2.8V (MX Package only)
	3.3 =	3.3V
Junction Temperature Range:	Y =	–40°C to +125°C, RoHS-Compliant
Package:	MT =	6-Lead 1.2 mm x 1.2 mm x 0.6 mm TDFN
	MX =	6-Lead 1.2 mm x 1.2 mm x 0.4 mm XTDFN
Media Type:	T5 =	500/Reel
	TR =	5,000/Reel

Note: Other voltage options available. Contact your Microchip Sales Office for more information.

Examples:

a) MIC5528-1.1YMX-T5: MIC5528, 1.1V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead XTDFN, 500/Reel

b) MIC5528-1.1YMX-TR: MIC5528, 1.1V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead XTDFN, 5,000/Reel

c) MIC5528-2.8YMX-T5: MIC5528, 2.8V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead XTDFN, 500/Reel

d) MIC5528-2.8YMX-TR: MIC5528, 2.8V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead XTDFN, 5,000/Reel

e) MIC5528-3.3YMT-T5: MIC5528, 3.3V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead TDFN, 500/Reel

f) MIC5528-3.3YMT-TR: MIC5528, 3.3V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead TDFN, 5,000/Reel

g) MIC5528-3.3YMX-T5: MIC5528, 3.3V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead XTDFN, 500/Reel

h) MIC5528-3.3YMX-TR: MIC5528, 3.3V Output Voltage, –40°C to +125°C Temperature Range, 6-Lead XTDFN, 5,000/Reel

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
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- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

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Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

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