# MIC5528

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

## 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 500mA of output current while only drawing 38µA of operating current. This high-performance LDO is a µCap design in a thermally enhanced 1.2mm × 1.2mm extra thin (0.4mm ht.) 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 (260mV @ 500mA), 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.

Datasheets and support documentation are available on Micrel's web site at: www.micrel.com.

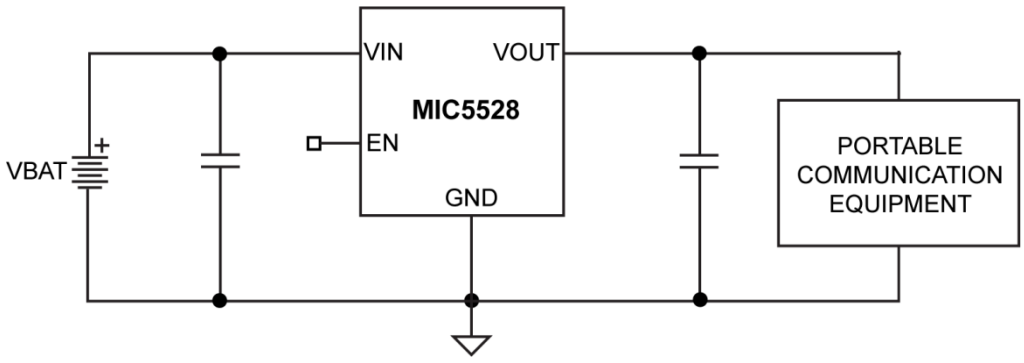
## Features

- Input voltage range: 2.5V to 5.5V
- Fixed output voltages down to 1.0V
- ±2% Room temperature accuracy
- Low quiescent current 38µA
- Stable with 2.2µF ceramic output capacitors
- Low dropout voltage 260mV @ 500mA
- Auto discharge and internal enable pulldown
- Thermal-shutdown and current-limit protection
- 6-pin 1.2mm × 1.2mm extra thin DFN package
- 6-pin 1.2mm × 1.2mm thin DFN package

## Applications

- Portable communication equipment
- DSC, GPS, PMP, and PDAs
- Portable medical devices
- 5V POL applications

## Typical Application



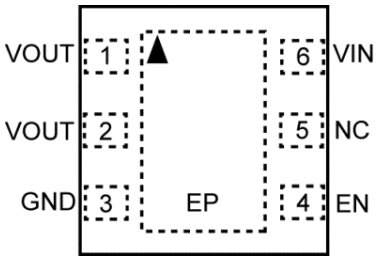
## Ordering Information

| Part Number | Marking Code | Output Voltage[1] | Auto-Discharge | EN Pulldown | Temperature Range | Package[2, 3, 4] |
|---|---|---|---|---|---|---|
| MIC5528-3.3YMT | CF | 3.3V | YES | YES | –40°C to +125°C | 6-Pin 1.2mm × 1.2mm TDFN |
| MIC5528-2.8YMX | CI | 2.8V | YES | YES | –40°C to +125°C | 6-Pin 1.2mm × 1.2mm XTDFN |
| MIC5528-3.3YMX | CF | 3.3V | YES | YES | –40°C to +125°C | 6-Pin 1.2mm × 1.2mm XTDFN |

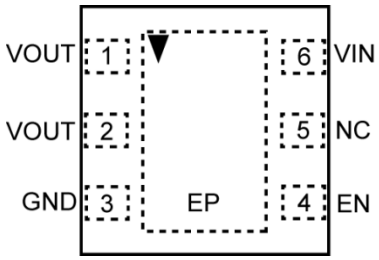
**Notes:**

1. Other voltages available. Contact Micrel for details.
2. Thin DFN ▲ = Pin 1 identifier.
3. Extra Thin DFN ▼ = Pin 1 identifier.
4. Extra Thin and Thin DFN are GREEN, RoHS-compliant packages. Lead finish is NiPdAu. Mold compound is Halogen Free.

## Pin Configuration




**6-Pin 1.2mm × 1.2mm Thin DFN (MT)**
**(Top View)**




**6-Pin 1.2mm × 1.2mm Extra Thin DFN (MX)**
**(Top View)**

## Pin Description

| Pin Number | Pin Name XTDFN-6 | Pin Function |
|---|---|---|
| 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 pulldown 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. |

## Absolute Maximum Ratings[5]

Supply Voltage ($V_{IN}$) ..... –0.3V to 6V
Enable Voltage ($V_{EN}$) ..... –0.3V to $V_{IN}$
Power Dissipation ($P_D$) ..... Internally Limited[7]
Lead Temperature (soldering, 10sec) ..... 260°C
Junction Temperature ($T_J$) ..... –40°C to +150°C
Storage Temperature ($T_s$) ..... –65°C to +150°C
ESD Rating[8] ..... 3kV

## Operating Ratings[6]

Supply Voltage ($V_{IN}$) ..... 2.5V to 5.5V
Enable Voltage ($V_{EN}$) ..... 0V to $V_{IN}$
Junction Temperature ($T_J$) ..... –40°C to +125°C
Junction Thermal Resistance
1.2mm × 1.2mm Extra Thin DFN-6 ($\theta_{JA}$) ..... 173°C/W

## Electrical Characteristics[9]

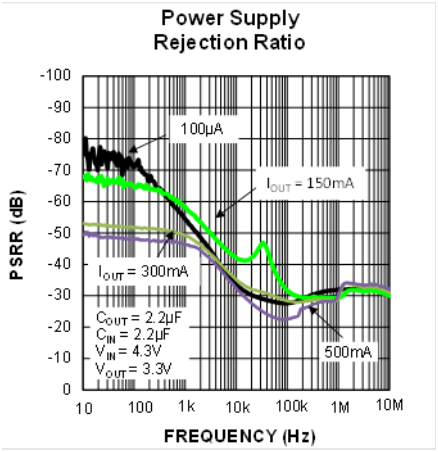
$V_{IN} = V_{EN} = V_{OUT} + 1V$; $C_{IN} = C_{OUT} = 2.2\mu F$; $I_{OUT} = 100\mu A$; $T_J = 25°C$, **bold** values indicate –40°C to +85°C, unless noted.

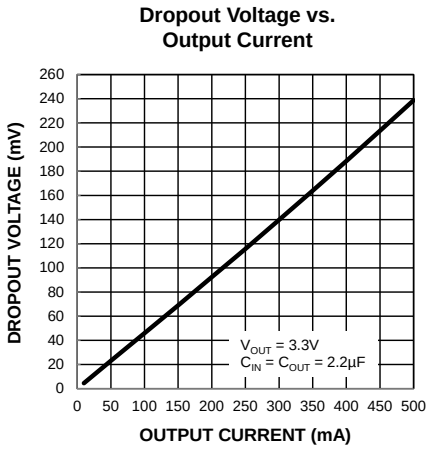
| Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| Output Voltage Accuracy | Variation from nominal $V_{OUT}$ | –2.0 | ±1 | +2.0 | % |
| | Variation from nominal $V_{OUT}$; –40°C to +85°C | **–3.0** | | **+3.0** | |
| Line Regulation | $V_{IN} = V_{OUT}$ +1V to 5.5V; $I_{OUT} = 100\mu A$ | | 0.02 | **0.3** | %/V |
| Load Regulation[10] | $I_{OUT} = 100\mu A$ to 500mA | | 14 | 65 | mV |
| Dropout Voltage[11] | $I_{OUT}$ = 150mA<br>$I_{OUT}$ = 500mA | | 80<br>260 | **180**<br>**500** | mV |
| Ground Pin Current[12] | $I_{OUT}$ = 0mA<br>$I_{OUT}$ = 500mA | | 38<br>42 | **55**<br>**65** | µA |
| Ground Pin Current in Shutdown | $V_{EN}$ = 0V | | 0.05 | 1 | µA |
| Ripple Rejection | f = 100Hz, $I_{OUT}$ = 100mA | | 70 | | dB |
| | f = 1kHz, $I_{OUT}$ = 100mA | | 60 | | dB |
| Current Limit | $V_{OUT}$ = 0V | **525** | 800 | | mA |
| Output Voltage Noise | f =10Hz to 100kHz | | 175 | | $\mu V_{RMS}$ |
| Auto-Discharge NFET Resistance | $V_{EN}$ = 0V; $V_{IN}$ = 3.6V ; $I_{OUT}$ = –3mA | | 25 | | Ω |
| **Enable Input** | | | | | |
| Enable Pulldown Resistor | | | 4 | | MΩ |
| Enable Input Voltage | Logic Low | | | **0.2** | V |
| | Logic High | **1.2** | | | |
| Enable Input Current | $V_{EN}$ = 0V | | 0.01 | 1 | µA |
| | $V_{EN}$ = 5.5V | | 1.4 | 2 | |
| Turn-On Time | $I_{OUT}$ = 150mA | | 50 | **125** | µs |

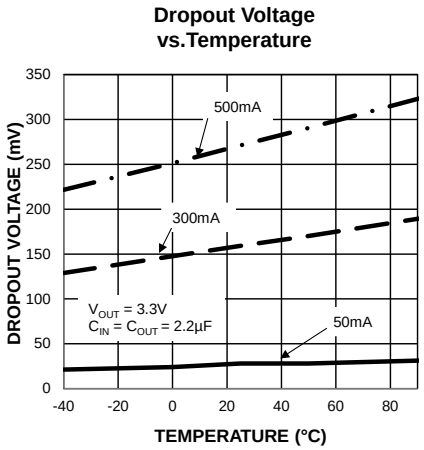
**Notes:**

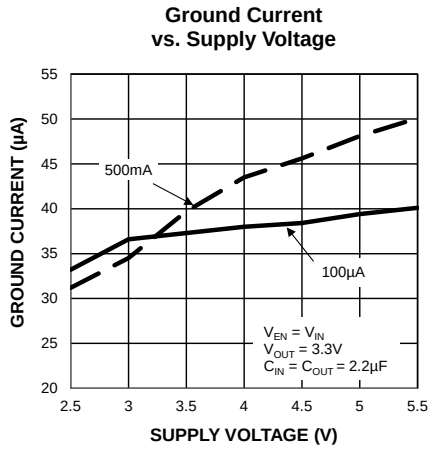
5. Exceeding the absolute maximum rating can damage the device.
6. The device is not guaranteed to function outside its operating rating.
7. The maximum allowable power dissipation of any $T_A$ (ambient temperature) is $P_{D(max)} = (T_{J(max)} – T_A) / \theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.
8. Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5kΩ in series with 100pF.
9. Specification for packaged product only.
10. 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.
11. 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.
12. 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.

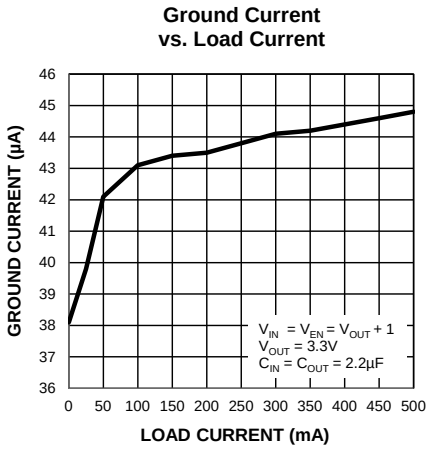
## Typical Characteristics

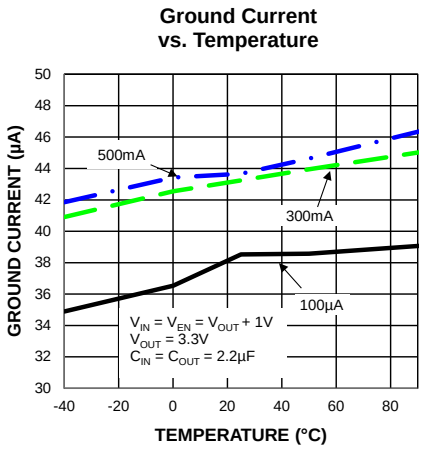


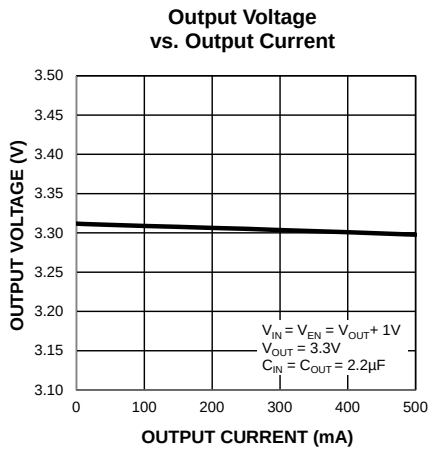



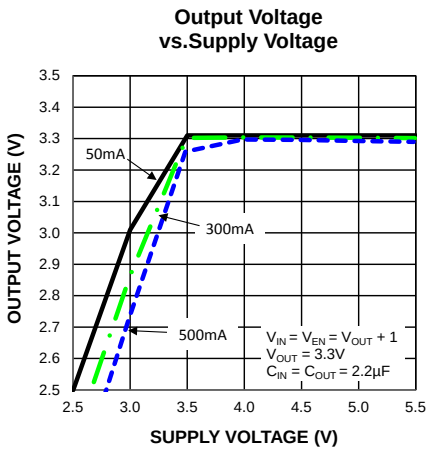



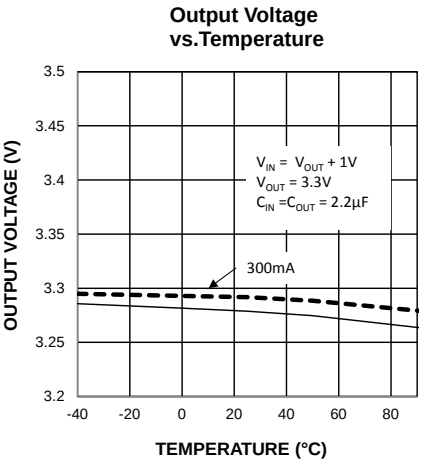



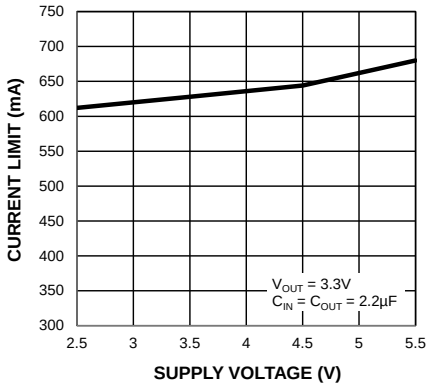



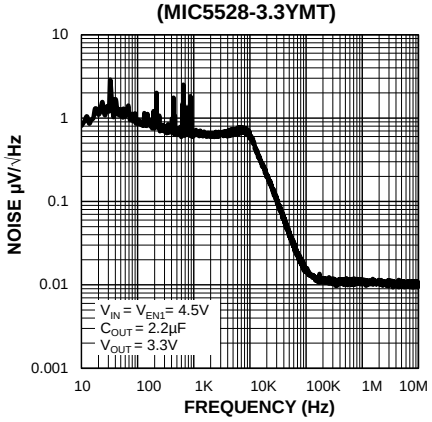



## Typical Characteristics (Continued)

**Current Limit vs. Supply Voltage**

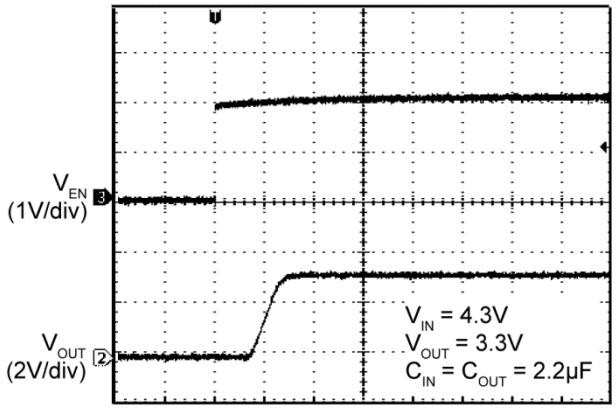



**Output Noise Spectral Density (MIC5528-3.3YMT)**

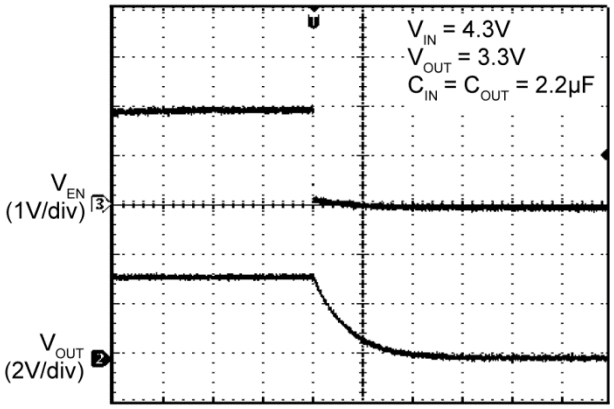


## Functional Characteristics

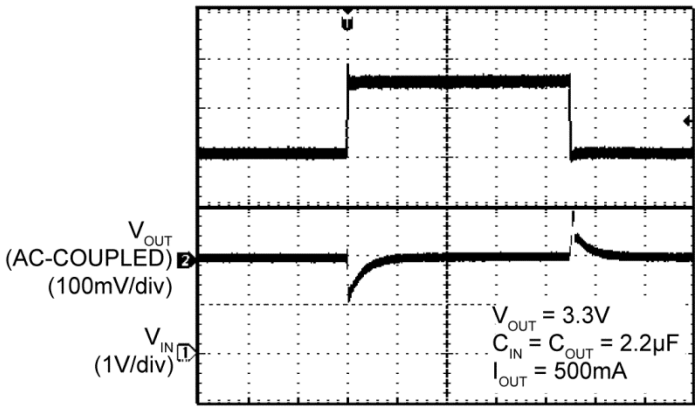
**Enable Turn-On**



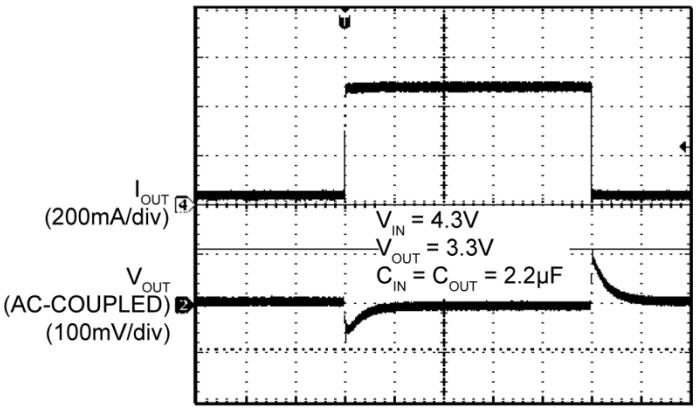

**Auto-Discharge (No Load)**



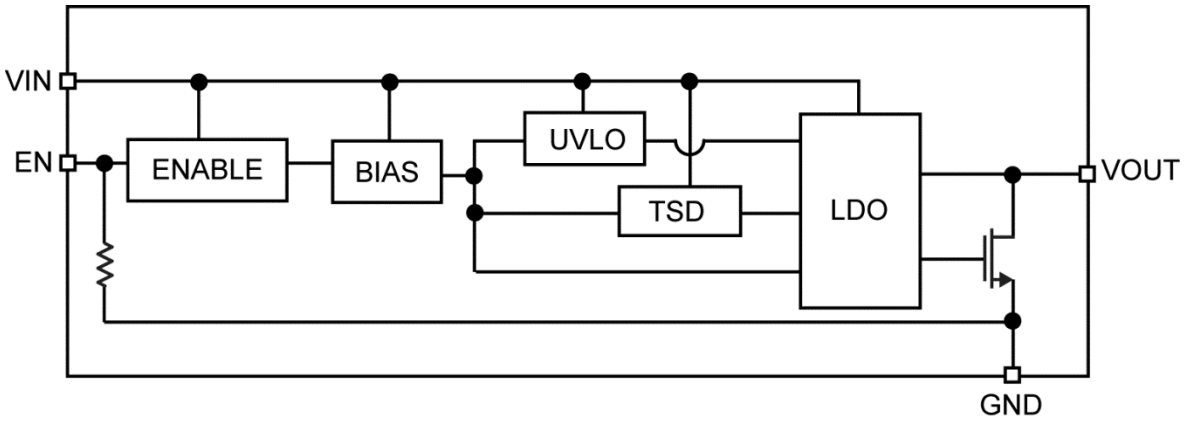

**Line Transient**




**Load Transient**



## Functional Block Diagram



## Application Information

The MIC5528 is a high-performance, low-power 500mA 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 pulldown 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.

### Input Capacitor

The MIC5528 is a high-performance, high-bandwidth device. An input capacitor of 2.2µF 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.

### Output Capacitor

The MIC5528 requires an output capacitor of 2.2µF 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 2.2µF 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.

### 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.

### 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.

### Thermal Considerations

The MIC5528 is designed to provide 500mA 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 = 500mA. The actual power dissipation of the regulator circuit can be determined using Equation 1:

$$P_D = (V_{IN} - V_{OUT})I_{OUT} + V_{IN}\, I_{GND} \qquad \text{Eq. 1}$$

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

$$P_D = (3.6V - 3.3V) \times 500mA$$
$$P_D = 0.150W \qquad \text{Eq. 2}$$

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

$$P_{D(MAX)} = \left( \frac{T_{J(MAX)} - T_A}{\theta_{JA}} \right) \qquad \text{Eq. 3}$$

$T_{J(MAX)}$ = 125°C, the maximum junction temperature of the die, $\theta_{JA}$ thermal resistance = 173°C/W for the XTDFN package.

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.

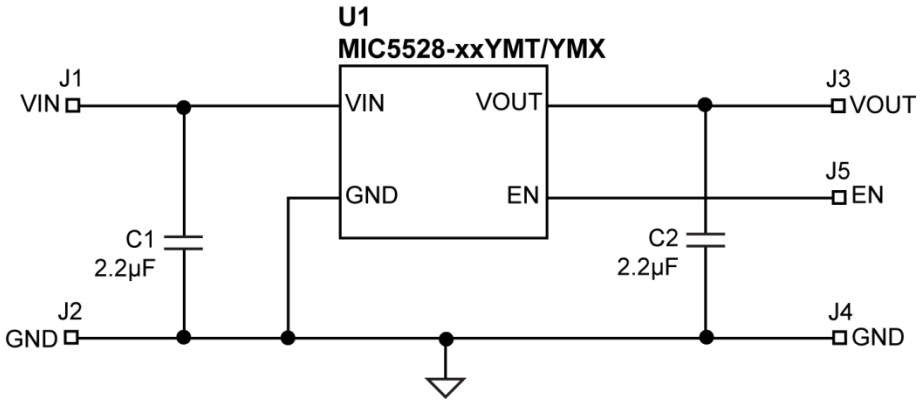
For example, when operating the MIC5528-3.3YMX at an input voltage of 3.6V and a 500mA load with a minimum footprint layout, the maximum ambient operating temperature $T_A$ can be determined as in Equation 4:

$$0.15W = (125°C - T_A)/(173°C/W)$$
$$T_A = 99°C \quad \text{Eq. 4}$$

Therefore, the maximum ambient operating temperature allowed in a thermally enhanced 1.2mm × 1.2mm 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 *Micrel's Designing with Low-Dropout Voltage Regulators* handbook. This information can be found on Micrel's website at:

http://www.micrel.com/_PDF/other/LDOBk_ds.pdf

## Typical Application Schematic



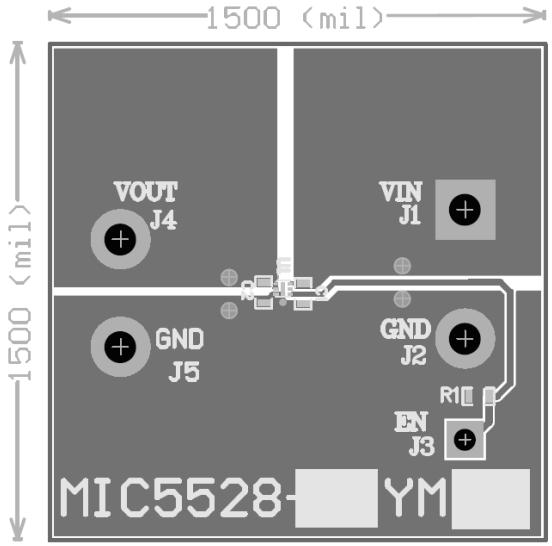

## Bill of Materials

| Item | Part Number | Manufacturer | Description | Qty. |
|---|---|---|---|---|
| C1, C2 | GRM188R71A225KE15D | Murata[13] | Capacitor, 2.2µF Ceramic, 10V, X5R, Size 0603 | 2 |
| **U1** | **MIC5528-xxYMT** | **Micrel, Inc.**[14] | **High-Performance 500mA LDO in Thin and Extra Thin DFN Packages** | **1** |
| | **MIC5528-xxYMX** | | | |

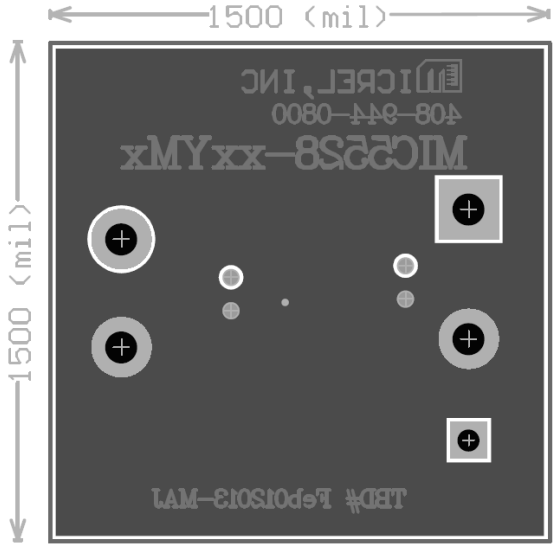
**Notes:**

13. Murata: www.murata.com.
14. **Micrel, Inc.: www.micrel.com**.

## PCB Layout Recommendations

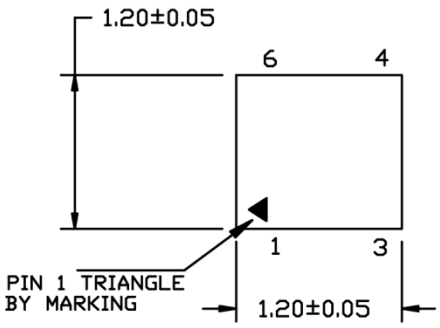



**Top Layer**



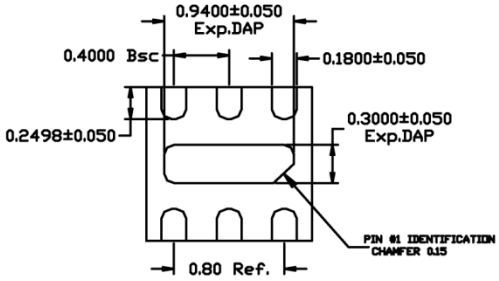

**Bottom Layer**

## Package Information[15] and Recommended Landing Pattern



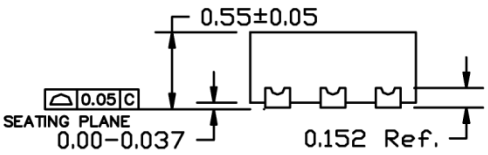

TOP VIEW

NOTE: 1, 2, 3



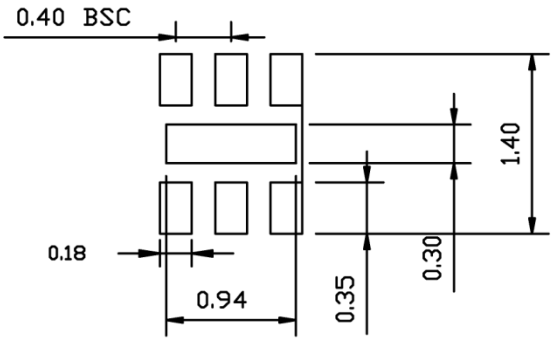

BOTTOM VIEW

NOTE: 1, 2, 3




SIDE VIEW

NOTE: 1, 2, 3




RECOMMENDED LAND PATTERN

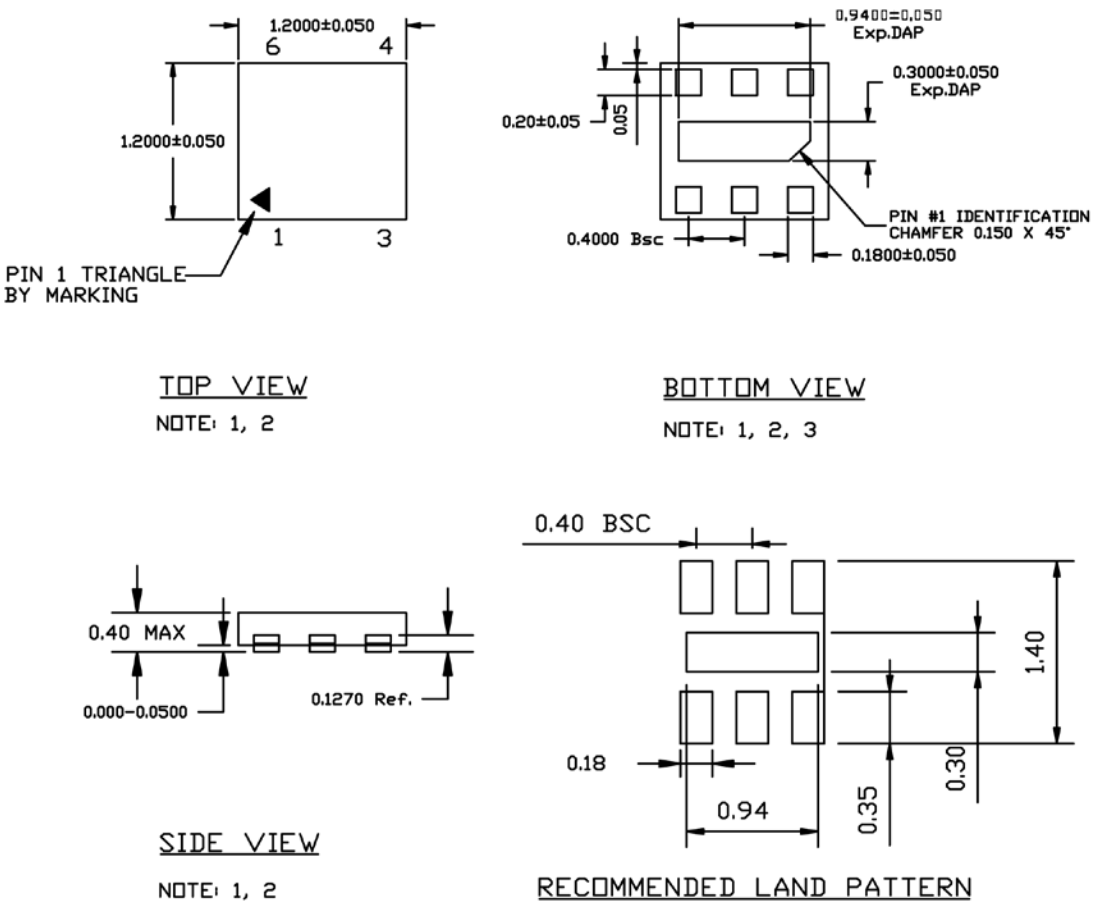
NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED

**6-Pin 1.2mm × 1.2mm Thin DFN (MT)**

**Note:**

15. Package information is correct as of the publication date. For updates and most current information, go to www.micrel.com.

## Package Information[15] and Recommended Landing Pattern (Continued)




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

**6-Pin 1.2mm × 1.2mm Extra Thin DFN (MX)**

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