## General Description

The MIC5501/2/3/4 is an advanced general-purpose LDO ideal for powering general-purpose portable devices. The MIC5501/2/3/4 family of products provides a high-performance 300mA LDO in an ultra-small 1mm × 1mm package. The MIC5502 and MIC5504 LDOs include an auto-discharge feature on the output that is activated when the enable pin is low. The MIC5503 and MIC5504 have an internal pull-down resistor on the enable pin that disables the output when the enable pin is left floating. This is ideal for applications where the control signal is floating during processor boot up.

Ideal for battery-powered applications, the MIC5501/2/3/4 offers 2% initial accuracy, low dropout voltage (160mV at 300mA), and low ground current (typically 38µA). The MIC5501/2/3/4 can also be put into a zero-off-mode current state, drawing virtually no current when disabled.

The MIC5501/2/3/4 has an operating junction temperature range of –40°C to 125°C.

Datasheets and support documentation can be found on Micrel's web site at: www.micrel.com.

## Features

- Input voltage range: 2.5V to 5.5V
- Fixed output voltages from 1.0V to 3.3V
- 300mA guaranteed output current
- High output accuracy (±2%)
- Low quiescent current: 38µA
- Stable with 1µF ceramic output capacitors
- Low dropout voltage: 160mV @ 300mA
- Output discharge circuit: MIC5502, MIC5504
- Internal enable pull-down: MIC5503, MIC5504
- Thermal-shutdown and current-limit protection
- 4-lead 1.0mm × 1.0mm Thin DFN package
- MIC5504 5-pin SOT23 package

## Applications

- Smartphones
- DSC, GPS, PMP, and PDAs
- Medical devices
- Portable electronics
- 5V systems

## Typical Application
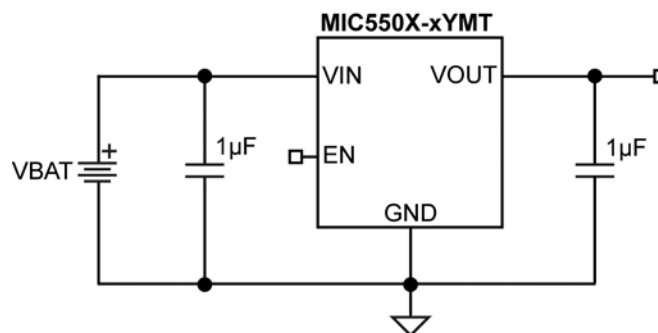
## Ordering Information

| Part Number | Marking Code | Output Voltage[1] | Auto-Discharge | EN Pull-Down | Temperature Range | Package[2,3] |
|---|---|---|---|---|---|---|
| MIC5501-3.3YMT[4] | VS | 3.3V | NO | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5501-3.0YMT | VP | 3.0V | NO | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5501-2.8YMT[4] | VM | 2.8V | NO | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5501-1.8YMT | VG | 1.8V | NO | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5501-1.2YMT[4] | V4 | 1.2V | NO | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5501-3.0YM5 | VX | 3.0V | NO | NO | −40°C to +125°C | 5-Pin SOT23 |
| MIC5502-3.3YMT[4] | XS | 3.3V | YES | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5502-3.0YMT[4] | XP | 3.0V | YES | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5502-2.8YMT | XM | 2.8V | YES | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5502-1.8YMT | XG | 1.8V | YES | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5502-1.2YMT[4] | X4 | 1.2V | YES | NO | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5503-3.3YMT[4] | SV | 3.3V | NO | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5503-3.0YMT[4] | ZV | 3.0V | NO | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5503-2.8YMT[4] | MV | 2.8V | NO | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5503-1.8YMT | YV | 1.8V | NO | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5503-1.2YMT[4] | XV | 1.2V | NO | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-3.3YMT | SX | 3.3V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-3.1YMT | TX | 3.1V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-3.0YMT | PX | 3.0V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-2.8YMT | MX | 2.8V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-2.5YMT | UX | 2.5V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-2.2YMT | UW | 2.2V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-1.8YMT | GX | 1.8V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-1.2YMT | ZX | 1.2V | YES | YES | −40°C to +125°C | 4-Pin 1mm x 1mm Thin DFN |
| MIC5504-3.3YM5 | WXS | 3.3V | YES | YES | −40°C to +125°C | 5-Pin SOT23 |
| MIC5504-2.8YM5 | WXM | 2.8V | YES | YES | −40°C to +125°C | 5-Pin SOT23 |
| MIC5504-2.5YM5 | WXJ | 2.5V | YES | YES | −40°C to +125°C | 5-Pin SOT23 |
| MIC5504-1.8YM5 | WXG | 1.8V | YES | YES | −40°C to +125°C | 5-Pin SOT23 |
| MIC5504-1.2YM5 | WX4 | 1.2V | YES | YES | −40°C to +125°C | 5-Pin SOT23 |

**Notes:**

1.  Other voltages available. Contact Micrel for details.

2.  Thin DFN ▲ = Pin 1 identifier.

3.  Thin DFN is a GREEN RoHS-compliant package. Lead finish is NiPdAu. Mold compound is Halogen Free.

4.  Contact Micrel Marketing for availability.

# Pin Configuration
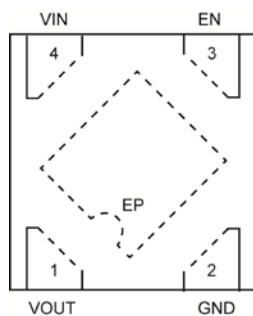


**4-Pin 1mm × 1mm Thin DFN (MT)**
**(Top View)**
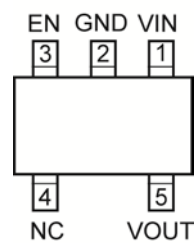
**5-Pin SOT23 (M5)**
**(Top View)**

# Pin Description

| Pin Name | Pin Number Thin DFN-4 | Pin Number SOT23-5 | Pin Function |
|---|---|---|---|
| VOUT | 1 | 5 | Output Voltage. When disabled the MIC5502 and MIC5504 switches in an internal 25Ω load to discharge the external capacitors. |
| GND | 2 | 2 | Ground |
| EN | 3 | 3 | Enable Input: Active High. High = ON; Low = OFF. For MIC5501 and MIC5502 do not leave floating. MIC5503 and MIC5504 have an internal pull-down and this pin may be left floating. |
| VIN | 4 | 1 | Supply Input. |
| NC | - | 4 | No Connection. Pin is not internally connected. |
| ePad | EP | - | 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, 10s)............................ 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
    1mm × 1mm Thin DFN-4 ($\theta_{JA}$)........................250°C/W
    5-pin SOT23 ($\theta_{JA}$) ..........................................253°C/W

## Electrical Characteristics[9]

$V_{IN} = V_{EN} = V_{OUT} + 1V$; $C_{IN} = C_{OUT} = 1\mu F$; $I_{OUT} = 100\mu A$; $T_J = 25°C$, **bold** values indicate −40°C to +125°C, unless noted.

| Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| Output Voltage Accuracy | Variation from nominal $V_{OUT}$ | −2.0 | | +2.0 | % |
| | Variation from nominal $V_{OUT}$; −40°C to +125°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 300mA | | 8 | 40 | mV |
| Dropout Voltage[11] | $I_{OUT} = 150mA$ | | 80 | **190** | mV |
| | $I_{OUT} = 300mA$ | | 160 | **380** | mV |
| Ground Pin Current[12] | $I_{OUT} = 0mA$ | | 38 | **55** | μA |
| | $I_{OUT} = 300mA$ | | 42 | **65** | |
| Ground Pin Current in Shutdown | $V_{EN} = 0V$ | | 0.05 | 1 | μA |
| Ripple Rejection | f = 1kHz; $C_{OUT} = 1\mu F$ | | 60 | | dB |
| Current Limit | $V_{OUT} = 0V$ | 400 | 630 | 900 | mA |
| Output Voltage Noise | $C_{OUT} = 1\mu F$, 10Hz to 100kHz | | 175 | | $\mu V_{RMS}$ |
| Auto-Discharge NFET Resistance | MIC5502, MIC5504 Only; $V_{EN} = 0V$; $V_{IN} = 3.6V$; $I_{OUT} = -3mA$ | | 25 | | Ω |
| **Enable Input** | | | | | |
| Enable Pull-Down Resistor | For MIC5503 and MIC5504 use only | | 4 | | MΩ |
| Enable Input Voltage | Logic Low | | | **0.2** | V |
| | Logic High | **1.2** | | | V |
| Enable Input Current MIC5501, MIC5502 | $V_{EN} = 0V$ | | 0.01 | 1 | μA |
| | $V_{EN} = 5.5V$ | | 0.01 | 1 | μA |
| Enable Input Current MIC5503, MIC5504 | $V_{EN} = 0V$ | | 0.01 | 1 | μA |
| | $V_{EN} = 5.5V$ | | 1.4 | 2 | μA |
| Turn-On Time | $C_{OUT} = 1\mu F$; $I_{OUT} = 150mA$ | | 50 | **125** | μs |

**Notes:**

5.  Exceeding the absolute maximum rating may 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.
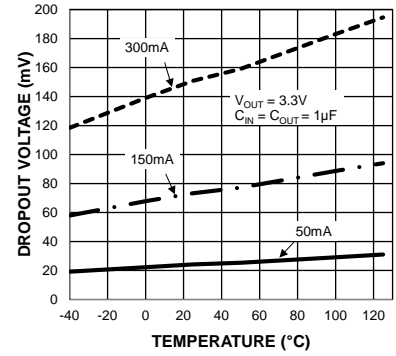
# Typical Characteristics
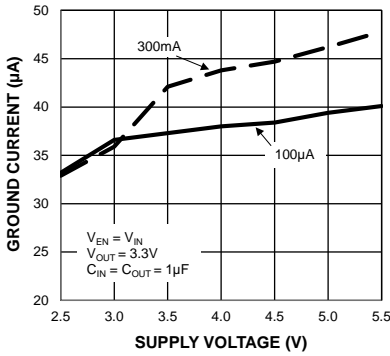
**Power Supply
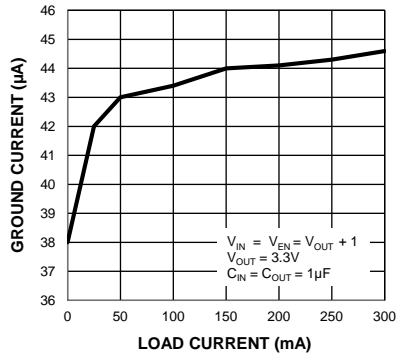Rejection Ratio**
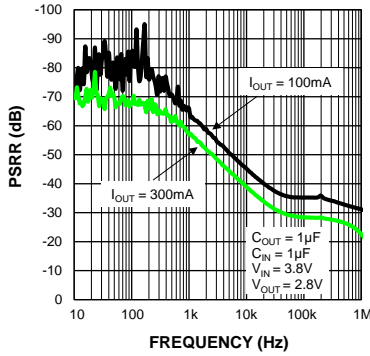
**Dropout Voltage
vs. Output Current**
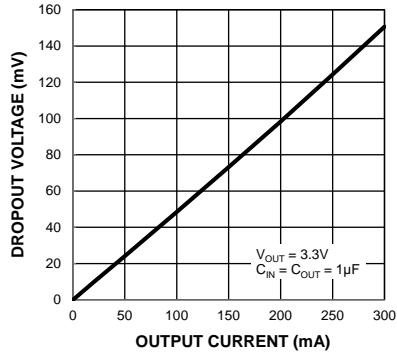
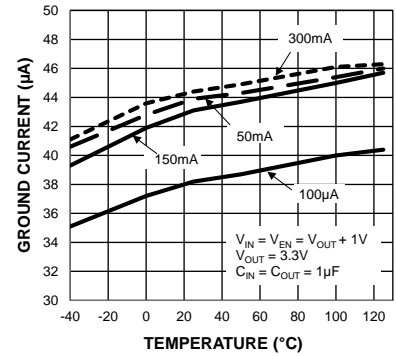**Dropout Voltage
vs.Temperature**
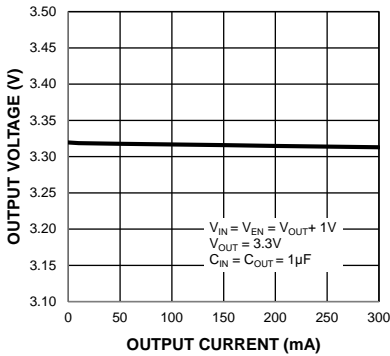
**Ground Current
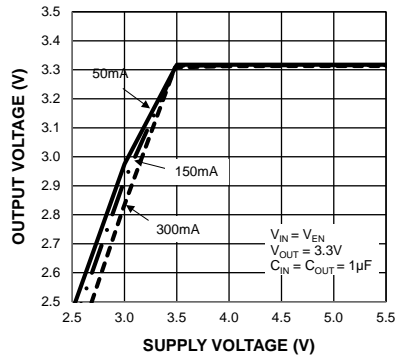vs. Supply Voltage**

**Ground Current
vs. Load Current**

**Ground Current
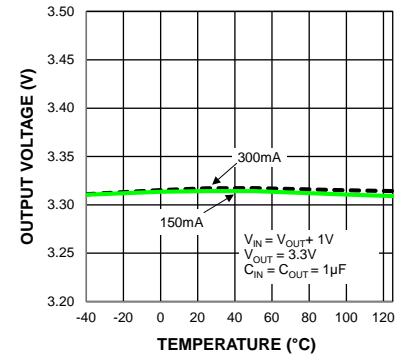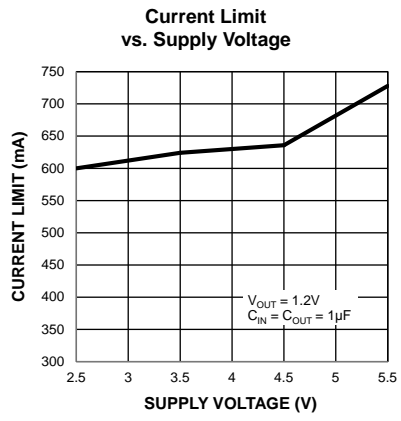vs. Temperature**

**Output Voltage
vs. Output Current**

**Output Voltage
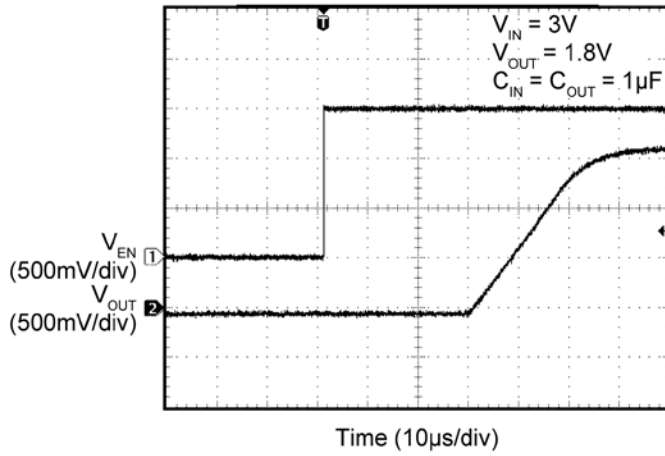vs. Supply Voltage**

**Output Voltage
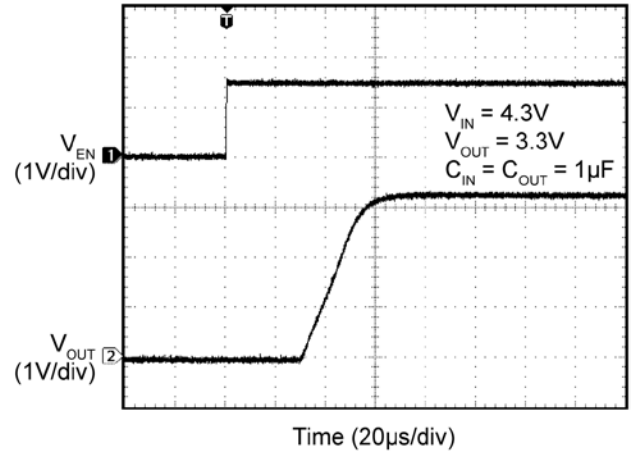vs. Temperature**

# Typical Characteristics (Continued)

**Current Limit
vs. Supply Voltage**



$V_{OUT}$ = 1.2V
$C_{IN}$ = $C_{OUT}$ = 1µF

# Functional Characteristics

**Enable Turn-On**

$V_{IN}$ = 3V
$V_{OUT}$ = 1.8V
$C_{IN}$ = $C_{OUT}$ = 1µF

$V_{EN}$ ①
(500mV/div)
$V_{OUT}$ ②
(500mV/div)

Time (10µs/div)

**Enable Turn-On**

$V_{IN}$ = 4.3V
$V_{OUT}$ = 3.3V
$C_{IN}$ = $C_{OUT}$ = 1µF

$V_{EN}$ ①
(1V/div)

$V_{OUT}$ ②
(1V/div)

Time (20µs/div)

**Load Transient**

$V_{IN}$ = 3.8V
$V_{OUT}$ = 2.8V
$C_{IN}$ = $C_{OUT}$ = 1µF

$I_{OUT}$ ④
(100mA/div)

$V_{OUT}$ ②
(AC-COUPLED)
(100mV/div)

Time (100µs/div)

**Load Transient**

$V_{IN}$ = 4.3V
$V_{OUT}$ = 3.3V
$C_{IN}$ = $C_{OUT}$ = 1µF

$I_{OUT}$ ④
(100mA/div)

$V_{OUT}$ ②
(AC-COUPLED)
(100mV/div)

Time (100µs/div)

**Line Transient**

$V_{OUT}$ = 2.8V
$C_{IN}$ = $C_{OUT}$ =1µF
$I_{OUT}$ = 300mA

5.5V

3.8V

$V_{IN}$ ①
(2mV/div)
$V_{OUT}$ ②
(AC-COUPLED
(50mV/div)

Time (100µs/div)

**Auto Discharge (No Load)**

$V_{OUT}$ = 3.3V
$C_{IN}$ = $C_{OUT}$ = 1µF

$V_{EN}$ ①
(1V/div)

$V_{OUT}$ ②
(1V/div)

Time (20µs/div)
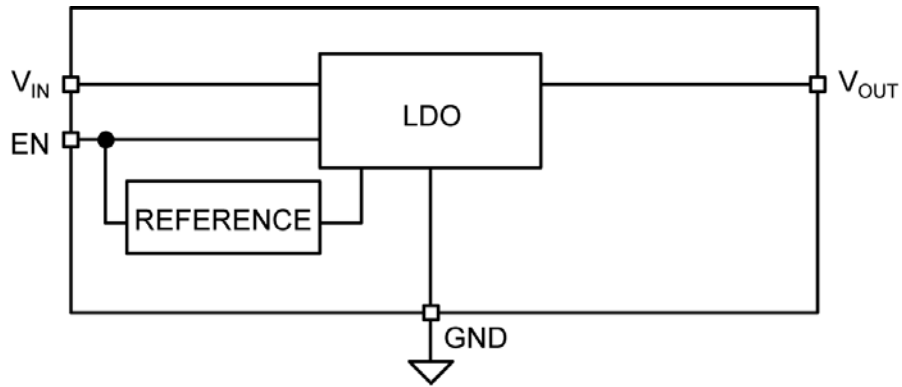
# Block Diagram



**MIC550x Block Diagram**

# Application Information

MIC5501/2/3/4 are low-noise 300mA LDOs. The MIC5502 and MIC5504 include an auto-discharge circuit that is switched on when the regulator is disabled through the enable (EN) pin. The MIC5503 and MIC5504 have an internal pull-down resistor on the EN pin to ensure the output is disabled if the control signal is tri-stated. The MIC5501/2/3/4 regulator is fully protected from damage due to fault conditions, offering linear current limiting and thermal shutdown.

## Input Capacitor

The MIC5501/2/3/4 is a high-performance, high-bandwidth device. An input capacitor of 1µF 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 MIC5501/2/3/4 requires an output capacitor of 1µF 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 1µF 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 MIC5501/2/3/4 remains stable and in regulation with no load. This is especially important in CMOS RAM keep-alive applications.

## Enable/Shutdown

The MIC5501/2/3/4 comes with an active-high enable pin that allows the regulator to be disabled. Forcing the EN pin low disables the regulator and sends it into an off mode current state drawing virtually zero current. When disabled the MIC5502 and MIC5504 switches an internal 25Ω load on the regulator output to discharge the external capacitor.

Forcing the EN pin high enables the output voltage. The MIC5501 and MIC5502 enable pin uses CMOS technology and the EN pin cannot be left floating; a floating EN pin may cause an indeterminate state on the output. The MIC5503 and MIC5504 have an internal pull-down resistor on the enable pin to disable the output when the enable pin is floating.

## Thermal Considerations

The MIC5501/2/3/4 is designed to provide 300mA 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 2.8V, and the output current = 300mA. The actual power dissipation of the regulator circuit can be determined using Equation 1:

$$P_D = (V_{IN} - V_{OUT1})\, I_{OUT} + V_{IN}\, I_{GND} \qquad \text{Eq. 1}$$

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 for this calculation:

$$P_D = (3.6V - 2.8V) \times 300mA$$

$$P_D = 0.240W$$

To determine the maximum ambient operating temperature of the package, use the junction-to-ambient thermal resistance of the device and Equation 2:

$$P_{D(max)} = \left( \frac{T_{J(max)} - T_A}{\theta_{JA}} \right) \qquad \text{Eq. 2}$$

$T_{J(max)}$ = 125°C, the maximum junction temperature of the die, $\theta_{JA}$ thermal resistance = 250°C/W for the DFN 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 250°C/W.

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

For example, when operating the MIC5501-MYMT at an input voltage of 3.6V and 300mA load with a minimum footprint layout, the maximum ambient operating temperature $T_A$ can be determined as follows:

$$0.240W = (125°C – T_A)/(250°C/W)$$
$$T_A = 65°C$$

Therefore, the maximum ambient operating temperature allowed in a 1mm × 1mm DFN package is 65°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
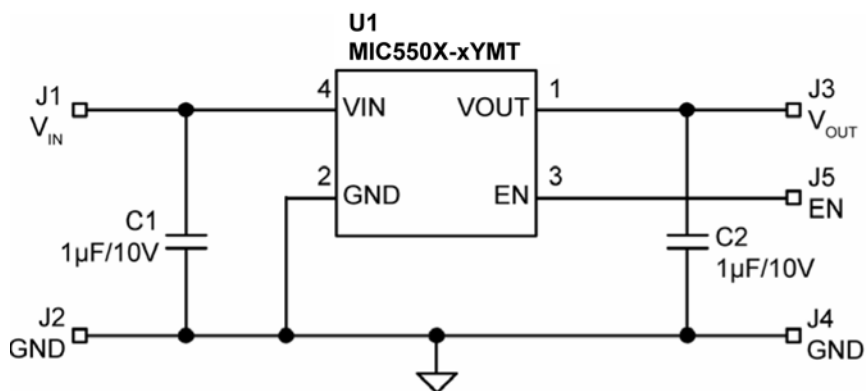


# Bill of Materials

| Item | Part Number | Manufacturer | Description | Qty. |
|---|---|---|---|---|
| C1, C2 | GRM155R61A105KE15D | Murata[13] | Capacitor, 1µF Ceramic, 10V, X5R, Size 0402 | 2 |
| U1 | **MIC5501-xYMT** | **Micrel, Inc.[14]** | **Single 300mA LDO in 1.0mm × 1.0mm DFN Package** | 1 |
| | **MIC5502-xYMT** | | | |
| | **MIC5503-xYMT** | | | |
| | **MIC5504-xYMT** | | | |

**Notes:**

13.  Murata:  www.murata.com.

14.  **Micrel, Inc.:  www.micrel.com.**

## PCB Layout Recommendations (1mm × 1mm Thin DFN)
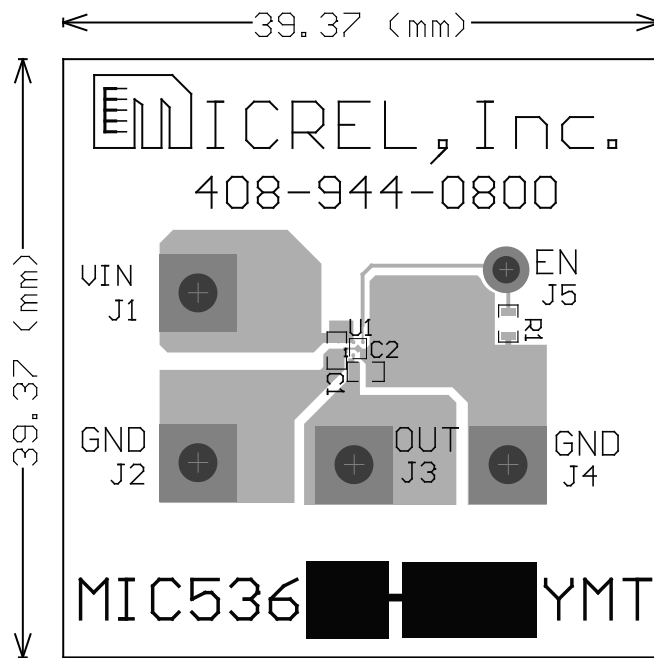


**Top Layer**
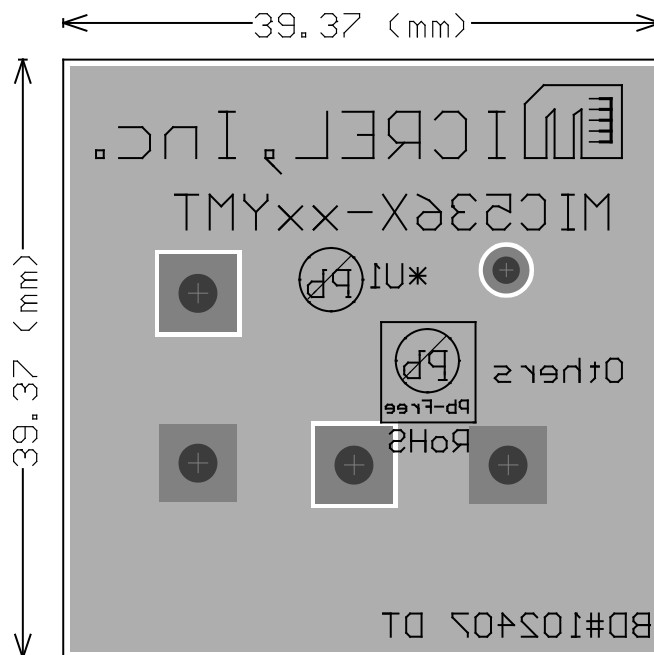


**Bottom Layer**

# Package Information[15] and Recommended Landing Pattern



TOP VIEW

BOTTOM VIEW

SIDE VIEW

RECOMMENDED LAND PATTERN
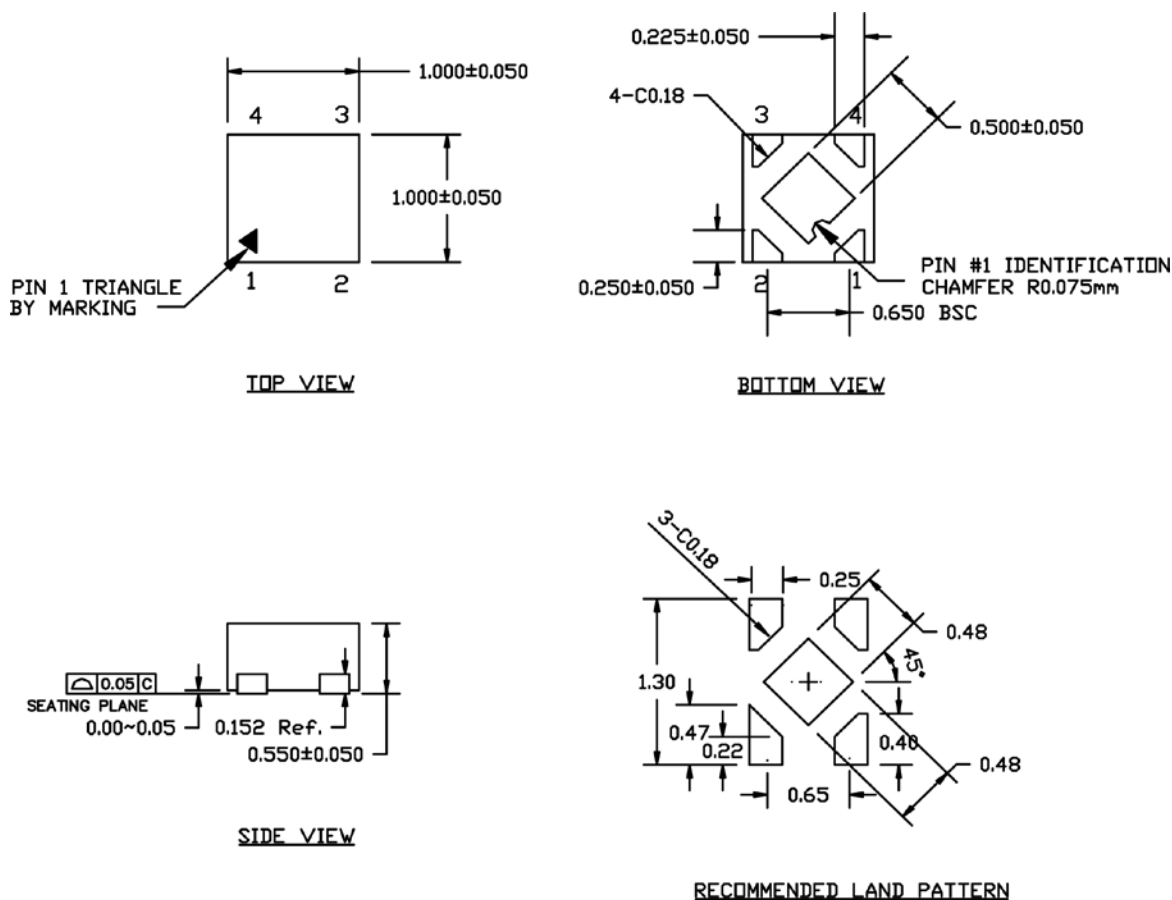
NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM  IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. UNSPECIFIED TOLERANCE IS +/- 0.05 MM

**4-Pin 1mm x 1mm 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)
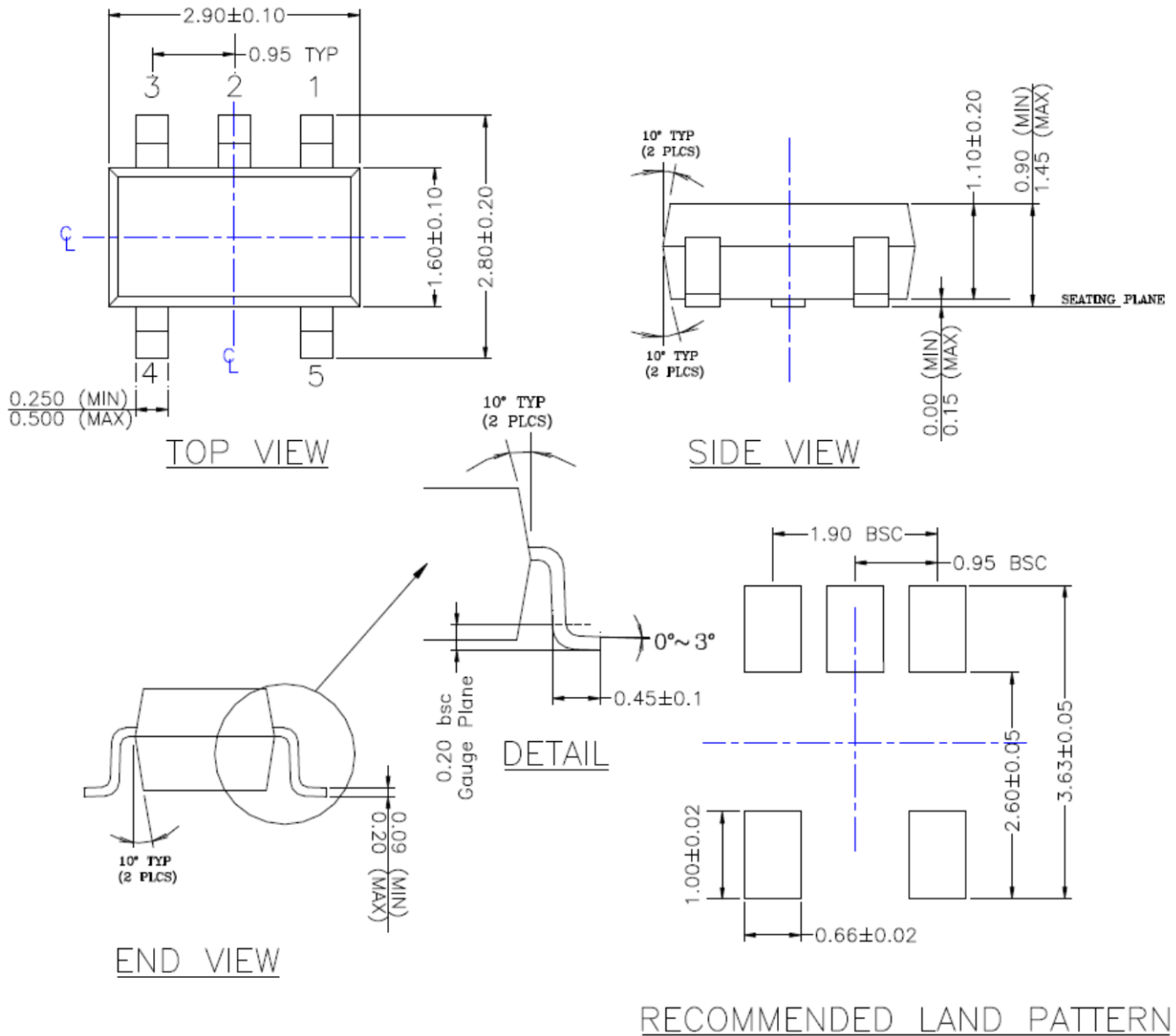


NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & BURR.
2. PACKAGE OUTLINE INCLUSIVE OF SOLER PLATING.
3. DIMENSION AND TOLERANCE PER ANSI Y14.5M, 1982.
4. FOOT LENGTH MEASUREMENT BASED ON GAUGE PLANE METHOD.
5. DIE FACES UP FOR MOLD, AND FACES DOWN FOR TRIM/FORM.
6. ALL DIMENSIONS ARE IN MILLIMETERS.

**5-Pin SOT23 (M5)**

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| MIC5504-3.1YMT-TZ | MIC5504-2.8YMT-TZ | MIC5501-3.0YMT-T5 | MIC5504-3.1YMT-T5 | MIC5504-1.8YMT-TZ |
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| MIC5501-3.0YM5-TR | MIC5504-1.2YMT-TR | MIC5504-3.3YM5-T5 | MIC5504-1.8YM5-T5 | MIC5504-2.8YM5-TR |
| MIC5504-1.8YM5-TR | MIC5503-1.8YMT-TR | MIC5504-1.2YM5-TR | MIC5504-3.1YMT-TR | MIC5501-1.8YMT-TR |
| MIC5504-2.2YMT-T5 | MIC5504-1.2YM5-T5 | MIC5504-2.5YM5-TR | MIC5501-3.0YMT-TR | MIC5504-2.8YMT-TR |
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| MIC5502-2.8YMT-TR | MIC5501-3.0YM5-T5 | MIC5504-2.5YMT-TZ | MIC5504-2.5YM5-T5 | MIC5504-2.5YMT-T5 |