# MIC5355/6

## Dual 500mA µCap Low Dropout, Micropower Linear Regulator

## General Description

The MIC5355/6 is an advanced dual, micropower, low dropout linear regulator. The MIC5355/6 provides low quiescent current operation, using only 70µA with both outputs enabled making it ideal for battery-powered systems. In shutdown, the quiescent current drops to less than 1µA. The MIC5355/6 provides two independently-controlled high-performance 500mA LDOs with typical dropout voltage of 350mV at rated load. In addition, the MIC5355/6 is optimized to provide fast load and line transient performance with low-ESR ceramic output capacitors, requiring a minimum of only 2.2µF.

The MIC5356 also incorporates an active discharge feature when the part is disabled that switches in a 30Ω load to pull down the output of the regulator. The MIC5355/6 is available in fixed output voltages in a thermally-enhanced 8-pin ePad MSOP package or 8-pin ePad 3mm x 3mm MLF® package.

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

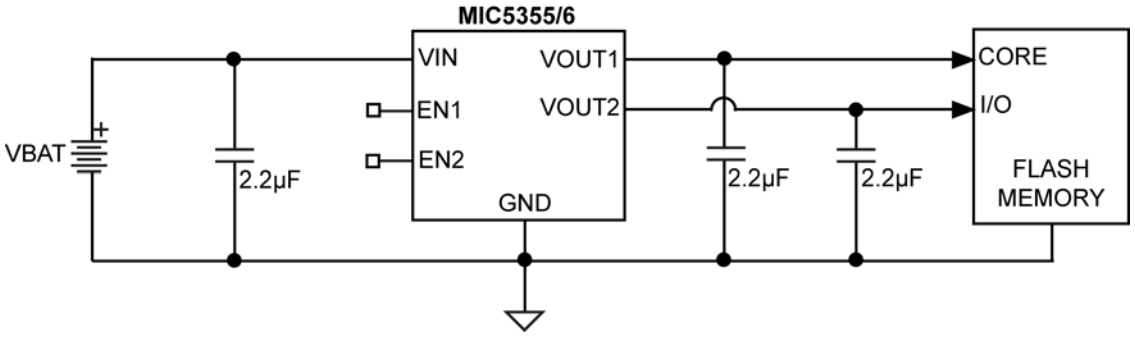
## Features

- 2.5V to 5.5V input voltage range
- 2% initial output accuracy
- Wide output voltage range: 1.0V to 3.3V
- Low quiescent current: 38µA per output
- Very low quiescent current in shutdown: <1µA typical
- µCap stable with 2.2µF ceramic capacitor
- Low dropout voltage: 350mV at 500mA
- Excellent load/line transient response
- Independent logic controlled enable pins
- Output discharge circuit: MIC5356
- Current and thermal limit protection
- Power 8-pin ePad MSOP package or 8-pin ePad 3mm x 3mm MLF® package

## Applications

- Smart phones
- GPS, PMP, DSC
- Notebooks and desktops
- Digital TV
- Portable electronics

## Typical Application

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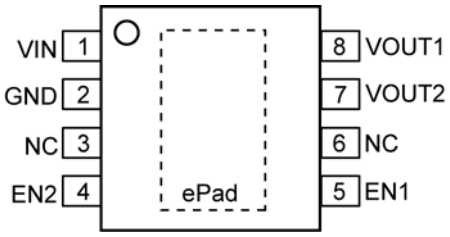
## Ordering Information

| Manufacturer Ordering Part Number | Part Number[1] | Marking Code | Voltage[2] | Junction Temperature Range | Package |
|---|---|---|---|---|---|
| MIC5355-SGYMME | MIC5355-3.3/1.8YMME | 55SG | 3.3V/1.8V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5355-S4YMME | MIC5355-3.3/1.2YMME | 55S4 | 3.3V/1.2V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5355-SCYMME | MIC5355-3.3/1.0YMME | 55SC | 3.3V/1.0V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5355-G4YMME | MIC5355-1.8/1.2YMME | 55G4 | 1.8V/1.2V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5355-JGYMME | MIC5355-2.5/1.8YMME | 55JG | 2.5V1.8V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5356-SGYMME | MIC5356-3.3/1.8YMME | 56SG | 3.3V/1.8V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5356-S4YMME | MIC5356-3.3/1.2YMME | 56S4 | 3.3V/1.2V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5356-SCYMME | MIC5356-3.3/1.0YMME | 56SC | 3.3V/1.0V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5356-G4YMME | MIC5356-1.8/1.2YMME | 56G4 | 1.8V/1.2V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5356-JGYMME | MIC5356-2.5/1.8YMME | 56JG | 2.5V/1.8V | –40° to +125°C | 8-Pin ePad MSOP |
| MIC5356-MMYML | MI5356-2.8/2.8YML | M3M | 2.8V/2.8V | –40° to +125°C | 8-Pin ePad 3mm x 3mm MLF® |
| MIC5356-MGYML | MI5356-2.8/1.8YML | M3G | 2.8V/1.8V | –40° to +125°C | 8-Pin ePad 3mm x 3mm MLF® |

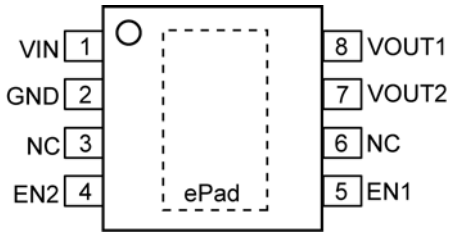
**Notes:**

1. MIC5356 offers Auto-Discharge function.
2. Other voltage available. Contact Micrel for detail.

## Pin Configuration




**8-Pin ePad MSOP (MME)**




**8-Pin ePad 3mm x 3mm MLF® (ML)**

## Pin Description

| Pin Number | Pin Name | Pin Function |
|---|---|---|
| 1 | VIN | Supply Input. |
| 2 | GND | Ground. |
| 3 | NC | Not internally connected. |
| 4 | EN2 | Enable Input LDO2. Active High Input. Logic High = On; Logic Low = Off; Do not leave floating. |
| 5 | EN1 | Enable Input LDO1. Active High Input. Logic High = On; Logic Low = Off; Do not leave floating. |
| 6 | NC | Not internally connected. |
| 7 | VOUT2 | LDO2 Output. |
| 8 | VOUT1 | LDO1 Output. |
| ePad | HSPAD | Heatsink pad. Connect to ground. |

## Absolute Maximum Ratings[1]

Supply Voltage ($V_{IN}$) ..... –0.3V to +6V
Enable Voltage ($V_{EN1}$, $V_{EN2}$) ..... –0.3V to $V_{IN}$ +0.3V
Power Dissipation ($P_D$) ..... Internally Limited[3]
Lead Temperature (soldering, 10sec.) ..... 260°C
Junction Temperature ($T_J$) ..... –40°C to +125°C
Storage Temperature ($T_s$) ..... –65°C to +150°C
ESD Rating[4] ..... ESD Sensitive

## Operating Ratings[2]

Supply Voltage ($V_{IN}$) ..... +2.5V to 5.5V
Enable Voltage ($V_{EN1}$, $V_{EN2}$) ..... 0V to $V_{IN}$
Junction Temperature ($T_J$) ..... –40°C to +125°C
Junction Thermal Resistance
8-Pin ePad MSOP ($\theta_{JA}$) ..... 64.4°C/W
8-Pin ePad 3mm x 3mm MLF® ($\theta_{JA}$) ..... 61°C/W

## Electrical Characteristics[5]

$V_{IN} = V_{EN1} = V_{EN2} = V_{OUT}$ +1V; higher of the two outputs; $I_{OUTLDO1} = I_{OUTLDO2}$ = 100µA; $C_{OUT1} = C_{OUT2}$= 2.2 µF; $T_J$ = +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 $V_{OUT}$ | **–3.0** | | **+3.0** | |
| Line Regulation | $V_{IN} = V_{OUT}$ + 1V to 5.5V, $I_{OUT}$ = 100µA | | 0.02 | **0.3** | %/V |
| Load Regulation | $I_{OUT}$ = 100µA to 500mA | | 0.3 | **1** | % |
| Dropout Voltage | $I_{OUT}$ = 50mA | | 40 | **100** | mV |
| | $I_{OUT}$ = 500mA | | 350 | **800** | |
| Ground Pin Current | $V_{EN1}$ = High; $V_{EN2}$ = Low; $I_{OUT1}$ = 0mA | | 38 | **53** | µA |
| | $V_{EN1}$ = Low; $V_{EN2}$ = High; $I_{OUT2}$ = 0mA | | 38 | **53** | |
| | $V_{EN1} = V_{EN2}$ = High; $I_{OUT1} = I_{OUT2}$ = 0mA | | 70 | **100** | |
| | $V_{EN1}$ = High; $V_{EN2}$ = Low; $I_{OUT1}$ = 500mA | | 55 | **90** | |
| | $V_{EN1}$ = Low; $V_{EN2}$ = High; $I_{OUT2}$ = 500mA | | 55 | **90** | |
| | $V_{EN1} = V_{EN2}$ = High; $I_{OUT1} = I_{OUT2}$ = 500mA | | 105 | **200** | |
| Shutdown Current | $V_{EN1} = V_{EN2} \leq 0.2V$ | | 0.05 | 1 | µA |
| Ripple Rejection | f = 1kHz; $C_{OUT}$ = 2.2µF; $I_{OUT}$ = 250mA | | 60 | | dB |
| Current Limit | $V_{OUT}$ = 0V | 525 | 750 | 1050 | mA |
| Output Voltage Noise | $C_{OUT}$ = 2.2µF, 10Hz to 100kHz | | 146 | | $\mu V_{RMS}$ |
| Auto-Discharge NFET Resistance | MIC5356 only; $V_{EN1} = V_{EN2}$ = 0V; $V_{IN}$ = 3.6V; $I_{OUT}$ = –3mA | | 30 | | Ω |

**Notes:**

1. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. 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 register will go into thermal shutdown.
4. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5kΩ in series with 100pF.
5. Specification for packaged product only.

## Electrical Characteristics[4]

$V_{IN} = V_{EN1} = V_{EN2} = V_{OUT}$ +1V; higher of the two outputs; $I_{OUTLDO1} = I_{OUTLDO2}$ = 100µA; $C_{OUT1} = C_{OUT2}$= 2.2 µF; $T_J$ = +25°C, **bold** values indicate –40°C to +125°C, unless noted.

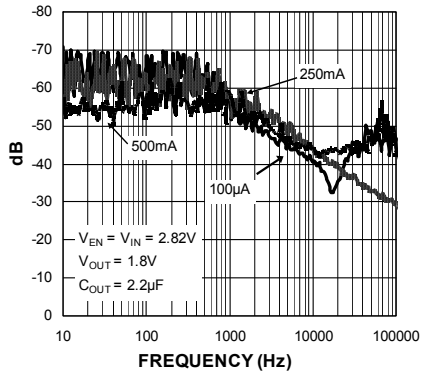
| Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| **Enable Inputs (EN1/EN2)** | | | | | |
| Enable Input Voltage | Logic Low | | | **0.2** | V |
| | Logic High | **1.2** | | | |
| Enable Input Current | $V_{IL} \leq 0.2V$ | | 0.01 | 1 | µA |
| | $V_{IH} \geq 1.2V$ | | 0.01 | 1 | |
| Turn-On Time | | | 50 | 125 | µs |

**Notes:**

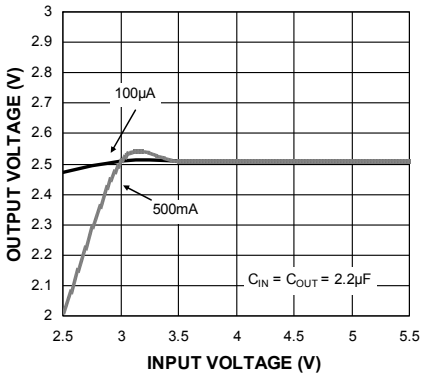
1. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5kΩ in series with 100pF.
4. Specification for packaged product only.

# Typical Characteristics

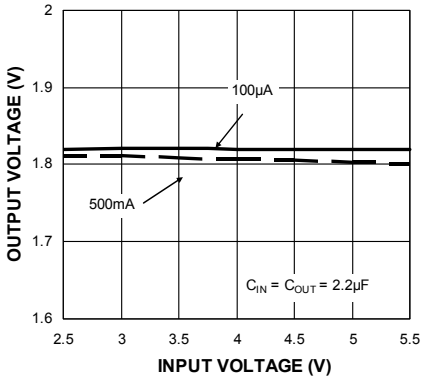
**Power Supply Rejection Ratio**



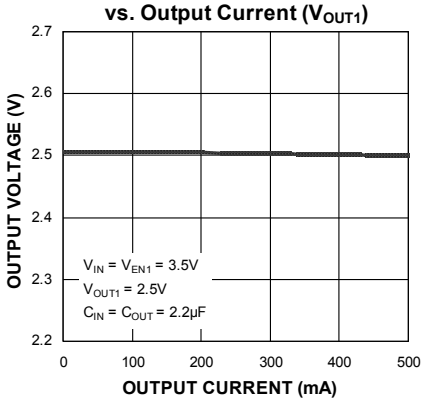

**Output Voltage vs. Input Voltage**



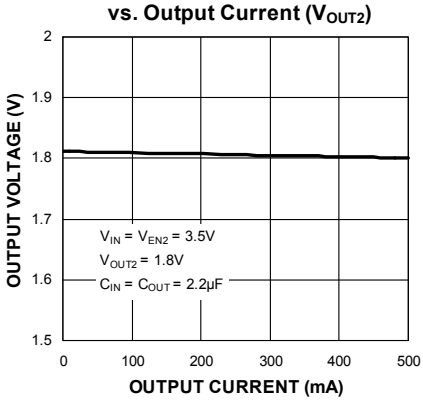

**Output Voltage vs. Input Voltage**



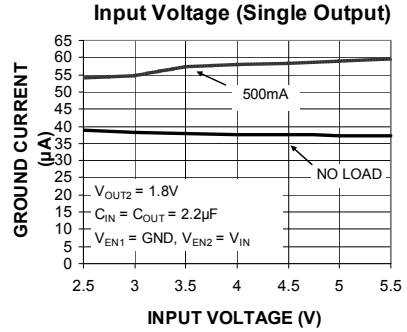

**Output Voltage vs. Output Current ($V_{OUT1}$)**



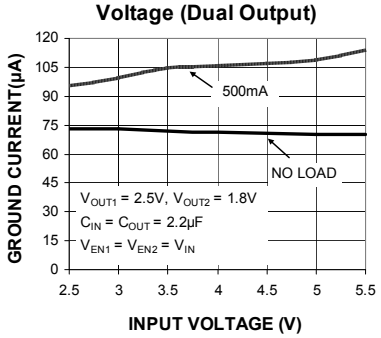

**Output Voltage vs. Output Current ($V_{OUT2}$)**



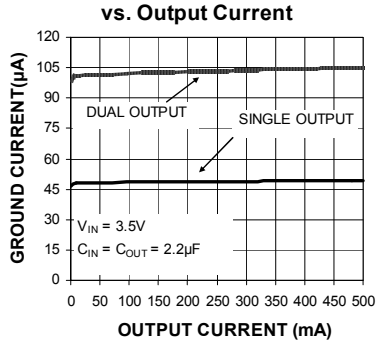

**Ground Current vs. Input Voltage (Single Output)**



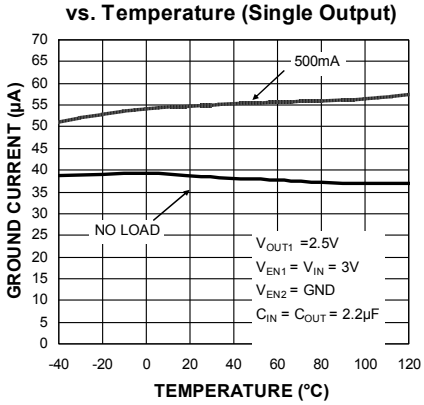

**Ground Current vs. Input Voltage (Dual Output)**




**Ground Current vs. Output Current**

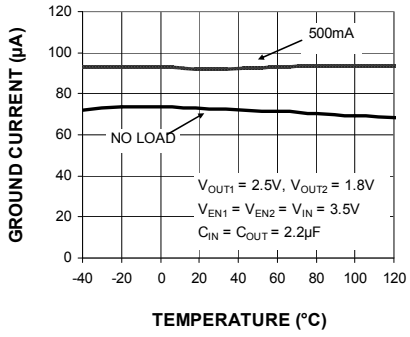



**Ground Current vs. Temperature (Single Output)**

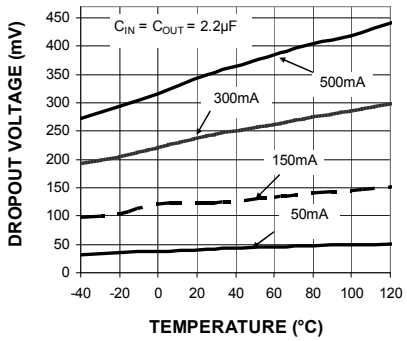


## Typical Characteristics (Continued)

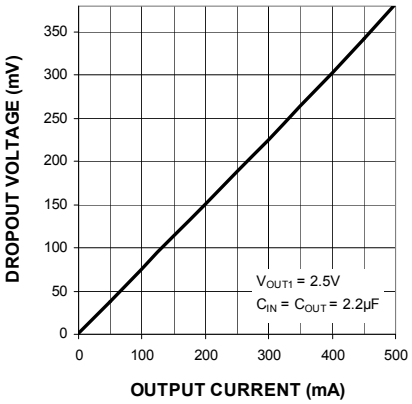
**Ground Current vs. Temperature (Dual Output)**



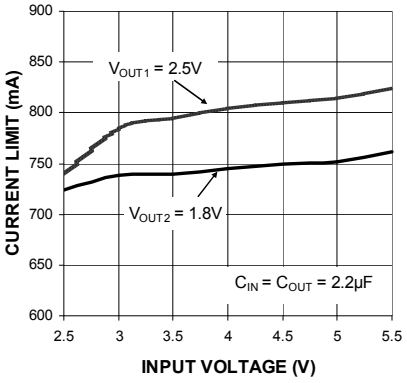

**Dropout Voltage vs. Temperature**



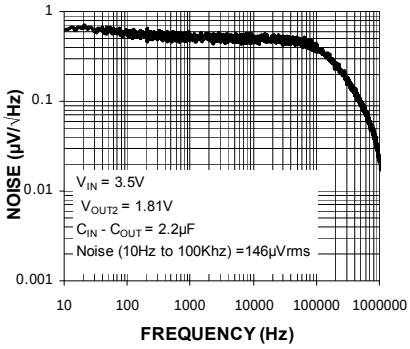

**Dropout Voltage vs. Output Current**




**Current Limit vs. Input Voltage**

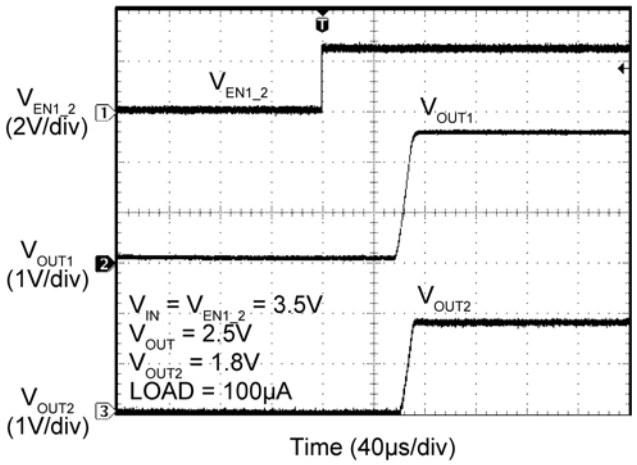



**Output Noise Spectral Density**

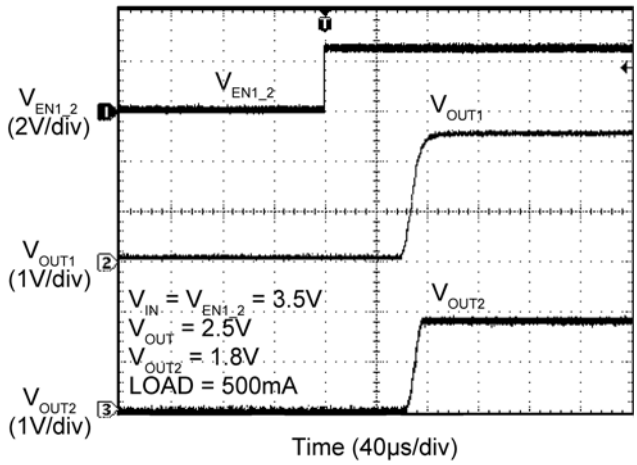


## Functional Characteristics

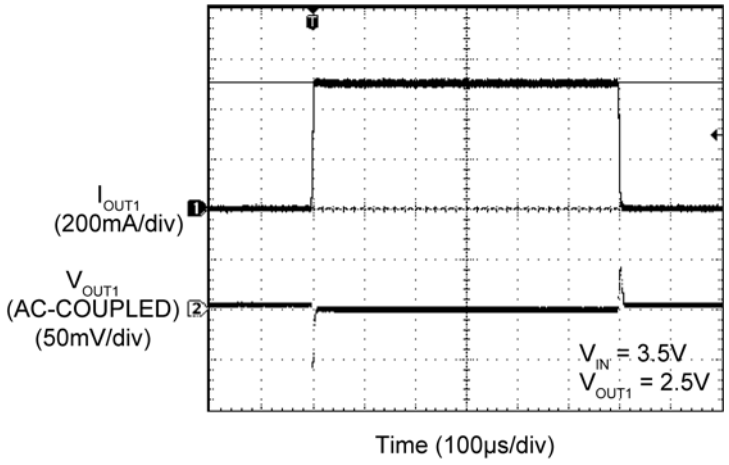
**Enable Turn-On**



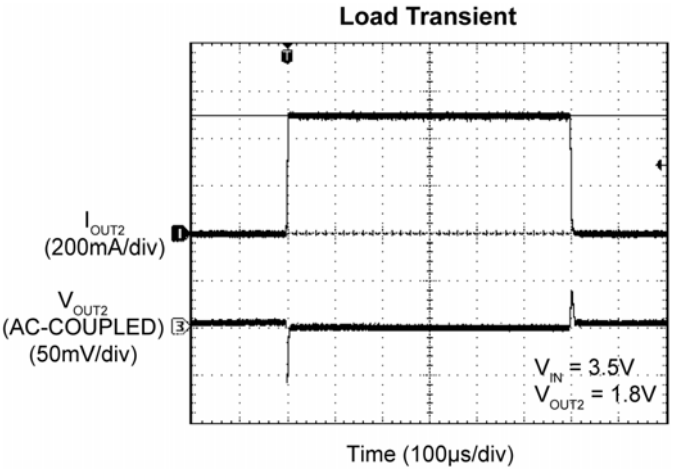

**Enable Turn-On**



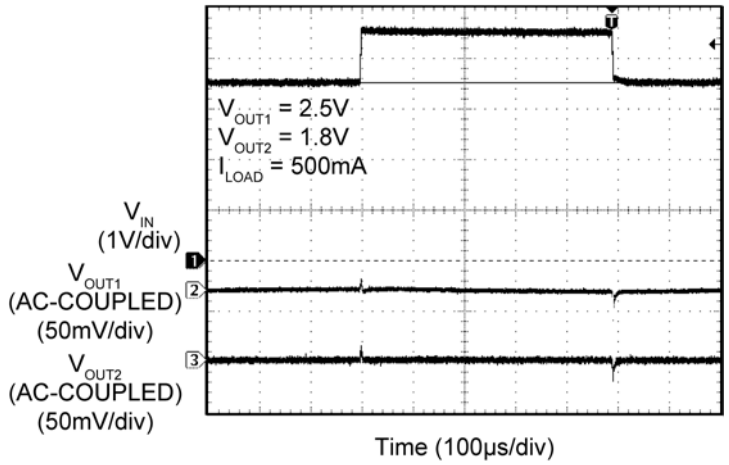

**Load Transient**



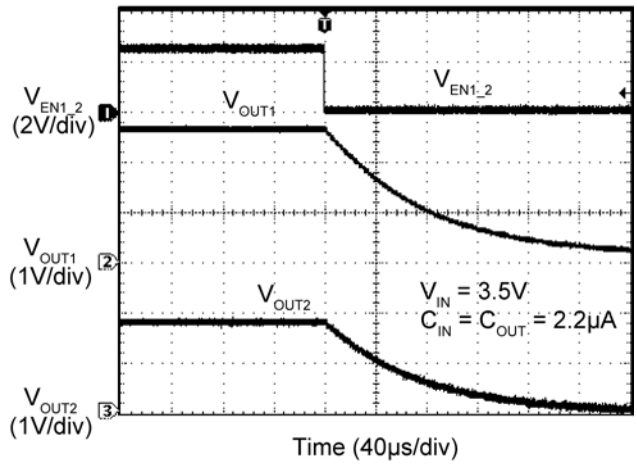

**Load Transient**



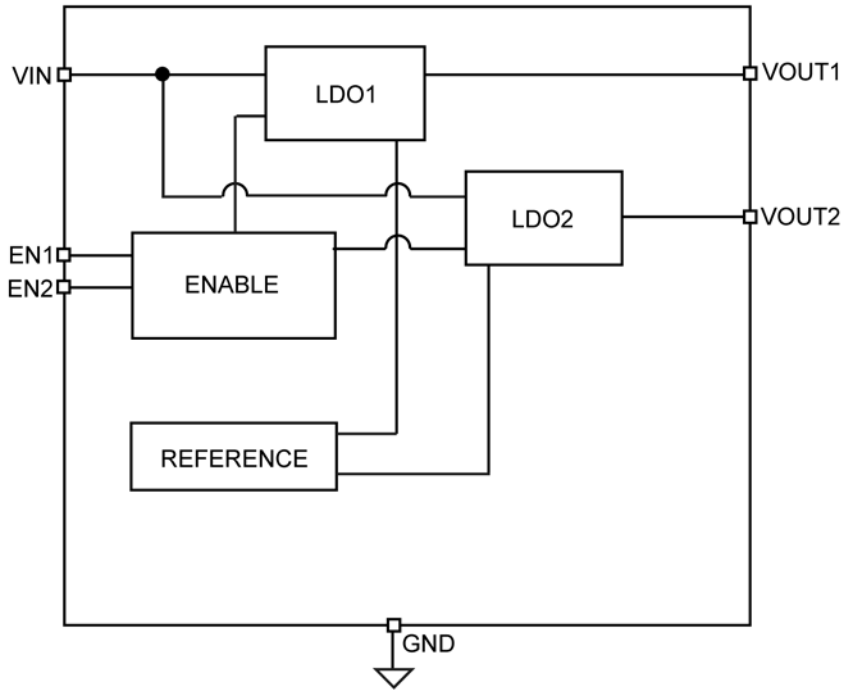

**Line Transient**



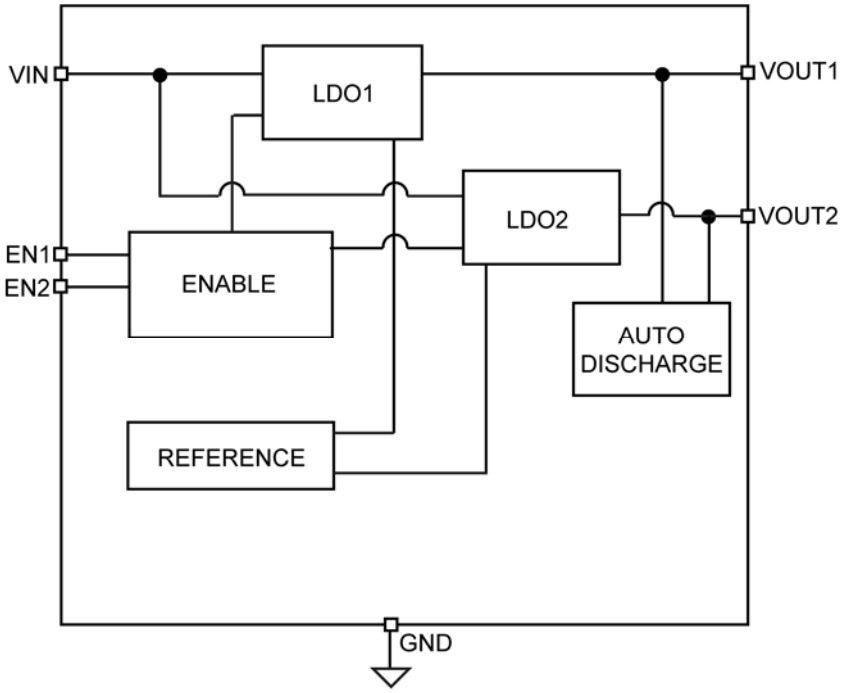

**Auto Discharge (No Load)**



## Functional Diagrams




**MIC5355 Block Diagram**




**MIC5356 Block Diagram**

## Application Information

MIC5355/6 is a dual 500mA LDO. The MIC5356 includes an auto-discharge circuit for each LDO output that is activated when the output is disabled. The MIC5355/6 regulator is fully protected from damage due to fault conditions through linear current limiting and thermal shutdown.

### Input Capacitor

The MIC5355/6 is a high-performance, high-bandwidth device. A 2.2µF input capacitor from the input pin to ground is required to provide stability. Low-ESR ceramic capacitors provide optimal performance in small board area. 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 MIC5355/6 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 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 and X5R dielectric ceramic capacitors are recommended because of their temperature performance. X7R 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 MIC5355/6 will remain stable and in regulation with no load.

### Enable/Shutdown

The MIC5355/6 comes with two active high enable pins that allow each regulator to be disabled independently. Forcing the enable pin low disables the regulator and places it into an off mode current state drawing virtually zero current. When disabled, the MIC5356 switches an internal 30Ω load on the regulator output to discharge the external capacitor.

Forcing the enable pin high enables the output voltage. The active high enable pin uses CMOS technology and cannot be left floating. A floating enable pin may cause an indeterminate state on the output.

### Thermal Considerations

The MIC5355/6 is designed to provide two 500mA continuous current outputs in a small package. Maximum operating temperature can be calculated based on the output currents and the voltage drop across the part. For example, if the input voltage is 3.0V, $V_{OUT1}$ = 2.5V, $V_{OUT2}$ = 1.8V and each with an output current = 500mA. The actual power dissipation of the regulator circuit can be determined using the equation:

$$P_D = (V_{IN} - V_{OUT1})\ I_{OUT} + (V_{IN} - V_{OUT2})\ I_{OUT2} + V_{IN}\ I_{GND}$$

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

$$P_D = (3.0V - 2.5V) \times 500mA + (3.0V - 1.8V) \times 500mA$$
$$P_D = 0.85W$$

To determine the maximum ambient operating temperature of the package, use the junction to ambient thermal resistance of the device and the following basic equation:

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

$T_{J(MAX)}$ = 125°C
$\theta_{JA}$ = 64.4°C/W

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 64.4°C/W.

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

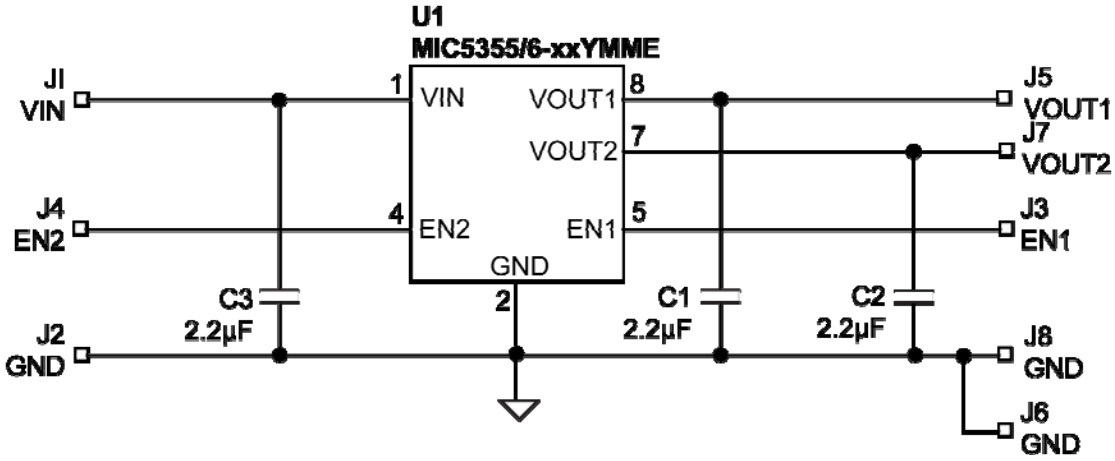
For example, when operating a 2.5V/1.8V application with an input voltage of 3.0V and 500mA at each output with a minimum footprint layout, the maximum ambient operating temperature $T_A$ can be determined as follows:

$$0.85W = (125°C – T_A)/(64.4°C/W)$$
$$T_A = 70.3°C$$

Therefore, a MIC5355-JGYMME application with 500mA at each output current can accept an ambient operating temperature of 70.3°C in a small 8-pin ePad MSOP package. 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



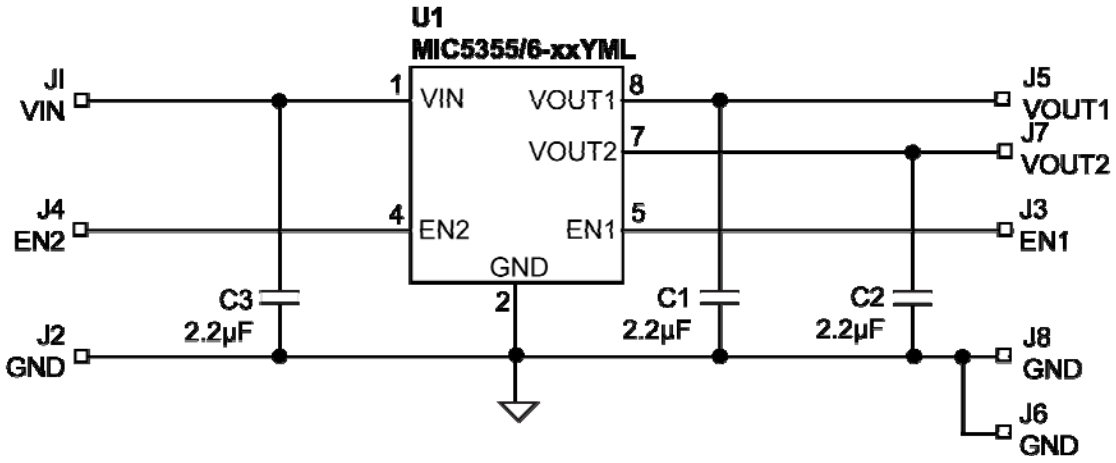

## Bill of Materials

| Item | Part Number | Manufacturer | Description | Qty. |
|---|---|---|---|---|
| C1, C2, C3 | C1005X5R0J225M | TDK[1] | 2.2µF ceramic capacitor, 6.3V, X5R, size 0402 | 3 |
| **U1** | **MIC5355/6-xxYMME** | **Micrel, Inc.[2]** | **Dual 500mA µCap Low-Dropout, Micropower Linear Regulator** | **1** |

**Notes:**

1. TDK: www.tdk.com.
2. **Micrel, Inc.: www.micrel.com.**

## Typical Application Schematic (Continued)



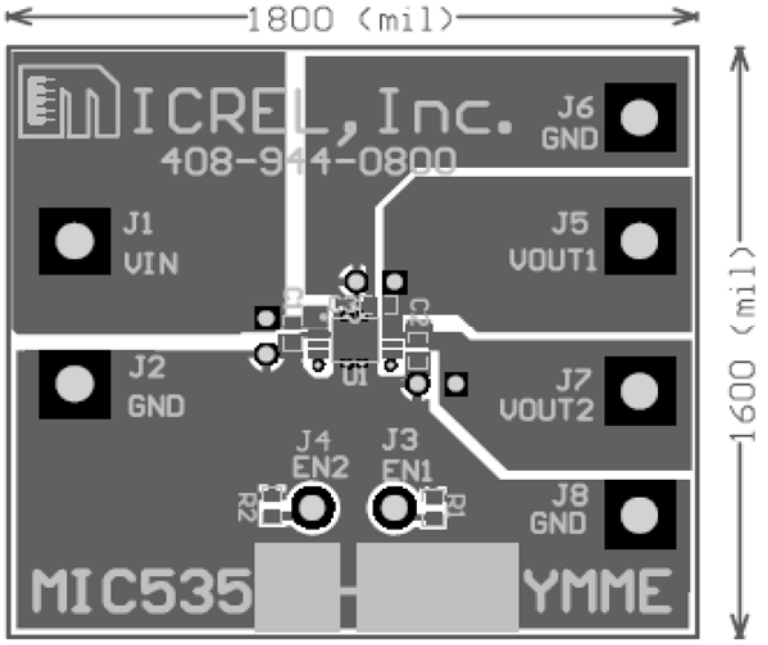

## Bill of Materials

| Item | Part Number | Manufacturer | Description | Qty. |
|---|---|---|---|---|
| C1, C2, C3 | C1005X5R0J225M | TDK[1] | 2.2µF ceramic capacitor, 6.3V, X5R, size 0402 | 3 |
| **U1** | **MIC5355/6-xxYML** | **Micrel, Inc.[2]** | **Dual 500mA µCap Low-Dropout, Micropower Linear Regulator** | **1** |

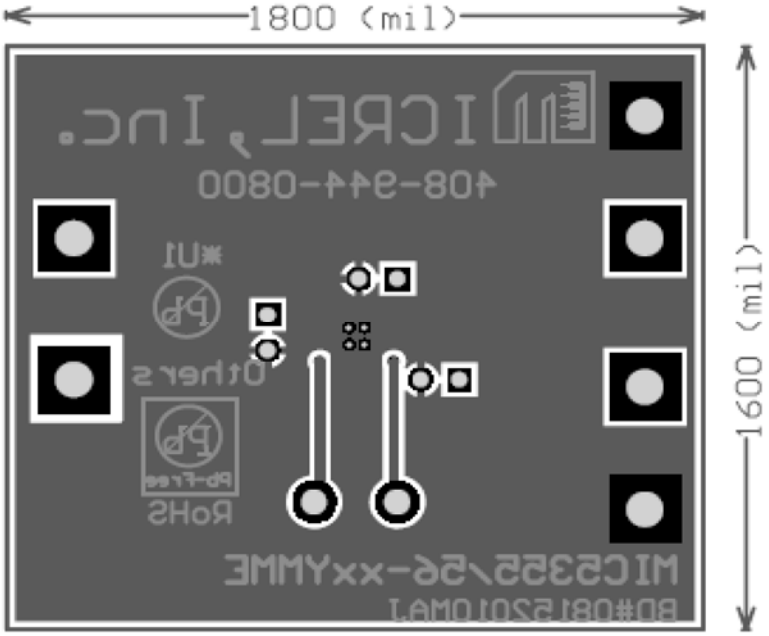
**Notes:**

3. TDK: www.tdk.com.
4. **Micrel, Inc.: www.micrel.com.**

## PCB Layout Recommendations (MME Package)

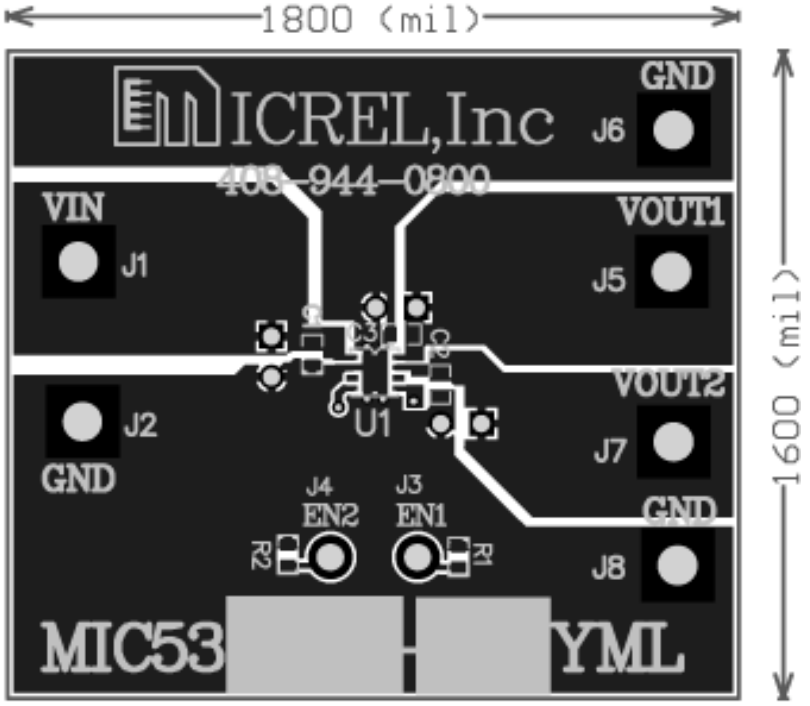



**Top Layer**

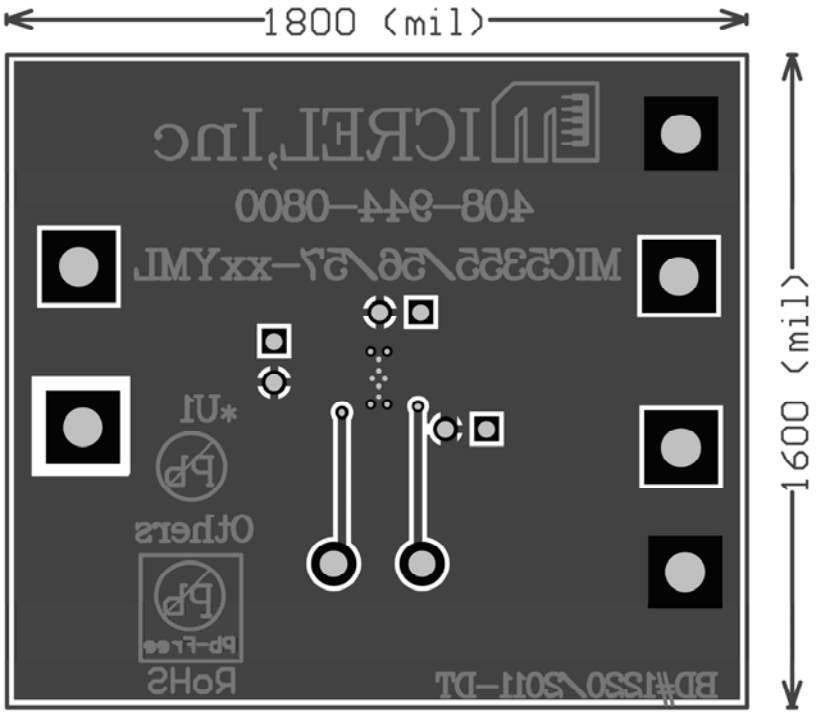



**Bottom Layer**

## PCB Layout Recommendations (ML Package)

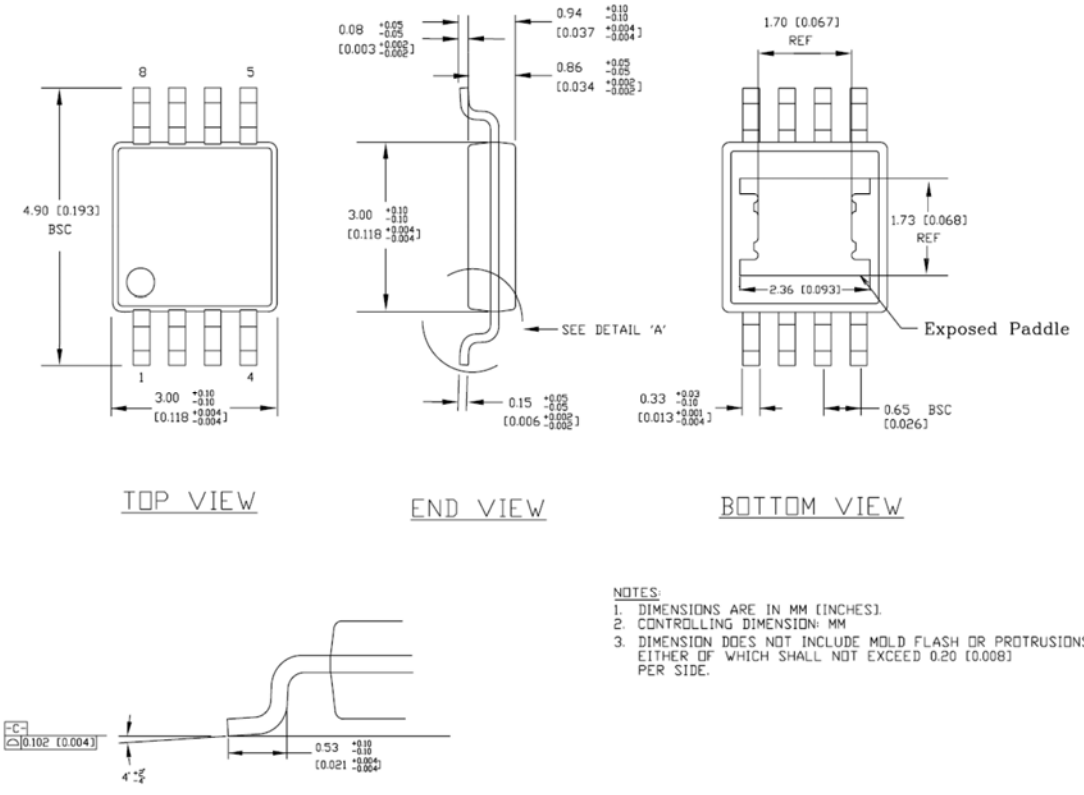



**Top Layer**

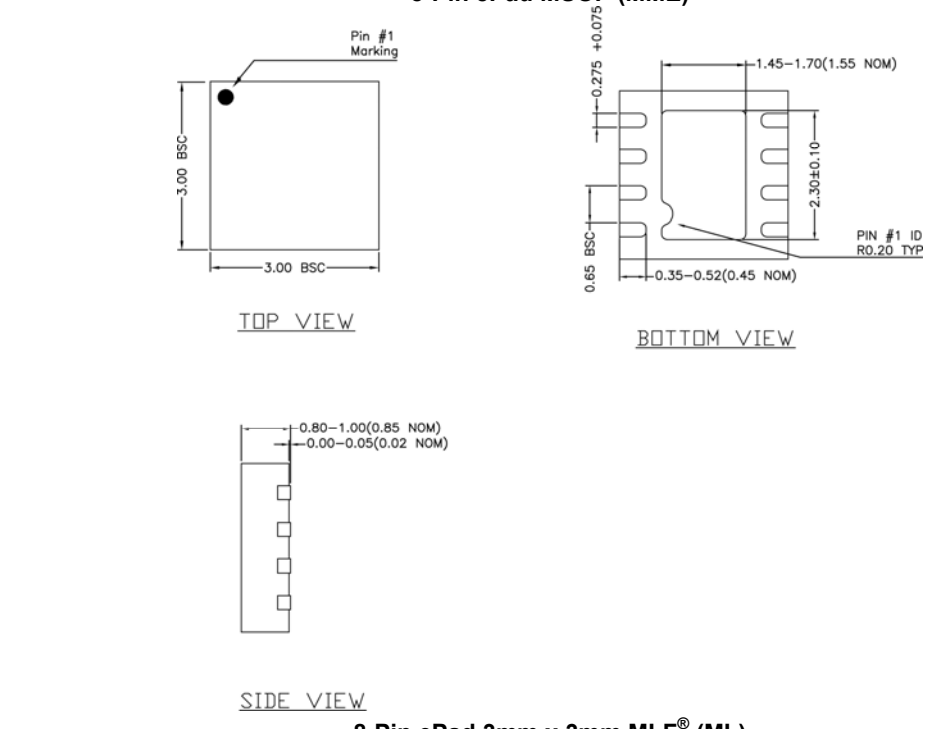



**Bottom Layer**

## Package Information



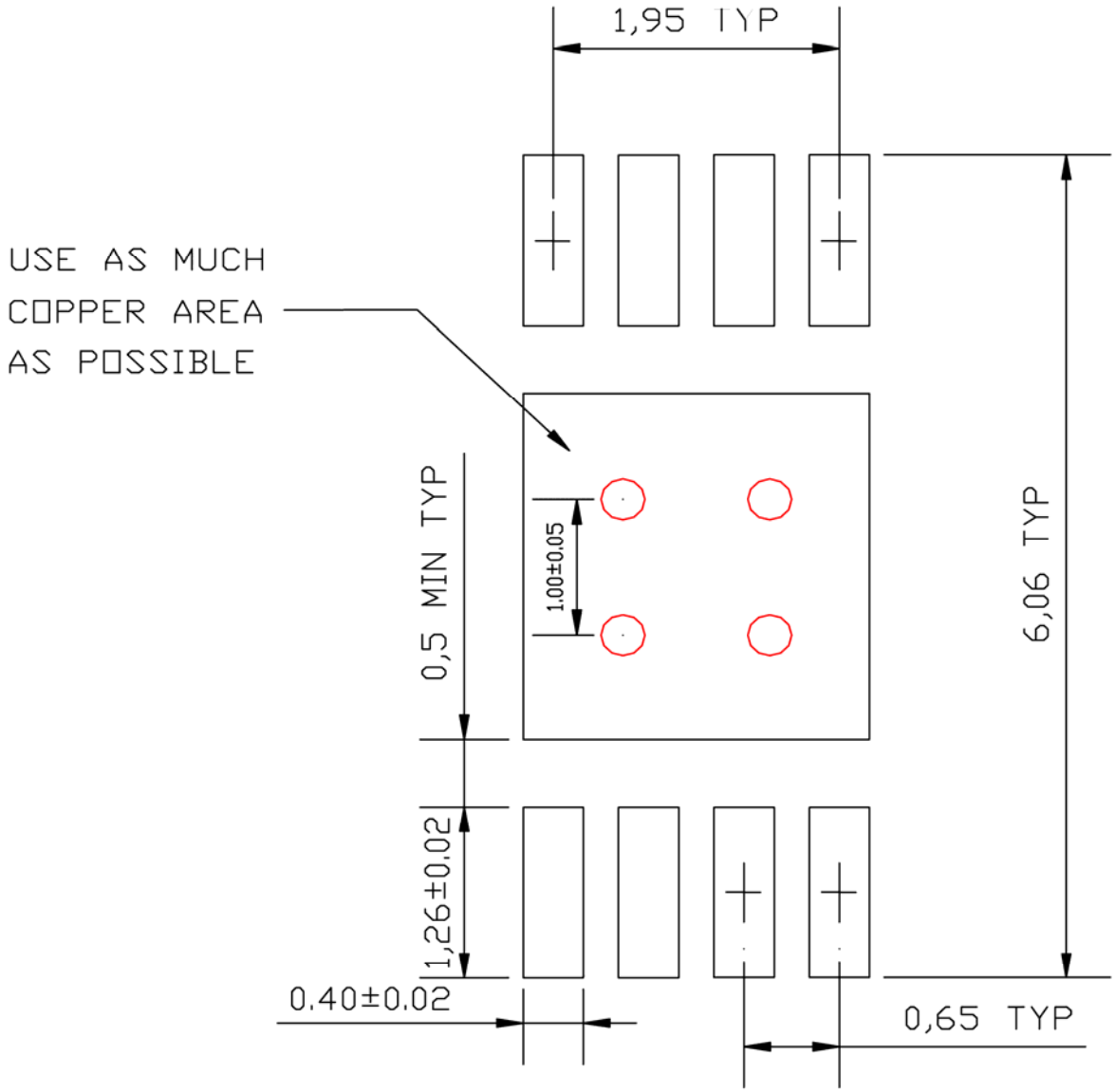

**8-Pin ePad MSOP (MME)**




**8-Pin ePad 3mm x 3mm MLF® (ML)**

## Package Information (Continued)

**LP # MSOPEP-8LD-LP-1**
All units are in mm
Tolerance ± 0.05 if not noted

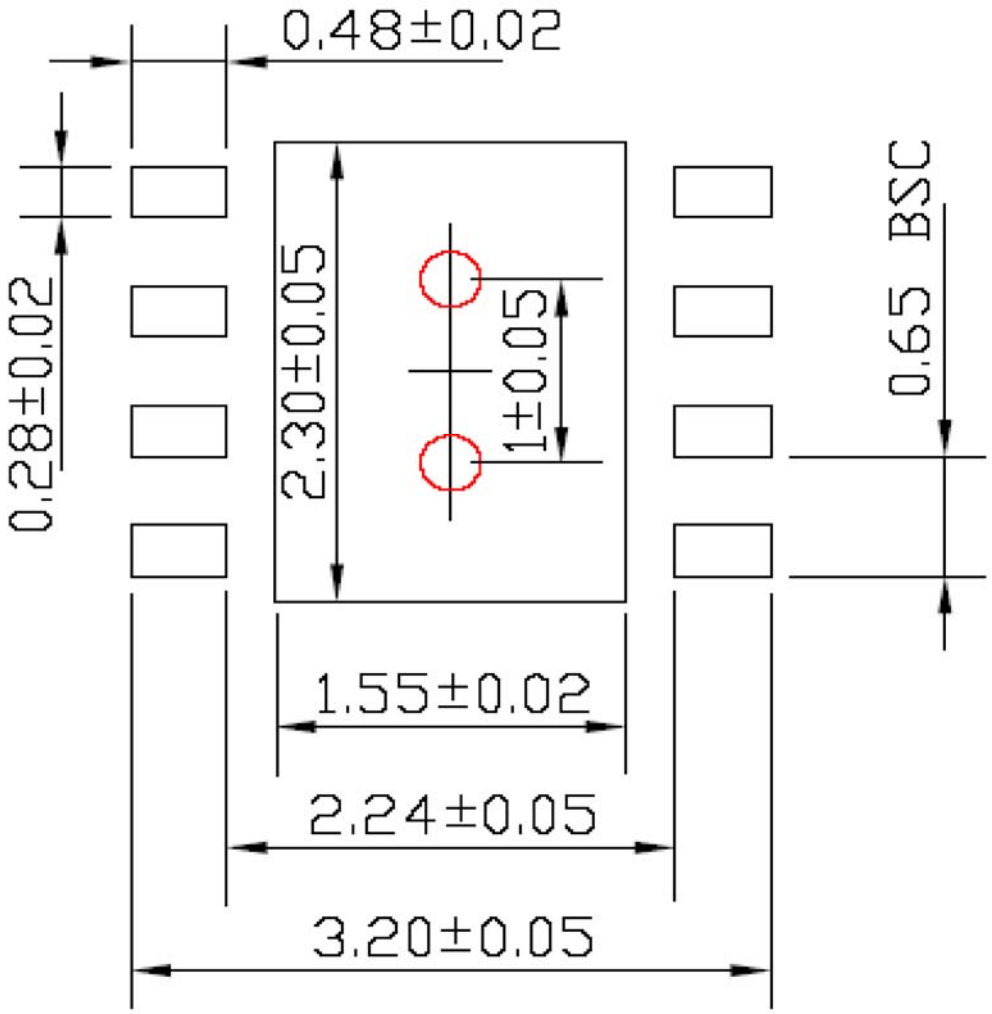



Red circle indicates Thermal Via. Size should be .300 −.350mm in diameter, 1/00mm pitch, and it should be connected to GND plane for maximum thermal performance.

**8-Pin ePad MSOP (MME)**

## Package Information (Continued)

**LP # MLF33D-8LD-LP-1**
All units are in mm
Tolerance ± 0.05 if not noted




Red circle indicates Thermal Via. Size should be .300 −.350mm in diameter, 1/00mm pitch, and it should be connected to GND plane for maximum thermal performance.

**8-Pin ePad 3mm x 3mm MLF® (ML)**

**MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA**
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