General Description
The MIC5353 is a high-performance, single-output, ultra-low LDO (ULDO™) regulator, offering a low total output noise of 30\(\mu\)VRMS. The MIC5353 is capable of sourcing 500mA output current and offers high-PSRR and low-output noise, making it an ideal solution for RF applications.

The MIC5353 provides 2% accuracy, extremely low dropout voltage (160mV @ 500mA), and low ground current (typically 90\(\mu\)A) making it ideal for battery-operated applications. When disabled, the MIC5353 enters a zero-off-mode current state, thereby drawing almost no current.

The MIC5353 is available in the 1.6mm x 1.6mm Thin MLF® package, occupying only 2.56mm\(^2\) of PCB area, a 36% reduction in board area compared to SC-70 and 2mm x 2mm Thin MLF® packages.

The MIC5353 has an operating junction temperature range of –40°C to +125°C and is available in fixed and adjustable output voltages in lead-free (RoHS-compliant) Thin MLF® package.

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

Features
- 500mA guaranteed output current
- Input voltage range: 2.6V to 6V
- Ultra low dropout voltage: 160mV @ 500mA
- ±2% initial accuracy
- Ultra low output noise: 30\(\mu\)VRms
- Low quiescent current: 90\(\mu\)A
- Stable with ceramic output capacitors
- 35\(\mu\)s turn-on time
- Thermal shutdown and current limit protection
- Tiny 6-pin 1.6mm x 1.6mm Thin MLF® leadless package

Applications
- Mobile Phones
- GPS, PDAs, PMP, handhelds
- Portable electronics
- Digital still and video cameras
- Digital TV

Typical Application

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**Reflector Application**

[Diagram of the MIC5353 application in a portable device]

ULDO is a trademark of Micrel, Inc
MLF and MicroLeadFrame are registered trademarks of Amkor Technology, Inc.

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October 27, 2015
Revision 2.0
Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Marking Code(1)</th>
<th>Output Voltage(2)</th>
<th>Temperature Range</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIC5353-1.8YMT</td>
<td>18R</td>
<td>1.8V</td>
<td>–40°C to +125°C</td>
<td>6-Pin 1.6mm x 1.6mm Thin MLF®</td>
</tr>
<tr>
<td>MIC5353-2.5YMT</td>
<td>25R</td>
<td>2.5V</td>
<td>–40°C to +125°C</td>
<td>6-Pin 1.6mm x 1.6mm Thin MLF®</td>
</tr>
<tr>
<td>MIC5353-2.6YMT</td>
<td>26R</td>
<td>2.6V</td>
<td>–40°C to +125°C</td>
<td>6-Pin 1.6mm x 1.6mm Thin MLF®</td>
</tr>
<tr>
<td>MIC5353-2.8YMT</td>
<td>28R</td>
<td>2.8V</td>
<td>–40°C to +125°C</td>
<td>6-Pin 1.6mm x 1.6mm Thin MLF®</td>
</tr>
<tr>
<td>MIC5353-3.0YMT</td>
<td>30R</td>
<td>3.0V</td>
<td>–40°C to +125°C</td>
<td>6-Pin 1.6mm x 1.6mm Thin MLF®</td>
</tr>
<tr>
<td>MIC5353-3.3YMT</td>
<td>33R</td>
<td>3.3V</td>
<td>–40°C to +125°C</td>
<td>6-Pin 1.6mm x 1.6mm Thin MLF®</td>
</tr>
<tr>
<td>MIC5353YMT</td>
<td>AAR</td>
<td>ADJ</td>
<td>–40°C to +125°C</td>
<td>6-Pin 1.6mm x 1.6mm Thin MLF®</td>
</tr>
</tbody>
</table>

Notes:
1. Pin 1 identifier = "▲".
2. For other voltage options contact Micrel Marketing.
3. Thin MLF® is a GREEN RoHS compliant package. Lead finish is NiPdAu, Mold compound is Halogen Free.

Pin Configuration

Pin Description

<table>
<thead>
<tr>
<th>Pin Number Thin MLF-6 Fixed</th>
<th>Pin Number Thin MLF-6 Adjustable</th>
<th>Pin Name</th>
<th>Pin Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>EN</td>
<td>Enable Input. Active High. High = ON, low = OFF. Do not leave floating.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>GND</td>
<td>Ground.</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>VIN</td>
<td>Supply Input.</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>VOUT</td>
<td>Output Voltage.</td>
</tr>
<tr>
<td>5</td>
<td>–</td>
<td>NC</td>
<td>No connection.</td>
</tr>
<tr>
<td>–</td>
<td>5</td>
<td>ADJ</td>
<td>Adjust Input. Connect to external resistor voltage divider network.</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>BYP</td>
<td>Reference Bypass: Connect external 0.1µF to GND for reduced Output Noise. May be left open.</td>
</tr>
<tr>
<td>EPad</td>
<td>EPad</td>
<td>HS PAD</td>
<td>Exposed Heat-sink Pad connected to ground internally.</td>
</tr>
</tbody>
</table>
**Absolute Maximum Ratings**

Supply Voltage \((V_{IN})\) ................................... \(-0.3V\) to \(+6.5V\)
Enable Input Voltage \((V_{EN})\) ................................ \(-0.3V\) to \(V_{IN}\)
Power Dissipation ........................................... Internally Limited

Lead Temperature (soldering, 3sec) ....................... \(260°C\)
Junction Temperature \((T_J)\) ................................ \(-40°C\) to \(+125°C\)
Storage Temperature \((T_S)\) .................. \(-65°C\) to \(+150°C\)

**ESD Rating** ................................................................. 2KV

**Operating Ratings**

Supply Voltage \((V_{IN})\) .................................. \(+2.6V\) to \(+6.0V\)
Enable Input Voltage \((V_{EN})\) .................. \(0V\) to \(V_{IN}\)
Junction Temperature \((T_J)\) .................. \(-40°C\) to \(+125°C\)
Junction Thermal Resistance ................................. 6-Pin 1.6mm x1.6mm Thin MLF® \((\theta_{JA})\) ......... 92.4°C/W

**Electrical Characteristics**

\(V_{IN} = V_{OUT} + 1.0V; C_{OUT} = 1.0\mu F; I_{OUT} = 100\mu A; T_J = 25°C\), **bold** values indicate \(-40°C\) to \(+125°C\), unless noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage Accuracy</td>
<td>Variation from nominal (V_{OUT})</td>
<td>-2.0</td>
<td>+2.0</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>Variation from nominal (V_{OUT}); (-40°C) to (+125°C)</td>
<td>-3.0</td>
<td>+3.0</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Line Regulation</td>
<td>(V_{IN} = V_{OUT} + 1V) to (6V); (I_{OUT} = 100\mu A)</td>
<td>0.05</td>
<td>0.3</td>
<td></td>
<td>%/V</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>(I_{OUT} = 100\mu A) to (500mA)</td>
<td>0.15</td>
<td>2.0</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Dropout Voltage (\text{(6)})</td>
<td>(I_{OUT} = 150mA)</td>
<td>50</td>
<td>100</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(I_{OUT} = 300mA)</td>
<td>100</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(I_{OUT} = 500mA)</td>
<td>160</td>
<td>350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Pin Current</td>
<td>(I_{OUT} = 0) to (500mA)</td>
<td>90</td>
<td>175</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>Ground Pin Current in Shutdown</td>
<td>(V_{EN} \leq 0.2V)</td>
<td>0.01</td>
<td>2</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>Ripple Rejection</td>
<td>(f = 1kHz); (C_{OUT} = 1.0\mu F; C_{BYP} = 0.1\mu F)</td>
<td>60</td>
<td></td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(f = 20kHz); (C_{OUT} = 1.0\mu F; C_{BYP} = 0.1\mu F)</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Limit</td>
<td>(V_{OUT} = 0V)</td>
<td>600</td>
<td>1100</td>
<td>1600</td>
<td>mA</td>
</tr>
<tr>
<td>Output Voltage Noise</td>
<td>(C_{OUT} = 1.0\mu F; C_{BYP} = 0.1\mu F; 10Hz) to (100kHz)</td>
<td>30</td>
<td></td>
<td>μVRMS</td>
<td></td>
</tr>
</tbody>
</table>

**Enable Input**

| Enable Input Voltage | Logic Low | 0.2 | V |
| Enable Input Current | \(V_{IL} \leq 0.2V\) | 0.01 | 1 | μA |
| | \(V_{IH} \geq 1.2V\) | 0.01 | 1 | |

**Turn-on Time**

| Turn-on Time | \(C_{OUT} = 1.0\mu F; C_{BYP} = 0.1\mu F\) | 35 | 100 | 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. 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.
4. Devices are ESD sensitive. Handling precautions recommended. Human body model 1.5KΩ in series with 100pF.
5. Specification for packaged product only.
6. 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.
Functional Diagram

MIC5353 Block Diagram – FIXED

MIC5353 Block Diagram – ADJUSTABLE
Typical Characteristics

Dropout Voltage vs. Output Current

Dropout Voltage vs. Temperature

Ground Current vs. Output Current

Ground Current vs. Temperature

Output Voltage vs. Output Current

Output Voltage vs. Input Voltage

Current Limit vs. Input Voltage

PSRR

Output Noise Spectral Density
Functional Characteristics

Load Transient (0 to 500mA)

- $V_{IN} = V_{EN} = 3.8V$
- $V_{OUT} = 1.8V$
- $C_{IN} = C_{OUT} = 1\mu F$

Line Transient ($V_{IN} = 4.0V$ to $5.5V$)

- $V_{OUT} = 3.3V$
- $C_{IN} = C_{OUT} = 1\mu F$
- $I_{OUT} = 500mA$

Turn-On Time

- $V_{IN} = 4.5V$
- $V_{OUT} = 2.8V$
- $C_{IN} = C_{OUT} = 1\mu F$
- $C_{BYP} = 0.1\mu F$
- $I_{OUT} = 500mA$

Time scales:
- Load Transient: (100μs/div)
- Line Transient: (20μs/div)
- Turn-On Time: (40μs/div)
Applications Information

Enable/Shutdown
The MIC5353 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 a “zero” off-mode-current state. In this state, current consumed by the regulator goes nearly to zero. Forcing the enable pin high enables the output voltage. The active-high enable pin uses CMOS technology and the enable pin cannot be left floating; a floating enable pin may cause an indeterminate state on the output.

Input Capacitor
The MIC5353 is a high-performance, high bandwidth device. Therefore, it requires a well-bypassed input supply for optimal performance. A 1μF capacitor is required from the input-to-ground to provide stability. Low-ESR ceramic capacitors provide optimal performance at a minimum of space. The use of 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.

Output Capacitor
The MIC5353 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 may cause high-frequency oscillation. The output capacitor can be increased, although performance has been optimized for a 1μF ceramic output capacitor and doing so does not improve significantly with larger capacitance. X7R/X5R dielectric-type ceramic capacitors are recommended because of their temperature performance. The 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 thereby ensuring the same minimum capacitance over the equivalent operating temperature range.

Bypass Capacitor
A capacitor can be placed from the noise bypass pin-to-ground to reduce output voltage noise. The capacitor bypasses the internal reference. A 0.1μF capacitor is recommended for applications that require low-noise outputs. The bypass capacitor can be increased, further reducing noise and improving PSRR. Turn-on time increases slightly with respect to bypass capacitance.

A unique, quick-start circuit allows the MIC5353 to drive a large capacitor on the bypass pin without significantly slowing turn-on time.

No-Load Stability
Unlike many other voltage regulators, the MIC5353 will remain stable and in regulation with no load. This is especially important in CMOS RAM keep-alive applications.

Adjustable Regulator Application
Adjustable regulators use the ratio of two resistors to multiply the reference voltage to produce the desired output voltage. The MIC5353 can be adjusted from 1.25V to 5.5V by using two external resistors (Figure 1). The resistors set the output voltage based on the following equation:

$$ V_{OUT} = V_{REF} \left(1 + \frac{R1}{R2}\right) $$

$$ V_{REF} = 1.25V $$

Figure 1. Adjustable Voltage Output

Thermal Considerations
The MIC5353 is designed to provide 500mA of continuous current. Maximum ambient operating temperature can be calculated based on the output current and the voltage drop across the part. Given that the input voltage is 3.3V, the output voltage is 2.8V and the output current = 500mA.

The actual power dissipation of the regulator circuit can be determined using the equation:

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

\[ P_D = (3.3V - 2.8V) \times 500mA \]
\[ P_D = 0.25W \]

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:

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

\( T_{J(max)} = 125^\circ C \), the maximum junction temperature of the die \( \theta_{JA} \) thermal resistance = 92.4°C/W.

**Thermal Resistance**

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 92.4°C/W.

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

For example, when operating the MIC5353-2.8YMT at an input voltage of 3.3V and 500mA load with a minimum footprint layout, the maximum ambient operating temperature \( T_A \) can be determined as follows:

\[ 0.25W = (125^\circ C - T_A)/(92.4^\circ C/W) \]
\[ T_A = 101^\circ C \]

Therefore, a 2.8V application with 500mA of output current can accept an ambient operating temperature of 101°C in a 1.6mm x 1.6mm Thin MLF® 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 (Fixed Output)

Bill of Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Part Number</th>
<th>Manufacturer</th>
<th>Description</th>
<th>Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1,C3</td>
<td>06036D105KAT2A</td>
<td>AVX</td>
<td>Capacitor, 1µF Ceramic, 6.3V, X5R, Size 0603</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GRM188R60J105KE19D</td>
<td>muRata</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>06035C104KAT2A</td>
<td>AVX</td>
<td>Capacitor, 0.1µF Ceramic, 50V, X5R, Size 0603</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>GRM188R71H104KA93D</td>
<td>muRata</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U1</td>
<td>MIC5353-XXYMT</td>
<td>Micrel, Inc.</td>
<td>500mA LDO, 1.6mm x 1.6mm Thin MLF®</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes:
1. AVX:  [www.avx.com](http://www.avx.com).
Typical Application Schematic (Adjustable Output)

![Schematic Diagram](image)

Bill of Materials

<table>
<thead>
<tr>
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<th>Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1,C3</td>
<td>06036D105KAT2A</td>
<td>AVX</td>
<td>Capacitor, 1µF Ceramic, 6.3V, X5R, Size 0603</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GRM188R60J105KE19D</td>
<td>muRata</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>06035C104KAT2A</td>
<td>AVX</td>
<td>Capacitor, 0.1µF Ceramic, 50V, X5R, Size 0603</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>GRM188R71H104KA93D</td>
<td>muRata</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>CRCW060320K0FKEA</td>
<td>Vishay</td>
<td>Resistor, 20kΩ, 1%, 1/16W, Size 0603</td>
<td>1</td>
</tr>
<tr>
<td>R2</td>
<td>CRCW060310K0FKEA</td>
<td>Vishay</td>
<td>Resistor, 10kΩ, 1%, 1/16W, Size 0603</td>
<td>1</td>
</tr>
<tr>
<td>U1</td>
<td>MIC5353YMT</td>
<td>Micrel, Inc.</td>
<td>Adjustable 500mA LDO, 1.6mm x 1.6mm Thin MLF®</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes:
1. AVX: [www.avx.com](http://www.avx.com).
2. Murata Tel: [www.murata.com](http://www.murata.com).
3. Vishay Tel: [www.vishay.com](http://www.vishay.com).
PCB Layout Recommendations

TOP LAYER

BOTTOM LAYER
Package Information

TOP VIEW

BOTTOM VIEW

SIDES VIEW

6-Pin 1.6mm x 1.6mm Thin MLF® (MT)

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. MAX. PACKAGE WARPAGE IS 0.05 mm.
3. MAXIMUM ALLOWABLE BURRS IS 0.076 mm IN ALL DIRECTIONS.
4. PIN #1 ID ON TOP WILL BE LASER/INK MARKER.
5. DIMENSION APPLIES TO METALIZED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.25 mm FROM TERMINAL TIP.
6. APPLIED ONLY FOR TERMINALS.
7. APPLIED FOR EXPOSED PAD AND TERMINALS.
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