General Description

The MIC29302A is a high-current, low-cost, low-dropout voltage regulator that uses Micrel’s proprietary Super βeta PNP® process with a PNP pass element. The 3A LDO regulator features 450mV (full load) dropout voltage and very low ground current. Designed for high-current loads, these devices also find applications in lower current, low-dropout critical systems, where their dropout voltages and ground current values are important attributes.

Along with a total accuracy of ±2% (over temperature, line, and load regulation) the regulator features very fast transient recovery from input voltage surges and output load current changes.

The MIC29302A has an adjustable output that can be set by two external resistors to a voltage between 1.24V and 15V. In addition, the device is fully protected against overcurrent faults, reversed input polarity, reversed lead insertion, and overtemperature operation. A TTL logic enable (EN) pin is available in the MIC29302A to shutdown the regulator. When not used, the device can be set to continuous operation by connecting EN to the input (IN). The MIC29302A is available in the standard and 5-pin TO-263 and TO-252 packages with an operating junction temperature range of −40°C to +125°C.

Datasheets and support documentation can be found on Micrel’s website at: www.micrel.com.

Features

- High-current capability
  - 3A over full temperature range
- Low-dropout voltage of 450mV at full load
- Low ground current
- Accurate 1% guaranteed tolerance
- Extremely fast transient response
- Zero-current shutdown mode
- Error flag signals output out-of-regulation
- Adjustable output voltage
- Packages: TO-263-5L and TO-252-5L

Applications

- Processor peripheral and I/O supplies
- High-efficiency “green” computer systems
- Automotive electronics
- High-efficiency linear lower supplies
- Battery-powered equipment
- PC add-in cards
- High-efficiency post-regulator for switching supply

Typical Application

\[
V_{\text{OUT}} = 1.242 \times \left( \frac{R_1}{R_2} + 1 \right)
\]

Dropout Voltage vs. Output Current

Super βeta PNP is a registered trademark of Micrel, Inc.

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October 3, 2014

Revision 2.0
Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Voltage</th>
<th>Junction Temperature Range</th>
<th>Package</th>
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</thead>
<tbody>
<tr>
<td>MIC29302AWU</td>
<td>Adjustable</td>
<td>–40°C to +125°C</td>
<td>5-Pin TO-263</td>
</tr>
<tr>
<td>MIC29302AWD</td>
<td>Adjustable</td>
<td>–40°C to +125°C</td>
<td>5-Pin TO-252</td>
</tr>
</tbody>
</table>

Pin Configuration

5-Pin TO-263 (D²Pak) Adjustable Voltage (U)
MIC29302AWU

5-Pin TO-252 (D-Pak) Adjustable Voltage (D)
MIC29302AWD

Pin Description

<table>
<thead>
<tr>
<th>Pin Number TO-263</th>
<th>Pin Number TO-252</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 CMOS compatible control input. Do not float.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>IN</td>
<td>INPUT: Unregulated input, +3V to +16V maximum</td>
</tr>
<tr>
<td>3, TAB</td>
<td>3, TAB</td>
<td>GND</td>
<td>GND: TAB is also connected internally to the IC’s ground on both packages.</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>OUT</td>
<td>OUTPUT: The regulator output voltage</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>ADJ</td>
<td>Feedback Voltage: 1.24V feedback from external resistor divider.</td>
</tr>
</tbody>
</table>
Absolute Maximum Ratings\(^{(1)}\)

- Input Supply Voltage \((V_{\text{IN}})\) \(-20\text{V} \text{ to } +20\text{V}\)
- Enable Input Voltage \((V_{\text{EN}})\) \(-0.3\text{V} \text{ to } V_{\text{IN}}\)
- Lead Temperature (soldering, 5 sec.) \(260°C\)
- Power Dissipation: Internally Limited
- Storage Temperature Range \(-65°C \text{ to } +150°C\)
- ESD Rating all pins \(^{(3)}\)

Operating Ratings\(^{(2)}\)

- Operating Junction Temperature \(-40°C \text{ to } +125°C\)
- Operating Input Voltage \(3\text{V} \text{ to } 16\text{V}\)
- Package Thermal Resistance
  - TO-263 \((\theta_{JC})\): \(3°C/W\)
  - TO-252 \((\theta_{JC})\): \(3°C/W\)
  - TO-252 \((\theta_{JA})\): \(35°C/W\)
  - TO-263 \((\theta_{JA})\): \(28°C/W\)

Electrical Characteristics\(^{(4)}\)

\(V_{\text{IN}} = 4.2\text{V}; I_{\text{OUT}} = 100\text{mA}; T_{\text{A}} = 25°C\), **bold** values indicate \(-40°C \leq T_{\text{J}} \leq 125°C\), unless noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage Accuracy(^{(5)})</td>
<td>(100\text{mA} \leq I_{\text{OUT}} \leq 3\text{A}, (V_{\text{OUT}} + 1\text{V}) \leq V_{\text{IN}} \leq 16\text{V})</td>
<td>(-2)</td>
<td>2</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Line Regulation</td>
<td>(I_{\text{OUT}} = 100\text{mA}, (V_{\text{OUT}} + 1\text{V}) \leq V_{\text{IN}} \leq 16\text{V})</td>
<td>0.1</td>
<td>0.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Load Regulation</td>
<td>(V_{\text{IN}} = V_{\text{OUT}} + 1\text{V}, 100\text{mA} \leq I_{\text{OUT}} \leq 3\text{A})</td>
<td>0.2</td>
<td>1</td>
<td>%</td>
<td></td>
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<tr>
<td>Dropout Voltage(^{(6)})</td>
<td>(I_{\text{OUT}} = 100\text{mA})</td>
<td>80</td>
<td>200</td>
<td>mV</td>
<td></td>
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<tr>
<td></td>
<td>(I_{\text{OUT}} = 750\text{mA})</td>
<td>220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(I_{\text{OUT}} = 1.5\text{A})</td>
<td>275</td>
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<td></td>
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<tr>
<td></td>
<td>(I_{\text{OUT}} = 2.0\text{A})</td>
<td>375</td>
<td>630</td>
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<tr>
<td></td>
<td>(I_{\text{OUT}} = 2.5\text{A})</td>
<td>430</td>
<td>720</td>
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<tr>
<td></td>
<td>(I_{\text{OUT}} = 3\text{A})</td>
<td>450</td>
<td>800</td>
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<td>Ground Current</td>
<td>(I_{\text{OUT}} = 750\text{mA}, V_{\text{IN}} = V_{\text{OUT}} + 1\text{V})</td>
<td>5</td>
<td>20</td>
<td>mA</td>
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<tr>
<td></td>
<td>(I_{\text{OUT}} = 1.5\text{A})</td>
<td>15</td>
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<tr>
<td></td>
<td>(I_{\text{OUT}} = 3\text{A})</td>
<td>60</td>
<td>150</td>
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<tr>
<td>(I_{\text{GRINDDO}}) Ground Pin Current @ Dropout</td>
<td>(V_{\text{IN}} = 0.5\text{V} \text{ less than specified } V_{\text{OUT}} \times I_{\text{OUT}} = 10\text{mA})</td>
<td>2</td>
<td></td>
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<td></td>
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<tr>
<td>Current Limit</td>
<td>(V_{\text{OUT}} = 0\text{V})(^{(7)})</td>
<td>3</td>
<td>4</td>
<td>A</td>
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<tr>
<td>(e_n), Output Noise Voltage (10Hz to 100kHz)</td>
<td>(C_L = 10\mu\text{F})</td>
<td>400</td>
<td>(\mu\text{VRMS})</td>
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<td></td>
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<tr>
<td></td>
<td>(I_L = 100\text{mA})</td>
<td>260</td>
<td></td>
<td></td>
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<tr>
<td>Ground Pin Current in Shutdown</td>
<td>Input Voltage (V_{\text{IN}} = 16\text{V})</td>
<td>32</td>
<td>(\mu\text{A})</td>
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</table>

**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, \(1.5k\Omega\) in series with \(100\text{pF}\).
4. Specification for packaged product only
5. Output voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature change.
6. Dropout voltage is defined as the input-to-output differential when output voltage drops to 99% of its normal value with \(V_{\text{OUT}} + 1\text{V}\) applied to \(V_{\text{IN}}\).
7. \(V_{\text{IN}} = V_{\text{OUT}} \text{(nominal)} + 1\text{V}\). For example, use \(V_{\text{IN}} = 4.3\text{V}\) for a 3.3V regulator or use 6V for a 5V regulator. Employ pulse testing procedure for current limit.
Electrical Characteristics (Continued)

VIN = 4.2V; IOUT = 10mA; TA = 25°C, bold values indicate −40°C ≤ TJ ≤ +125°C, unless noted.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Note 8</th>
<th>1.215</th>
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<td>Adjust Pin Bias Current</td>
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<td>40</td>
<td></td>
<td>nA</td>
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<th>ENABLE Input</th>
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<tr>
<td>Input Logic Voltage</td>
<td>Low (OFF)</td>
<td>0.8 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High (ON)</td>
<td>2.4 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enable Pin Input Current</td>
<td>VEN = 4.2V</td>
<td>15 µA</td>
<td>75 µA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VEN = 0.8V</td>
<td>2 µA</td>
<td>4 µA</td>
<td></td>
</tr>
<tr>
<td>Regulator Output Current</td>
<td>Note 10</td>
<td>10 µA</td>
<td>20 µA</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

8. VREF ≤ VOUT ≤ VIN - 1, 3V ≤ VOUT ≤ 16V, 10mA ≤ IOUT ≤ IL, TJ ≤ TJmax.

9. Thermal regulation is defined as the change in the output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a 250mA load pulse at VIN = 16V (a 4W pulse) for T = 10ms.

10. VEN ≤ 0.8V, VIN ≤ 16V and VOUT = 0V.
Typical Characteristics

**Dropout Voltage vs. Input Voltage**

- **I\textsubscript{OUT} = 3A**
- **I\textsubscript{OUT} = 1.8A**

**GND Pin Current vs. Input Voltage**

**Adjust Pin Voltage vs. Input Voltage**

- **V\text{OUT} = 1.8V**
- **I\text{OUT} = 3A**

**Adjust Pin Current vs. Input Voltage**

- **I\text{LOAD} = 10mA**

**Load Regulation vs. Input Voltage**

- **V\text{OUT} = 1.8V**
- **I\text{OUT} = 10mA to 3A**

**Short-Circuit Current vs. Input Voltage**

- **V\text{OUT} = 0V**

**Enable Pin Current vs. Input Voltage**

- **V\text{OUT} = 1.8V**
- **I\text{OUT} = 10mA**
- **V\text{EN} = V\text{IN}**

**Output Voltage vs. Input Voltage**

- **V\text{OUT} = 1.24V**
- **I\text{OUT} = 10mA**
Typical Characteristics (Continued)

**GND Pin Current vs. Temperature**

- $V_{IN} = 4.2V$
- $V_{OUT} = 1.8V$
- $I_{OUT} = 750mA$

**Enable Bias Current vs. Temperature**

- $V_{IN} = V_{EN} = 8V$
- $V_{OUT} = 2.5V$
- $I_{OUT} = 10mA$

**Dropout Voltage vs. Temperature**

- $I_{OUT} = 1.5A$
- $V_{IN} = 4.2V$

**Dropout Voltage vs. Temperature**

- $I_{OUT} = 3A$
- $V_{IN} = 4.2V$

**Short-Circuit Current vs. Temperature**

- $VIN = 4.2V$
- $I_{OUT} = 750mA$
- $I_{OUT} = 100mA$

**Adjust Pin Voltage vs. Temperature**

- $VIN = 4.2V$
- $VOUT = 1.8V$
- $IOUT = 10mA$

**Line Regulation vs. Temperature**

- $V_{IN} = 3V$ to $16V$
- $V_{OUT} = 1.8V$
- $I_{OUT} = 10mA$
Typical Characteristics (Continued)

**Dropout Voltage vs. Output Current**
- **VIN = 3V**
- **VOUT = 0V**
- ADJUSTABLE OPTION
- **VIN = 4.2V**
- **VADJ = 0V**

**Line Regulation vs. Output Current**
- **VIN = 4.2V**
- **VOUT = 1.8V**

**Adjust Pin Voltage vs. Output Current**
- **VIN = 4.2V**
- **VOUT = 1.8V**

**Output Noise vs. Frequency**
- **VIN = 3.3V**
- **VOUT = 1.8V**
- **IOUT = 3A**
- **COUT = 47µF**

**Ripple Rejection (IOUT = 10mA) vs. Frequency**
- **VIN = 3.3V**
- **VOUT = 1.8V**
- **IOUT = 10mA**
- **COUT = 22µF**

**Ripple Rejection (IOUT = 1.5A) vs. Frequency**
- **VIN = 3.3V**
- **VOUT = 1.8V**
- **IOUT = 1.5A**
- **COUT = 22µF**

**Ripple Rejection (IOUT = 3A) vs. Frequency**
- **VIN = 3.3V**
- **VOUT = 1.8V**
- **IOUT = 3A**
- **COUT = 22µF**
Functional Characteristics

Figure 1. MIC29302A Load Transient Response Test Circuit

MIC29302A Line Transient Response with 3A Load, 1000μF Output Capacitance

MIC29302A Load Transient Response with 3A Load, 1000μF Output Capacitance

MIC29302A Line Transient Response with 3A Load, 10μF Output Capacitance

Time (1.00ms/div)
Functional Diagram
Application Information

The MIC29302A is a high-performance, low-dropout voltage regulator suitable for all moderate to high-current voltage regulation applications. Its 450mV typical dropout voltage at full load makes it especially valuable in battery-powered systems and as high efficiency noise filters in post-regulator applications. Unlike older NPN-pass transistor designs, where the minimum dropout voltage is limited by the base-emitter voltage drop and collector-emitter saturation voltage, dropout performance of the PNP output is limited merely by the low $V_{CE}$ saturation voltage.

A trade-off for the low-dropout voltage is a varying base driver requirement. But Micrel’s Super βeta PNP® process reduces this drive requirement to merely 1% of the load current.

The MIC29302A regulator is fully protected from damage due to fault conditions. Current limiting is linear; output current under overload conditions is constant. Thermal shutdown disables the device when the die temperature exceeds the $+125°C$ maximum safe operating temperature. The output structure of the regulators allows voltages in excess of the desired output voltage to be applied without reverse current flow. The MIC29302A offers a logic-level ON/OFF control. When disabled, the device draws nearly zero current.

![Figure 2. Linear Regulators Require Only Two Capacitors for Operation](image)

Thermal Design

Linear regulators are simple to use. The most complicated set of design parameters to consider are thermal characteristics. Thermal design requires the following application-specific parameters:

- Maximum ambient temperature, $T_A$
- Output Current, $I_{OUT}$
- Output Voltage, $V_{OUT}$
- Input Voltage, $V_{IN}$

First, we calculate the power dissipation of the regulator from these numbers and the device parameters from this datasheet:

$$P_D = I_{OUT}(1.02V_{IN} - V_{OUT})$$

Where the ground current is approximated by 2% of $I_{OUT}$. Then the heatsink thermal resistance is determined with this formula:

$$\theta_{SA} = \frac{T_{JMAX} - T_A}{P_D} - (\theta_{JC} + \theta_{CS})$$

where:

$T_{JMAX} \leq 125°C$ and $\theta_{CS}$ is between $0°C/W$ and $2°C/W$.

The heatsink may be significantly reduced in applications where the minimum input voltage is known and is large compared to the dropout voltage. A series input resistor can be used to drop excessive voltage and distribute the heat between this resistor and the regulator. The low-dropout properties of Micrel Super βeta PNP® regulators allow very significant reductions in regulator power dissipation and the associated heatsink without compromising performance. When this technique is employed, a capacitor of at least 0.1µF is needed directly between the input and regulator ground.

Please refer to Application Note 9 and Application Hint 17 on Micrel's website (www.micrel.com) for further details and examples on thermal design and heatsink specification.

With no heatsink in the application, calculate the junction temperature to determine the maximum power dissipation that will be allowed before exceeding the maximum junction temperature of the MIC29302A. The maximum power allowed can be calculated using the thermal resistance ($\theta_{JA}$) of the D-Pak (TO252) adhering to the following criteria for the PCB design: 2oz. copper and 100mm² copper area for the MIC29302A.

For example, given an expected maximum ambient temperature ($T_A$) of $75°C$ with $V_{IN} = 3.3V$, $V_{OUT} = 2.5V$, and $I_{OUT} = 3A$, first calculate the expected $P_D$ using:

$$P_D = (3.3V - 2.5V) \times 3A - (3.3V) \times (0.016A) = 2.3472W$$
Next, calculate the junction temperature for the expected power dissipation:

\[ T_J = (\theta_J A \times P_D) + T_A = (35^\circ\text{C/W} \times 2.3472\text{W}) + 75^\circ\text{C} = 157.15^\circ\text{C} \]

Now determine the maximum power dissipation allowed that would not exceed the IC’s maximum junction temperature (125°C) without the use of a heatsink by:

\[ P_D(\text{MAX}) = \frac{(T_J(\text{MAX}) - T_A)}{\theta_J A} = \frac{(125^\circ\text{C} - 75^\circ\text{C})}{(35^\circ\text{C/W})} = 1.428\text{W} \]

Capacitor Requirements
For stability and minimum output noise, a capacitor on the regulator output is necessary. The value of this capacitor is dependent upon the output current; lower currents allow smaller capacitors. The MIC29302A is stable with a 10μF capacitor at full load.

This capacitor need not be an expensive low-ESR type; aluminum electrolytics are adequate. In fact, extremely low-ESR capacitors may contribute to instability. Tantalum capacitors are recommended for systems where fast load transient response is important.

When the regulator is powered from a source with high AC impedance, a 0.1μF capacitor connected between input and GND is recommended.

Transient Response and 5V to 3.3V Conversion
The MIC29302A has excellent response to variations in input voltage and load current. By virtue of its low dropout voltage, the device does not saturate into dropout as readily as similar NPN-based designs. A 3.3V output Micrel LDO will maintain full speed and performance with an input supply as low as 4.2V, and will still provide some regulation with supplies down to 3.8V, unlike NPN devices that require 5.1V or more for good performance and become nothing more than a resistor under 4.6V of input. Micrel’s PNP regulators provide superior performance in “5V to 3.3V” conversion applications than NPN regulators, especially when all tolerances are considered.

Minimum Load Current
The MIC29302A regulator operates within a specified load range. If the output current is too small, leakage currents dominate and the output voltage rises. A minimum load current of 10mA is necessary for proper regulation and to swamp any expected leakage current across the operating temperature range.

For best performance the total resistance (R1+R2) should be small enough to pass the minimum regulator load current of 10mA.

Adjustable Regulator Design
The output voltage can be programmed anywhere between 1.25V and the 15V. Two resistors are used. The resistor values are calculated by:

\[ R_1 = R_2 \times \left( \frac{V_{\text{OUT}}}{1.240} - 1 \right) \]

where \( V_{\text{OUT}} \) is the desired output voltage.

Figure 3 shows component definition. Applications with widely varying load currents may scale the resistors to draw the minimum load current required for proper operation (see “Minimum Load Current” section).

![Figure 3. Adjustable Regulator with Resistors](image)

Enable Input
MIC29302A features an enable (EN) input that allows ON/OFF control of the device. Special design allows “zero” current drain when the device is disabled—only microamperes of leakage current flows. The EN input has TTL/CMOS compatible thresholds for simple interfacing with logic, or may be directly tied to \( V_{\text{IN}} \). Enabling the regulator requires approximately 20μA of current into the EN pin.
Evaluation Board Schematic
## 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>C5</td>
<td>EEU-FM1E102</td>
<td>Panasonic[14]</td>
<td>1000µF, 25V, Electrolytic Capacitor, through hole, 10X22-case</td>
<td>1</td>
</tr>
<tr>
<td>C6</td>
<td>T495D107K016ATE125</td>
<td>Kemet</td>
<td>100µF, 20V, Tantalum Capacitor, 2917</td>
<td>1</td>
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<tr>
<td></td>
<td>TR3D107K016C0125</td>
<td>Vishay</td>
<td>100µF, 20V, Tantalum Capacitor, 2917</td>
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<tr>
<td>R1</td>
<td>CRCW06031K00FKTA</td>
<td>Vishay</td>
<td>1k, Resistor, 1%, 0603</td>
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<td>Open (CRCW06031002FRT1)</td>
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<td>10k, Resistor, 1%, 0603</td>
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<td>CRCW06038061FRT1</td>
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<td>8.06k, Resistor, 1%, 0603</td>
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<td>U1</td>
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<td>Micrel[15]</td>
<td>3A Fast-Response LDO Regulator</td>
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**Notes:**

11. TDK: [www.tdk.com](http://www.tdk.com).
PCB Layout Recommendations

MIC29302A Evaluation Board Top Layer

MIC29302A Evaluation Board Top Silk
PCB Layout Recommendations (Continued)

MIC29302A Evaluation Board Bottom Layer

MIC29302A Evaluation Board Bottom Silk
Package Information

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

5-Pin TO-263 (U)

Note:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
2. PACKAGE OUTLINE INCLUSIVE OF PLATING THICKNESS.
3. FOOT LENGTH USING GAUGE PLANE METHOD MEASUREMENT 0.010".
4. PACKAGE TOP MARK MAY BE IN TOP CENTER OR LOWER LEFT CORNER
5. ALL DIMENSIONS ARE IN INCHES/MILLIMETERS.

Note: 16. Package information is correct as of the publication date. For updates and most current information, go to www.micrel.com.
Package Information (Continued)

### Package Dimensions

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<thead>
<tr>
<th>PD5</th>
<th>INCH</th>
<th>MM</th>
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**Recommended Land Pattern**

- **NOTE**: unit in mm

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**5-Pin TO-252 (D)**

**NOTE**: unit in mm

1. Package outline exclusive of mold flash & metal burr.
2. Package outline inclusive of plating thickness.
3. Foot length using gauge plane method measurement 0.010".
4. All dimensions are in inches/millimeters.
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