

## Automotive Qualified Single Output 300 mA $\mu$ Cap LDO

### Features

- Small 2 mm x 2 mm VDFN Package
- Low Dropout Voltage: 100 mV at 300 mA
- Output Noise 120  $\mu$ V<sub>RMS</sub>
- Input Voltage Range: 2.3V to 5.5V
- 300 mA Guaranteed Output Current
- Stable with Ceramic Output Capacitors
- Low Quiescent Current: 85  $\mu$ A Total
- 30  $\mu$ s Turn-On Time
- High Output Accuracy
  - $\pm$ 2% Initial Accuracy
  - $\pm$ 3% over Temperature
- Thermal Shutdown and Current-Limit Protection

### Applications

- CMOS image sensors
- Backup camera modules
- GPS Receivers
- Infotainment

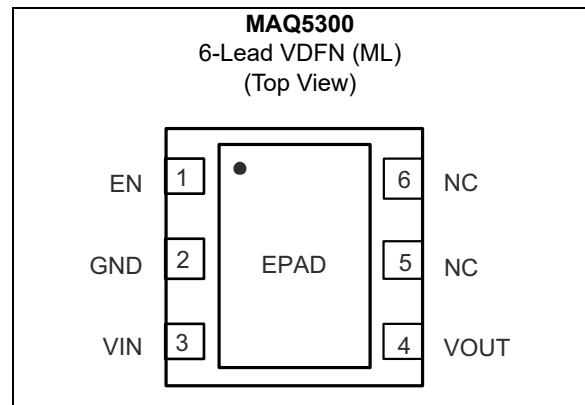
### General Description

The MAQ5300 is an automotive-qualified, ultra-small, ultra-low dropout CMOS regulator (ULDO) that is ideal for today's most demanding automotive applications including infotainment, camera module, image sensors, and anywhere PCB space is limited. It offers extremely low dropout voltage, very low output noise and can operate from a 2.3V to 5.5V input while delivering up to 300 mA.

The MAQ5300 offers 2% initial accuracy, low ground current (typically 85  $\mu$ A total), thermal shutdown, and current-limit protection. The MAQ5300 can also be put into a zero-off-mode current state, drawing no current when disabled.

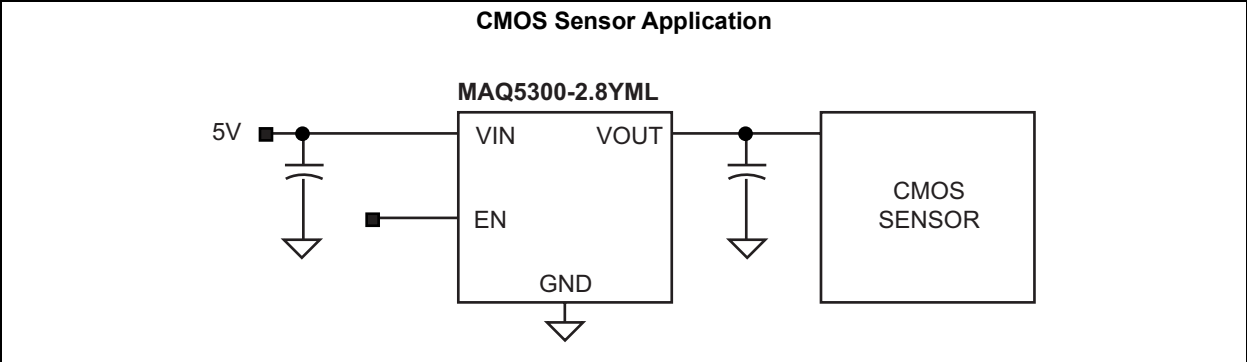
The MAQ5300's operating junction temperature range is  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  and it is available in fixed output voltages in a lead-free (RoHS-compliant) 6-pin 2 mm x 2 mm VDFN package.

### Package Type

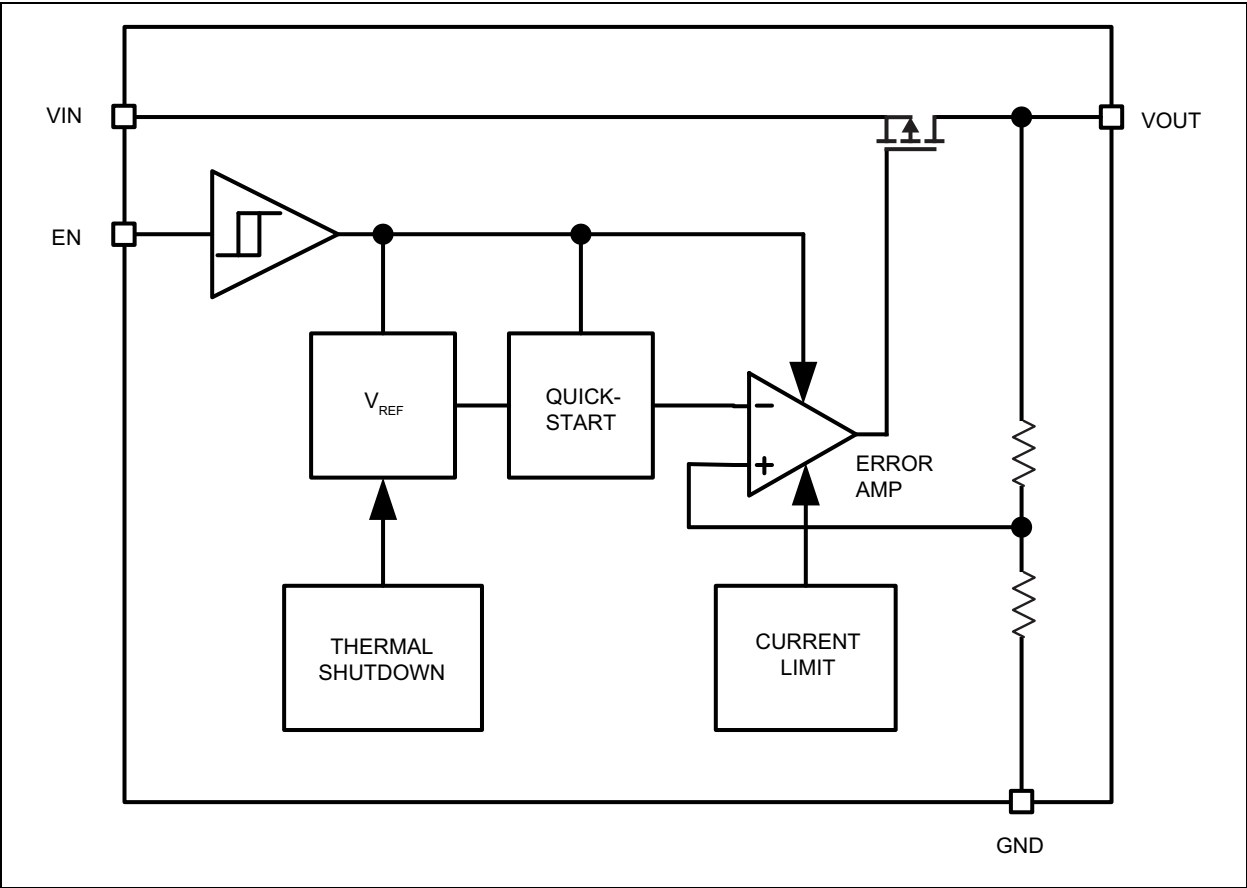


# MAQ5300

## Typical Application Circuit



## Functional Block Diagram



## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

Supply Voltage ( $V_{IN}$ )	0V to +6.0V
Enable Input ( $V_{EN}$ )	0V to $V_{IN}+0.3V$
Power Dissipation (Note 1)	Internally Limited
ESD Rating (Note 2)	2 kV (HBM)
ESD Rating	100V (MM)

### Operating Ratings ‡

Supply Voltage ( $V_{IN}$ )	+2.3V to +5.5V
Enable Input ( $V_{EN}$ )	0V to $V_{IN}$

† **Notice:** Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

‡ **Notice:** The device is not guaranteed to function outside its operating rating.

- Note 1:** The maximum allowable power dissipation for 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.
- 2:** Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5 k $\Omega$  in series with 100 pF.

## ELECTRICAL CHARACTERISTICS

**Electrical Characteristics:**  $V_{IN} = V_{OUT}+1V$ ;  $C_{OUT} = 1.0 \mu F$ ;  $I_{OUT} = 100 \mu A$ ;  $T_J = +25^\circ C$ , **bold** values valid for  $-40^\circ C \leq T_J \leq +125^\circ C$ , unless noted. (Note 1)

Parameter	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy	-2	—	2	%	Variation from nominal $V_{OUT}$
	<b>-3</b>	—	<b>3</b>		Variation from nominal $V_{OUT}$ ; $-40^\circ C$ to $+125^\circ C$
Line Regulation	—	0.02	<b>0.6</b>	%/V	$V_{IN} = V_{OUT} + 1V$ to 5.5V; $I_{OUT} = 100 \mu A$
Load Regulation (Note 2)	—	0.03	<b>0.6</b>	%	$I_{OUT} = 100 \mu A$ to 300 mA
Dropout Voltage (Note 3)	—	50	<b>100</b>	mV	$I_{OUT} = 150$ mA
	—	100	<b>200</b>		$I_{OUT} = 300$ mA
Ground Pin Current (Note 4)	—	85	<b>120</b>	$\mu A$	$I_{OUT} = 0$ mA to 300 mA, EN = High
Ground Pin Current in Shutdown	—	0.1	<b>1</b>	$\mu A$	$V_{EN} = 0V$
Ripple Rejection	—	65	—	dB	$f =$ Up to 1 kHz; $C_{OUT} = 1.0 \mu F$
	—	42	—		$f = 1$ kHz to 20 kHz; $C_{OUT} = 1.0 \mu F$

**Note 1:** Specification for packaged product only.

- 2:** 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.
- 3:** 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.
- 4:** 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.

# MAQ5300

## ELECTRICAL CHARACTERISTICS (CONTINUED)

**Electrical Characteristics:**  $V_{IN} = V_{OUT} + 1V$ ;  $C_{OUT} = 1.0 \mu F$ ;  $I_{OUT} = 100 \mu A$ ;  $T_J = +25^\circ C$ , **bold** values valid for  $-40^\circ C \leq T_J \leq +125^\circ C$ , unless noted. (Note 1)

Parameter	Min.	Typ.	Max.	Units	Conditions
Current Limit	<b>325</b>	650	<b>875</b>	mA	$V_{OUT} = 0V$
Output Voltage Noise	—	120		$\mu V_{RMS}$	$C_{OUT} = 1 \mu F$ , 10 Hz to 100 kHz
<b>Enable Input</b>					
Enable Input Voltage	—	—	<b>0.2</b>	V	Logic Low
	<b>1.1</b>	—	—		Logic High
Enable Input Current	—	0.01	—	$\mu A$	$V_{IL} \leq 0.2V$
	—	0.01	—		$V_{IH} \geq 1.0V$
Turn-On Time	—	30	<b>100</b>	$\mu s$	$C_{OUT} = 1.0 \mu F$
<b>Thermal Protection</b>					
Overtemperature Shutdown	—	155	—	$^\circ C$	$T_J$ rising
Overtemperature Shutdown Hysteresis	—	5	—	$^\circ C$	—

- Note 1:** Specification for packaged product only.
- 2:** 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.
- 3:** 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.
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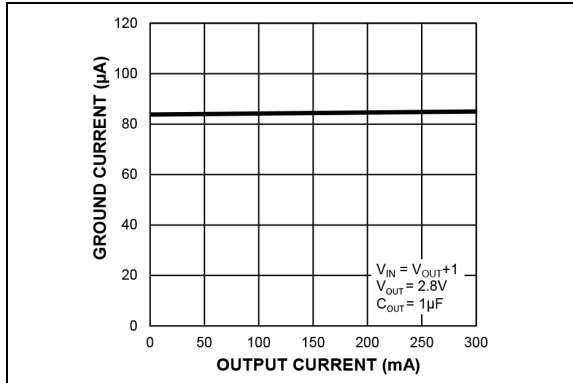
## TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Temperature Ranges</b>						
Ambient Temperature Range	$T_A$	-40	—	+125	$^\circ C$	—
Junction Temperature Range	$T_J$	-40	—	+125	$^\circ C$	—
Storage Temperature Range	$T_S$	-65	—	+150	$^\circ C$	—
Lead Temperature	—	—	—	+260	$^\circ C$	Soldering, 10 sec.
<b>Package Thermal Resistance</b>						
Thermal Resistance, VDFN 6-Ld	$\theta_{JA}$	—	90	—	$^\circ C/W$	—

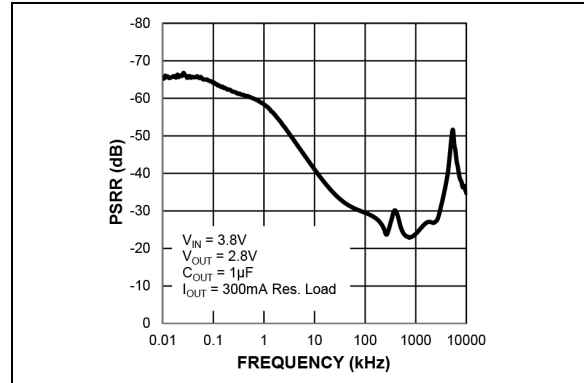
- Note 1:** The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e.,  $T_A$ ,  $T_J$ ,  $\theta_{JA}$ ). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +125 $^\circ C$  rating. Sustained junction temperatures above +125 $^\circ C$  can impact the device reliability.

## 2.0 TYPICAL PERFORMANCE CURVES

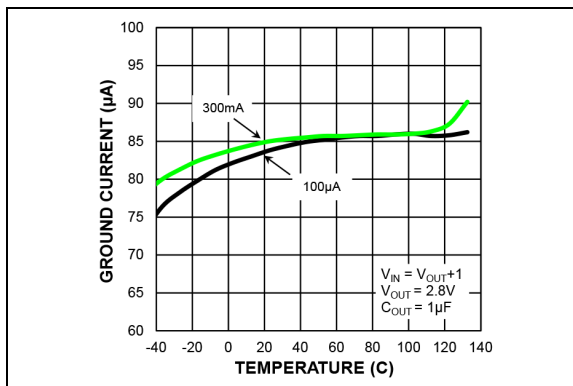
**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.



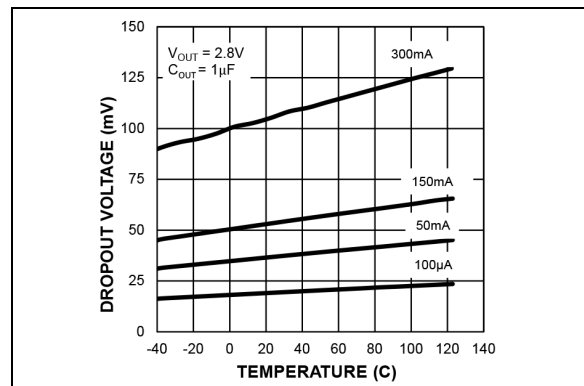
**FIGURE 2-1:** Ground Pin Current vs. Output Current.



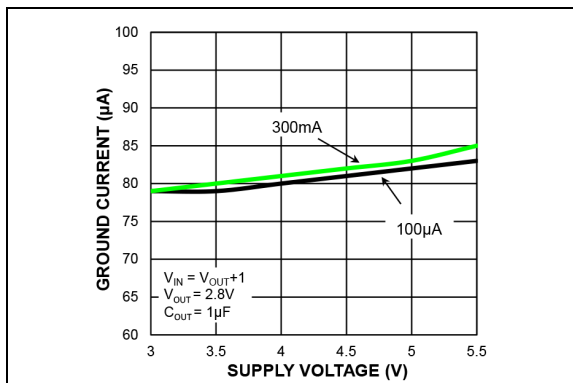
**FIGURE 2-4:** Power Supply Rejection Ratio.



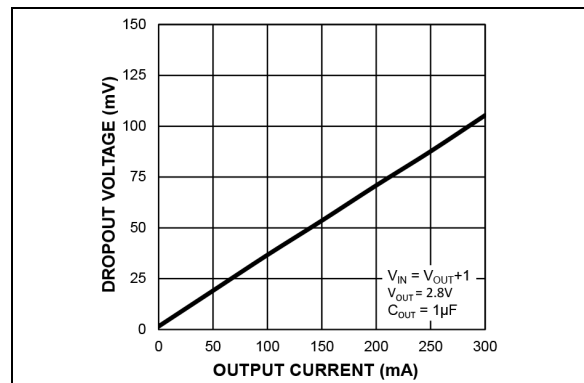
**FIGURE 2-2:** Ground Pin Current vs. Temperature.



**FIGURE 2-5:** Dropout Voltage vs. Temperature.

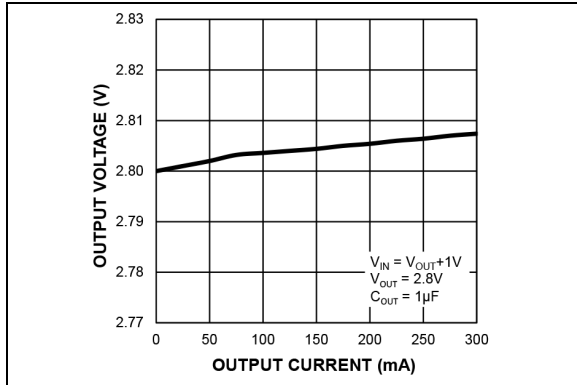


**FIGURE 2-3:** Ground Pin Current vs. Supply Voltage.

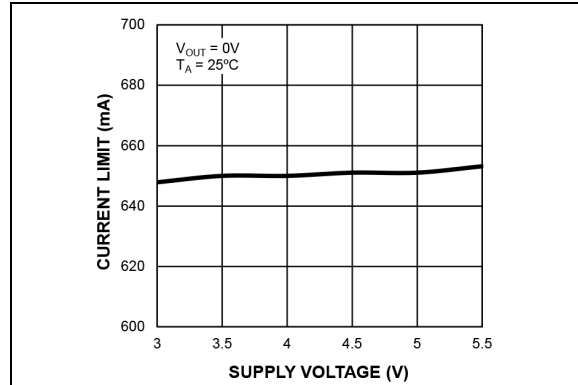


**FIGURE 2-6:** Dropout Voltage vs. Output Current.

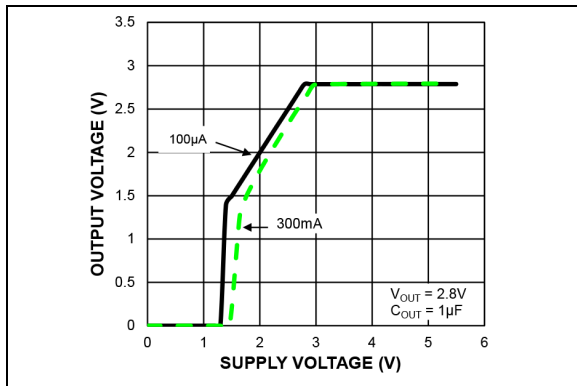
# MAQ5300



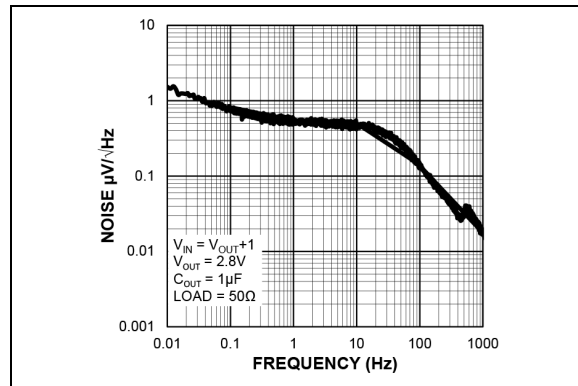
**FIGURE 2-7:** Output Voltage vs. Output Current.



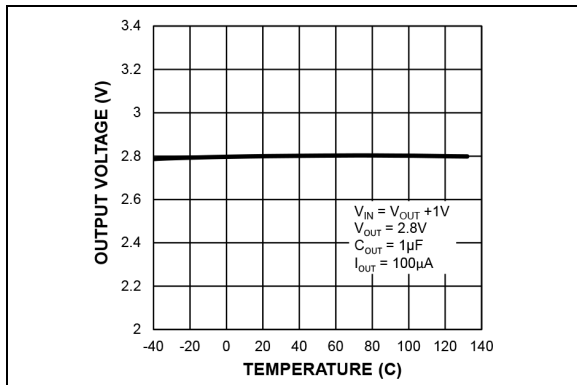
**FIGURE 2-10:** Current Limit vs. Supply Voltage.



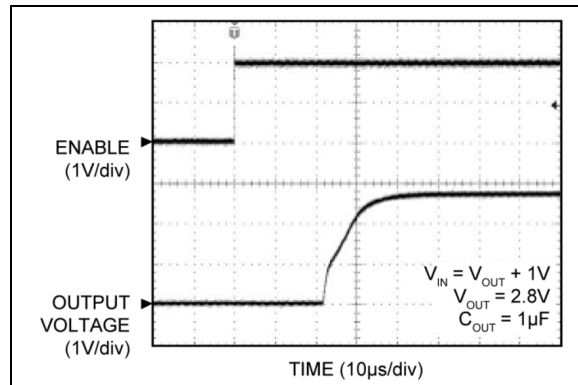
**FIGURE 2-8:** Output Voltage vs. Supply Voltage.



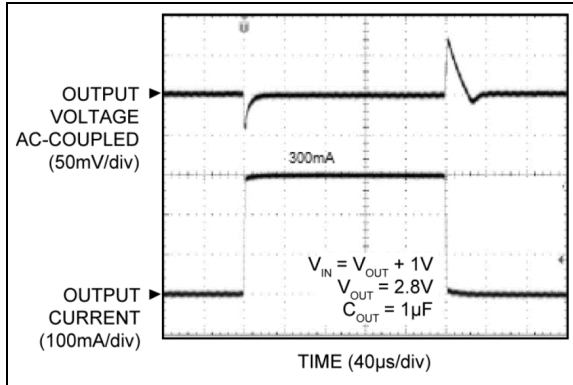
**FIGURE 2-11:** Output Noise Spectral Density.



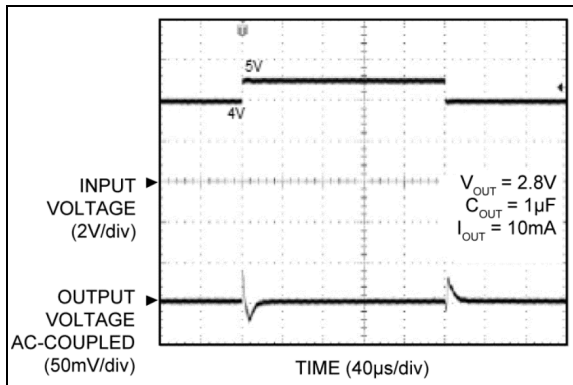
**FIGURE 2-9:** Output Voltage vs. Temperature.



**FIGURE 2-12:** Enable Turn-On.



**FIGURE 2-13:** Load Transient Response.



**FIGURE 2-14:** Line Transient Response.

# MAQ5300

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## 3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in [Table 3-1](#).

**TABLE 3-1: PIN FUNCTION TABLE**

Pin Number	Pin Name	Description
1	EN	Enable (Input): Active High. High = on, low = off. Do not leave this pin floating.
2	GND	Power Ground.
3	VIN	Supply Voltage (Input): Decouple with a minimum 1 $\mu$ F ceramic capacitor.
4	VOUT	Regulated Output Voltage (Output): Decouple with a minimum 1 $\mu$ F ceramic capacitor.
5	NC	No Connection.
6	NC	No Connection.
EP	ePAD	Exposed pad heat sink. Internally connected to ground. Connect to ground copper on board to lower thermal resistance.



## 4.0 APPLICATION INFORMATION

### 4.1 Enable/Shutdown

The MAQ5300 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.

### 4.2 Input Capacitor

The MAQ5300 is a high-performance, high bandwidth device that requires a well-bypassed input supply for optimal performance. A minimum 1  $\mu\text{F}$  X7R ceramic capacitor is required from the VIN pin to ground for stability and decoupling. The capacitor must be placed next to the VIN pin and the VIN pin to capacitor connection routed with a wide (low inductance) PCB trace. The ground terminal of the capacitor is connected directly to the GND pin with a similar low impedance trace. If a ground plane is used, the capacitor ground terminal and GND pin should be connected to the ground plane with a via. Refer to the PCB recommended layout section for a typical layout. X7R dielectric-type ceramic capacitors are used because of their  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  temperature range. X7R-type capacitors have a stable dielectric and change capacitance by  $\pm 15\%$  over their operating temperature range. X5R dielectrics have a maximum temperature of only  $85^{\circ}\text{C}$ , while Z5U and Y5V and other lower quality dielectric capacitors must not be used as their capacitance range changes by as much as 50% to 60%. This change may cause problems with stability and regulation. Additional high-frequency capacitors, such as small-valued NPO dielectric-type capacitors, help filter out high-frequency noise.

Larger value, ceramic, tantalum and aluminum electrolytic capacitors may be used at the input, in parallel with the ceramic input capacitor described above.

### 4.3 Output Capacitor

The MAQ5300 requires an X7R ceramic output capacitor of 1  $\mu\text{F}$  or greater to maintain stability. The LDO is optimized for use with low-ESR ceramic chip capacitors. Higher ESR capacitors, such as aluminum electrolytic and tantalum may cause high frequency oscillation. The output capacitance can be increased, but performance has been optimized for a 1  $\mu\text{F}$  ceramic output capacitor and does not improve significantly with larger capacitance.

The capacitor must be placed next to the VOUT pin and the VOUT pin to capacitor connection routed with a wide (low inductance) PCB trace. The ground terminal of the capacitor is connected directly to the GND plane with a similar low impedance trace. If a ground plane is used, the capacitor ground terminal and GND pin should be connected to the ground plane with a via. Refer to the PCB recommended layout section for a typical layout.

X7R dielectric-type ceramic capacitors are used because of their temperature performance. X7R-type capacitors have a stable dielectric and change capacitance by  $\pm 15\%$  over their operating temperature range. As with the input capacitor, X5R capacitors may not meet the maximum ambient temperature specification and Z5U, Y5V and other lower quality dielectric capacitors must not be used to prevent stability and regulation problems. Additional high-frequency capacitors, such as small-valued NPO dielectric-type capacitors, help filter out high-frequency noise.

### 4.4 No-Load Stability

The MAQ5300 is stable when operating at no load.

### 4.5 Dropout Voltage

An LDO's dropout voltage is the minimum operating voltage difference between  $V_{IN}$  and  $V_{OUT}$  at a given output current. Once the dropout voltage is reached, lowering the input voltage will cause the output voltage to decrease and the LDO will cease to operate properly. The typical and worst case dropout voltages are listed in the electrical characteristic table.

### 4.6 Thermal Considerations

The MAQ5300 is designed to provide 300 mA of continuous current. Maximum ambient operating temperature can be calculated based on the output current and the voltage drop across the part. For example, given that the input voltage is 3.6V, the output voltage is 2.8V and the output current equals 300 mA.

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

#### EQUATION 4-1:

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

# MAQ5300

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Because this device is CMOS and the ground current is typically <100  $\mu$ A over the load range, the power dissipation contributed by the ground current is < 1% and can be ignored for this calculation.

## EQUATION 4-2:

$$P_D = (3.6V - 2.8V) \times 300mA = 0.24W$$

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:

## EQUATION 4-3:

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

Where:

$T_{J(MAX)}$  = 125°C, the max. junction temperature of the die.

$\theta_{JA}$  = The thermal resistance of 90°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 is 90°C/W.

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

For example, when operating the MAQ5300-2.8YML at an input voltage of 3.6V and 300mA load, the maximum ambient operating temperature  $T_A$  can be determined as follows:

## EQUATION 4-4:

$$0.24W = (125^\circ C - T_A) / (90^\circ C/W)$$

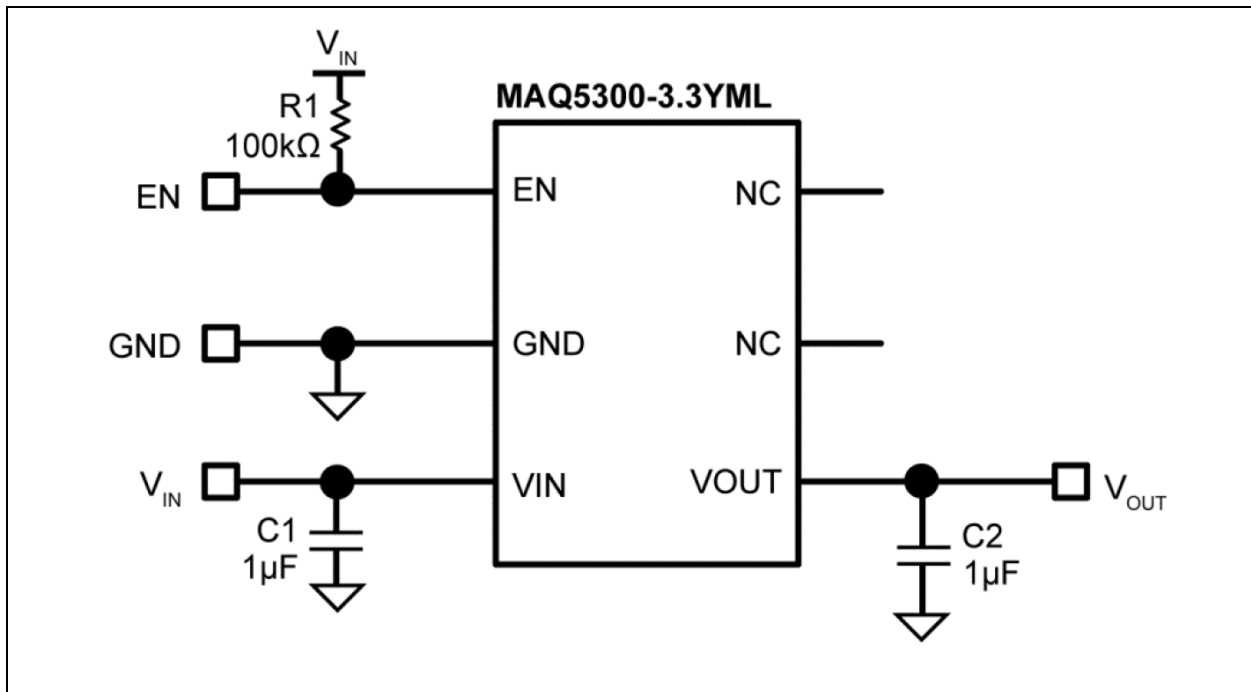
$$T_A = 103^\circ C$$

Therefore, a 2.8V application with 300mA of output current can accept an ambient operating temperature of 103°C.

A via can be placed under the package to maximize thermal performance. Refer to the PCB Layout Recommendations section for a typical layout.

For a full discussion of heat sinking and thermal effects on voltage regulators, refer to the “Regulator Thermals” section of Microchip’s [Designing with Low-Dropout Voltage Regulators](#) handbook.

## 5.0 TYPICAL APPLICATION SCHEMATIC



### Bill of Materials

TABLE 5-1: BILL OF MATERIALS

Item	Part Number	Manufacturer	Description	Qty.
R1	CRCW0603100KFKEA	Vishay Dale <sup>1</sup>	100 kΩ, 1%, 0603 resistor	1
C1, C2	06036C105MAT2A	AVX <sup>2</sup>	1 μF, 6.3V, X7R, 0603, Ceramic Capacitor	2
U1	MAQ5300-3.3YML	Microchip <sup>3</sup>	Automotive Qualified Single Output 300mA μCap LDO, 3.3V Fixed Output	1

**Note 1:** Vishay: [www.vishay.com](http://www.vishay.com)

**2:** AVX: [www.avx.com](http://www.avx.com)

**3:** Microchip: [www.microchip.com](http://www.microchip.com)

# MAQ5300

## 6.0 PCB LAYOUT RECOMMENDATIONS

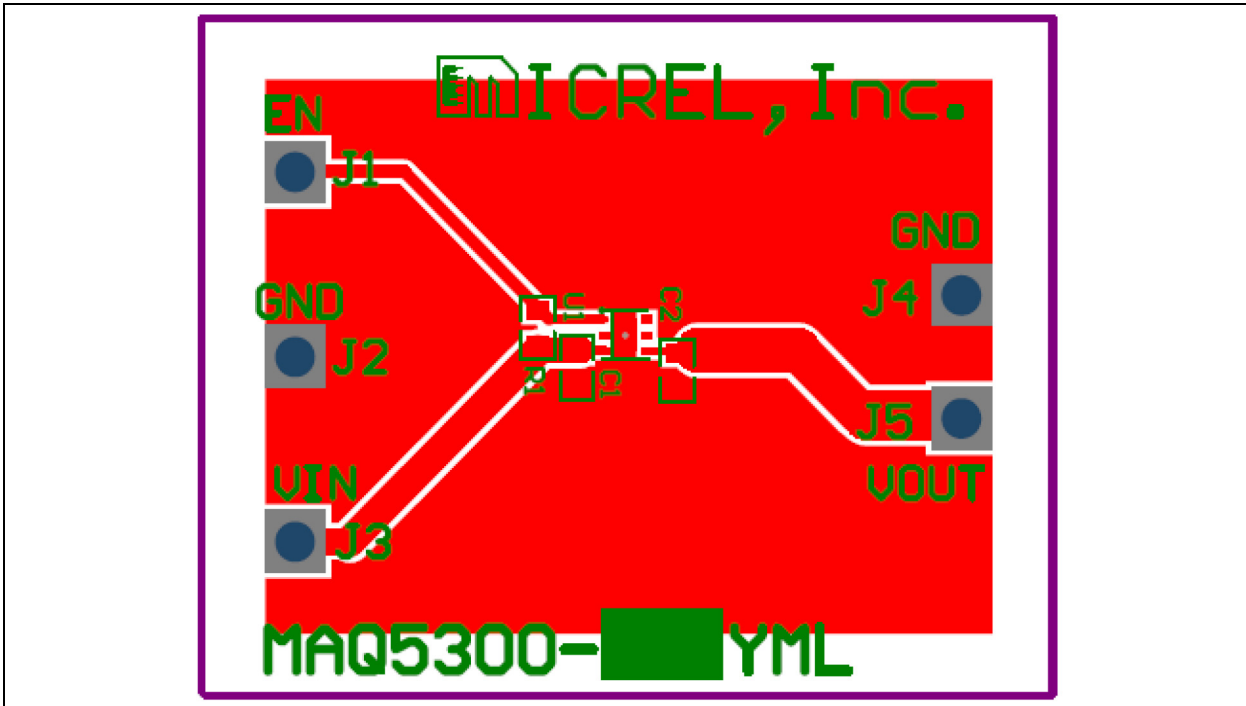


FIGURE 6-1: Top Layer.

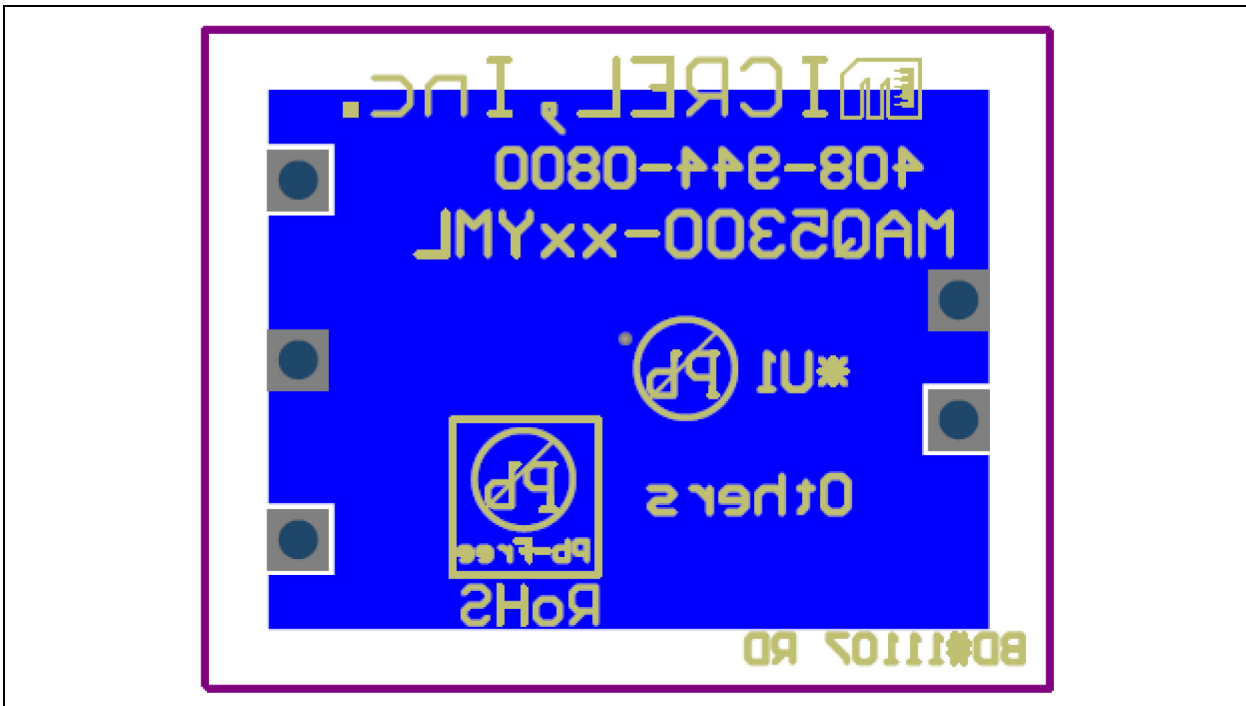
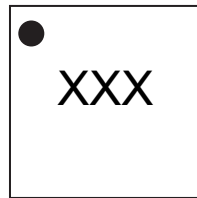


FIGURE 6-2: Bottom Layer.

## 7.0 PACKAGING INFORMATION

### 7.1 Package Marking Information

6-Lead VDFN\*



Example



<b>Legend:</b>	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.
	•, ▲, ▼	Pin one index is identified by a dot, delta up, or delta down (triangle mark).
<b>Note:</b>	In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.	
	Underbar ( _ ) and/or Overbar ( ¯ ) symbol may not be to scale.	

**TABLE 7-1: MARKING CODES**

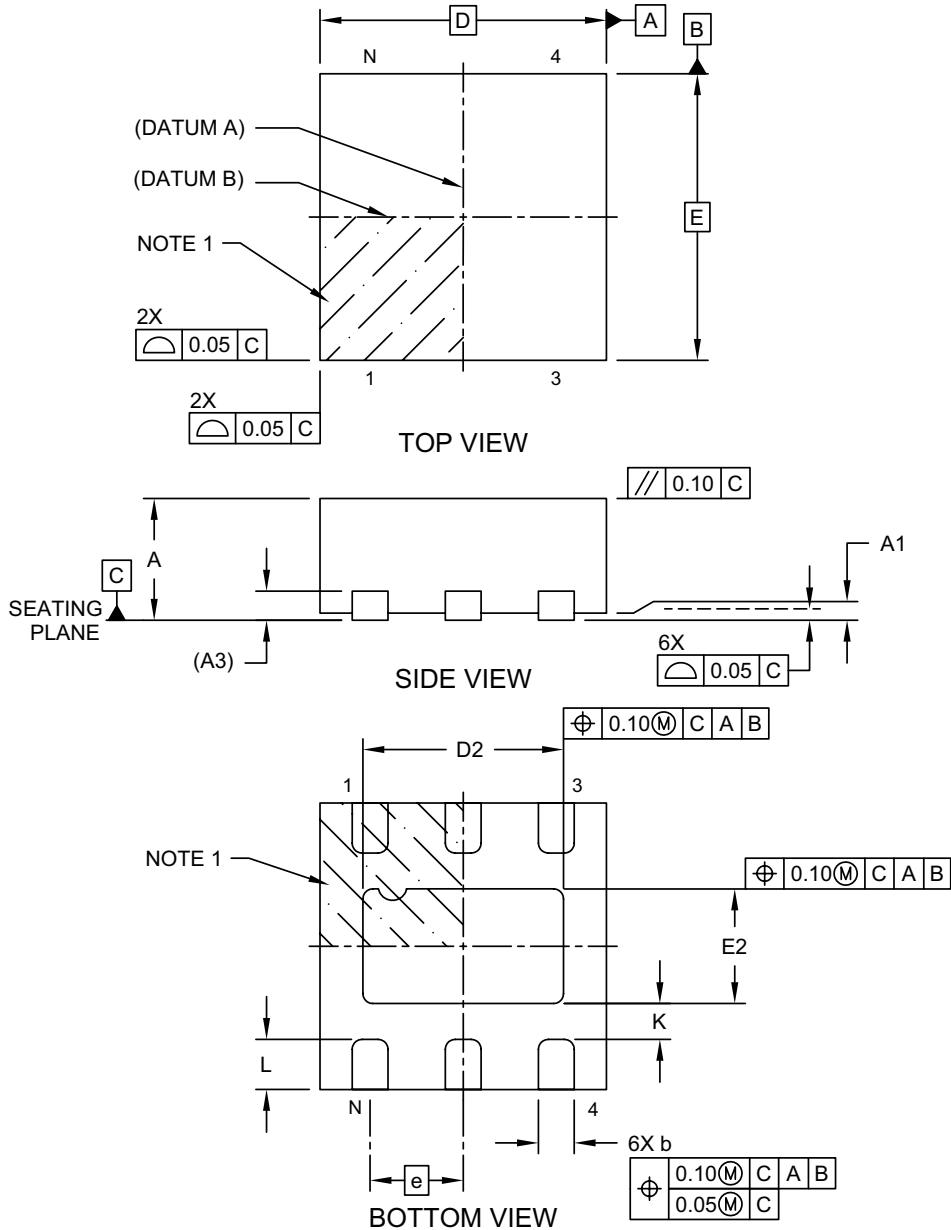
Part Number	Marking Code	Voltage
MAQ5300-1.5YML	QMF	1.5V
MAQ5300-1.8YML	QMG	1.8V
MAQ5300-2.5YML	QMJ	2.5V
MAQ5300-2.8YML	QMM	2.8V
MAQ5300-2.85YML	QMN	2.85V
MAQ5300-3.0YML	QMP	3.0V
MAQ5300-3.3YML	QMS	3.3V

# MAQ5300

## 6-Lead 2 mm x 2 mm VDFN Package Outline and Recommended Land Pattern

### 6-Lead Very Thin Plastic Dual Flat, No Lead Package (JDA) - 2x2 mm Body [VDFN] Micrel Legacy Package

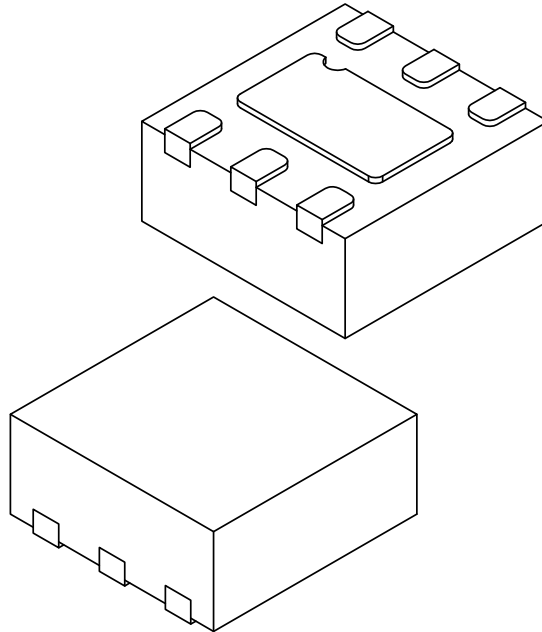
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-1016A Sheet 1 of 2

## 6-Lead Very Thin Plastic Dual Flat, No Lead Package (JDA) - 2x2 mm Body [VDFN] Micrel Legacy Package

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N	6		
Pitch	e	0.65 BSC		
Overall Height	A	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3	0.203 REF		
Overall Length	D	2.00 BSC		
Exposed Pad Length	D2	1.35	1.40	1.45
Overall Width	E	2.00 BSC		
Exposed Pad Width	E2	0.75	0.80	0.85
Terminal Width	b	0.20	0.25	0.30
Terminal Length	L	0.30	0.35	0.40
Terminal-to-Exposed-Pad	K	0.20	-	-

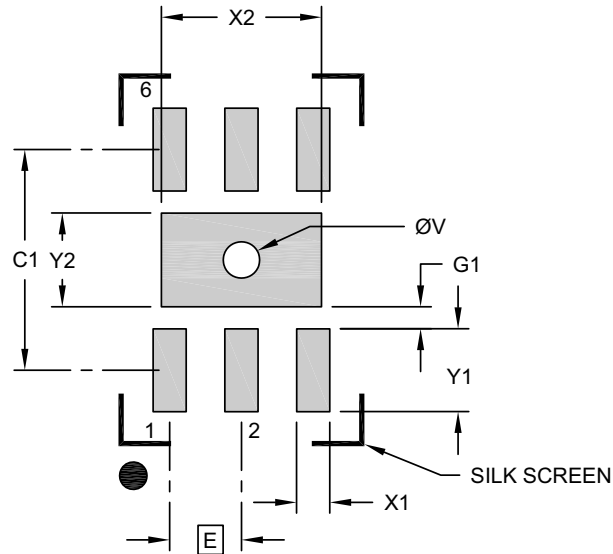
**Notes:**

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated
- Dimensioning and tolerancing per ASME Y14.5M  
 BSC: Basic Dimension. Theoretically exact value shown without tolerances.  
 REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-1016A Sheet 2 of 2

## 6-Lead Very Thin Plastic Dual Flat, No Lead Package (JDA) - 2x2 mm Body [VDFN] Micrel Legacy Package

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



### RECOMMENDED LAND PATTERN

Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Optional Center Pad Width	X2			0.85
Optional Center Pad Length	Y2			1.45
Contact Pad Spacing	C1		2.00	
Contact Pad Width (X6)	X1			0.30
Contact Pad Length (X6)	Y1			0.75
Contact Pad to Center Pad (X6)	G1	0.20		
Thermal Via Diameter	V	0.27	0.30	0.33

**Notes:**

1. Dimensioning and tolerancing per ASME Y14.5M  
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-21016A



## APPENDIX A: REVISION HISTORY

### Revision A (March 2021)

- Converted Micrel document MAQ5300 to Microchip data sheet template DS20006504A.
- Minor grammatical text changes throughout.

# MAQ5300

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NOTES:

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

<u>Device</u>	<u>-X.X</u>	<u>X</u>	<u>XX</u>	<u>-XX</u>
Part No.	Voltage	Temp. Range	Package	Media Type
<b>Device:</b>	MAQ5300:	Automotive Qualified Single Output 300 mA $\mu$ Cap LDO		
<b>Voltage:</b>	1.5 = 1.5V 1.8 = 1.8V 2.5 = 2.5V 2.8 = 2.8V 2.85 = 2.85V 3.0 = 3.0V 3.3 = 3.3V			
<b>Temperature Range:</b>	Y = -40°C to +125°C			
<b>Package:</b>	ML = 6-Lead 2 mm x 2 mm VDFN			
<b>Media Type:</b>	TR = 5,000/Reel T5 = 500/Reel (1.8V & 2.8V Options Only)			
<b>Examples:</b>				
a) MAQ5300-1.5YML-TR: MAQ5300, 1.5V Voltage, -40°C to +125°C Temp. Range, 6-Lead VDFN, 5,000/Reel				
b) MAQ5300-1.8YML-T5: MAQ5300, 1.8V Voltage, -40°C to +125°C Temp. Range, 6-Lead VDFN, 500/Reel				
c) MAQ5300-2.5YML-TR: MAQ5300, 2.5V Voltage, -40°C to +125°C Temp. Range, 6-Lead VDFN, 5,000/Reel				
d) MAQ5300-2.85YML-TR: MAQ5300, 2.85V Voltage, -40°C to +125°C Temp. Range, 6-Lead VDFN, 5,000/Reel				
e) MAQ5300-3.0YML-TR: MAQ5300, 3.0V Voltage, -40°C to +125°C Temp. Range, 6-Lead VDFN, 5,000/Reel				
f) MAQ5300-3.3YML-TR: MAQ5300, 3.3V Voltage, -40°C to +125°C Temp. Range, 6-Lead VDFN, 5,000/Reel				
<b>Note 1:</b> Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.				

# MAQ5300

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NOTES:

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**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
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ISBN: 978-1-5224-7771-6

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