

## 500 mA LDO with Ripple Blocker Technology

### Features

- 1.8V to 3.6V Input Voltage Range
- Active Noise Rejection over a Wide Frequency Band
  - >50dB from 10 Hz to 5 MHz at 500 mA Load
- Rated to 500 mA Output Current
- Fixed and Adjustable Output Voltages
- Optional Output Auto-Discharge when Disabled
- Current-Limit and Thermal-Limit Protection
- 1.6 mm x 1.6 mm, 6-Pin Thin DFN
- Logic-Controlled Enable Pin
- -40°C to +125°C Junction Temperature Range

### Applications

- Smart Phones
- Tablet PC/Notebooks and Webcams
- Digital Still and Video Cameras
- Global Positioning Systems
- Mobile Computing
- Automotive and Industrial Applications

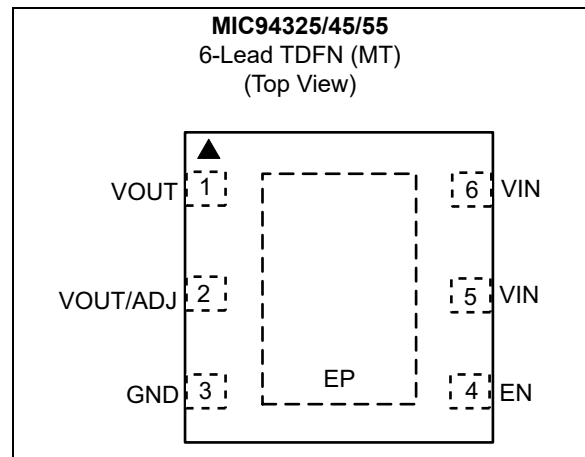
### General Description

The MIC94325, MIC94345, and MIC94355 Ripple Blocker™ devices are monolithic integrated circuits that provide low-frequency ripple attenuation (switching noise rejection) to a regulated output voltage. This is important for applications where a DC/DC switching converter is required to lower or raise a battery voltage, but where switching noise cannot be tolerated by sensitive downstream circuits such as in RF applications. The MIC94325/45/55 maintain high power supply ripple rejection (PSRR) with input voltages operating near the output voltage level to improve overall system efficiency. A low-voltage logic enable pin facilitates ON/OFF control at typical GPIO voltage levels.

The MIC94325/45/55 operate from an input voltage of 1.8V to 3.6V. Options include fixed (MIC94345/55) or adjustable (MIC94325) output voltages. The MIC94355 version offers an auto-discharge to discharge the output capacitor when the part is disabled.

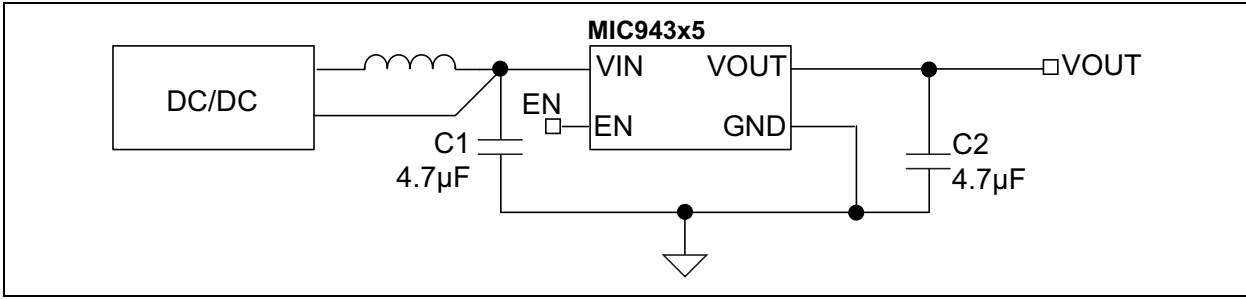
Packaged in a 6-pin 1.6 mm x 1.6 mm Thin DFN, the MIC94325/45/55 have a junction operating temperature range of -40°C to +125°C.

### Package Type

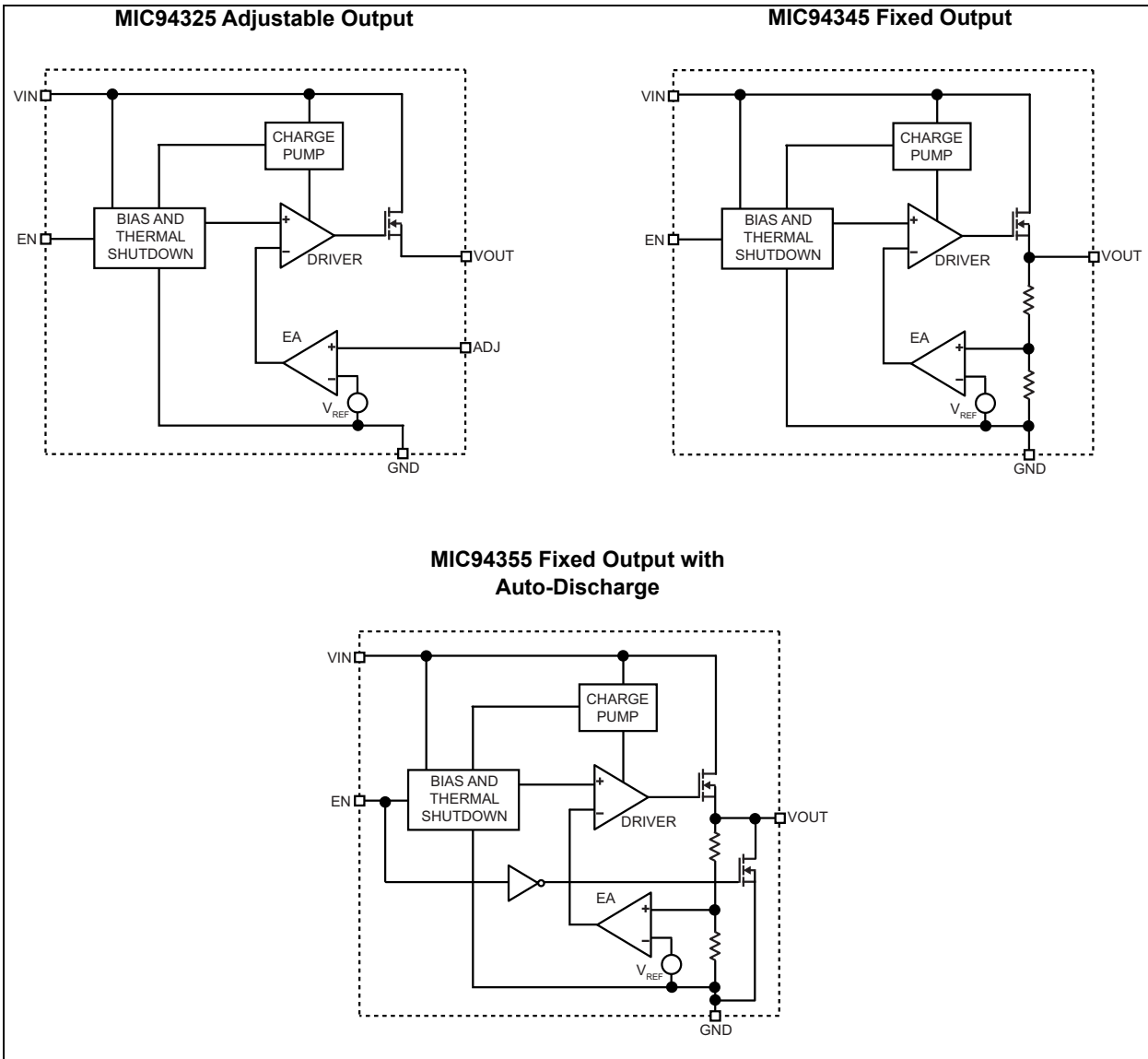


# MIC94325/45/55

## Typical Application Circuit



## Functional Block Diagrams



## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

Input Voltage ( $V_{IN}$ )	–0.3V to +4V
Output Voltage ( $V_{OUT}$ )	–0.3V to $V_{IN} + 0.3V$ or +4V
Enable Voltage ( $V_{EN}$ )	–0.3V to $V_{IN} + 0.3V$ or +4V
ESD Rating (Note 1)	3 kV

### Operating Ratings ††

Input Voltage ( $V_{IN}$ )	+1.8V to +3.6V
Enable Voltage ( $V_{EN}$ )	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 ratings.

**Note 1:** Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5 k $\Omega$  in series with 100 pF.

## ELECTRICAL CHARACTERISTICS

**Electrical Characteristics:**  $V_{IN} = V_{EN} = V_{OUT} + 500$  mV ( $V_{IN} = V_{EN} = 3.6V$  for  $V_{OUT} \geq 3.1V$ );  $I_{OUT} = 1$  mA;  $C_{OUT} = 4.7$   $\mu$ F;  $T_A = +25^\circ C$ , **bold** values are valid for  $-40^\circ C \leq T_J \leq +125^\circ C$ , unless noted. [Note 1](#)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Input Voltage	$V_{IN}$	<b>1.8</b>	—	<b>3.6</b>	V	—
Output Voltage Range	$V_{OUT}$	<b>1.2</b>	—	<b>3.4</b>	V	MIC94325
Output Voltage Accuracy	—	<b>–3</b>	$\pm 1$	<b>+3</b>	%	Variation from nominal $V_{OUT}$
Adjust Reference	$V_{ADJ}$	—	1.1	—	V	MIC94325
Dropout Voltage	$V_{DROP}$	—	10	—	mV	$V_{IN}$ to $V_{OUT}$ dropout at 50 mA output current
		—	100	<b>200</b>		$V_{IN}$ to $V_{OUT}$ dropout at 500 mA output current
Load Regulation	$\Delta V_{OUT}$	—	10	—	mV	1 mA to 500 mA
Line Regulation	$(\Delta V_{OUT}/V_{OUT}) \times 100\% / \Delta V_{IN}$	—	0.1	<b>1</b>	%/V	$V_{IN} = V_{OUT} + 500$ mV to 3.6V, $I_{OUT} = 100$ mA
Ground Current	$I_{GND}$	—	170	<b>250</b>	$\mu$ A	$I_{OUT} = 100$ $\mu$ A
Shutdown Current	$I_{EN}$	—	0.2	5	$\mu$ A	$V_{EN} = 0V$
$V_{IN}$ Ripple Rejection	PSRR	—	85	—	dB	f = 100 Hz
		—	85	—		f = 1 kHz
		—	57	—		f = 100 kHz
		—	60	—		f = 1 MHz
		—	50	—		f = 5 MHz
Current Limit	$I_{LIMIT}$	<b>530</b>	800	<b>1100</b>	mA	$V_{OUT} = 0V$
Total Output Noise	$e_N$	—	83	—	$\mu$ V <sub>RMS</sub>	10 Hz to 100 kHz
Turn-On Time	$t_{ON}$	—	100	<b>150</b>	$\mu$ s	—

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

# MIC94325/45/55

## ELECTRICAL CHARACTERISTICS (CONTINUED)

**Electrical Characteristics:**  $V_{IN} = V_{EN} = V_{OUT} + 500\text{ mV}$  ( $V_{IN} = V_{EN} = 3.6\text{V}$  for  $V_{OUT} \geq 3.1\text{V}$ );  $I_{OUT} = 1\text{ mA}$ ;  $C_{OUT} = 4.7\text{ }\mu\text{F}$ ;  $T_A = +25^\circ\text{C}$ , **bold** values are valid for  $-40^\circ\text{C} \leq T_J \leq +125^\circ\text{C}$ , unless noted. [Note 1](#)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Auto Discharge NFET Resistance	$R_{DS}$	—	50	—	$\Omega$	$V_{IN} = 3.6\text{V}$ , $V_{EN} = 0\text{V}$ , $I_{OUT} = -3\text{ mA}$ MIC94355 Only
<b>Enable</b>						
Input Logic Low	$V_{EN-LOW}$	—	—	<b>0.35</b>	V	—
Input Logic High	$V_{EN-HIGH}$	<b>1.0</b>	—	—	V	—
Input Current	$I_{IN}$	—	0.01	1	$\mu\text{A}$	—

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

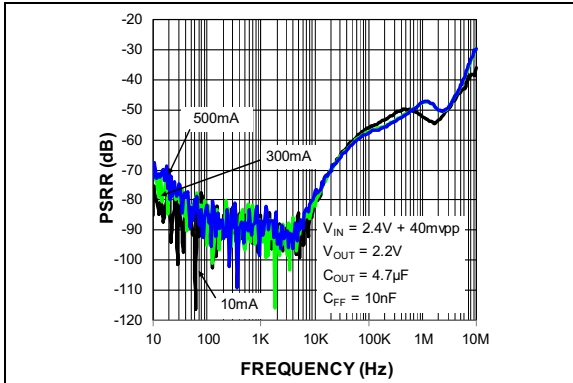
## TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Temperature Ranges</b>						
Junction Temperature Range	$T_J$	-40	—	+125	$^\circ\text{C}$	—
Storage Temperature Range	$T_S$	-65	—	+150	$^\circ\text{C}$	—
Lead Temperature	—	—	—	+260	$^\circ\text{C}$	Soldering, 10 sec.
<b>Package Thermal Resistances</b>						
Thermal Resistance, TDFN 6-Ld	$\theta_{JA}$	—	92	—	$^\circ\text{C/W}$	—

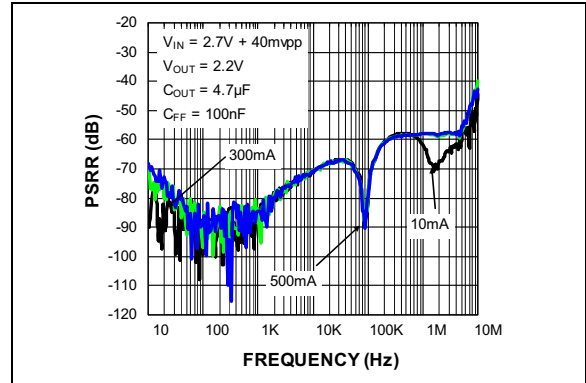
**Note 1:** The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e.,  $T_A$ ,  $T_J$ ,  $\theta_{JA}$ ). Exceeding the maximum allowable power dissipation will cause the device operating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

## 2.0 TYPICAL PERFORMANCE CURVES

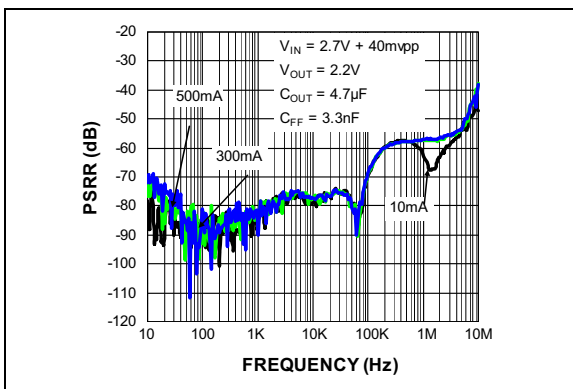
**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be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



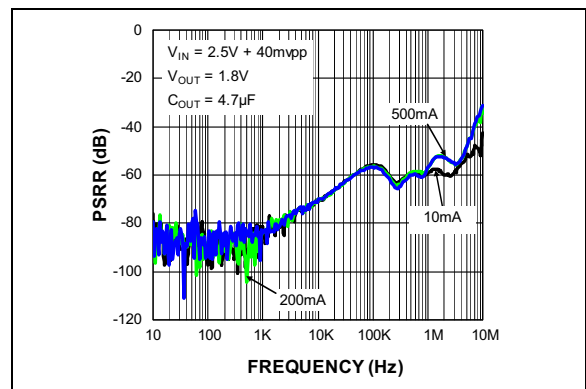
**FIGURE 2-1:** MIC94325 PSRR,  $C_{OUT} = 4.7 \mu\text{F}$ ,  $C_{FF} = 10 \text{ nF}$ .



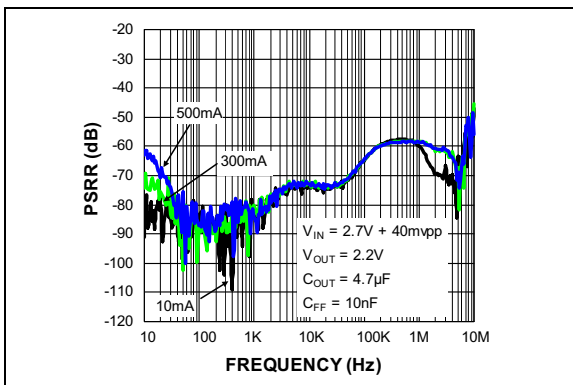
**FIGURE 2-4:** MIC94325 PSRR,  $C_{OUT} = 4.7 \mu\text{F}$ ,  $C_{FF} = 100 \text{ nF}$ .



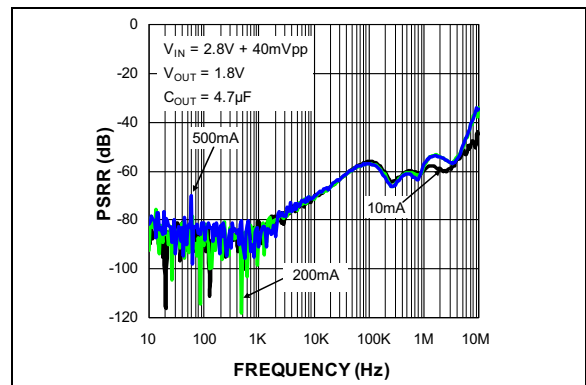
**FIGURE 2-2:** MIC94325 PSRR,  $C_{OUT} = 4.7 \mu\text{F}$ ,  $C_{FF} = 3.3 \text{ nF}$ .



**FIGURE 2-5:** MIC94355 PSRR,  $C_{OUT} = 4.7 \mu\text{F}$ .

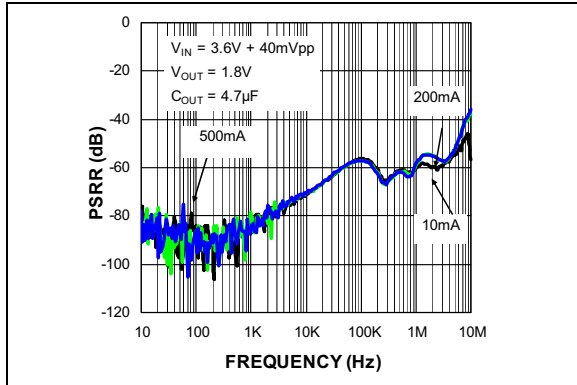


**FIGURE 2-3:** MIC94325 PSRR,  $C_{OUT} = 4.7 \mu\text{F}$ ,  $C_{FF} = 10 \text{ nF}$ .

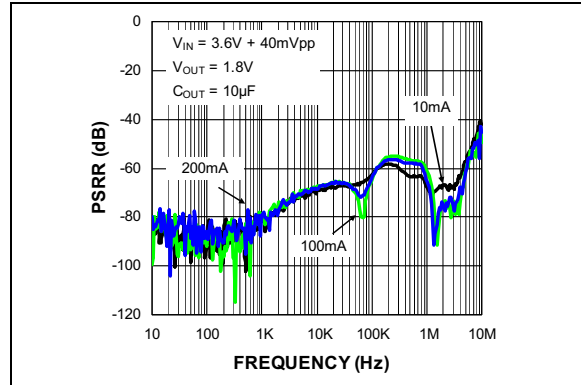


**FIGURE 2-6:** MIC94355 PSRR,  $C_{OUT} = 4.7 \mu\text{F}$ .

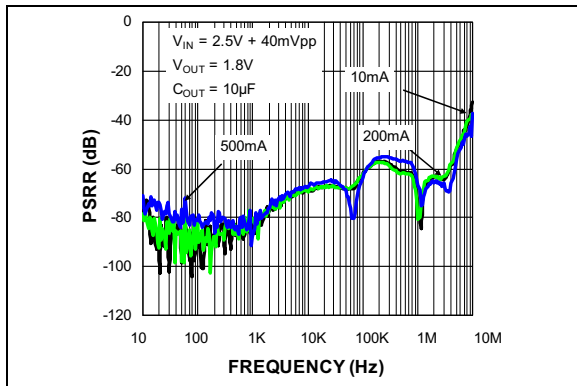
# MIC94325/45/55



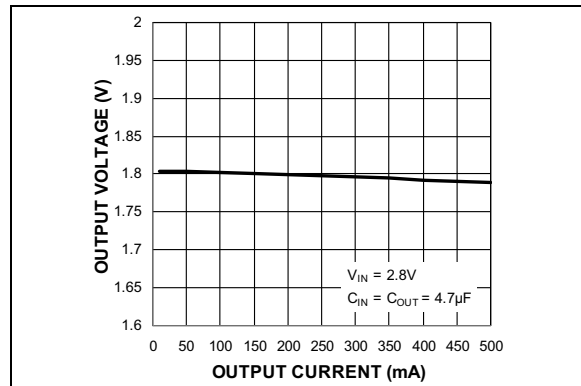
**FIGURE 2-7:** MIC94355 PSRR,  $C_{OUT} = 4.7 \mu F$ .



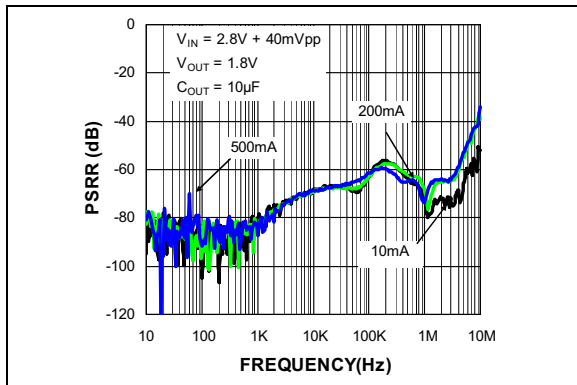
**FIGURE 2-10:** MIC94355 PSRR,  $C_{OUT} = 10 \mu F$ .



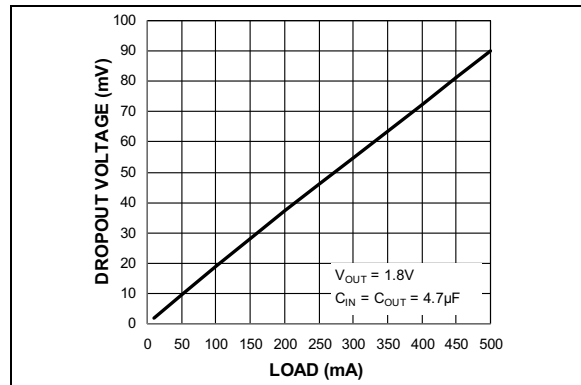
**FIGURE 2-8:** MIC94355 PSRR,  $C_{OUT} = 10 \mu F$ .



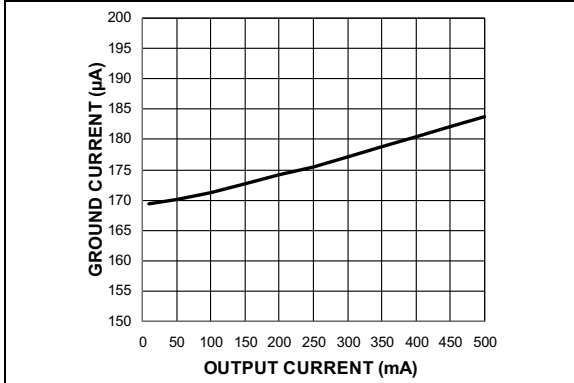
**FIGURE 2-11:** Output Voltage vs. Output Current.



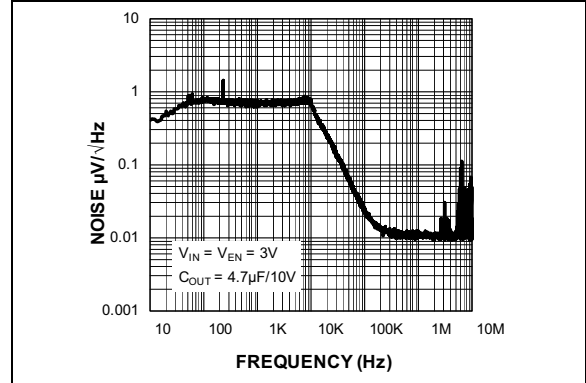
**FIGURE 2-9:** MIC94355 PSRR,  $C_{OUT} = 10 \mu F$ .



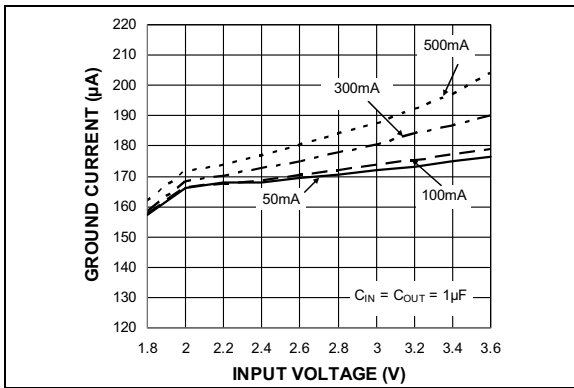
**FIGURE 2-12:** Dropout Voltage vs. Load.



**FIGURE 2-13:** Ground Current vs. Output Current.

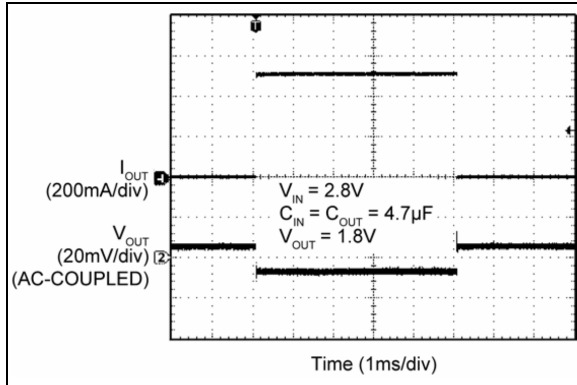


**FIGURE 2-15:** MIC94355YMT Output Noise Spectral Density.

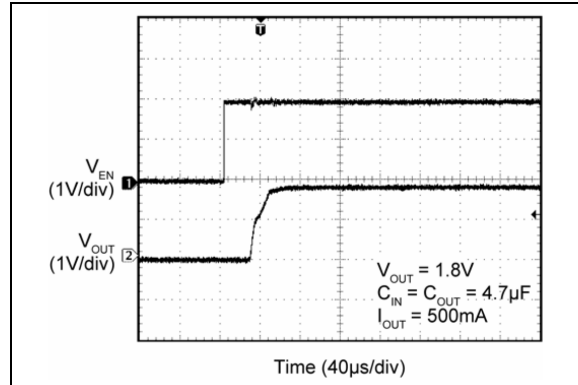


**FIGURE 2-14:** Ground Current vs. Input Voltage.

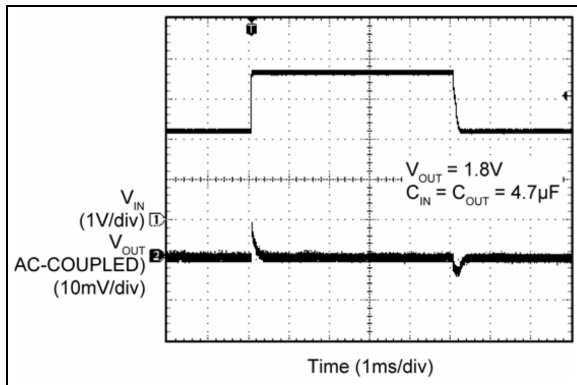
# MIC94325/45/55



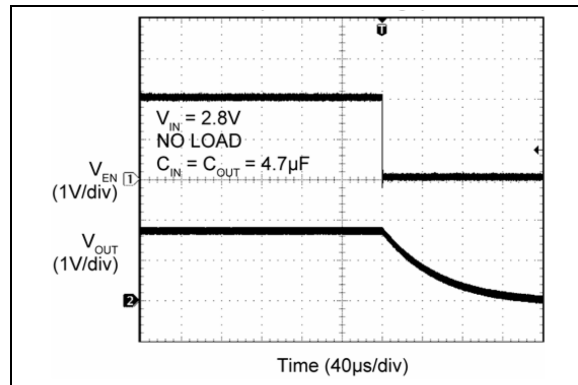
**FIGURE 2-16:** Load Transient.



**FIGURE 2-18:** Turn-On Time.



**FIGURE 2-17:** Line Transient.



**FIGURE 2-19:** Turn-Off Time (Auto-Discharge).

## 3.0 PIN DESCRIPTIONS

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

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

Pin Number TDFN, Fixed	Pin Number TDFN, Adj.	Pin Name	Description
1, 2	1	VOUT	Power Switch Output.
—	2	ADJ	Adjust input. Connect to resistive divider at VOUT to set the output voltage. Do not leave floating.
3	3	GND	Ground.
4	4	EN	Enable Input. A logic HIGH signal on this pin enables the part. Logic LOW disables the part. Do not leave floating.
5, 6	5, 6	VIN	Power Switch Input and Chip Supply.
EP	EP	ePAD	Exposed Heatsink Pad. Connect to Ground plane for best thermal performance.

# MIC94325/45/55

## 4.0 APPLICATION INFORMATION

The MIC943x5 family of products are very high PSRR, fixed-output, 500 mA LDOs that use Ripple Blocker™ technology. The MIC943x5 are fully protected from damage due to fault conditions, offering linear current limiting and thermal shutdown.

### 4.1 Input Capacitor

The MIC943x5 are high-performance, high-bandwidth devices. An input capacitor of 4.7 μF 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.

### 4.2 Output Capacitor

In order to maintain stability, the MIC943x5 require an output capacitor of 4.7 μF or greater. For optimal input voltage ripple rejection performance a 4.7 μF capacitor is recommended. 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 4.7 μF 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 their value by as much as 50% and 60%, respectively, over their operating temperature ranges. To use a ceramic chip capacitor with the 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.

### 4.3 No Load Stability

The MIC943x5 will remain stable and in regulation with no load. This is especially important in CMOS RAM keep-alive applications.

### 4.4 Enable/Shutdown

Forcing the enable (EN) pin low disables the MIC943x5 and sends it into a “zero” off mode current state. In this state, current consumed by the MIC943x5 goes nearly to zero. Forcing EN high enables the output voltage.

The EN pin uses CMOS technology and cannot be left floating as it could cause an indeterminate state on the output.

For the MIC94325 adjustable part, the turn-on time is affected by the selection of the external feedback resistors and feed-forward capacitor. The relationship is approximately  $2.2 \times R2 \times C_{FF}$ , where R2 is the bottom resistor (connected from ADJ to GND) and  $C_{FF}$  is the capacitor connected across R1 (from VOUT to ADJ). For stability, the feed-forward capacitor must be greater than 1 nF. 10 nF is recommended for best performance.

When disabled, the MIC94355 switches a 50Ω (typical) load on the regulator output to discharge the external capacitors.

## 4.5 Adjustable Regulator Application

The MIC94325 output voltage can be adjusted by using two external resistors (Figure 4-1). The resistors set the output voltage based on the following equation:

### EQUATION 4-1:

$$V_{OUT} = V_{ADJ} \left( 1 + \frac{R1}{R2} \right)$$
$$V_{ADJ} = 1.1V$$

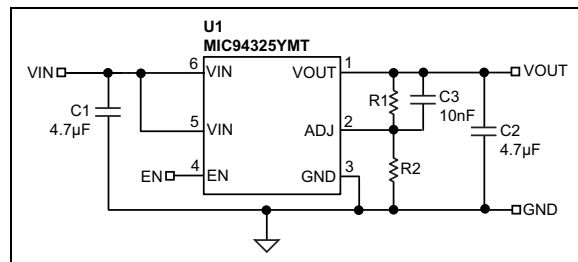


FIGURE 4-1: Adjustable Output Voltage.

## 4.6 Thermal Considerations

The MIC943x5 are designed to provide 500 mA 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 2.5V, the output voltage is 1.8V, and the output current is 500 mA. The actual power dissipation of the Ripple Blocker™ can be determined using the equation:

### EQUATION 4-2:

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

Because this device is CMOS and the ground current is typically <170 μA over the load range, the power dissipation contributed by the ground current is <1% and can be ignored for this calculation.

### EQUATION 4-3:

$$P_D = (2.5V - 1.8V) \times 500mA = 0.35W$$

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 4-4:

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

Where:

$T_{J(MAX)} = 125^\circ\text{C}$

$\theta_{JA}$  = Thermal resistance.  $92^\circ\text{C/W}$  for the TDFN 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 maximum power dissipation must not be exceeded for proper operation.

For example, when operating the MIC94325-GYMT at an input voltage of 2.5V and 500 mA load with a minimum footprint layout, the maximum ambient operating temperature  $T_A$  can be determined as follows:

### EQUATION 4-5:

$$0.35W = (125^\circ\text{C} - T_A) / (92^\circ\text{C/W})$$

$$T_A = 92^\circ\text{C}$$

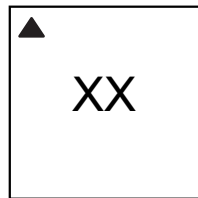
Therefore, the maximum ambient operating temperature allowed in a 1.6 mm x 1.6 mm Thin DFN package is  $92^\circ\text{C}$ . For a full discussion of heat sinking and thermal effects on voltage regulators, refer to the "Regulator Thermals" section of Microchip's [Designing with Low-Dropout Voltage Regulators handbook](#).

# MIC94325/45/55

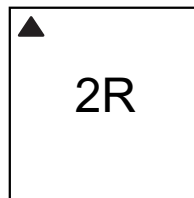
## 5.0 PACKAGING INFORMATION

### 5.1 Package Marking Information

6-Lead TDFN\*



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 5-1: MARKING CODES

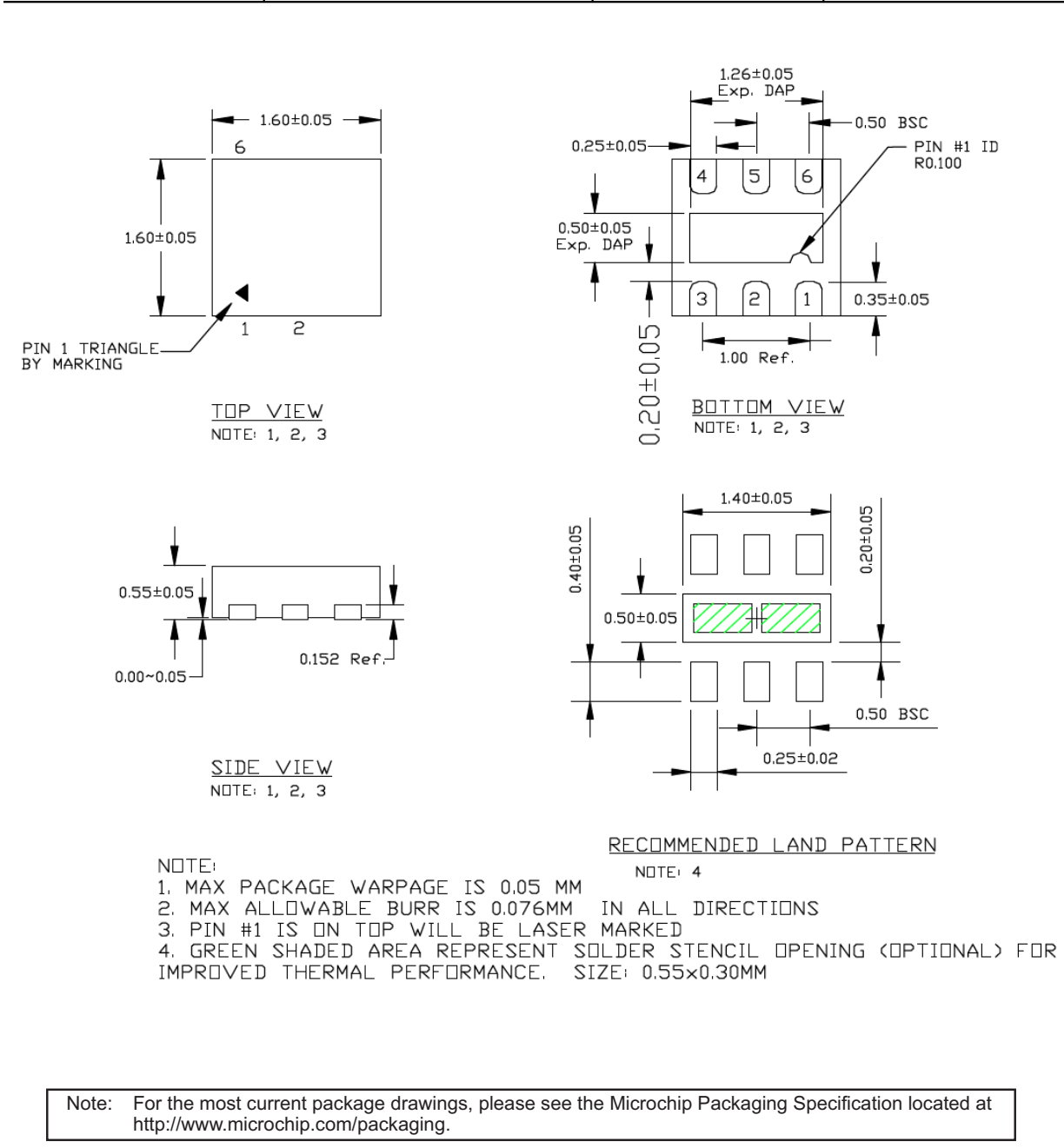
Part Number	Marking Code	Output Voltage	Auto-Discharge
MIC94325YMT	2R	Adjustable	No
MIC94345-4YMT	4L	1.2V	No
MIC94345-FYMT	FL	1.5V	No
MIC94345-GYMT	1X	1.8V	No
MIC94345-MYMT	2X	2.8V	No
MIC94345-SYMT	3X	3.3V	No
MIC94355-4YMT	9G	1.2V	Yes
MIC94355-FYMT	0G	1.5V	Yes
MIC94355-GYMT	2G	1.8V	Yes
MIC94355-MYMT	7G	2.8V	Yes
MIC94355-SYMT	8G	3.3V	Yes

## 6-Lead 1.6 mm x 1.6 mm TDFN Package Outline & Recommended Land Pattern

**TITLE**

6 LEAD TDFN 1.6x1.6mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	TDFN1616-6LD-PL-1	UNIT	MM
-----------	-------------------	------	----



# MIC94325/45/55

---

NOTES:

## APPENDIX A: REVISION HISTORY

### Revision A (March 2021)

- Converted Micrel document MIC94325/45/55 to Microchip data sheet template DS20006524A.
- Minor grammatical text changes throughout.
- Removed reference to the 6-Ball CSP package option.
- All schematic and BOM references removed as they are found in the User's Guide for these parts.

# MIC94325/45/55

---

NOTES:

## PRODUCT IDENTIFICATION SYSTEM

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

Device	-X	X	XX	-XX	Examples:	
Part No.	Output Voltage	Junction Temp. Range	Package	Media Type		
<b>Device:</b>	MIC94325:	500 mA LDO with Ripple Blocker Technology and Adjustable Output Voltage			a) MIC94325YMT-TR:	MIC94325, Adjustable Output Voltage, -40°C to +125°C Temperature Range, 6-Lead TDFN, 5,000/Reel
	MIC94345:	500 mA LDO with Ripple Blocker Technology and Fixed Output Voltage			b) MIC94345-FYMT-T5:	MIC94345, 1.5V Output Voltage, -40°C to +125°C Temperature Range, 6-Lead TDFN, 500/Reel
	MIC94355:	500 mA LDO with Ripple Blocker Technology, Fixed Output Voltage, & Auto-Discharge			c) MIC94355-SYMT-TR:	MIC94355, 3.3V Output Voltage, -40°C to +125°C Temperature Range, 6-Lead TDFN, 5,000/Reel
<b>Output Voltage:</b>	<blank> = Adjustable (MIC94325 only) 4 = 1.2V F = 1.5V G = 1.8V M = 2.8V S = 3.3V				d) MIC94325YMT-T5:	MIC94325, Adjustable Output Voltage, -40°C to +125°C Temperature Range, 6-Lead TDFN, 500/Reel
<b>Junction Temperature Range:</b>	Y	=	-40°C to +125°C		e) MIC94345-4YMT-TR:	MIC94345, 1.2V Output Voltage, -40°C to +125°C Temperature Range, 6-Lead TDFN, 5,000/Reel
<b>Package:</b>	MT	=	6-Lead 1.6 mm x 1.6 mm TDFN		f) MIC94355-MYMT-T5:	MIC94355, 2.8V Output Voltage, -40°C to +125°C Temperature Range, 6-Lead TDFN, 500/Reel
<b>Media Type:</b>	TR	=	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.
	T5	=	500/Reel			

# MIC94325/45/55

---

NOTES:

---

**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.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable." Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

---

Information contained in this publication is provided for the sole purpose of designing with and using Microchip products. Information regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL OR CONSEQUENTIAL LOSS, DAMAGE, COST OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

**Trademarks**

The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, HELDO, IGL00, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maxStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PackeTime, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AgileSwitch, APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, FlashTec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, Augmented Switching, BlueSky, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, IdealBridge, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, Inter-Chip Connectivity, JitterBlocker, maxCrypto, maxView, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, RTAX, RTG4, SAM-ICE, Serial Quad I/O, simpleMAP, SimpliPHY, SmartBuffer, SMART-I.S., storClad, SQI, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, TSHARC, USBCheck, VariSense, VectorBlox, VeriPHY, ViewSpan, WiperLock, XpressConnect, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2021, Microchip Technology Incorporated, All Rights Reserved.

ISBN: 978-1-5224-7984-0

For information regarding Microchip's Quality Management Systems, please visit [www.microchip.com/quality](http://www.microchip.com/quality).



# MICROCHIP

## Worldwide Sales and Service

### AMERICAS

**Corporate Office**  
2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7200  
Fax: 480-792-7277  
Technical Support:  
<http://www.microchip.com/support>  
Web Address:  
[www.microchip.com](http://www.microchip.com)

#### Atlanta

Duluth, GA  
Tel: 678-957-9614  
Fax: 678-957-1455

#### Austin, TX

Tel: 512-257-3370

#### Boston

Westborough, MA  
Tel: 774-760-0087  
Fax: 774-760-0088

#### Chicago

Itasca, IL  
Tel: 630-285-0071  
Fax: 630-285-0075

#### Dallas

Addison, TX  
Tel: 972-818-7423  
Fax: 972-818-2924

#### Detroit

Novi, MI  
Tel: 248-848-4000

#### Houston, TX

Tel: 281-894-5983

#### Indianapolis

Noblesville, IN  
Tel: 317-773-8323  
Fax: 317-773-5453  
Tel: 317-536-2380

#### Los Angeles

Mission Viejo, CA  
Tel: 949-462-9523  
Fax: 949-462-9608  
Tel: 951-273-7800

#### Raleigh, NC

Tel: 919-844-7510

#### New York, NY

Tel: 631-435-6000

#### San Jose, CA

Tel: 408-735-9110  
Tel: 408-436-4270

#### Canada - Toronto

Tel: 905-695-1980  
Fax: 905-695-2078

### ASIA/PACIFIC

**Australia - Sydney**  
Tel: 61-2-9868-6733

**China - Beijing**  
Tel: 86-10-8569-7000

**China - Chengdu**  
Tel: 86-28-8665-5511

**China - Chongqing**  
Tel: 86-23-8980-9588

**China - Dongguan**  
Tel: 86-769-8702-9880

**China - Guangzhou**  
Tel: 86-20-8755-8029

**China - Hangzhou**  
Tel: 86-571-8792-8115

**China - Hong Kong SAR**  
Tel: 852-2943-5100

**China - Nanjing**  
Tel: 86-25-8473-2460

**China - Qingdao**  
Tel: 86-532-8502-7355

**China - Shanghai**  
Tel: 86-21-3326-8000

**China - Shenyang**  
Tel: 86-24-2334-2829

**China - Shenzhen**  
Tel: 86-755-8864-2200

**China - Suzhou**  
Tel: 86-186-6233-1526

**China - Wuhan**  
Tel: 86-27-5980-5300

**China - Xian**  
Tel: 86-29-8833-7252

**China - Xiamen**  
Tel: 86-592-2388138

**China - Zhuhai**  
Tel: 86-756-3210040

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-3090-4444

**India - New Delhi**  
Tel: 91-11-4160-8631

**India - Pune**  
Tel: 91-20-4121-0141

**Japan - Osaka**  
Tel: 81-6-6152-7160

**Japan - Tokyo**  
Tel: 81-3-6880-3770

**Korea - Daegu**  
Tel: 82-53-744-4301

**Korea - Seoul**  
Tel: 82-2-554-7200

**Malaysia - Kuala Lumpur**  
Tel: 60-3-7651-7906

**Malaysia - Penang**  
Tel: 60-4-227-8870

**Philippines - Manila**  
Tel: 63-2-634-9065

**Singapore**  
Tel: 65-6334-8870

**Taiwan - Hsin Chu**  
Tel: 886-3-577-8366

**Taiwan - Kaohsiung**  
Tel: 886-7-213-7830

**Taiwan - Taipei**  
Tel: 886-2-2508-8600

**Thailand - Bangkok**  
Tel: 66-2-694-1351

**Vietnam - Ho Chi Minh**  
Tel: 84-28-5448-2100

### EUROPE

**Austria - Wels**  
Tel: 43-7242-2244-39  
Fax: 43-7242-2244-393

**Denmark - Copenhagen**  
Tel: 45-4485-5910  
Fax: 45-4485-2829

**Finland - Espoo**  
Tel: 358-9-4520-820

**France - Paris**  
Tel: 33-1-69-53-63-20  
Fax: 33-1-69-30-90-79

**Germany - Garching**  
Tel: 49-8931-9700

**Germany - Haan**  
Tel: 49-2129-3766400

**Germany - Heilbronn**  
Tel: 49-7131-72400

**Germany - Karlsruhe**  
Tel: 49-721-625370

**Germany - Munich**  
Tel: 49-89-627-144-0  
Fax: 49-89-627-144-44

**Germany - Rosenheim**  
Tel: 49-8031-354-560

**Israel - Ra'anana**  
Tel: 972-9-744-7705

**Italy - Milan**  
Tel: 39-0331-742611  
Fax: 39-0331-466781

**Italy - Padova**  
Tel: 39-049-7625286

**Netherlands - Drunen**  
Tel: 31-416-690399  
Fax: 31-416-690340

**Norway - Trondheim**  
Tel: 47-7288-4388

**Poland - Warsaw**  
Tel: 48-22-3325737

**Romania - Bucharest**  
Tel: 40-21-407-87-50

**Spain - Madrid**  
Tel: 34-91-708-08-90  
Fax: 34-91-708-08-91

**Sweden - Gothenberg**  
Tel: 46-31-704-60-40

**Sweden - Stockholm**  
Tel: 46-8-5090-4654

**UK - Wokingham**  
Tel: 44-118-921-5800  
Fax: 44-118-921-5820