

High Performance 500 mA LDO

Features

- Input Voltage Range: 2.5V to 5.5V
- Fixed Output Voltages Down to 1.0V
- Ensured 500 mA Output Current
- High Output Initial Accuracy ($\pm 1\%$)
- High PSRR: 80 dB
- Low Quiescent Current: 38 μA
- Stable with 2.2 μF Ceramic Output Capacitors
- Low Dropout Voltage 260 mV at 500 mA
- Auto-Discharge and Internal Enable Pull-Down
- Thermal Shutdown and Current-Limit Protection
- 4-Lead 1 mm x 1 mm UDFN Package

Applications

- Portable Communication Equipment
- DSC, GPS, PMP, and PDAs
- Portable Medical Devices
- 5V POL Applications

General Description

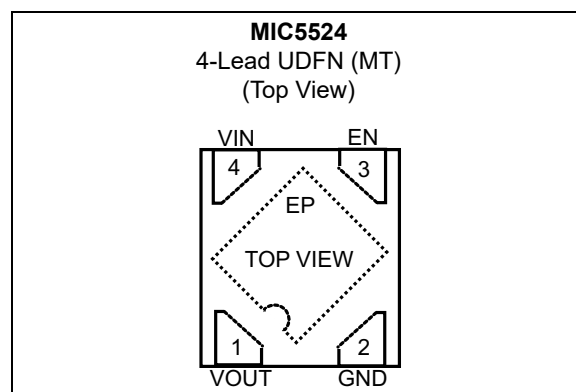
The MIC5524 is a low-power, μCap , low dropout regulator designed for optimal performance in a very small footprint. It is capable of sourcing 500 mA of output current and only draws 38 μA of operating current to do so. The MIC5524 includes an auto-discharge feature on the output that is activated when the enable pin is low and it has an internal pull-down resistor on the enable pin that will disable the output when the enable pin is left floating. This is ideal for applications where the control signal is floating during processor boot up.

This high-performance LDO offers fast transient response and good PSRR in a 1 mm x 1 mm (0.55 mm ht.) UDFN package.

Ideal for battery-operated applications, the MIC5524 offers 2% accuracy, extremely low dropout voltage (260 mV at 500 mA), and can regulate output voltages down to 1.0V. Equipped with a TTL logic-compatible enable pin, the MIC5524 can be put into a zero off-mode current state, drawing no current when disabled.

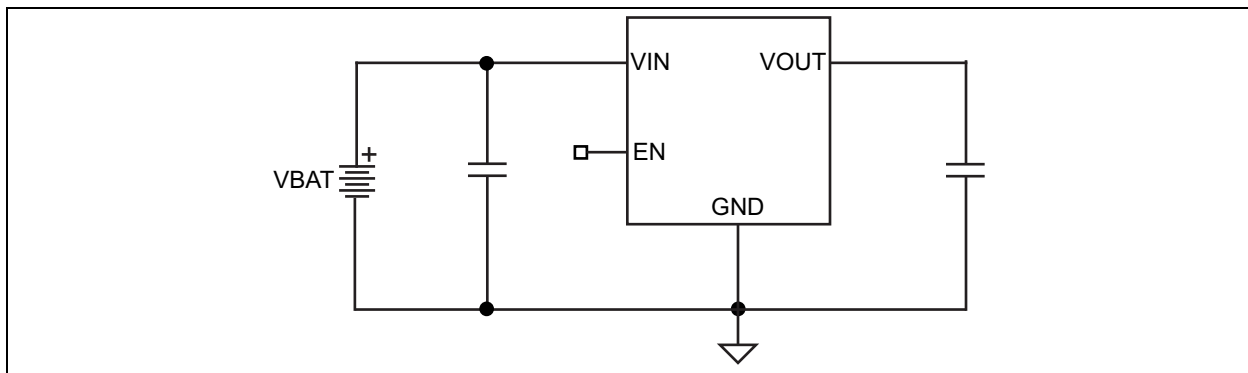
The MIC5524 is a μCap design, operating with very small ceramic output capacitors for stability, reducing required board space and component cost for space-critical applications. The MIC5524 has an operating junction temperature range of -40°C to 125°C .

Package Type

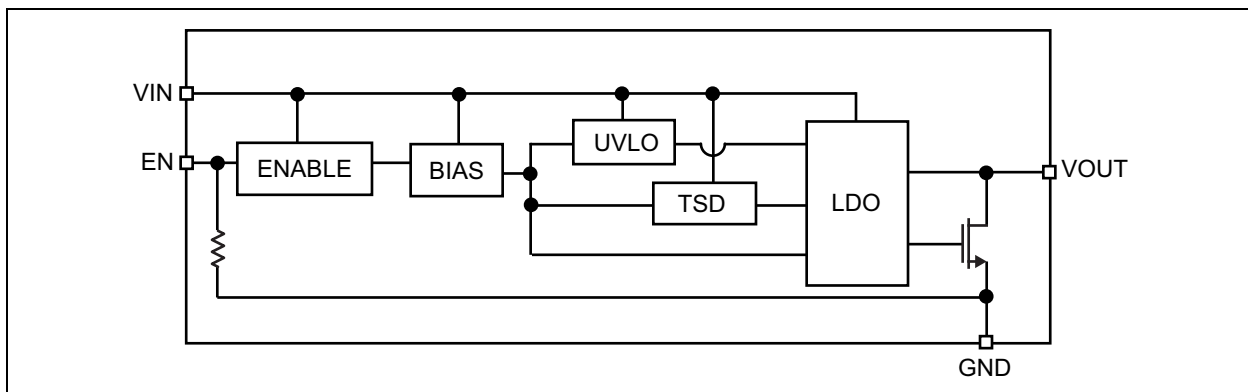


MIC5524

Typical Application Circuit



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN})	–0.3V to +6V
Enable Voltage (V_{EN})	–0.3V to V_{IN}
Power Dissipation (P_D , Note 1)	Internally Limited
ESD Rating (Note 2)	3 kV

Operating Ratings ‡

Supply Voltage (V_{IN})	+2.5V to +5.5V
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: 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.

2: Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5 k Ω in series with 100 pF.

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: $V_{IN} = V_{EN} = V_{OUT} + 1V$; $C_{IN} = C_{OUT} = 2.2 \mu F$; $I_{OUT} = 100 \mu A$; $T_J = +25^\circ C$. **Bold** values valid for $-40^\circ C$ to $+125^\circ C$; unless otherwise specified. [Note 1](#)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy	V_O	–2.0	± 1	2.0	%	Variation from nominal V_{OUT}
		–3.0	—	3.0		Variation from nominal V_{OUT}
Line Regulation	$\Delta V_{OUT}/(V_{OUT} \times \Delta V_{IN})$	—	0.02	0.3	%/V	$V_{IN} = V_{OUT} + 1V$ to 5.5V; $I_{OUT} = 100 \mu A$
Load Regulation	ΔV_{OUT}	—	10	—	mV	Note 2 , $I_{OUT} = 100 \mu A$ to 500 mA
Dropout Voltage (Note 3)	V_{DROP}	—	80	175	mV	$I_{OUT} = 150$ mA
		—	260	500		$I_{OUT} = 500$ mA
Ground Pin Current (Note 4)	I_{GND}	—	38	55	μA	$I_{OUT} = 0$ mA
		—	42	—		$I_{OUT} = 500$ mA
Ground Pin Current in Shutdown	$I_{GND(SHDN)}$	—	0.05	1	μA	$V_{EN} = 0V$
Ripple Rejection	PSRR	—	80	—	dB	f = 100 Hz
		—	65	—		f = 1 kHz
Current Limit	I_{LIM}	525	800	—	mA	$V_{OUT} = 0V$
Output Voltage Noise	e_N	—	80	—	μV_{RMS}	f = 10 Hz to 100 kHz
Auto-Discharge NFET Resistance	R_{NFET}	—	25	—	Ω	$V_{EN} = 0V$; $V_{IN} = 3.6V$ $I_{OUT} = -3$ mA

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: $V_{IN} = V_{EN} = V_{OUT} + 1V$; $C_{IN} = C_{OUT} = 2.2 \mu F$; $I_{OUT} = 100 \mu A$; $T_J = +25^\circ C$. **Bold** values valid for $-40^\circ C$ to $+125^\circ C$; unless otherwise specified. [Note 1](#)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Enable Input						
Enable Pull-Down Resistor	$R_{EN(PD)}$	—	4	—	$M\Omega$	
Enable Input Voltage	V_{EN}	—	—	0.2	V	Logic Low
		1.2	—	—		Logic High
Enable Input Current	I_{EN}	—	0.01	1	μA	$V_{EN} = 0V$
		—	1.4	2		$V_{EN} = 5.5V$
Turn-On Time	t_{ON}	—	50	125	μs	$I_{OUT} = 150 mA$

Note 1: Specification for packaged product only.

- Regulation is measured at constant junction temperature using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered by the speculation for thermal regulation.
- Dropout voltage is defined as the input-to-output differential at which the output voltage drops 2% below its nominal value measured at $V_{IN} = V_{OUT} + 1V$.
- 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 current.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Absolute Maximum Junction Temperature Range	$T_{J(ABS)}$	-40	—	+150	$^\circ C$	—
Junction Temperature Range	T_J	-40	—	+125	$^\circ C$	—
Storage Temperature	T_S	-65	—	+150	$^\circ C$	—
Lead Temperature	T_{LEAD}	—	—	+260	$^\circ C$	Soldering, 10 sec.
Package Thermal Resistances						
Thermal Resistance, UDFN 4-Ld	θ_{JA}	—	250	—	$^\circ C/W$	—

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.

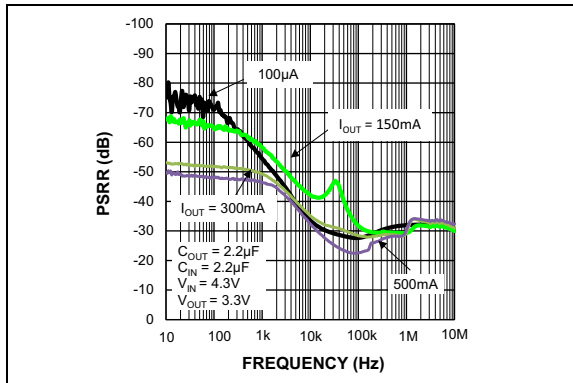


FIGURE 2-1: Power Supply Rejection Ratio.

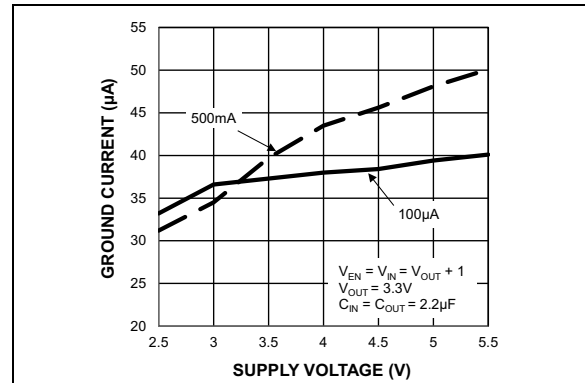


FIGURE 2-4: Ground Current vs. Supply Voltage.

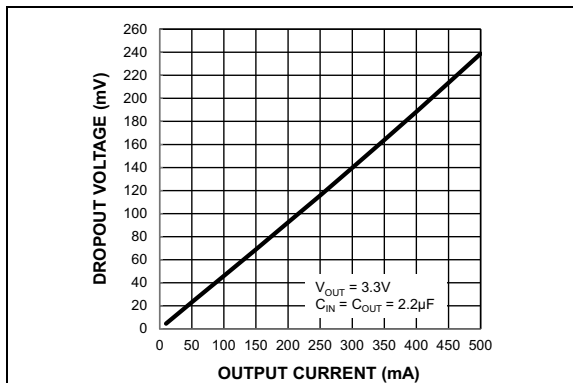


FIGURE 2-2: Dropout Voltage vs. Output Current.

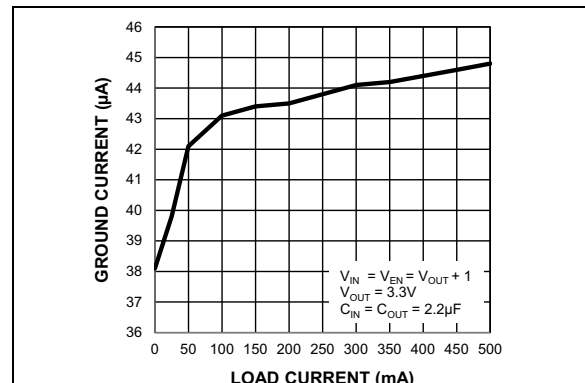


FIGURE 2-5: Ground Current vs. Load Current.

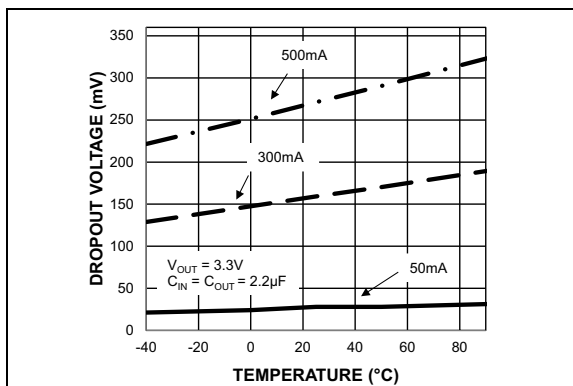


FIGURE 2-3: Dropout Voltage vs. Temperature.

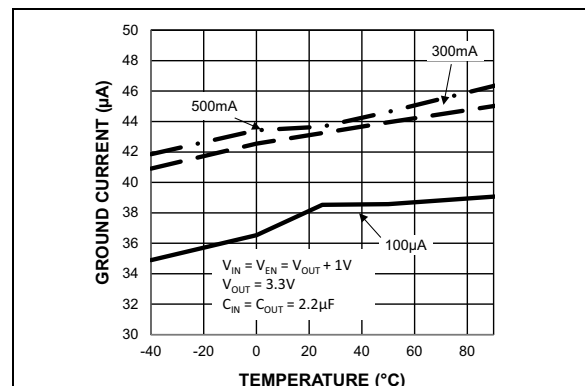


FIGURE 2-6: Ground Current vs. Temperature.

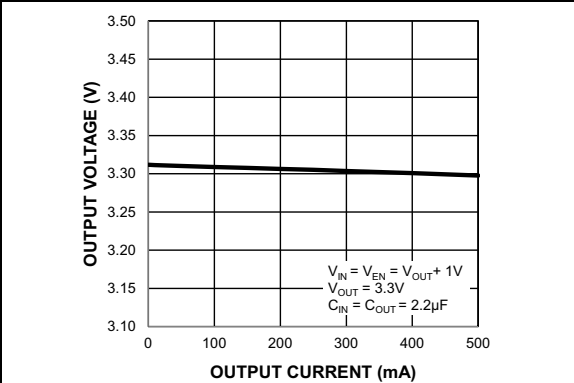


FIGURE 2-7: Output Voltage vs. Output Current.

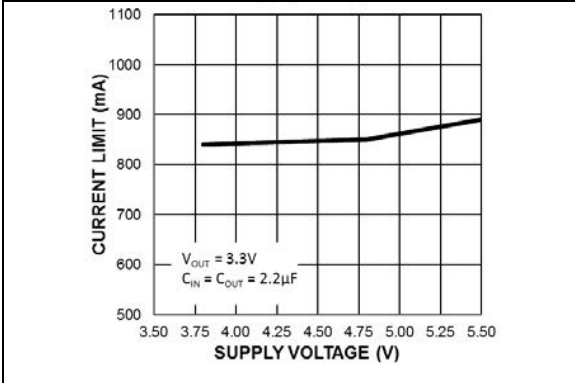


FIGURE 2-10: Current Limit vs. Supply Voltage.

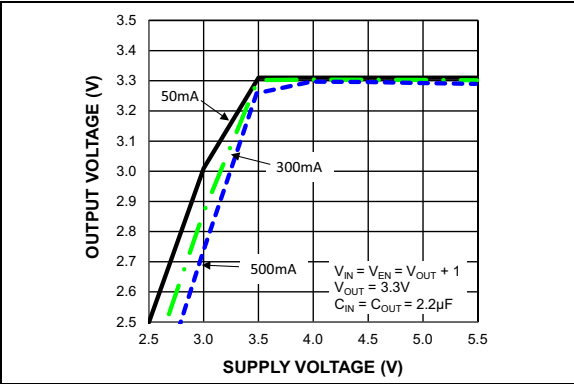


FIGURE 2-8: Output Voltage vs. Supply Voltage.

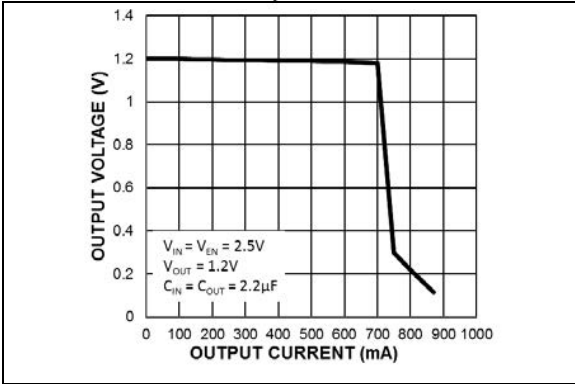


FIGURE 2-11: Output Voltage vs. Output Current.

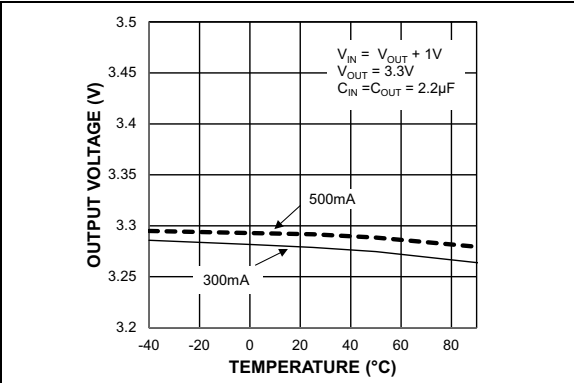


FIGURE 2-9: Output Voltage vs. Temperature.

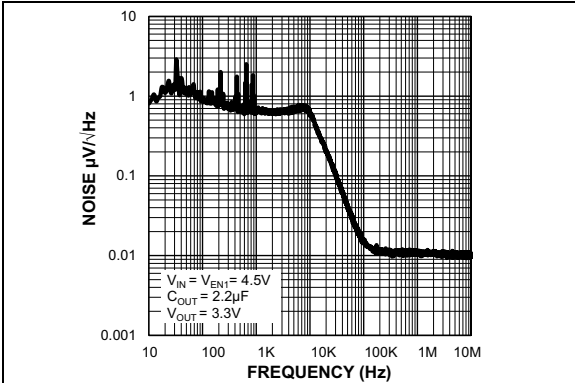


FIGURE 2-12: Output Noise Spectral Density (MIC5524-3.3YMT).

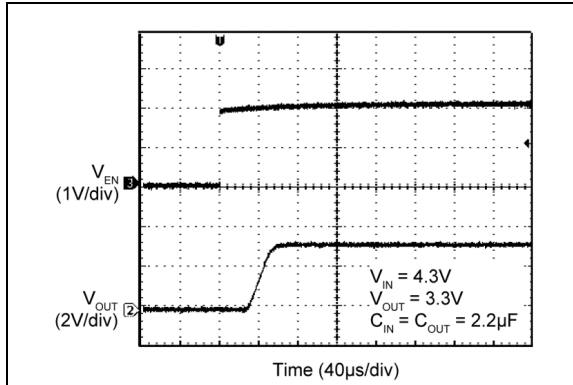


FIGURE 2-13: *Enable-Turn On.*

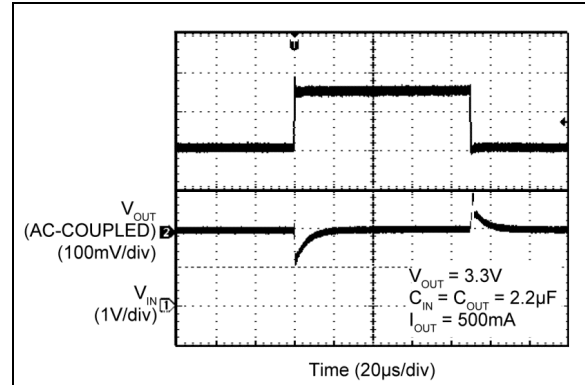


FIGURE 2-15: *Line Transient.*

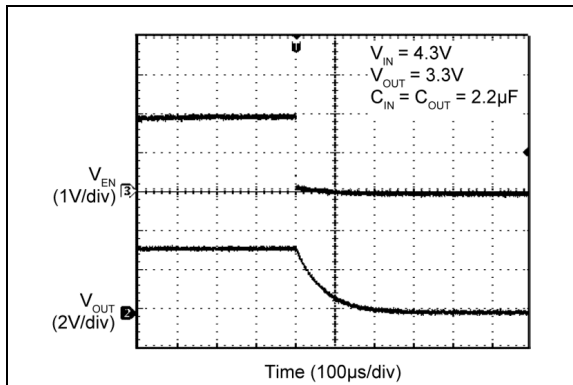


FIGURE 2-14: *Auto-Discharge (No Load).*

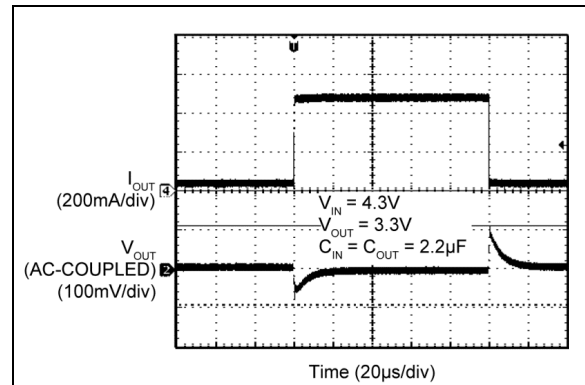


FIGURE 2-16: *Load Transient.*

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	VOUT	Output Voltage. When disabled, the MIC5524 switches in an internal 25 Ω load to discharge the external capacitors.
2	GND	Ground.
3	EN	Enable Input. Active High. High = ON; Low = OFF. The MIC5524 has an internal 4 M Ω pull-down and this pin can be left floating.
4	VIN	Supply Input.
EP	ePad	Exposed Heatsink Pad. Connect to GND.

4.0 APPLICATION INFORMATION

The MIC5524 is a high-performance, low-power 500 mA LDO. The MIC5524 includes an auto-discharge circuit that is switched on when the regulator is disabled through the enable pin. The MIC5524 also offers an internal pull-down resistor on the enable pin to ensure the output is disabled if the control signal is tri-stated. The MIC5524 regulator is fully protected from damage due to fault conditions, offering linear current limiting and thermal shutdown.

4.1 Input Capacitor

The MIC5524 is a high-performance, high-bandwidth device. An input capacitor of 2.2 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

The MIC5524 requires an output capacitor of 2.2 μF or greater to maintain stability. 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 2.2 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 value by as much as 50% and 60%, respectively, over their operating temperature ranges. To use a ceramic chip capacitor with Y5V dielectric, the value must be much higher than an X7R ceramic capacitor to ensure the same minimum capacitance over the equivalent operating temperature range.

4.3 No-Load Stability

Unlike many other voltage regulators, the MIC5524 remains stable and in regulation with no load. This is especially important in CMOS RAM keep-alive applications.

4.4 Enable/Shutdown

The MIC5524 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 an off-mode current state that draws virtually zero current. When disabled, the MIC5524 switches an internal 25 Ω load on the regulator output to discharge the external capacitor.

Forcing the enable pin high enables the output voltage. The MIC5524 has an internal pull-down resistor on the enable pin to disable the output when the enable pin is floating.

4.5 Thermal Considerations

The MIC5524 is 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 3.6V, the output voltage is 3.3V, and the output current is 500 mA. The actual power dissipation of the regulator circuit can be determined using Equation 4-1:

EQUATION 4-1:

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

Because this device is CMOS and the ground current is typically <100 μA over the load range, the power dissipation contributed by the ground current is <1% and can be ignored Equation 4-2:

EQUATION 4-2:

$$P_D = (3.6V - 3.3V) \times 500mA = 0.150W$$

To determine the maximum ambient operating temperature of the package, use the junction-to-ambient thermal resistance of the device Equation 4-3:

EQUATION 4-3:

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

Where:

$T_{J(MAX)}$ = 125°C, the max. junction temp. of the die
 θ_{JA} = Thermal resistance of 250°C/W for the UDFN package.

MIC5524

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 $250^{\circ}C/W$.

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

For example, when operating the MIC5524-3.3YMT at an input voltage of 3.6V and a 500 mA load with a minimum footprint layout, the maximum ambient operating temperature T_A can be determined as in Equation 4-4:

EQUATION 4-4:

$$0.15 W = (125^{\circ}C - T_A) \div 250^{\circ}C/W$$
$$T_A = 87.5^{\circ}C$$

Therefore, the maximum ambient operating temperature allowed in a 1 mm x 1 mm UDFN package is $87.5^{\circ}C$. 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](#).

5.0 TYPICAL APPLICATION SCHEMATIC

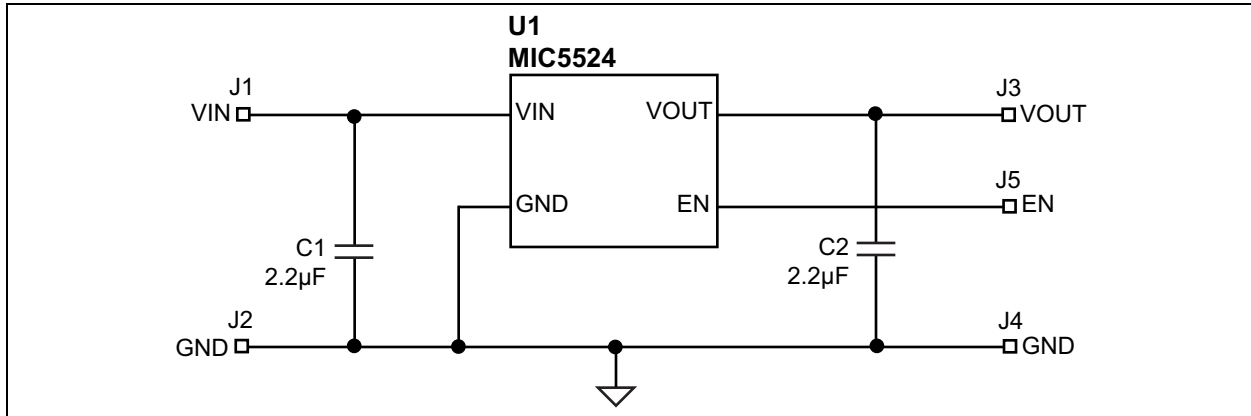


TABLE 5-1: BILL OF MATERIALS

Item	Part Number	Manufacturer	Description	Qty.
C1, C2	GRM188R71A225KE15D	Murata	Capacitor, 2.2 µF Ceramic, 10V, X5R, Size 0603	2
U1	MIC5524-x.xYMT	Microchip	High-Performance 500 mA LDO	1

6.0 PCB LAYOUT RECOMMENDATIONS

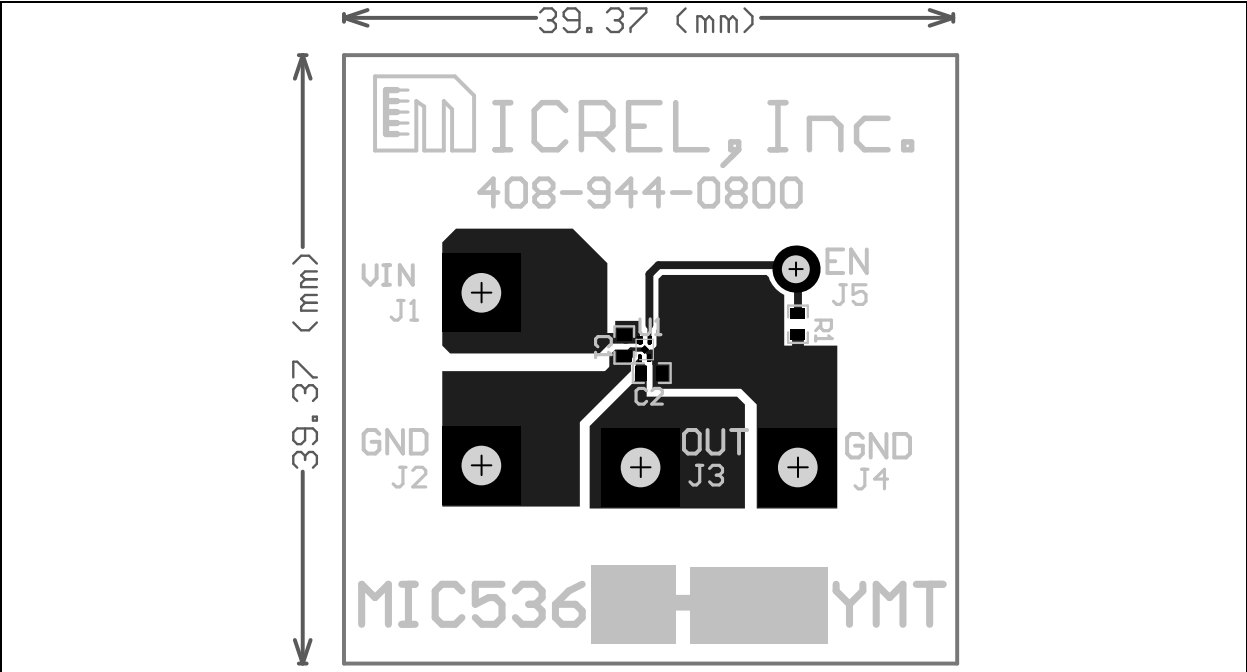


FIGURE 6-1: Top Layer.

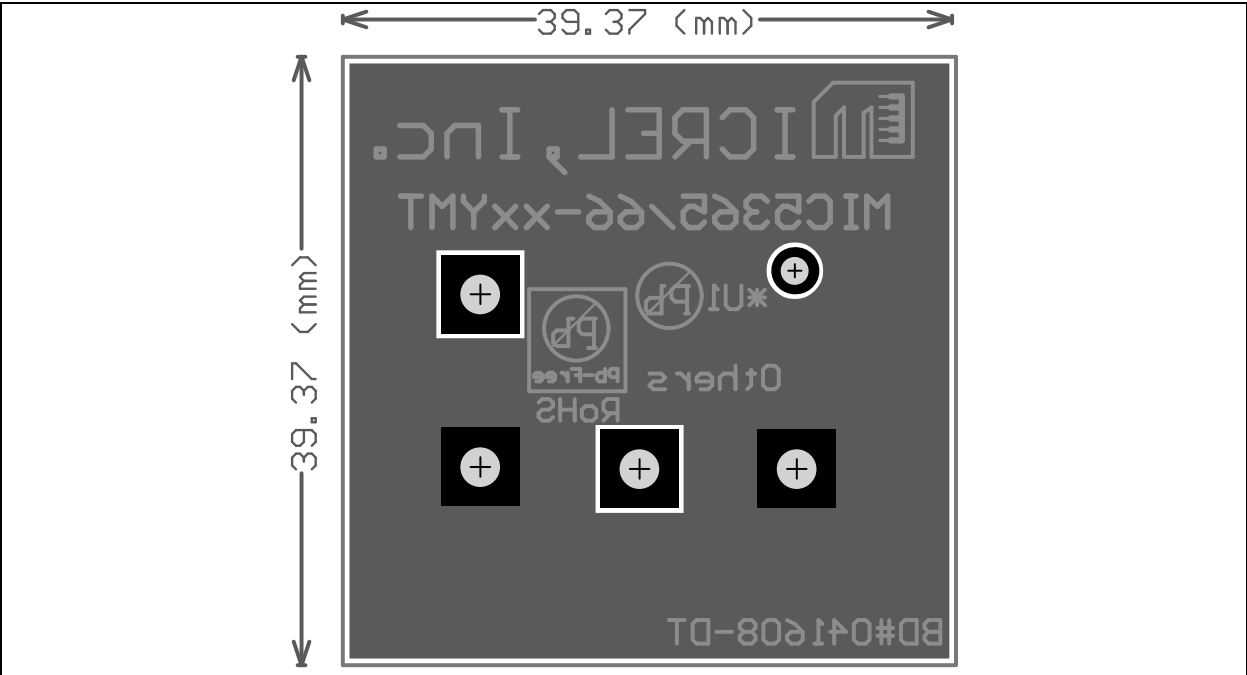
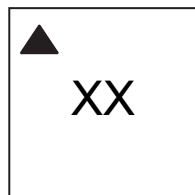


FIGURE 6-2: Bottom Layer.

7.0 PACKAGING INFORMATION

7.1 Package Marking Information

4-Lead UDFN*



Example

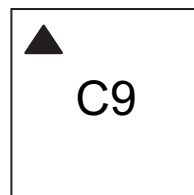


TABLE 7-1: MARKING CODES

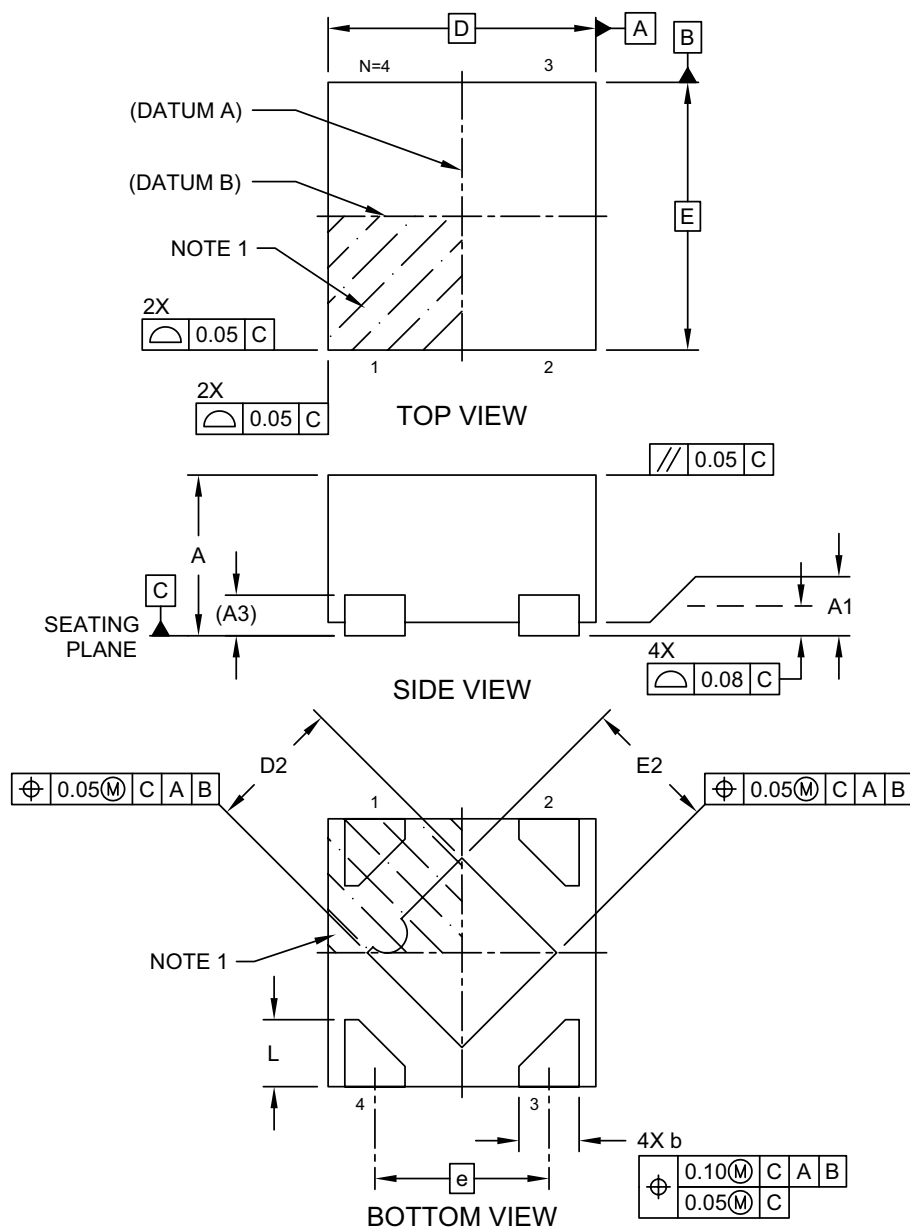
Part Number	Marking Code	Output Voltage
MIC5524-1.2YMT	C9	1.2V
MIC5524-1.8YMT	C6	1.8V
MIC5524-2.5YMT	8C	2.5V
MIC5524-2.8YMT	4C	2.8V
MIC5524-3.0YMT	3C	3.0V
MIC5524-3.3YMT	C3	3.3V

Legend:	<p>XX...X Product code or customer-specific information</p> <p>Y Year code (last digit of calendar year)</p> <p>YY Year code (last 2 digits of calendar year)</p> <p>WW Week code (week of January 1 is week '01')</p> <p>NNN Alphanumeric traceability code</p> <p>(e3) Pb-free JEDEC® designator for Matte Tin (Sn)</p> <p>* This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.</p> <p>•, ▲, ▼ Pin one index is identified by a dot, delta up, or delta down (triangle mark).</p>
Note:	<p>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.</p> <p>Underbar (_) symbol may not be to scale.</p>

Note: If the full seven-character YYWWNNN code cannot fit on the package, the following truncated codes are used based on the available marking space:
 6 Characters = YWWNNN; 5 Characters = WWNNN; 4 Characters = WNNN; 3 Characters = NNN;
 2 Characters = NN; 1 Character = N

4-Lead Ultra Thin Plastic Dual Flat, No Lead Package (HCA) - 1x1 mm Body [UDFN]

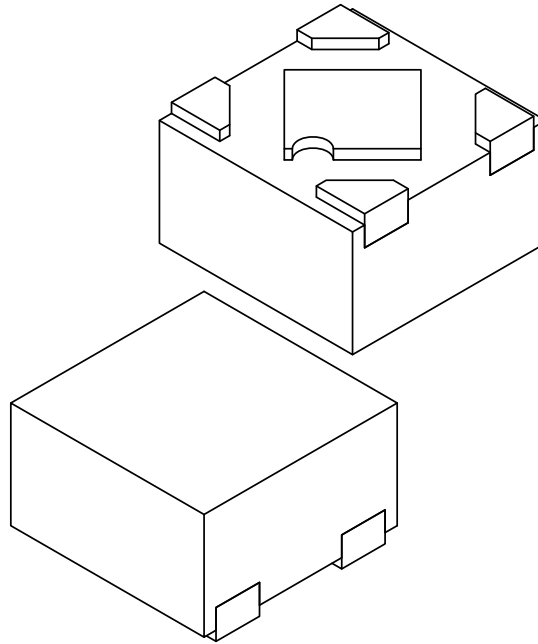
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-1149 Rev A Sheet 1 of 2

4-Lead Ultra Thin Plastic Dual Flat, No Lead Package (HCA) - 1x1 mm Body [UDFN]

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	4		
Pitch	e	0.65 BSC		
Overall Height	A	0.50	0.55	0.60
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3	0.152 REF		
Overall Length	D	1.00 BSC		
Exposed Pad Length	D2	0.45	0.50	0.55
Overall Width	E	1.00 BSC		
Exposed Pad Width	E2	0.45	0.50	0.55
Terminal Width	b	0.175	0.225	0.275
Terminal Length	L	0.20	0.25	0.30

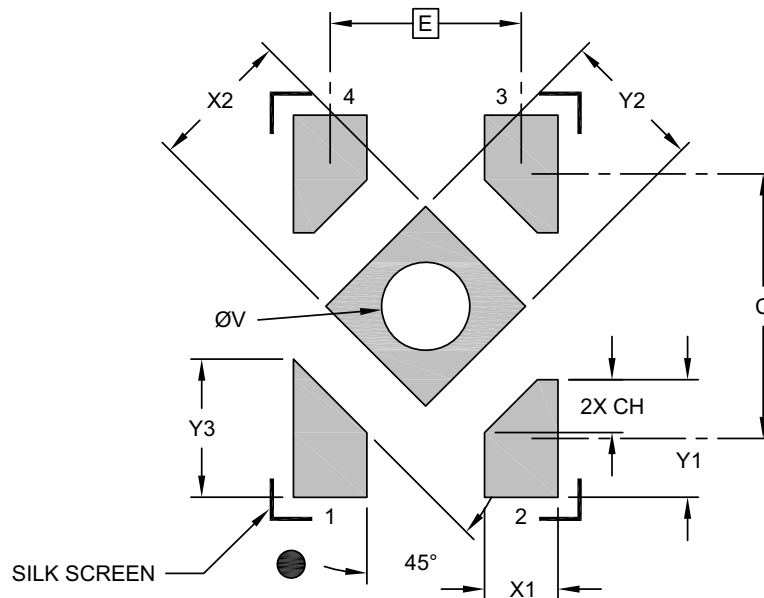
Notes:

- 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 C04-1149 Rev A Sheet 2 of 2

4-Lead Ultra Thin Plastic Dual Flat, No Lead Package (HCA) - 1x1 mm Body [UDFN]

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	
Center Pad Width	X2			0.48
Center Pad Length	Y2			0.48
Contact Pad Spacing	C		0.90	
Contact Pad Width (X4)	X1			0.25
Contact Pad Length (X3)	Y1			0.40
Terminal 1 Pad Length	Y3			0.47
Contact Pad Chamfer (X3)	CH		0.18	
Thermal Via Diameter	V		0.30	

Notes:

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

Microchip Technology Drawing C04-3149 Rev A

APPENDIX A: REVISION HISTORY

Revision A (September 2022)

- Converted Micrel document MIC5524 to Microchip data sheet DS20006732A.
- Minor text changes throughout.

MIC5524

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

<u>Part Number</u>	<u>[X]</u>	<u>X</u>	<u>XX</u>	<u>-XX</u>
Device	Output Voltage	Temp. Range	Package	Media Type
Device:	MIC5524:	High-Performance 500 mA LDO		
	1.2	= 1.2V		
	1.8	= 1.8V		
Output Voltage:	2.5	= 2.5V		
	2.8	= 2.8V		
	3.0	= 3.0V		
	3.3	= 3.3V		
Temperature Range:	Y	= -40°C to +125°C		
Package:	MT	= 4-Lead 1 mm x 1 mm UDFN		
Media Type:	TZ	= 10,000/Reel		
	TR	= 5,000/Reel		

Examples:

a) MIC5524-1.2YMT-TR: MIC5524, 1.2V Output Voltage, -40°C to +125°C Temp. Range, 4-Lead UDFN, 5,000/Reel

b) MIC5524-1.8YMT-TZ: MIC5524, 1.8V Output Voltage, -40°C to +125°C Temp. Range, 4-Lead UDFN, 10,000/Reel

c) MIC5524-2.5YMT-TR: MIC5524, 2.5V Output Voltage, -40°C to +125°C Temp. Range, 4-Lead UDFN, 5,000/Reel

d) MIC5524-2.8YMT-TZ: MIC5524, 2.8V Output Voltage, -40°C to +125°C Temp. Range, 4-Lead UDFN, 10,000/Reel

e) MIC5524-3.0YMT-TR: MIC5524, 3.0V Output Voltage, -40°C to +125°C Temp. Range, 4-Lead UDFN, 5,000/Reel

f) MIC5524-3.3YMT-TZ: MIC5524, 3.3V Output Voltage, -40°C to +125°C Temp. Range, 4-Lead UDFN, 10,000/Reel

Note 1: 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.

MIC5524

NOTES:

Note the following details of the code protection feature on Microchip products:

- 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, within operating specifications, and under normal conditions.
 - Microchip values and aggressively protects its intellectual property rights. Attempts to breach the code protection features of Microchip product is strictly prohibited and may violate the Digital Millennium Copyright Act.
 - 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. Microchip is committed to continuously improving the code protection features of our products.
-

This publication and the information herein may be used only with Microchip products, including to design, test, and integrate Microchip products with your application. Use of this information in any other manner violates these terms. Information regarding device applications 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. Contact your local Microchip sales office for additional support or, obtain additional support at <https://www.microchip.com/en-us/support/design-help/client-support-services>.

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.

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, CryptoMemory, CryptoRF, dsPIC, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Klear, LANCheck, LinkMD, maxStylus, maxTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, 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, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, TrueTime, 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, Clockstudio, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, GridTime, IdealBridge, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, IntelliMOS, Inter-Chip Connectivity, JitterBlocker, Knob-on-Display, KoD, 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, SmartHLS, SMART-I.S., storClad, SQI, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, Trusted Time, 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.

© 2022, Microchip Technology Incorporated and its subsidiaries.

All Rights Reserved.

ISBN: 978-1-6683-1350-3

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

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