

150 mA Low Voltage μ Cap Linear Regulator

Features

- Ultra-Low Noise
- Low Voltage Outputs
- Load Independent, Ultra-Low Ground Current: 85 μ A
- 150 mA Output Current
- Current Limiting
- Thermal Shutdown
- Tight Load and Line Regulation
- “Zero” Off-Mode Current
- Stability with Low-ESR Capacitors
- Fast Transient Response
- Logic-Controlled Enable Input

Applications

- Cellular Phones and Pagers
- Cellular Accessories
- Battery-Powered Equipment
- Laptop, Notebook, and Palmtop Computers
- PCMCIA VCC and VPP Regulation/Switching
- Consumer/Personal Electronics
- SMPS Post-Regulator/DC-to-DC Modules
- High-Efficiency Linear Power Supplies

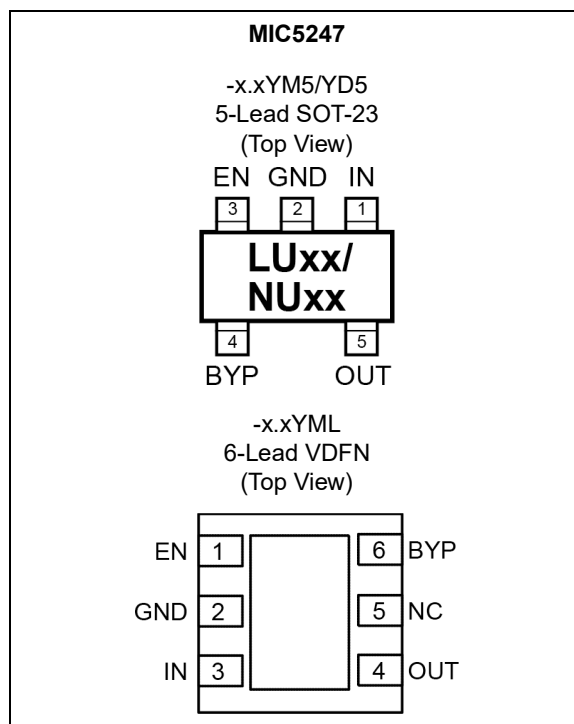
General Description

The MIC5247 is an efficient and precise, low-voltage CMOS linear regulator optimized for ultra-low noise applications. The MIC5247 offers better than 1% initial accuracy and 85 μ A constant ground current over load (typically 85 μ A). The MIC5247 provides a very low-noise output, ideal for RF applications where quiet voltage sources are required. A noise bypass pin is also available for further reduction of output noise.

Designed specifically for handheld and battery-powered devices, the MIC5247 provides a logic compatible enable pin. When disabled, power consumption drops nearly to zero. The MIC5247 also works with low-ESR ceramic capacitors, reducing the amount of board space necessary for power applications, critical in handheld wireless devices.

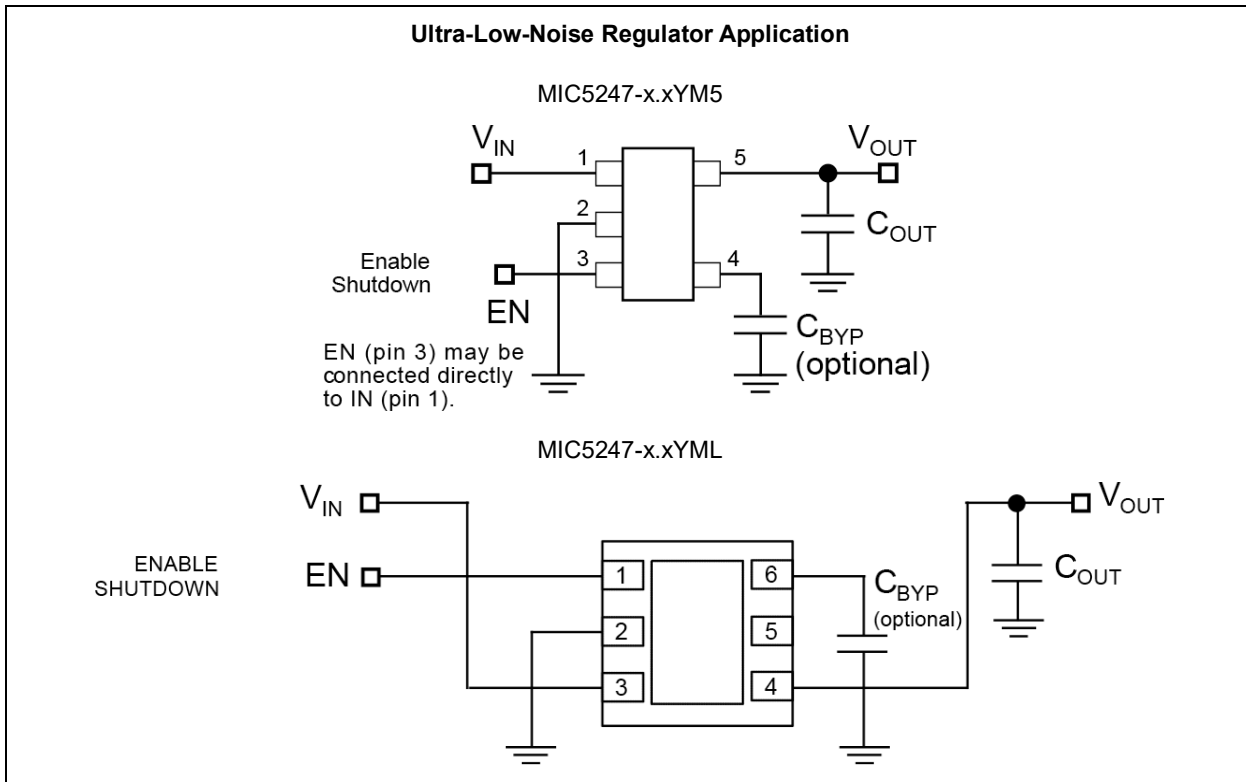
Key features include current limit, thermal shutdown, a push-pull output for faster transient response, and an active clamp to speed up device turnoff. Available in the 6-lead 2 mm \times 2 mm VDFN package and the 5-lead SOT-23 package, the MIC5247 also offers a range of fixed output voltages.

Package Types

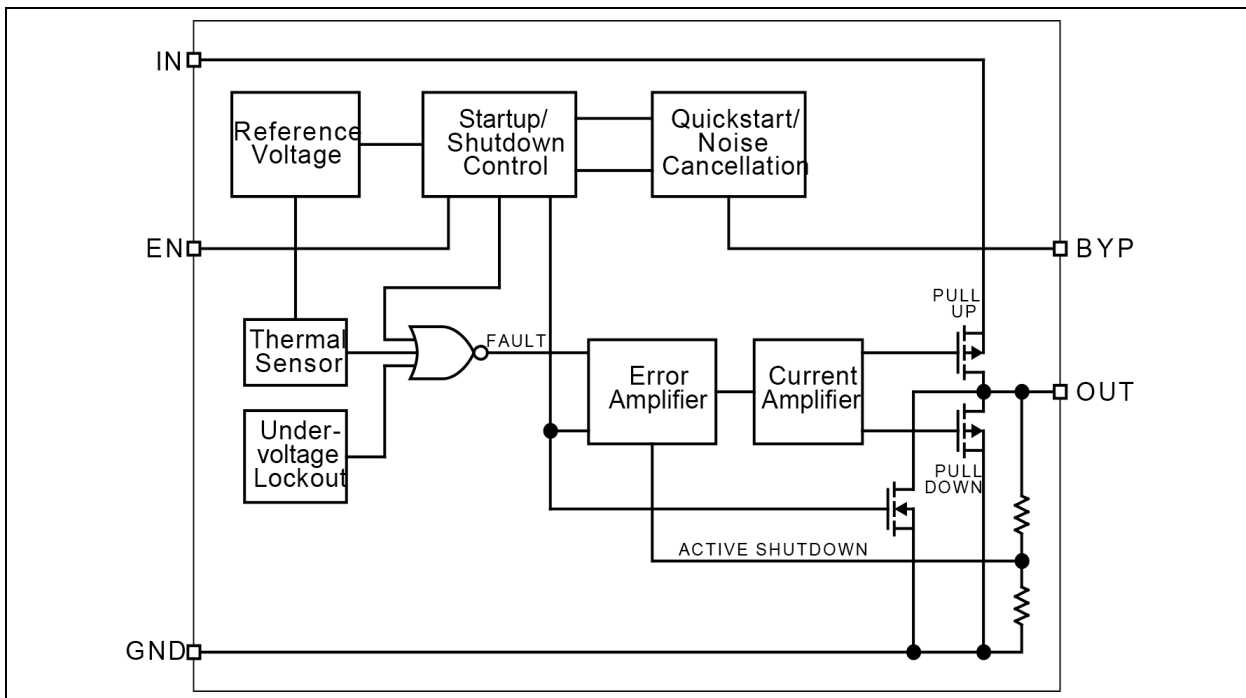


MIC5247

Typical Application Circuits



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Input Voltage (V_{IN})	0V to +7V
Enable Input Voltage (V_{EN})	0V to V_{IN}
ESD Rating	Note 1

Operating Ratings ‡

Input Voltage (V_{IN})	+2.7V to +6V
Enable Input 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.

ELECTRICAL CHARACTERISTICS

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

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy	V_O	-1	—	+1	%	$I_{OUT} = 0 \text{ mA}$
		-2	—	+2		
Line Regulation	ΔV_{LNR}	-0.3	—	+0.3	%/V	$V_{IN} = 2.7V \text{ to } 6V$
Load Regulation	ΔV_{LDR}	—	2	3	%	$I_{OUT} = 0.1 \text{ mA to } 150 \text{ mA}$ (Note 2)
		—	3	4	%	$I_{OUT} = 0.1 \text{ mA to } 150 \text{ mA}$, $V_{OUT} = 1.5V \text{ or } 1.6V$
Dropout Voltage	$V_{IN} - V_{OUT}$	—	150	—	mV	$I_{OUT} = 150 \text{ mA}$ (Note 3)
Quiescent Current	I_Q	—	0.2	1	μA	$V_{EN} \leq 0.4V$ (shutdown)
Ground Pin Current (Note 4)	I_{GND}	—	85	150	μA	$I_{OUT} = 0 \text{ mA}$
		—	85	150	μA	$I_{OUT} = 150 \text{ mA}$
Power Supply Rejection	PSRR	—	50	—	dB	$f \leq 1 \text{ kHz}$
Current Limit	I_{LIM}	160	300	—	mA	$V_{OUT} = 0V$
Output Voltage Noise	e_n	—	30	—	μV_{rms}	$C_{OUT} = 10 \mu F$, $C_{BYP} = 0.01 \mu F$, $f = 10 \text{ Hz to } 100 \text{ kHz}$
Enable Input						
Enable Input Logic-Low Voltage	V_{IL}	—	0.8	0.4	V	$V_{IN} = 2.7V \text{ to } 5.5V$, regulator shutdown
Enable Input Logic-High Voltage	V_{IH}	1.6	1	—	V	$V_{IN} = 2.7V \text{ to } 5.5V$, regulator enabled
Enable Input Current	I_{EN}	—	0.01	—	μA	$V_{IL} \leq 0.4V$
		—	0.01	—	μA	$V_{IH} \geq 1.6V$
Shutdown Resistance Discharge	—	—	500	—	Ω	—

MIC5247

ELECTRICAL CHARACTERISTICS

$V_{IN} = V_{OUT} + 1.0V$; $V_{IN} = V_{EN}$; $I_{OUT} = 100 \mu A$; $T_J = 25^\circ C$, **bold** values valid for $-40^\circ C \leq T_J \leq +125^\circ C$; unless noted. (See [Note 1](#))

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Thermal Protection						
Thermal Shutdown Temperature	—	—	+150	—	$^\circ C$	—
Thermal Shutdown Hysteresis	—	—	+10	—	$^\circ C$	—

Note 1: Specification for packaged product only.

- Regulation is measured at constant junction temperature using low duty cycle pulse testing. Parts are tested for load regulation in the load range from 0.1 mA to 150 mA. Changes in output voltage due to heating effects are covered by the thermal regulation specification.
- Dropout voltage is defined as the input-to-output differential at which the output voltage drops 2% below its nominal value measured a 1V differential. For outputs below 2.7V, dropout voltage is the input-to-output voltage differential with the minimum input voltage 2.7V. Minimum input operating voltage is 2.7V.
- Ground pin current is the regulator quiescent current plus pass transistor base current. The total current drawn from the supply is the sum of the load current plus the ground pin current.

TEMPERATURE SPECIFICATIONS ([Note 1](#))

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Operating Junction Temperature Range	T_J	-40	—	+125	$^\circ C$	—
Maximum Junction Temperature	$T_{J(MAX)}$	—	—	+150	$^\circ C$	—
Lead Temperature	—	—	—	+260	$^\circ C$	Soldering, 5 seconds
Storage Temperature	T_S	-65	—	+150	$^\circ C$	—
Package Thermal Resistance						
Thermal Resistance, 5-Lead SOT-23	θ_{JA}	—	+235	—	$^\circ C/W$	—
Thermal Resistance, 6-Lead VDFN	θ_{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 , θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum rating. Sustained junction temperatures above that maximum can impact 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.

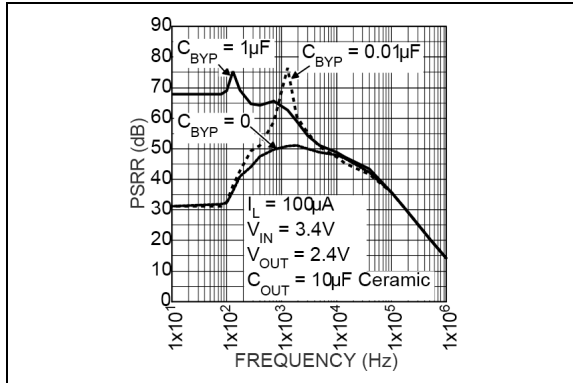


FIGURE 2-1: Power Supply Rejection Ratio.

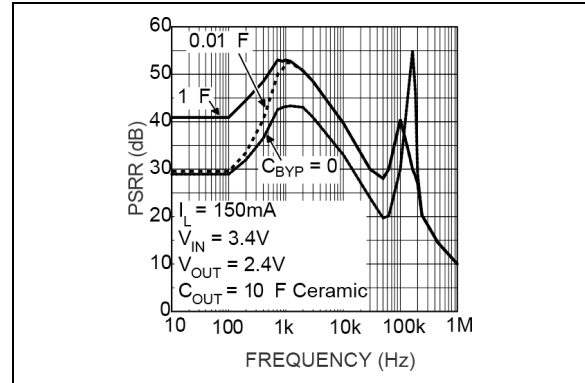


FIGURE 2-4: Power Supply Rejection Ratio.

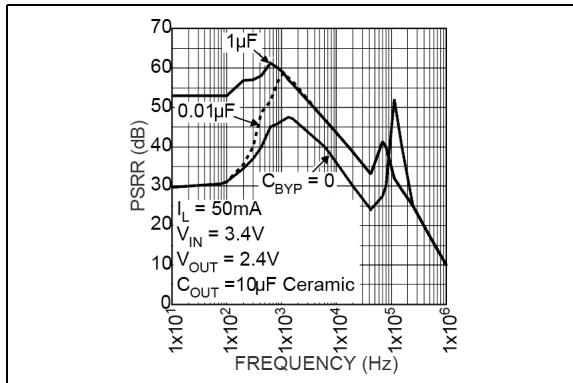


FIGURE 2-2: Power Supply Rejection Ratio.

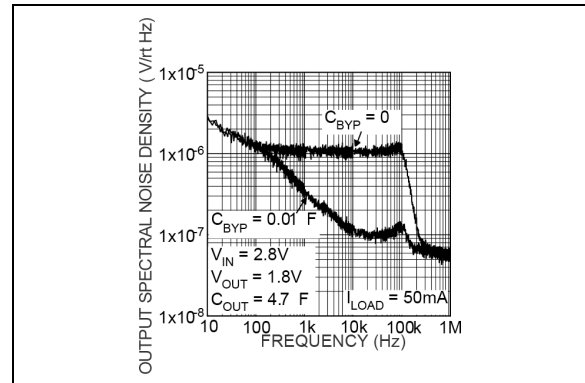


FIGURE 2-5: Noise Performance.

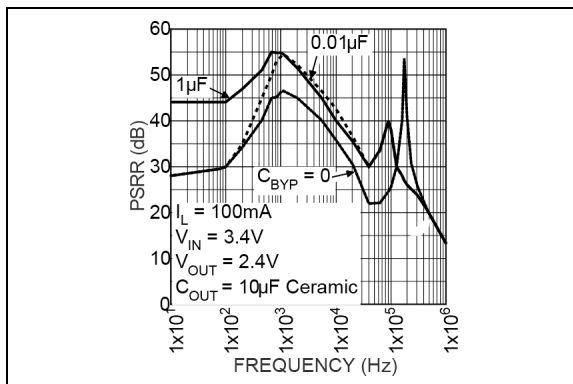


FIGURE 2-3: Power Supply Rejection Ratio.

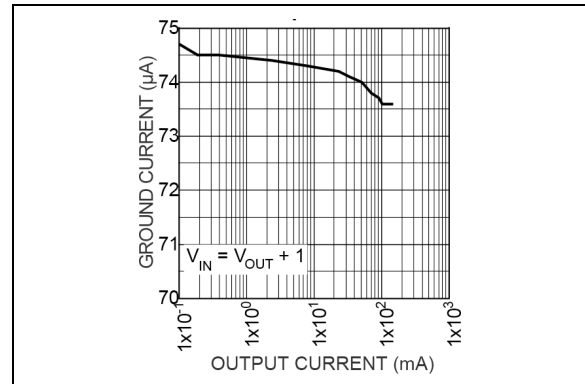


FIGURE 2-6: Ground Current vs. Output Current.

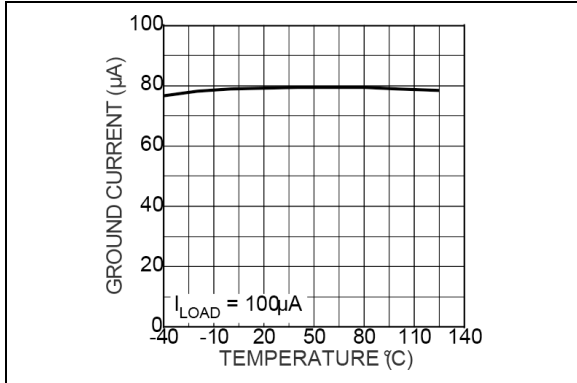


FIGURE 2-7: Ground Pin Current.

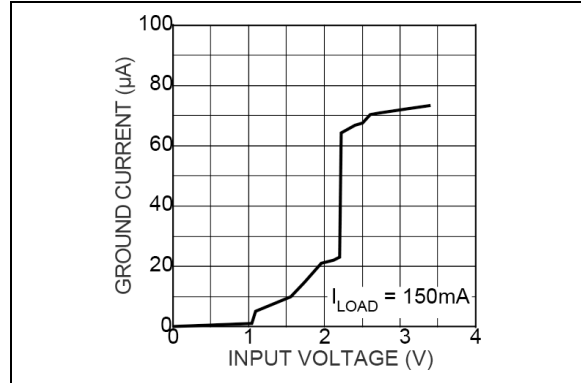


FIGURE 2-10: Ground Pin Current.

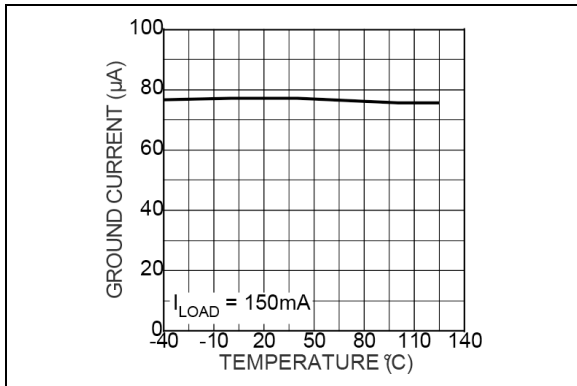


FIGURE 2-8: Ground Pin Current.

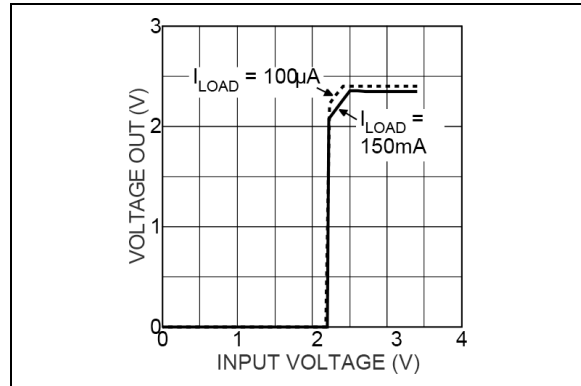


FIGURE 2-11: Dropout Characteristics.

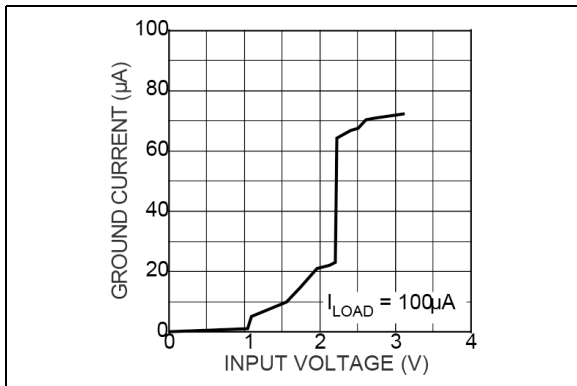


FIGURE 2-9: Ground Pin Current.

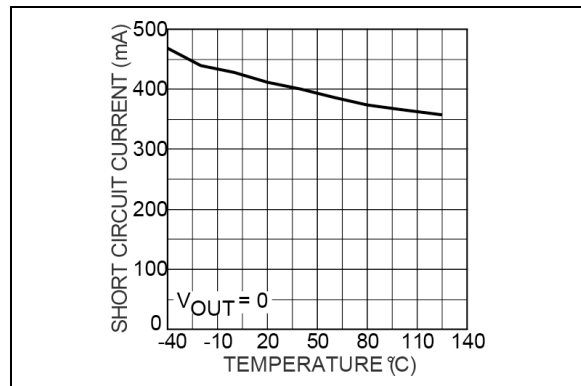


FIGURE 2-12: Short Circuit Current vs. Temperature.

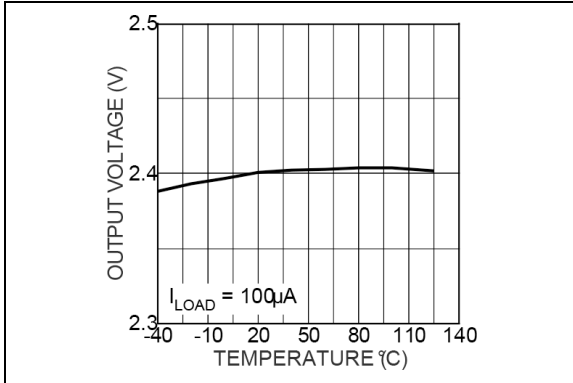


FIGURE 2-13: Output Voltage vs. Temperature.

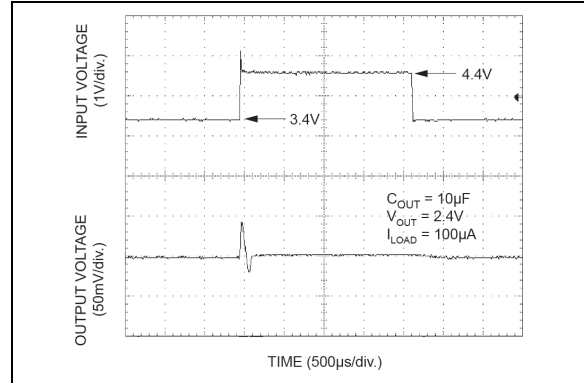


FIGURE 2-16: Line Transient Response.

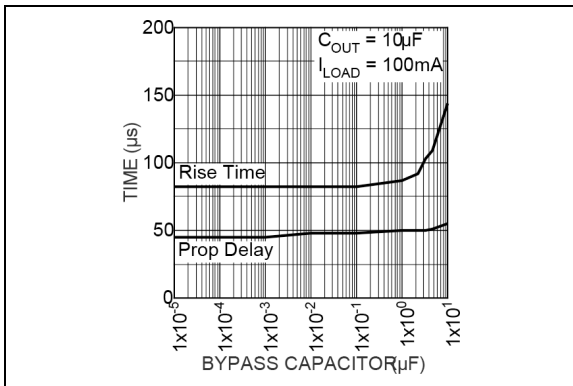


FIGURE 2-14: Turn-On Time vs. Bypass Capacitor.

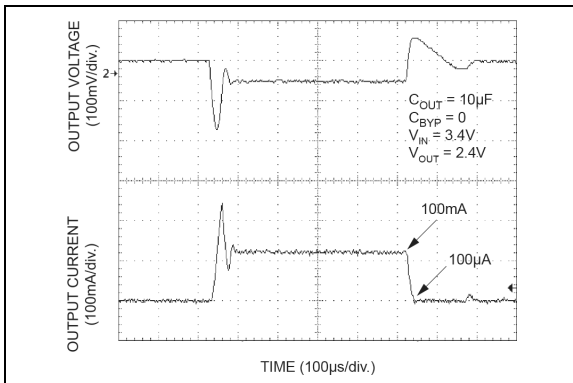


FIGURE 2-15: Load Transient Response.

MIC5247

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin Number 5-Lead SOT-23	Pin Number 6-Lead VDFN	Pin Name	Description
1	3	IN	Supply Input.
2	2	GND	Ground.
3	1	EN	Enable/Shutdown (Input): CMOS-compatible input. Logic high = enable; logic low = shutdown. Do not leave open.
4	6	BYP	Reference Bypass: Connect external 0.01 μ F capacitor to GND to reduce output noise. May be left open.
5	4	OUT	Regulator Output.
—	5	NC	No Internal Connection.
—	EP	GND	Ground. Internally connected to the exposed pad. Connect to ground pin.

4.0 APPLICATION INFORMATION

4.1 Enable/Shutdown

The MIC5247 comes with an active-high enable pin that can disable the regulator. 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.

This part is CMOS and the enable pin cannot be left floating, because a floating enable pin may cause an indeterminate state on the output.

4.2 Input Capacitor

An input capacitor is not required for stability. A 1 μF input capacitor is recommended when the bulk AC supply capacitance is more than 10 inches away from the device or when the supply is a battery.

4.3 Output Capacitor

The MIC5247 requires an output capacitor for stability. The design requires 1 μF or greater on the output to maintain stability. The capacitor can be a low-ESR ceramic chip capacitor.

The MIC5247 has been designed to work specifically with low-cost, small chip capacitors. Tantalum capacitors can also be used for improved capacitance over temperature. The value of the capacitor can be increased without bound.

4.4 Bypass Capacitor

A capacitor can be placed from the noise bypass pin to ground to reduce output voltage noise. The capacitor bypasses the internal reference. A 0.01 μF capacitor is recommended for applications that require low-noise outputs.

The bypass capacitor can be increased without bound, further reducing noise and improving PSRR. Turn-on time remains constant with respect to bypass capacitance. Refer to [Figure 2-14](#).

4.5 Transient Response

The MIC5247 implements a unique output stage to dramatically improve transient response recovery time. The output is a push-pull configuration with a P-Channel MOSFET pass device and an N-Channel MOSFET clamp. The N-Channel clamp is a significantly smaller device that prevents the output voltage from overshooting when a heavy load is removed.

This feature helps to speed up the transient response by significantly decreasing transient response recovery time during the transition from heavy load (100 mA) to light load (85 μA).

4.6 Active Shutdown

The MIC5247 also features an active shutdown clamp, which is an N-Channel MOSFET that turns on when the device is disabled. This allows the output capacitor and load to discharge, de-energizing the load.

4.7 Thermal Considerations

The MIC5247 is designed to provide 150 mA of continuous current in a very small package. Maximum power dissipation can be calculated based on the output current and the voltage drop across the part. To determine the maximum power dissipation of the package, use the junction-to-ambient thermal resistance of the device and the following basic equation:

EQUATION 4-1:

$$P_D = \left(\frac{T_{J(MAX)} - T_A}{\theta_{JA}} \right)$$

$T_{J(MAX)}$ is the maximum junction temperature of the die, 125°C, and T_A is the ambient operating temperature. θ_{JA} is layout dependent; [Table 4-1](#) shows examples of junction-to-ambient thermal resistance for the MIC5247.

TABLE 4-1: 5-LEAD SOT-23 THERMAL RESISTANCE

Package	θ_{JA} Recommended Minimum Footprint	θ_{JA} 1” Square Copper Clad	θ_{JC}
5-Lead SOT-23	235°C/W	185°C/W	145°C/W

The actual power dissipation of the regulator circuit can be determined using [Figure 4-2](#):

EQUATION 4-2:

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

MIC5247

Substituting $P_{D(MAX)}$ for P_D and solving for the operating conditions that are critical to the application will give the maximum operating conditions for the regulator circuit. For example, when operating the MIC5247-2.4YM5 at room temperature with a minimum footprint layout, the maximum input voltage for a set output current can be determined as follows:

EQUATION 4-3:

$$P_{D(MAX)} = \left(\frac{125^{\circ}C - 25^{\circ}C}{235^{\circ}C/W} \right)$$

Where:

$$P_{D(MAX)} = 425 \text{ mW}$$

The junction-to-ambient thermal resistance for the minimum footprint is $235^{\circ}C/W$, from [Table 4-1](#). The maximum power dissipation must not be exceeded for proper operation. Using the output voltage of 2.4V and an output current of 150 mA, the maximum input voltage can be determined. 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 for this calculation.

EQUATION 4-4:

$$425mW = (V_{IN} - 2.4V) \times 150mA$$

$$425mW = V_{IN} \times 150mA - 360mW$$

$$785mW = V_{IN} \times 150mA$$

$$V_{IN(MAX)} = 5.2V$$

Therefore, a 2.4V application at 150mA of output current can accept a maximum input voltage of 5.2V in a 5-Lead SOT-23 package. For a full discussion of heat sinking and thermal effects on voltage regulators, refer to the "Regulator Thermals" section of [Micrel's Designing with Low-Dropout Voltage Regulators handbook](#).

4.8 Fixed Regulator Applications

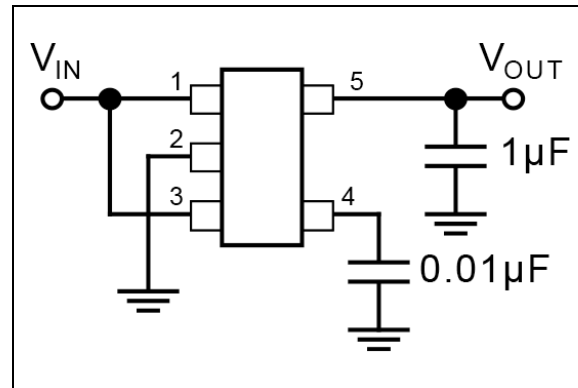


FIGURE 4-1: MIC5247-x.xYM5, Ultra-Low-Noise Fixed Voltage Application.

Figure 4-1 includes a 0.01 μF capacitor for low-noise operation and shows EN (pin 3) connected to IN (pin 1) for an application where enable/shutdown is not required. $C_{OUT} = 1 \mu F$ minimum.

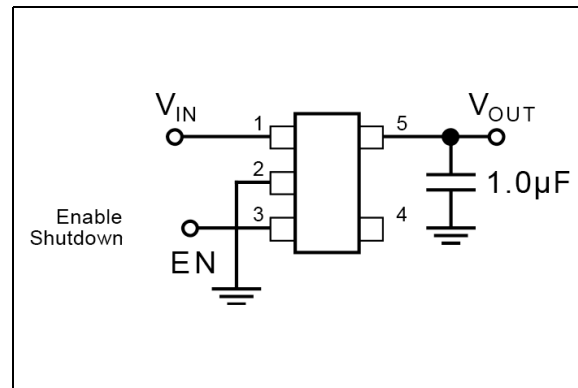


FIGURE 4-2: MIC5247-x.xYM5, Low-Noise Fixed Voltage Application.

Figure 4-2 is an example of a low-noise configuration where C_{BYP} is not required. $C_{OUT} = 1 \mu F$ minimum.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

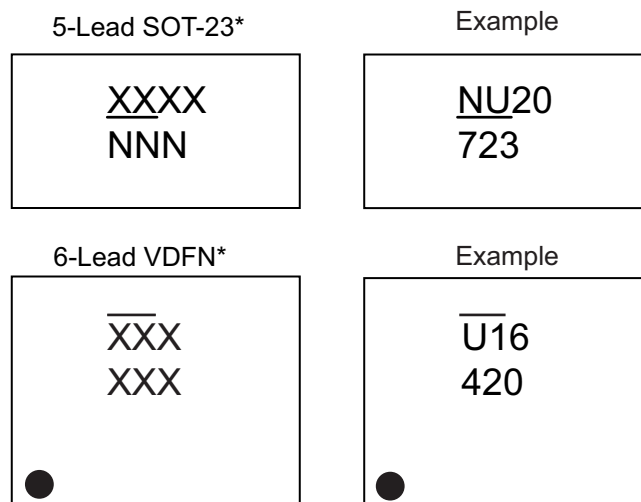


TABLE 5-1: ORDERING INFORMATION

Pb Free	Marking	Voltage	Pb Free	Marking	Voltage
MIC5247-1.5YM5	<u>LU</u> 15	1.5V	MIC5247-1.8YD5	<u>NU</u> 18	1.8V
MIC5247-1.6YM5	<u>LU</u> 16	1.6V	MIC5247-2.0YD5	<u>NU</u> 20	2.0V
MIC5247-1.8YM5	<u>LU</u> 18	1.8V	MIC5247-1.5YML	<u>U</u> 15	1.5V
MIC5247-1.85YM5	<u>LU</u> 1J	1.85V	MIC5247-1.6YML	<u>U</u> 16	1.6V
MIC5247-2.0YM5	<u>LU</u> 20	2.0V	MIC5247-1.8YML	<u>U</u> 18	1.8V
MIC5247-2.4YM5	<u>LU</u> 24	2.4V	MIC5247-1.85YML	<u>U</u> 1J	1.85V

<p>Legend: 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).</p>
<p>Note: 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 (<u> </u>) and/or Overbar (<u> </u>) symbol may not be to scale.</p>

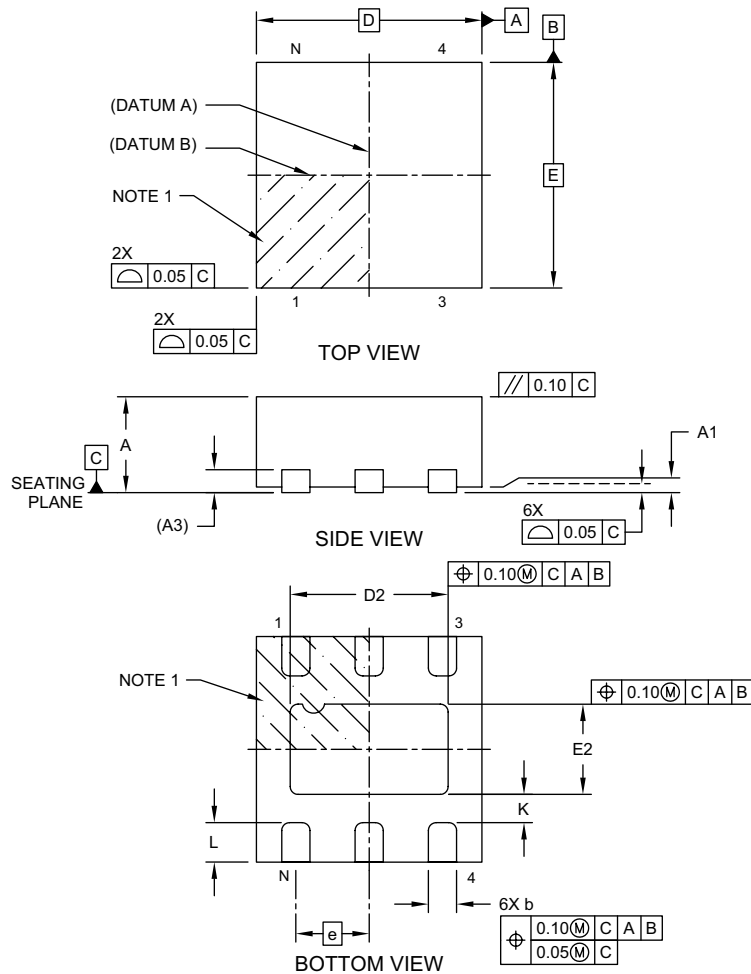
MIC5247

6-Lead 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>



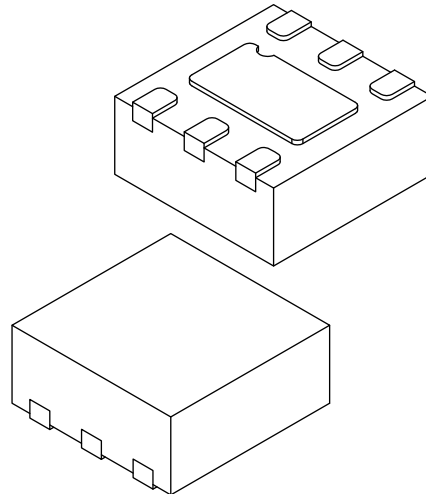
Microchip Technology Drawing C04-1016A Sheet 1 of 2

© 2017 Microchip Technology Incorporated



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>



Dimension Limits	Units	MILLIMETERS		
		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.

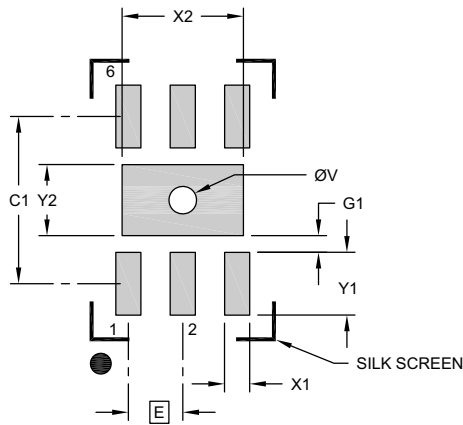
REF: Reference Dimension, usually without tolerance, for information purposes only.

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	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

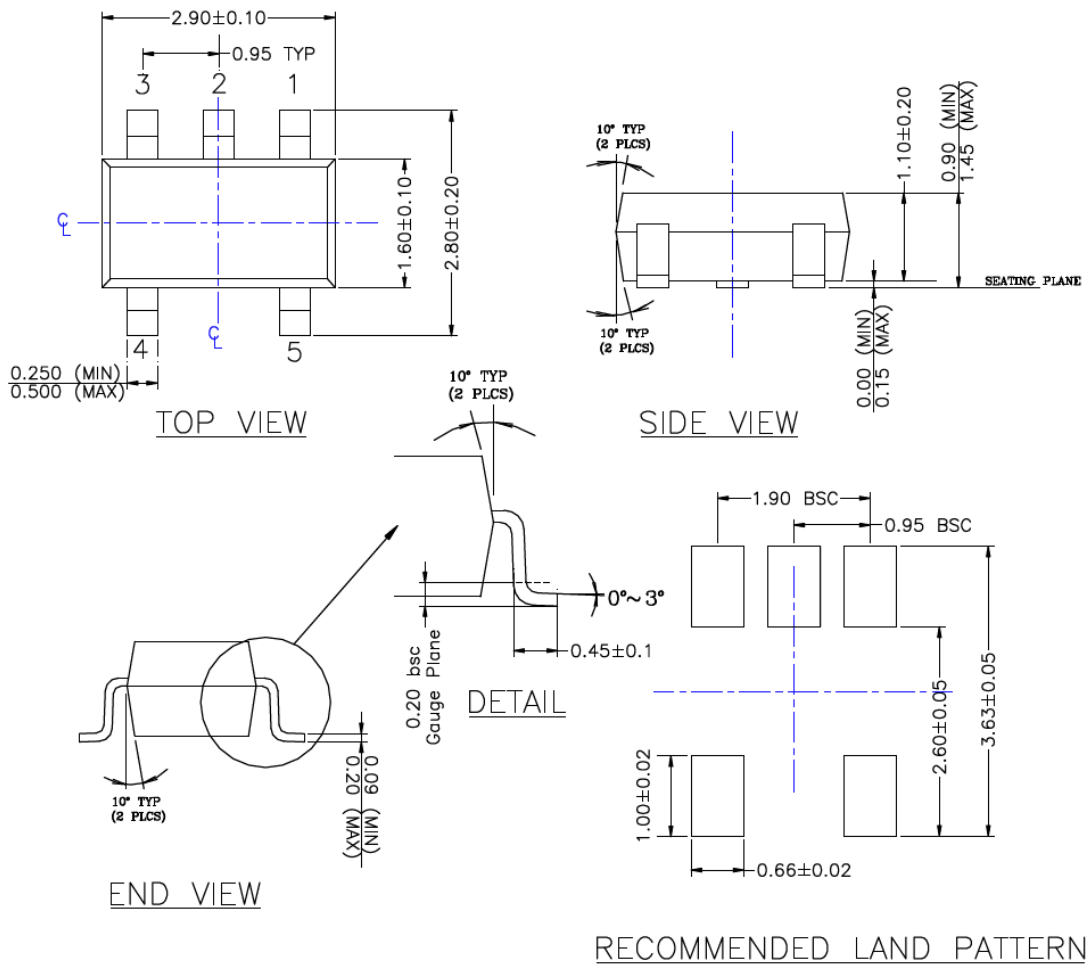
© 2017 Microchip Technology Incorporated

5-Lead SOT-23 Package Outline and Recommended Land Pattern

TITLE

5 LEAD SOT23 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	SOT23-5LD-PL-1	UNIT	MM
------------------	----------------	-------------	----



- NOTE:**
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & BURR.
 2. PACKAGE OUTLINE INCLUSIVE OF SOLER PLATING.
 3. DIMENSION AND TOLERANCE PER ANSI Y14.5M, 1982.
 4. FOOT LENGTH MEASUREMENT BASED ON GAUGE PLANE METHOD.
 5. DIE FACES UP FOR MOLD, AND FACES DOWN FOR TRIM/FORM.
 6. ALL DIMENSIONS ARE IN MILLIMETERS.

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

MIC5247

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (October 2021)

- Converted Micrel document MIC5247 to Microchip data sheet DS20006596A.
- Minor text changes throughout.

MIC5247

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 No.</u>	<u>-X.X</u>	<u>X</u>	<u>XX</u>	<u>-XX</u>	Examples:
Device	Output Voltage	Junction Temp. Range	Package	Media Type	
Device:	MIC5247:	150mA Low Voltage μ Cap Linear Regulator			a) MIC5247-1.6YM5-TX: MIC5247, 1.6V Output Voltage, -40°C to +125°C Temp. Range, 5-Lead SOT-23, 3000/Reverse Reel
Output Voltage:	-1.5 =	1.5V (M5 and ML option only)			b) MIC5247-1.5YM5-TR: MIC5247, 1.5V Output Voltage, -40°C to +125°C Temp. Range, 5-Lead SOT-23, 3000/Reverse Reel
	-1.6 =	1.6V (M5 and ML option only)			c) MIC5247-2.0YD5-TX: MIC5247, 2.0V Output Voltage, -40°C to +125°C Temp. Range, 5-Lead SOT-23, 3000/Reel
	-1.8 =	1.8V			d) MIC5247-1.8YD5-TR: MIC5247, 1.8V Output Voltage, -40°C to +125°C Temp. Range, 5-Lead SOT-23, 3000/Reel
	-1.85 =	1.85V (M5 and ML option only)			e) MIC5247-1.85YML-TR: MIC5247, 1.85V Output Voltage, -40°C to +125°C Temp. Range, 6-Lead VDFN, 5000/Reel
	-2.0 =	2.0V (M5 and D5 option only)			
	-2.4 =	2.4V (M5 option only)			
Junction Temperature Range:	Y =	-40°C to +125°C			
Package:	M5 =	5-Lead SOT-23			
	D5 =	5-Lead SOT-23			
	ML =	6-Lead VDFN			
Media Type:	-TX =	3000/Reverse Reel (M5 option only)			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.
	-TX =	3000/Reel (D5 option only)			
	-TR =	3000/Reverse Reel (M5 option only)			
	-TR =	3000/Reel (D5 option only)			
	-TR =	5000/Reel (ML option only)			

MIC5247

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, OptoLyzr, 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:978-1-5224-9158-3

For information regarding Microchip's Quality Management Systems, please visit 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

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