MIC2251

High-Efficiency Low EMI Boost Regulator

Features

- Over 80% Efficient at 1 mA Load
- 2.5V to 5.5V Input Voltage Range
- Output Voltage Adjustable to 37V
- 1.6A Switch Current (typ.)
- 52 µA (typ.) Quiescent Current
- Constant Peak Current Control Reduces Output Ripple
- EMI Reduction Circuitry
- Stable with Small Ceramic Capacitors
- <1 µA Shutdown Current
- UVLO and Thermal Shutdown
- 8-Pin 2 mm x 2 mm Leadless DFN Package (MIC2251)
- 5-Pin Thin SOT-23 Package (MIC2251-1 & MIC2251-2) Pin to Pin Compatible with MCP1661/3 (1.2A/1.8A Switch Current)
- –40°C to +125°C Junction Temperature Range

Applications

- LCD/OLED Display Bias Supply
- CCD Bias Supply
- Mobile Phones, PDA, Media Players, GPS PND
- Haptic Displays
- Local 5V, 15V, 24V Rail

General Description

The MIC2251 is a general purpose DC/DC boost switching regulator that features low noise, EMI reduction circuitry, and high efficiency across a wide output current range.

The MIC2251 is optimized for noise-sensitive hand held battery powered applications. A proprietary control method allows low ripple across the output voltage and current ranges. The MIC2251 incorporates a pseudo-random dithering function to reduce EMI levels up to 10 dB enabled by the DITH pin.

The MIC2251 is designed for use with inductor values from 4.7 µH to 22 µH, and is stable with ceramic capacitors from 1 µF to 22 µF.

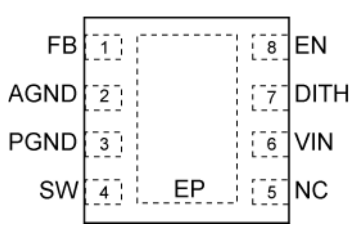
The MIC2251 attains a high peak efficiency up to 90% at 100 mA and excellent light load efficiency of 80% at 1 mA.

The MIC2251-1 is available in a 5-pin Thin SOT-23 package with dithering disabled, while the MIC2251-2 is available in a 5-pin Thin SOT-23 package with dithering enabled.

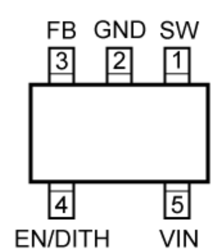
The MIC2251 is available in a 8-pin 2 mm x 2 mm DFN leadless package option with an operating junction temperature range of –40°C to +125°C.

Package Types

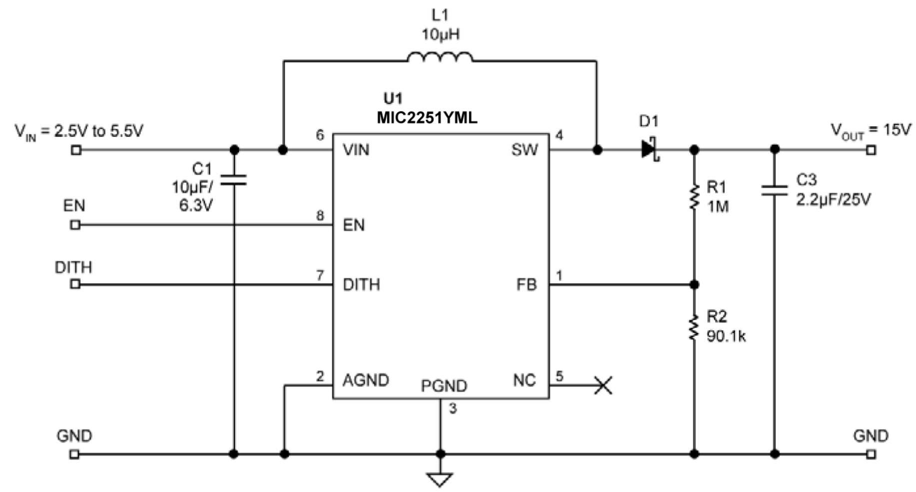
MIC2251
8-Pin 2 mm x 2 mm DFN (ML)
(Top View)



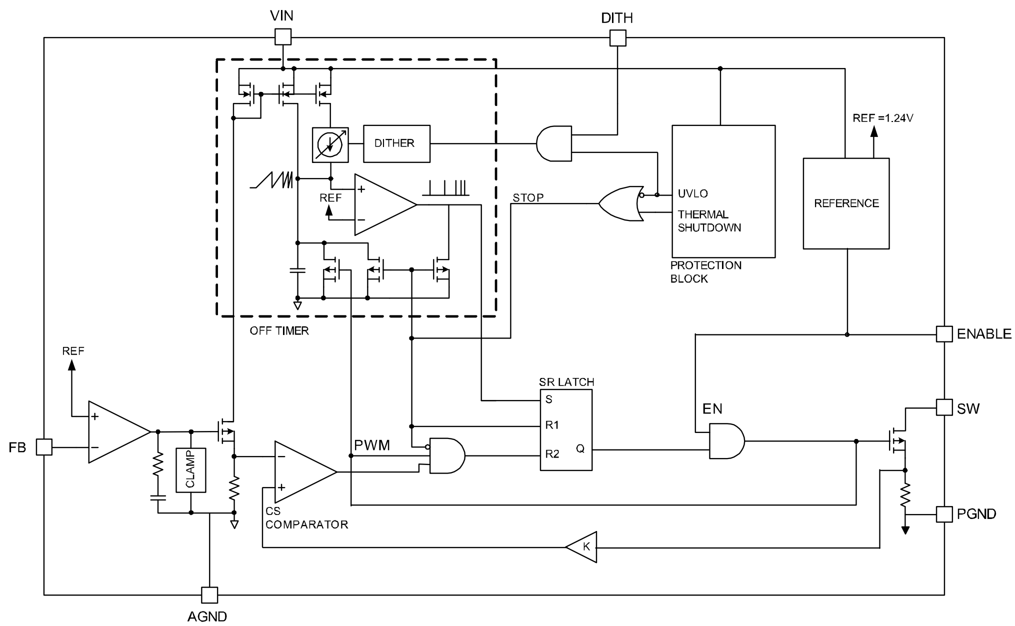
MIC2251
5-Pin SOT-23 (D5)
(Top View)



Typical Application Schematic



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}) .... +6V
Switch Voltage (V_{SW}) .... –0.3V to +40V
Enable Voltage (V_{EN}) .... –0.3V to V_{IN}
FB Voltage (V_{FB}) .... +6V
Switch Current (I_{SW}) 3.5A
ESD Rating (Note 1) 200V

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

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: V_{IN} = V_{EN} = 3.6V; V_{DITH} = 0V; V_{OUT} = 15V; I_{OUT} = 40 mA; T_A = +25°C, unless otherwise noted. **Bold** values indicate –40°C ≤ T_J ≤ +85°C. Specification for packaged product only.

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Input Voltage Range	V_{IN}	2.5	—	5.5	V	—
Undervoltage Lockout	V_{UVLO}	1.8	2	2.4	V	V_{IN} rising
Quiescent Current	I_Q	—	70	**120**	µA	V_{FB} = 1.5V (not switching)
Shutdown Current	I_{SD}	—	0.1	**1**	µA	V_{EN} = 0V, I_{SD} = I_{VIN}
Feedback Voltage	V_{FB}	1.20	1.24	1.277	V	—
		1.19	—	**1.29**	V	–40°C ≤ T_J ≤ +85°C
Feedback Input Current	I_{FB}	—	10	—	nA	V_{FB} = 1.24V
PFM Operation						
Soft-Start Time	t_{SS}	—	1	—	ms	—
Switch Off-Time	t_{SW}	—	1.6	—	µs	V_{IN} = 3.6V
Maximum Duty Cycle	D_{MAX}	75	87	—	%	—
Off-Time Dithering	t_{DITH}	—	±20	—	%	V_{DITH} = 3.6V. Percentage from nominal.
Line Regulation	LINE_REG	—	0.3	**2**	%	3V ≤ V_{IN} ≤ 5V
Load Regulation	LOAD_REG	—	0.1	**2**	%	1 mA ≤ I_{OUT} ≤ 40 mA
Switch Current-Limit	I_{SW}	0.9	1.6	—	A	—
Switch ON-Resistance	R_{ON}	—	0.7	1	Ω	I_{SW} = 200 mA
Switch Leakage Current	I_{LK}	—	0.01	**5**	µA	V_{EN} = 0V, V_{SW} = 10V
Logic Input Thresholds	V_{EN}, V_{DITH}	**1.5**	—	—	V	Turn On
		—	—	**0.4**	V	Turn Off
Enable Pin Current	I_{EN}	—	0.1	2	µA	V_{EN} = V_{IN} = 5.0V
Thermal Shutdown Threshold	T_{TSD}	—	130	—	°C	—
		—	15	—	°C	Hysteresis

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Operating Temperature	T_J	–40	—	+125	°C	(Note 1)
Ambient Storage Temperature Range	T_S	–65	—	+150	°C	—
Package Thermal Resistance						
Thermal Resistance, 2 mm x 2 mm DFN-8	θ_{JA}	—	90	—	°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 +125°C rating. Sustained junction temperatures above +125°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.

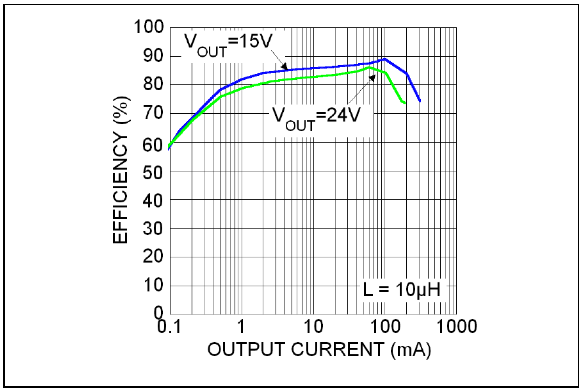


FIGURE 2-1: *Efficiency V_{IN} = 5V.*

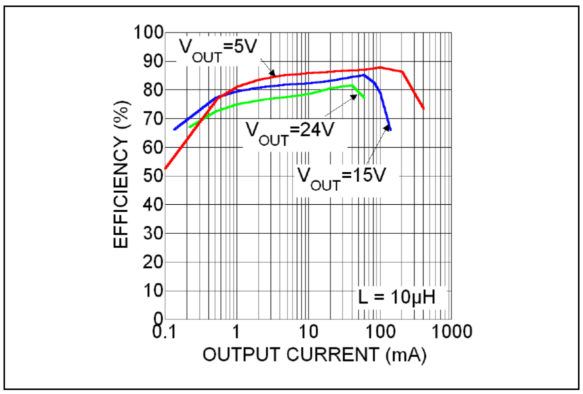


FIGURE 2-2: *Efficiency V_{IN} = 3.3V.*

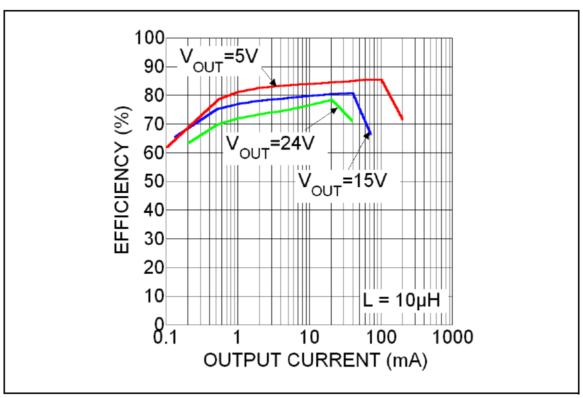


FIGURE 2-3: *Efficiency V_{IN} = 2.5V.*

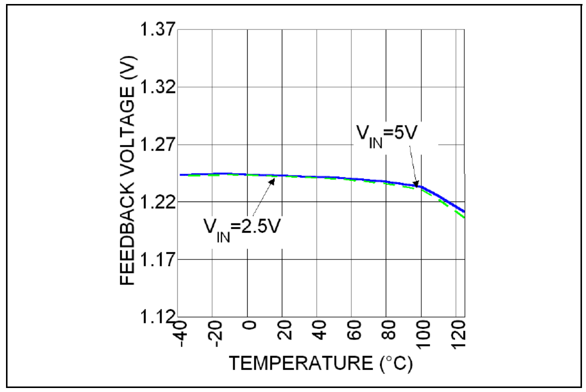


FIGURE 2-4: *Feedback Voltage vs. Temperature.*

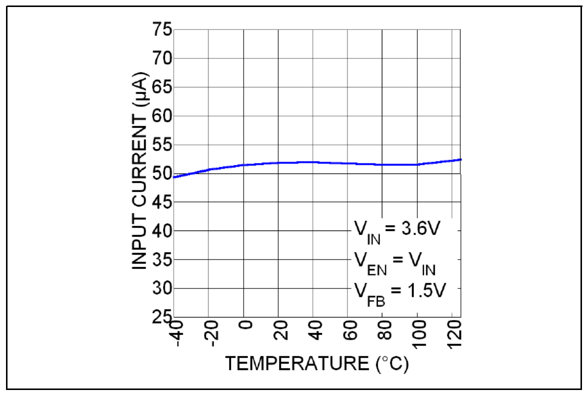


FIGURE 2-5: *Input Current vs. Temperature.*

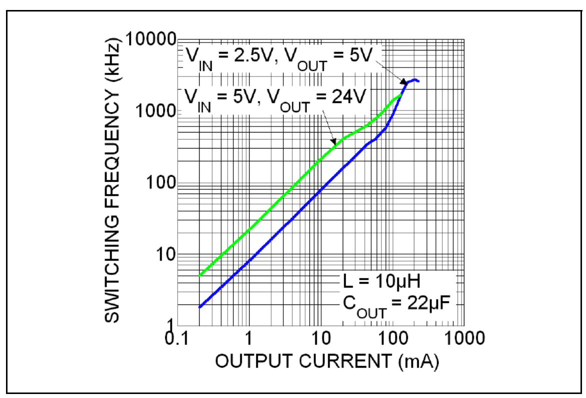


FIGURE 2-6: *Switching Frequency vs. Load Current.*

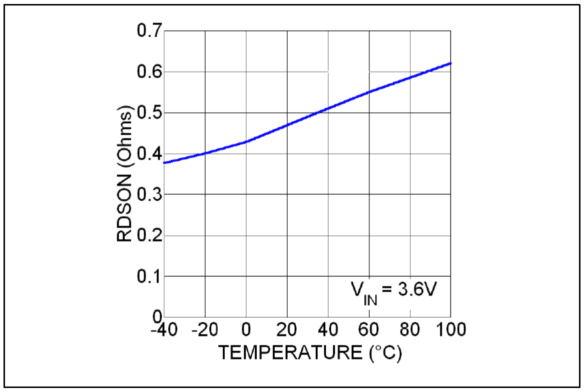


FIGURE 2-7: *$R_{DS(ON)}$ vs. Temperature.*

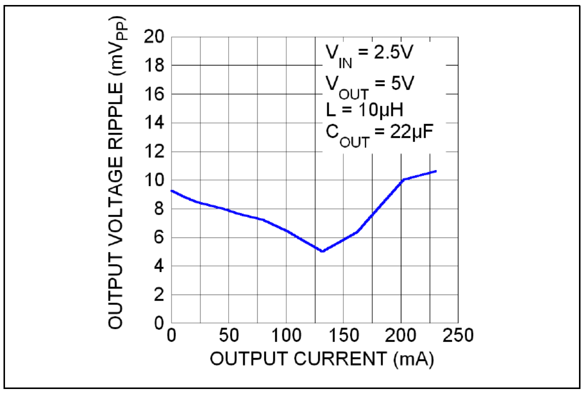


FIGURE 2-8: *Output Voltage Ripple vs. Load Current.*

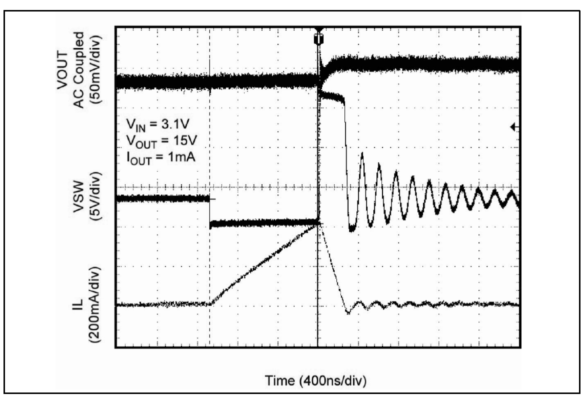


FIGURE 2-9: *Switching Waveform.*

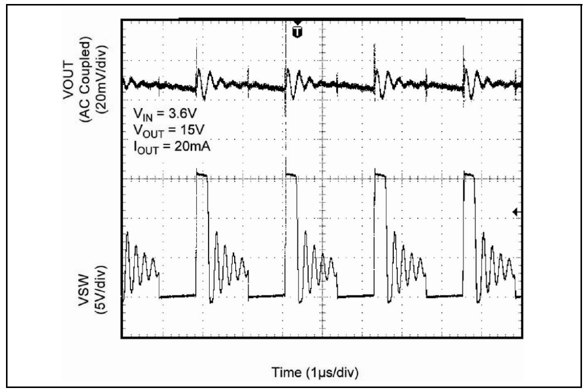


FIGURE 2-10: *Switching Waveform.*

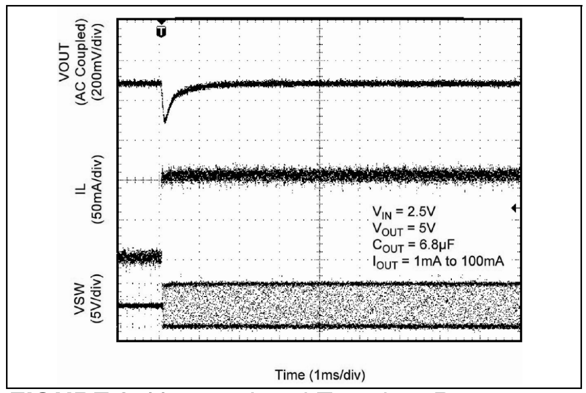


FIGURE 2-11: *Load Transient Response.*

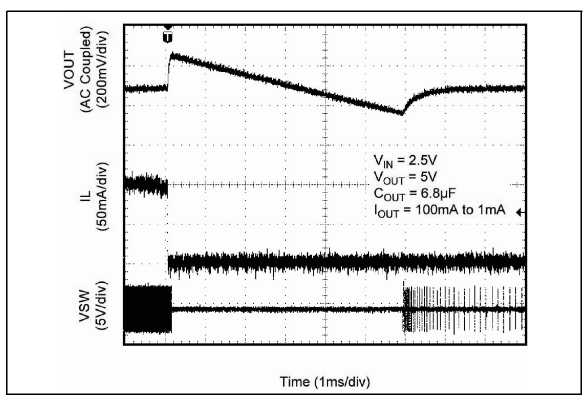


FIGURE 2-12: *Load Transient Response.*

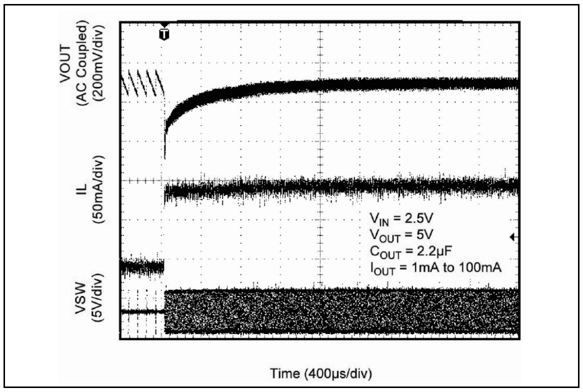


FIGURE 2-13: *Load Transient Response.*

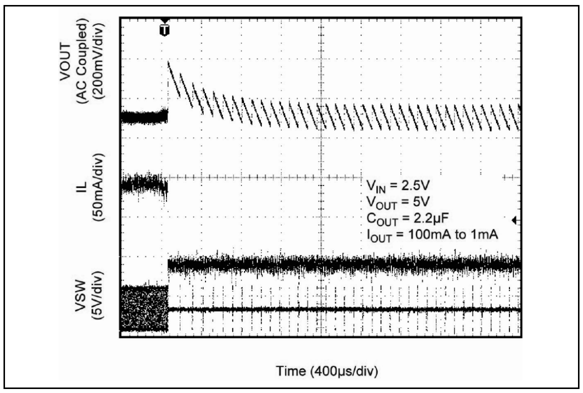


FIGURE 2-14: *Load Transient Response.*

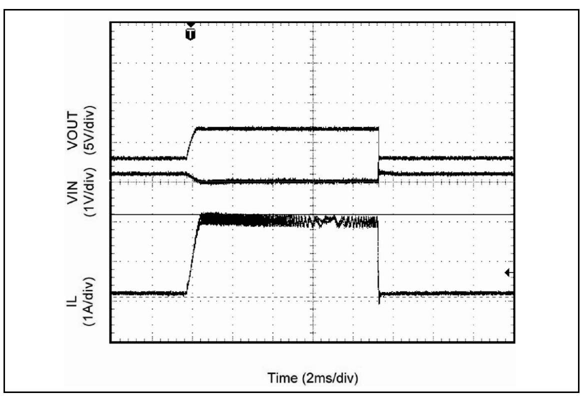


FIGURE 2-15: *Current Limit.*

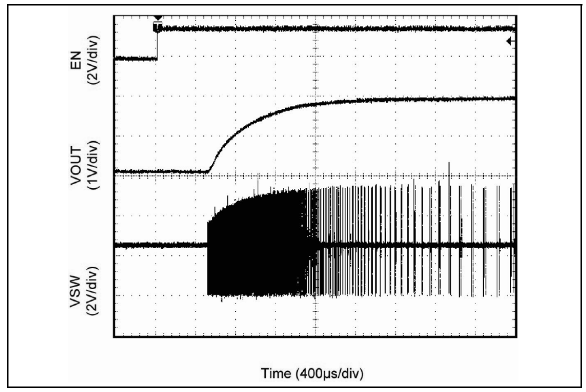


FIGURE 2-16: *Start-Up Waveform.*

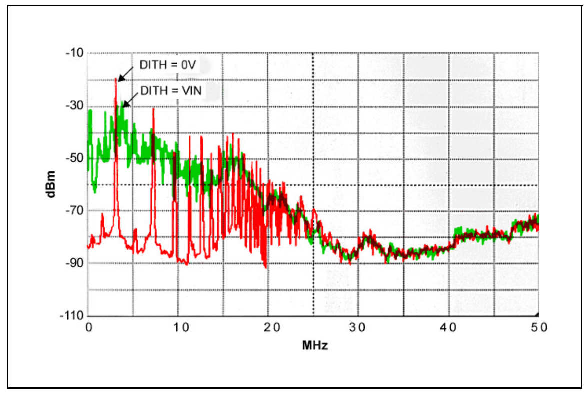


FIGURE 2-17: *EMI Improvement Using Dithering.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number MIC2251YML	Pin Number MIC2251-1YD5	Pin Number MIC2251-2YD5	Pin Name	Description
1	3	3	FB	Feedback (Input): 1.24V output voltage sense node. V_{OUT} = 1.24V (1 + R1/R2)
2	—	—	AGND	Analog Ground. Connect to power ground.
3	2	2	PGND	Power Ground.
4	1	1	SW	Switch Node (Input): Internal power NMOS drain.
5	—	—	NC	Not internally connected.
6	5	5	VIN	Supply (Input): 2.5V to 5.5V input voltage.
7	—	4	DITH	Frequency Dithering (Input): Connect this pin high to enable pseudo-random on-time dithering to reduce EMI. Connect this pin to ground to disable this function.
8	4	4	EN	Enable (Input): Logic high enables the regulator. Logic low shuts down the regulator. Do not leave floating.
EP	—	—	HS PAD	Ground (Return): Exposed backside pad. Connect to power ground.

4.0 FUNCTIONAL DESCRIPTION

4.1 VIN

The input supply (V_{IN}) provides power to the internal MOSFETs and control circuitry for the switch mode regulator. The operating input voltage range is from 2.5V to 5.5V. An input capacitor with a minimum voltage rating of 6.3V is recommended.

4.2 EN

A logic level input of 1.5V or higher enables the regulator. A logic input of 0.4V or less places the regulator in shutdown mode which reduces the supply current to less than 1 µA. The MIC2251 features built-in soft-start circuitry that reduces in-rush current and prevents the output voltage from overshooting during startup. Do not leave the Enable pin floating.

4.3 SW

The MIC2251 has an internal MOSFET switch that connects directly to one end of the inductor (SW pin) and provides a current path to ground during switching cycles. The source of the internal MOSFET connects through a current sense resistor to ground.

4.4 PGND

The power ground pin is the high current path to ground. The current loop for the power ground should be as small as possible and separate from the analog ground (AGND).

4.5 AGND

Analog ground (AGND) is the ground path for the biasing and control circuitry. The current loop for the signal ground should be separate from the power ground (PGND) loop.

4.6 DITH

The DITH function is a frequency dithering technique that reduces EMI noise by spreading the boost regulators' noise spectrum. This technique reduces the EMI peaks by distributing the switching frequency across a wider spectrum. Connect this pin high to enable the pseudo-random on-time dithering. Connect this pin to ground to disable this function.

4.7 FB

The feedback pin (FB) allows the regulated output voltage to be set by applying an external resistor divider network. The internal reference voltage is 1.24V. The output voltage is calculated from the following equation:

EQUATION 4-1:

$$V_{OUT} = 1.24V\left(1 + \frac{R1}{R2}\right)$$

5.0 APPLICATION INFORMATION

5.1 Overview

The MIC2251 boost regulator utilizes a combination of PFM and current mode regulation to achieve very high efficiency over a wide range of output load. This innovative design is the basis for the regulator's high efficiency, excellent stability and self-compensation technique. The boost regulator performs a power conversion that results in an output voltage that is greater than the input. Operation starts with activating an internal MOSFET switch that draws current through the inductor (L1). While one end of the inductor is fixed at V_{IN}, the other end is switched up and down. While the switch is on, the current through the inductor increases. When the switch is off the inductor current continues to flow through the output diode.

The current flow imposes a voltage across the inductor, which is added to V_{IN} to produce a higher voltage V_{OUT}. At low power levels (typically less than 1W), the period varies between switching cycles, indicative of pulse frequency modulation (PFM). As the output power increases beyond approximately 1W, the period between switching cycles continues to decrease and the power (switch current) delivered with each cycle increases indicative of current mode regulation.

5.2 PFM Regulation

The error amplifier compares the regulator's reference voltage with the feedback voltage obtained from the output resistor voltage divider network. The resulting error voltage acts as a correction input signal to the control block. The control block generates two signals that turn on and off the output MOSFET switch. An increase in load current causes V_{OUT} and V_{FB} to decrease in value. The control loop then changes the switching frequency to increase the energy transferred to the output capacitor to regulate the output voltage. A reduction in load causes V_{OUT} and V_{FB} to increase. Now the control loop compensates by reducing the effective switching frequency, thus reducing the amount of energy delivered to the output capacitor in order to keep the output voltage within regulation.

5.3 Current Mode Regulation

The control block's oscillator starts the cycle by setting the MOSFET switch control flip flop. The switch then turns on. This flip flop is reset when the switch current ramp reaches the threshold set by the error amplifier. If the error amplifier indicates that V_{FB} is either too high or too low, then the threshold for the comparator measuring the switch current is appropriately adjusted to bring V_{OUT} within regulation limits. The level of the error signal also sets the off time of the switch. A higher error signal (output voltage is low) will reduce off time to increase energy transfer to the output. A lower error signal (output voltage is high) will conversely, increase off time to reduce energy transfer to the output.

5.4 Component Selection

RESISTORS

An external resistive divider network (R1 and R2) with its center tap connected to the feedback pin sets the output voltage. The appropriate R1 and R2 values for the desired output voltage are calculated by:

EQUATION 5-1:

$$R2 = \frac{R1}{\left(\frac{V_{OUT}}{1.24V} - 1\right)}$$

Large resistor values are recommended to reduce light load operating current, and improve efficiency. The table below gives a good compromise between quiescent current and accuracy. Additionally, a feed-forward capacitor (C_{FF}) placed in parallel with R1 may be added to improve transient performance. Recommended values are suggested below:

TABLE 5-1: RECOMMENDED R1 AND C_{FF} VALUES

V_{OUT}	Suggested R1	C_{FF}
5V to 10V	100 kΩ	4.7 nF
10V to 15V	240 kΩ	2.2 nF
15V to 37V	1MΩ	470 pF

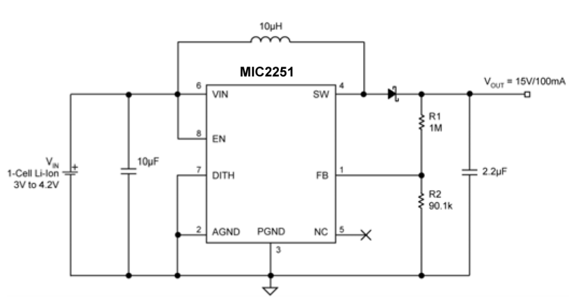


FIGURE 5-1: Typical Application Circuit.

INDUCTOR

Inductor selection is a balance between efficiency, stability, cost, size, and rated current. For most applications, inductors in the range 4.7 µH to 22 µH are recommended. Larger inductance values reduce the peak-to-peak ripple current, thereby reducing both the DC losses and the transition losses for better efficiency. The inductor's DC resistance (DCR) also plays an important role. Because the majority of the input current (minus the MIC2251 operating current) is passed through the inductor, higher DCR inductors will reduce efficiency at higher load currents. Figure 5-2 shows the comparison of efficiency between a 140 mΩ DCR, 4.7 µH inductor and a 190 mΩ DCR, 10 µH inductor. The switch current-limit for the MIC2251 is typically 1.6A. The saturation current rating of the selected inductor should be 20-30% higher than the 1.6A specification for proper operation.

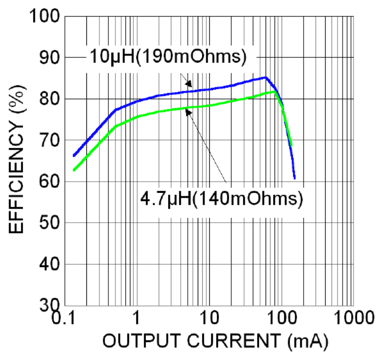


FIGURE 5-2: *Efficiency Comparison between Lower and Higher Inductor Values.*

INPUT CAPACITOR

The boost converter exhibits a triangular current waveform at its input, so an input capacitor is required to decouple this waveform and thereby reduce the input voltage ripple. A 10 µF to 22 µF ceramic capacitor should be sufficient for most applications. A minimum input capacitance of 1 µF is recommended. The input capacitor should be as close as possible to the inductor and the MIC2251, with short PCB traces for good noise performance.

OUTPUT CAPACITOR

Output capacitor selection is also a trade-off between performance, size, and cost. Increasing C_{OUT} will lead to an improved transient response however the size and cost also increase. X5R and X7R ceramic capacitors are recommended. For most applications, 2.2 µF to 22 µF should be sufficient.

DIODE

The MIC2251 requires an external diode for operation. The diode must be rated for the peak inductor current, and its reverse voltage rating must be greater than the output voltage. A Schottky diode is recommended for lower output voltages due to its lower forward voltage drop and reverse recovery time. However, at higher output voltages (>10V), a high speed diode such as LS4148 can be more efficient because it has the advantage of considerably lower leakage currents, especially at higher temperatures. This will greatly improve light load efficiency when compared to a Schottky diode.

For example: At 70°C ambient temperature, V_{IN} = 2.5V, V_{OUT} = 24V at no load.

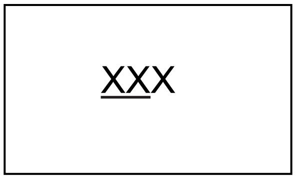
Input current (Vishay SL04 Schottky) = 2.1 mA.

Input current (Generic LS4148) = 0.37 mA.

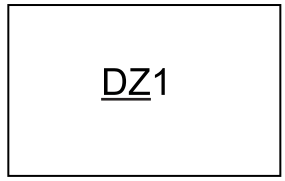
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

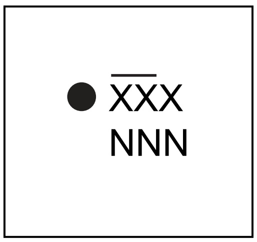
5-Lead SOT-23*



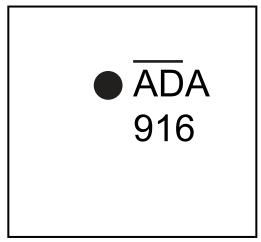
Example



8-Lead DFN*



Example



Legend:

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).

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.

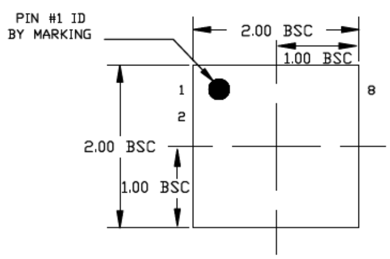
Underbar (_) symbol may not be to scale.

8-Lead DFN 2 mm x 2 mm Package Outline and Recommended Land Pattern

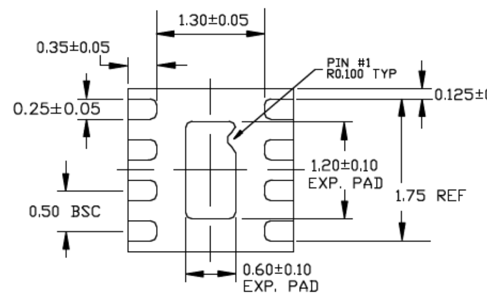
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging

TITLE
8 LEAD DFN 2x2mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

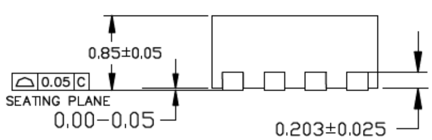
DRAWING #	DFN22-8LD-PL-1	**UNIT**	MM



TOP VIEW
NOTE: 1, 2, 3



BOTTOM VIEW
NOTE: 1, 2, 3



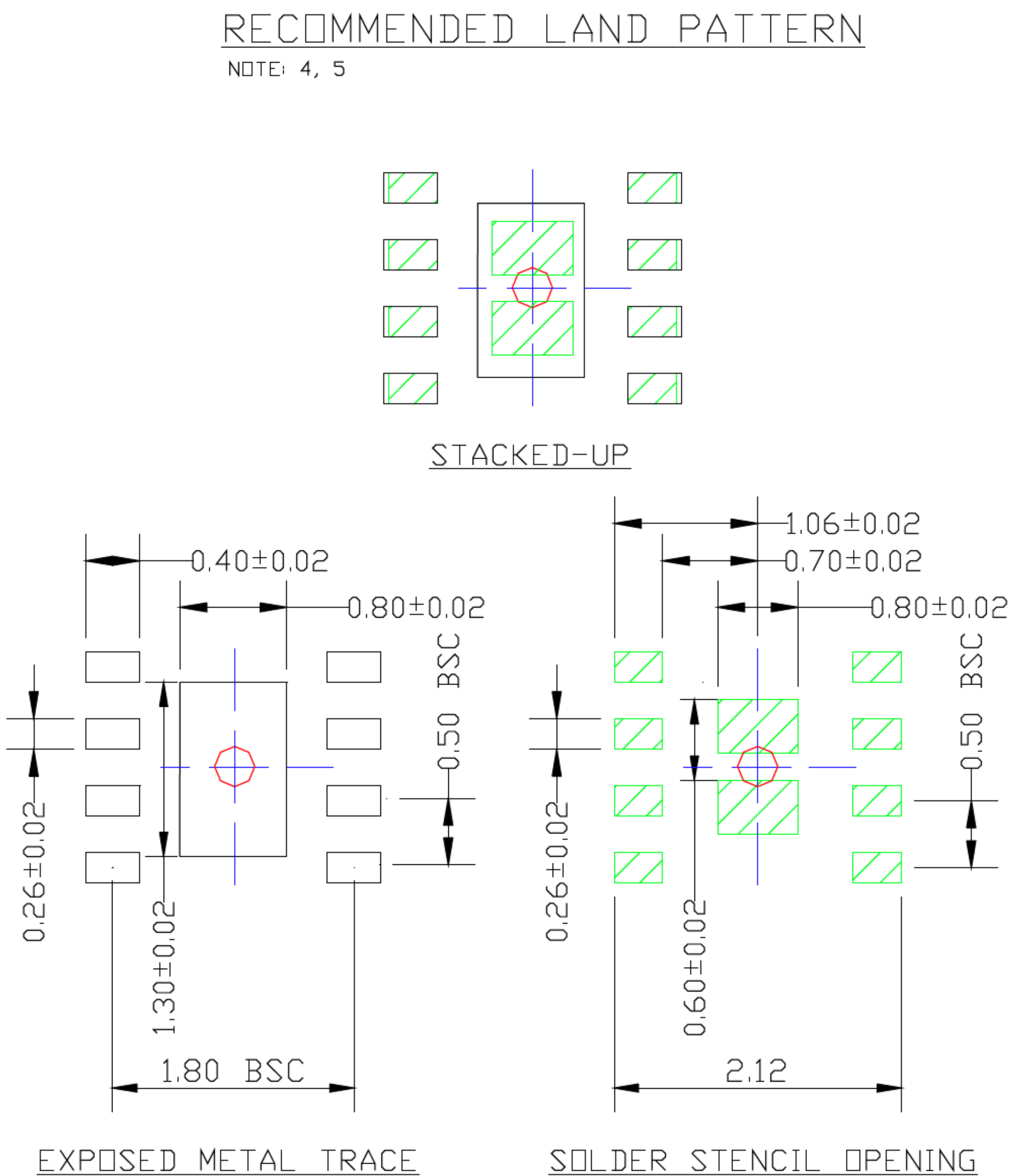
END VIEW
NOTE: 1, 2, 3

NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. RED CIRCLE IN LAND PATTERN INDICATE THERMAL VIA. SIZE SHOULD BE 0.30-0.35MM IN DIAMETER AND SHOULD BE CONNECTED TO GND FOR MAX THERMAL PERFORMANCE
5. GREEN RECTANGLES (SHADED AREA) INDICATE SOLDER STENCIL OPENING ON EXPOSED PAD AREA. SIZE SHOULD BE 0.60x0.40 MM IN SIZE, 0.20 MM SPACING.

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

8-Lead DFN 2 mm x 2 mm Package Recommended Land Pattern

POD-Land Pattern Drawing # DFN22-8LD-PL-1

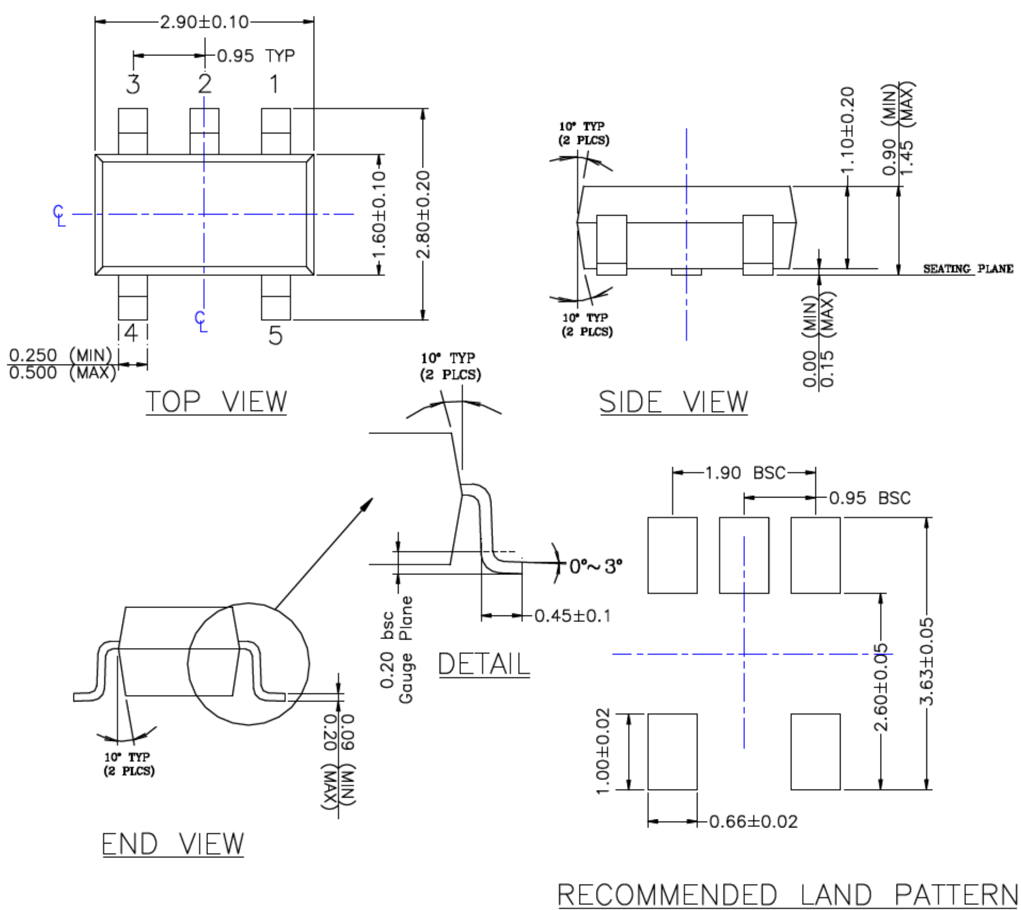


Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging.

5-Lead SOT-23-5 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.

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (January 2021)

- Converted Micrel document MIC2251 to Microchip data sheet DS20006487A.
- Minor text changes throughout.
- Added “Pin to Pin Compatible with MCP1661/3 (1.2A/1.8A Switch Current)” as a new bullet under Features.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

PART NO.	–X	X	XX	–XX
Device	Dithering Feature	Junction Temperature Range	Package	Media Type

Device:	MIC2251:		High-Efficiency Low EMI Boost Regulator
Feature:	-1	=	Dithering Disabled (TSOT Package)
	-2	=	Dithering Disabled (TSOT Package)
Temperature:	Y	=	–40°C to +125°C (Extended Industrial, RoHS Compliant)
Package:	D5	=	5-Lead Thin SOT-23
	ML	=	8-Lead Thin DFN, 2 mm x 2 mm x 0.9 mm
Media Type:	TR	=	3,000/Reel for D5 Package
	TR	=	5,000/Reel for ML Package

Examples:

a) MIC2251YML-TR: High-Efficiency Low EMI Boost Regulator, Extended Industrial 40°C to +125°C Junction Temperature Range, RoHS Compliant, 8-lead DFN Package, 5,000/Reel

b) MIC2251-1YD5-TR: High-Efficiency Low EMI Boost Regulator with Dithering Disabled, Extended Industrial -40°C to +125°C Junction Temperature Range, RoHS Compliant, 5-lead Thin SOT-23 Package, 3,000/Reel

c) MIC2251-2YD5-TR: High-Efficiency Low EMI Boost Regulator with Dithering Enabled, Extended Industrial -40°C to +125°C Junction Temperature Range, RoHS Compliant, 5-lead Thin SOT-23 Package, 3,000/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.

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.

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

Trademarks

ISBN: 978-1-5224-7488-3

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

02/28/20