MIC2253

High Current 1 MHz High Efficiency Boost Regulator with OVP and Soft-Start

Features

- 3.5A Minimum Switch Current
- 1.245V ±3% Feedback Voltage
- 2.5V to 10V Input Voltage
- Output Overvoltage Protection (OVP)
- Externally Programmable Soft-Start
- Output Voltage Up to 30V
- Fixed 1 MHz Operation
- <1% Line Regulation
- 0.1 µA Shutdown Current
- Overtemperature Protection
- Undervoltage Lockout (UVLO)
- 12-Pin 3 mm x 3 mm Leadless DFN Package
- –40°C to +125°C Junction Temperature Range

Applications

- Mobile Handsets
- Portable Media/MP3 Players
- Portable Navigation Devices (GPS)
- WiFi/WiMax/WiBro Modules
- Digital Cameras
- Wireless LAN Cards
- USB-Powered Devices
- Portable Applications

General Description

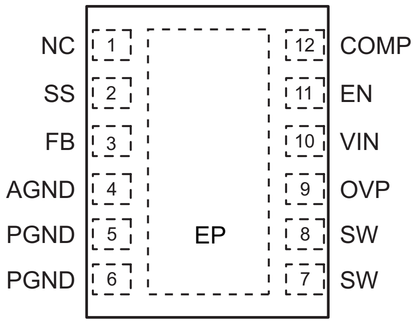
The MIC2253 is a high power-density, 1 MHz PWM DC/DC boost regulator. The 3.5A minimum switch current limit, combined with a 1 MHz switching frequency, allows the MIC2253 to use smaller inductors and deliver high power in a tiny solution size.

The 2.5V to 10V input voltage range of MIC2253 allows direct operation from 1- and 2-cell Li-ion as well as 3- to 4-cell NiCad, NiMH, alkaline, or lithium batteries. Maximum battery life is assured with a low 0.1 µA shutdown current.

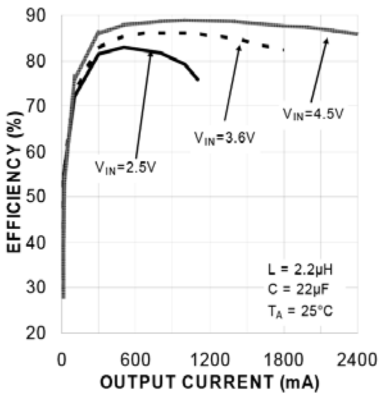
The MIC2253 is available in a low profile 12-pin 3 mm x 3 mm DFN package. To prevent a high inrush current, a minimum 1 ms soft-start period is set by default and the MIC2253 has the ability to extend the soft-start period with an external capacitor.

Package Type

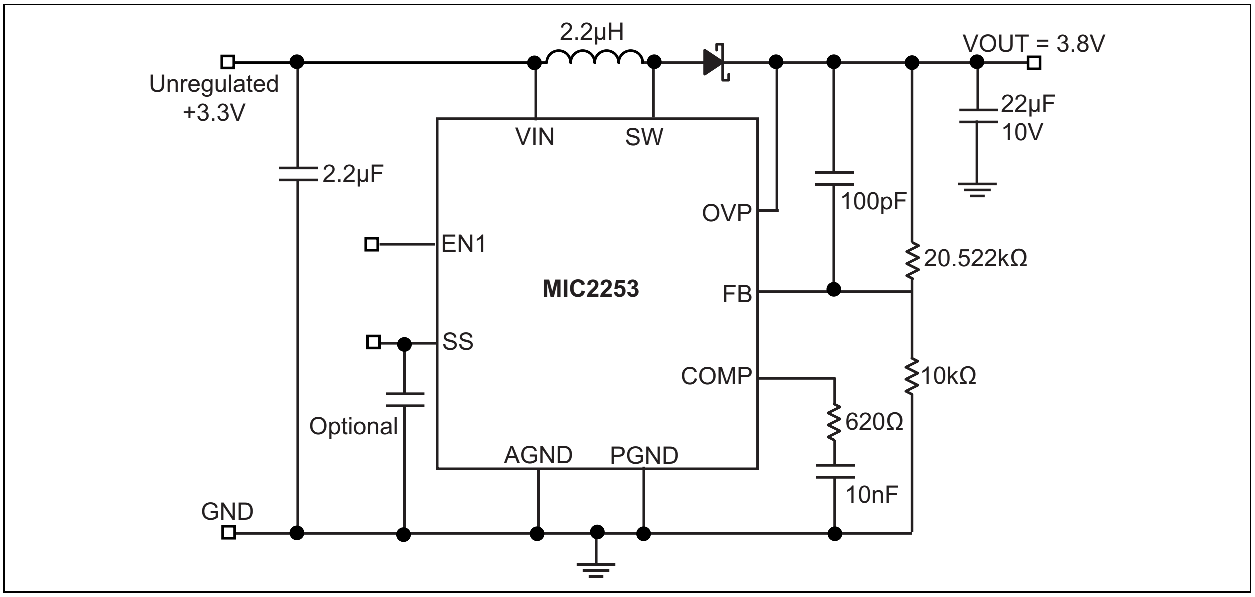
MIC2253
12-Pin 3 mm x 3 mm DFN (ML)
(Top View)



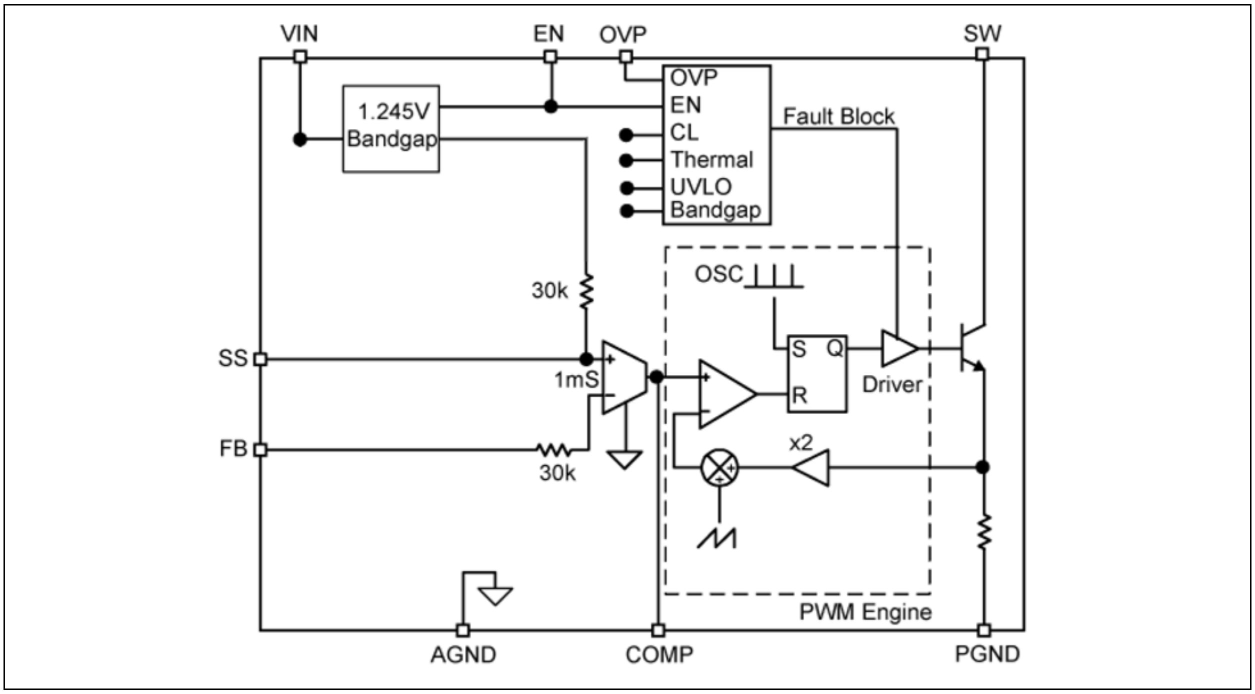
Efficiency vs. Output Current, V_{OUT} = 5.0V



Typical Application Circuit



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN})	+12V
Switch Voltage (V_{SW})	–0.3V to +34V
Enable Voltage (V_{EN})	–0.3V to 12V
FB Voltage (V_{FB})	+6V
Switch Current (I_{SW})	Internally Limited
Ambient Storage Temperature (T_S)	–65°C to +150°C
ESD Rating (Note 1)	2 kV

Operating Ratings ††

Supply Voltage (V_{IN})	+2.5V to +10V
Enable Voltage (V_{EN})	0V to V_{IN}
Junction Temperature (T_J)	–40°C to +125°C
Package Thermal Resistance 3 mm x 3 mm DFN-12 (θ_{JA})	60°C/W

† **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: T_A = +25°C; V_{IN} = V_{EN} = 3.6V; unless otherwise noted. **Bold** values indicate that parameters are valid across the whole temperature range of –40°C ≤ T_J ≤ +125°C. Note 1

Parameter	Sym.	Min.	Typ.	Max.	Units	Conditions
Supply Voltage Range	V_{IN}	2.5	—	10	V	—
Undervoltage Lockout	V_{UVLO}	1.8	2.1	2.4	V	—
Overvoltage Protection	V_{OVP}	**5.25**	5.6	**6.3**	V	—
Quiescent Current	I_{VIN}	—	15	23	mA	V_{FB} >1.245V, Not Switching
Shutdown Current	I_{SD}	—	0.1	1	µA	V_{EN} = 0V, Note 2
Feedback Voltage	V_{FB}	**1.208**	1.245	**1.283**	V	—
Feedback Input Current	I_{FB}	—	–450	—	nA	V_{FB} = 1.245V
Line Regulation	$\Delta V_{OUT}/V_{OUT}$	—	0.5	—	%	3.0V ≤ V_{IN} ≤ 4.5V
Minimum Duty Cycle	D_{MIN}	—	10	—	%	—
Maximum Duty Cycle	D_{MAX}	—	90	—	%	—
Switch Current Limit	I_{SW}	**3.5**	4.75	**8**	A	V_{IN} = 3.6V
Switch Saturation Voltage	V_{SW}	—	350	500	mV	V_{IN} = 3.6V, I_{SW} = 3.5A
Switch Leakage Current	I_{SW}	—	0.01	**10**	µA	V_{EN} = 0V, V_{SW} = 10V
Enable Threshold	V_{EN}	**1.5**	—	—	V	Turn on.
		—	—	**0.4**		Turn off.
Enable Pin Current	I_{EN}	—	20	40	µA	V_{EN} = 10V
Oscillator Frequency	f_{SW}	0.8	1	1.2	MHz	—
Soft-Start	I_{SS}	—	30	—	µA	V_{SS} = 0V
Overtemperature Shutdown Threshold	T_J	—	150	—	°C	—
		—	10	—		Hysteresis

Note 1: Specification for packaged product only.

2: I_{SD} = I_{VIN}.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Temperature Range	T_J	–40	—	+125	°C	—
Ambient Storage Temperature	T_S	–65	—	+150	°C	—
Package Thermal Resistances						
Thermal Resistance, 3x3 DFN 12-Ld	θ_{JA}	—	60	—	°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.

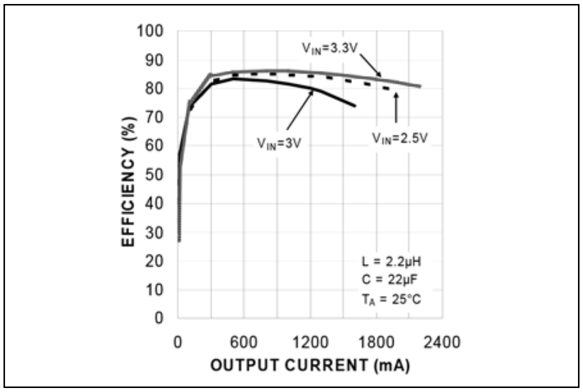


FIGURE 2-1: *Efficiency vs. Output Current, V_{OUT} = 3.8V.*

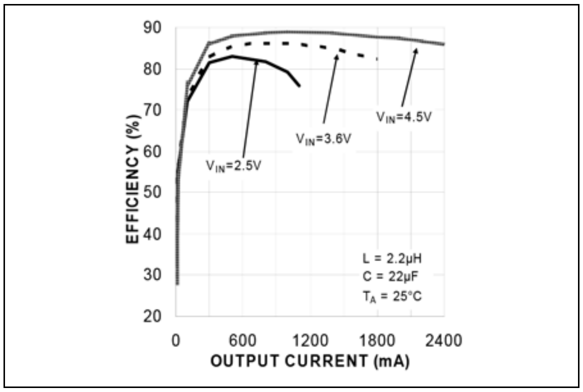


FIGURE 2-2: *Efficiency vs. Output Current, V_{OUT} = 5.0V.*

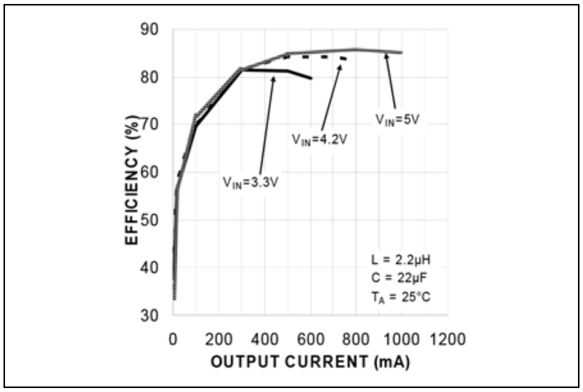


FIGURE 2-3: *Efficiency vs. Output Current, V_{OUT} = 12.0V.*

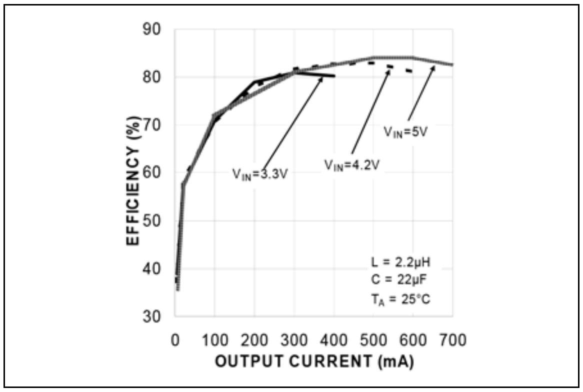


FIGURE 2-4: *Efficiency vs. Output Current, V_{OUT} = 15.0V.*

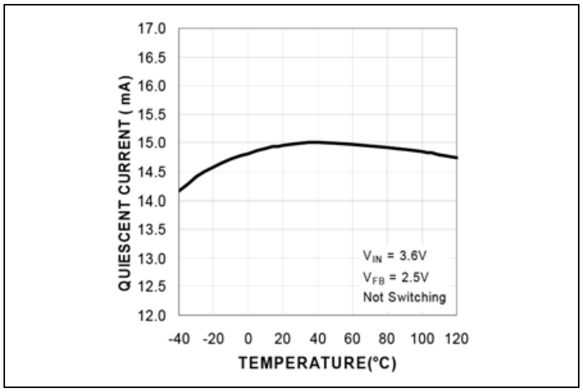


FIGURE 2-5: *Quiescent Current vs. Temperature.*

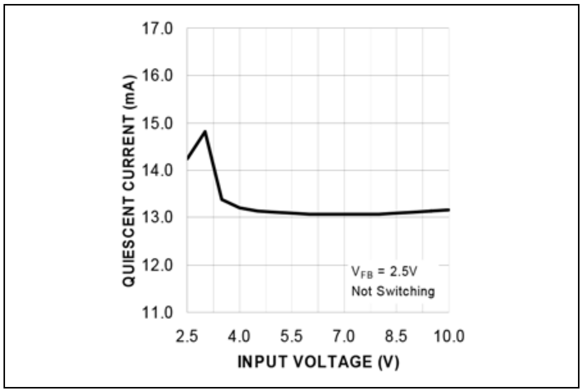


FIGURE 2-6: *Quiescent Current vs. Input Voltage.*

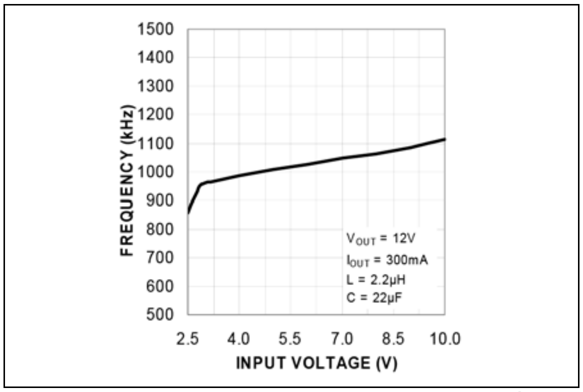


FIGURE 2-7: *Frequency vs. Input Voltage.*

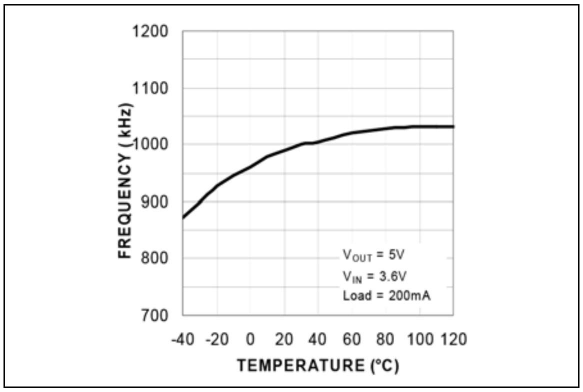


FIGURE 2-8: *Frequency vs. Temperature.*

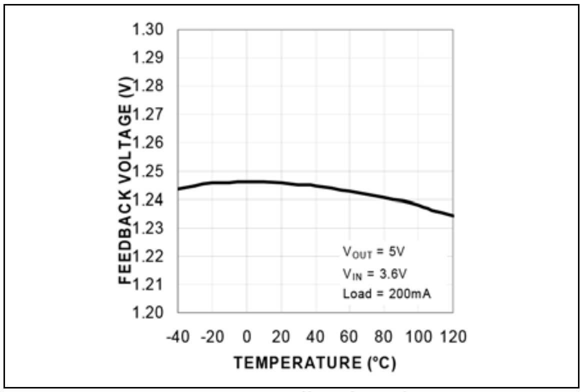


FIGURE 2-9: *Feedback Voltage vs Temperature.*

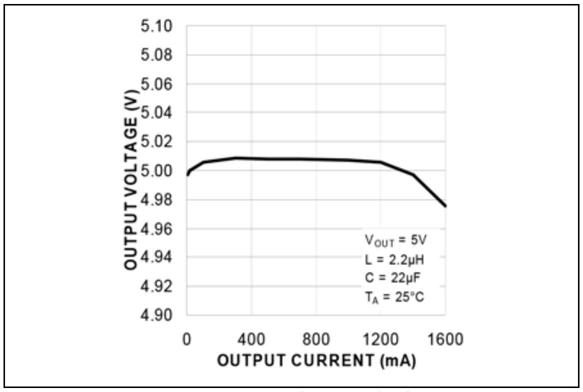


FIGURE 2-10: *Load Regulation.*

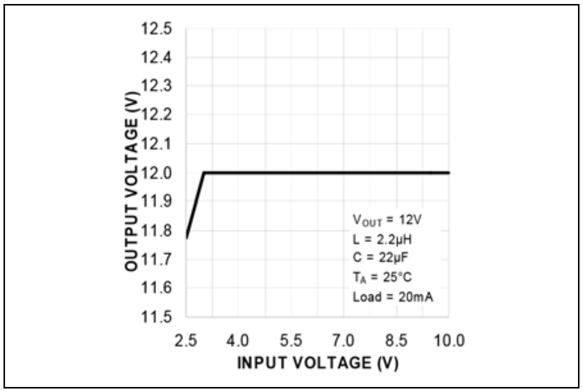


FIGURE 2-11: *Line Regulation.*

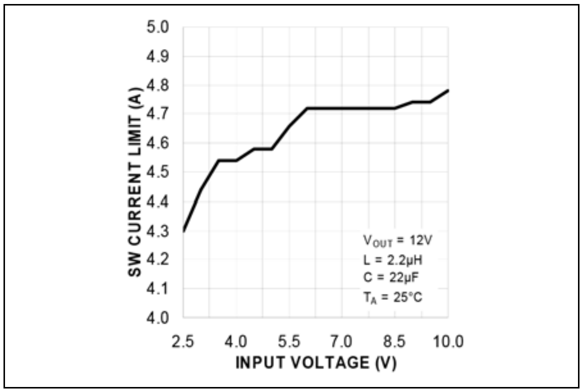


FIGURE 2-12: *Current Limit vs. Input Voltage.*

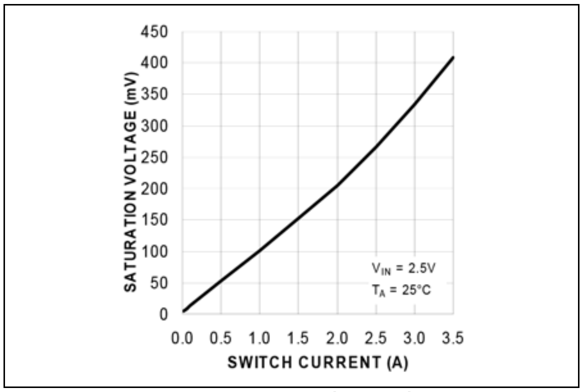


FIGURE 2-13: *Saturation Voltage vs. Switch Current.*

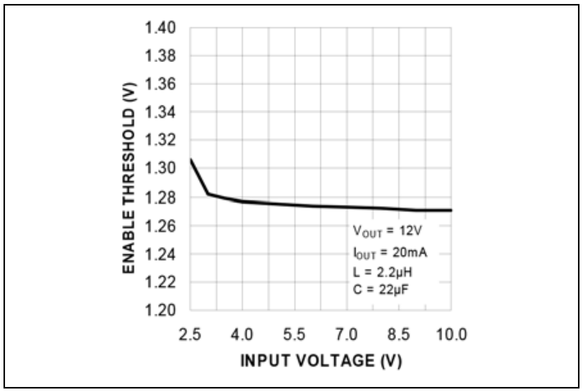


FIGURE 2-14: *Enable Threshold vs. Input Voltage.*

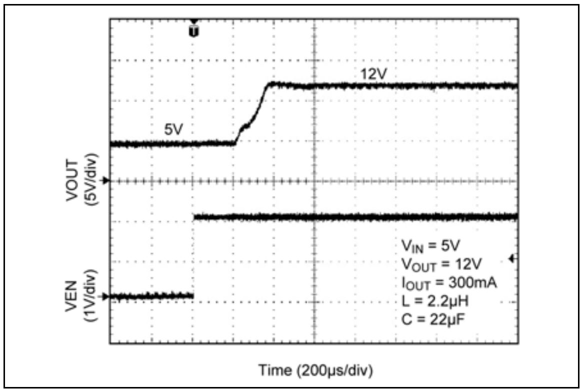


FIGURE 2-15: *Enable Turn-On Sequence.*

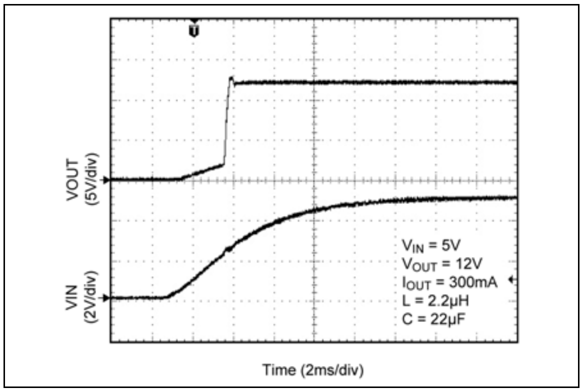


FIGURE 2-16: *Start-Up Sequence.*

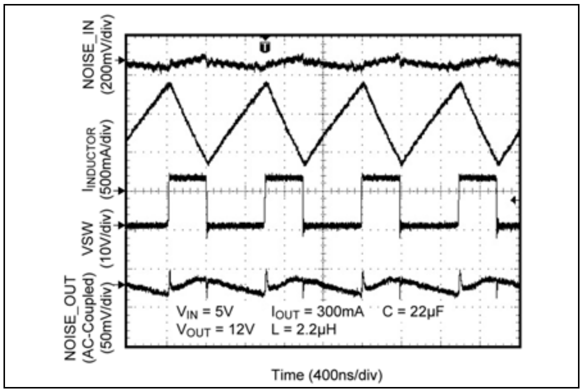


FIGURE 2-17: *Switching Waveforms.*

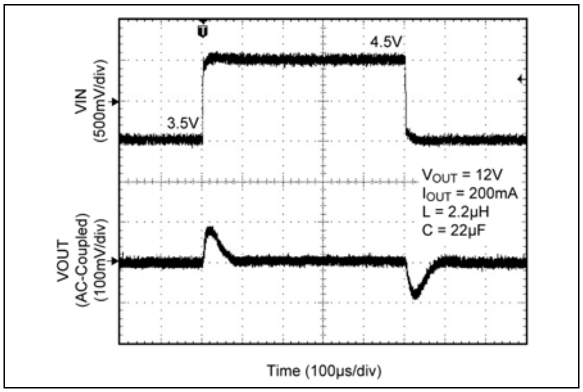


FIGURE 2-18: *Line Transient.*

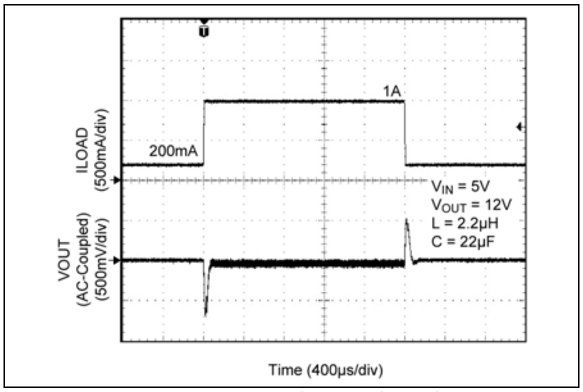


FIGURE 2-19: *Load Transient (12V Output).*

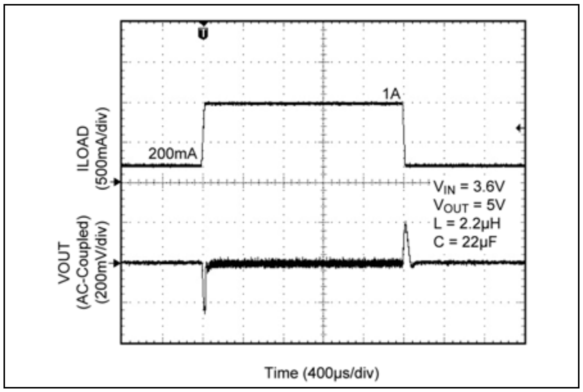


FIGURE 2-20: *Load Transient (5V Output).*

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	NC	No connect. Not internally connected.
2	SS	Soft-start (Input). Connect a capacitor to GND to slowly turn on the device. The higher the capacitance, the longer the turn-on time.
3	FB	Feedback (Input): Output voltage sense node. Connect external resistors to set the output voltage. Nominal feedback voltage is 1.245V.
4	AGND	Analog Ground.
5, 6	PGND	Power Ground.
7, 8	SW	Switch Node: Internal power bipolar collector.
9	OVP	Overvoltage Protection (OVP): Connect to the output voltage to clamp the maximum output voltage. A resistor divider from this pin to ground can be used to raise the OVP level beyond 6V (max.).
10	VIN	Supply (Input): 2.5V to 10V for internal circuitry.
11	EN	Enable (Input): Applying 1.5V or greater enables the regulator. Applying a voltage of 0.4V or less disables the MIC2253. Do not leave floating.
12	COMP	Compensation pin (Input): Add external resistor and capacitor to GND to stabilize the converter.
EP	HS Pad	Exposed heat sink pad.

4.0 APPLICATION INFORMATION

The MIC2253 is a constant frequency, pulse-width modulated (PWM) peak current-mode step-up regulator. The device's simplified control scheme is illustrated in the Functional Block Diagram. A reference voltage is fed into the PWM engine where the duty cycle output of the constant frequency PWM engine is computed from the error, or difference, between the REF and FB voltages. The PWM engine encompasses the necessary circuit blocks to implement a current-mode boost switching power supply. The necessary circuit blocks include, but are not limited to, an oscillator/ramp generator, slope compensation ramp generator, g_m error amplifier, current amplifier, PWM comparator, and drive logic for the internal 3.5A bipolar power transistor.

Inside the PWM engine, the oscillator functions as a trigger for the PWM comparator that turns on the bipolar power transistor and resets the slope compensation ramp generator. The current amplifier is used to measure the power transistor's current by amplifying the voltage signal from the sense resistor connected to the emitter of the bipolar power transistor. The output of the current amplifier is summed with the output of the slope compensation ramp generator where the result is connected to one of the inputs of the PWM comparator.

The g_m error amplifier measures the feedback voltage through the external resistor and amplifies the error between the detected voltage signal from the feedback and the internal reference voltage. The output of the g_m error amplifier provides the voltage loop signal that is fed to the other input of the PWM comparator. When the current loop signal exceeds the voltage loop signal the PWM comparator turns off the power transistor. The next oscillator/clock period initiates the next switching cycle, maintaining the constant frequency current-mode PWM control. The enable pin shuts down the output switching and disables control circuitry to reduce input current-to-leakage levels. Enable pin input current is approximately zero, at zero volts.

4.1 DC/DC PWM Boost Conversion

The MIC2253 is a constant-frequency boost converter. It can convert a low DC input voltage to a high DC output voltage. Figure 4-1 shows a typical circuit. Boost regulation is achieved by turning on an internal switch, which draws current through the inductor. When the switch turns off, the inductor's magnetic field collapses. This causes the current to be discharged into the output capacitor through an external Schottky diode. The Typical Performance Curves show Input Voltage ripple, Output Voltage ripple, SW Voltage, and Inductor Current for 300 mA load current. Regulation is achieved by modulating the pulse width (PWM).

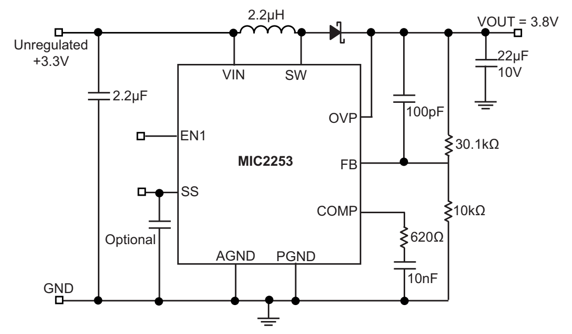


FIGURE 4-1: *Typical Application Circuit.*

4.2 Duty Cycle Considerations

Duty cycle refers to the switch on-to-off time ratio and can be calculated as follows for a boost regulator:

EQUATION 4-1:

$$D = 1 - \frac{V_{IN}}{V_{OUT}}$$

However, at light loads, the inductor will completely discharge before the end of a switching cycle. The current in the inductor reaches zero before the end of the switching cycle. This is known as discontinuous conduction mode (DCM). DCM occurs when:

EQUATION 4-2:

$$I_{OUT} < \frac{V_{IN}}{V_{OUT}} \times \frac{I_{PEAK}}{2}$$

Where:

$$I_{PEAK} < \frac{(V_{OUT} - V_{IN})}{L \times f} \times \left(\frac{V_{IN}}{V_{OUT}}\right)$$

L = The inductance of the switching coil.
f = Switching frequency.

In DCM, the duty cycle is smaller than in continuous conduction mode. In DCM, the duty cycle is given by:

EQUATION 4-3:

$$D = \frac{f \times \sqrt{2 \times L \times I_{OUT} \times (V_{OUT} - V_{IN})}}{V_{IN}}$$

The duty cycle required for voltage conversion should be less than the maximum duty cycle of 90%. Also, in light load conditions where the input voltage is close to the output voltage, the minimum duty cycle can cause pulse skipping. This is due to the energy stored in the inductor causing the output to slightly overshoot the regulated output voltage. During the next cycle, the error amplifier detects the output as being high and skips the following pulse. This effect can be reduced by increasing the minimum load or by increasing the inductor value. Increasing the inductor value also reduces the peak current. Minimum duty cycle is typically 10%.

4.3 Overvoltage Protection (OVP)

The MIC2253 provides a fixed 5.6V overvoltage protection. The overvoltage functionality will clamp the output voltage to a safe level in the event that a fault condition causes the output voltage to increase beyond control. To ensure the highest level of protection, the MIC2253 OVP pin will shut the switch off when an overvoltage condition is detected, saving itself, the output capacitor, and downstream devices from damage. Two external resistors can be used to change the OVP from the range of 6V to 30V. Be careful not to exceed the 30V rating of the switch. The OVP feature may be disabled by grounding the OVP pin.

The OVP pin is connected internally to a reference voltage via a voltage divider circuit. For a 5.6V OVP setting, connect the OVP pin directly to the output voltage as shown in Figure 4-1. To increase the OVP voltage above 5.6V, an external parallel resistor network can be configured, as shown in Figure 4-2, with the following equation:

EQUATION 4-4:

$$V_{OVP} = 1.245 \times \frac{67k\Omega \times (R1 + R2)}{15k\Omega \times R2}$$

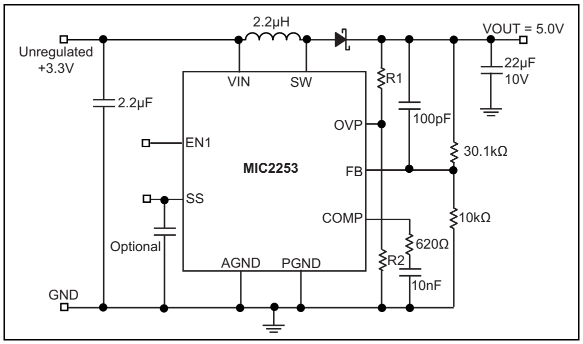


FIGURE 4-2: *Adjustable OVP Circuit.*

Please note the maximum value of R2 is 30 kΩ.

4.4 Soft-Start Functionality

The soft-start time is dependent upon both C_{SS} and the comparator capacitor values. C_{COMP} is fixed for stable operation (typically 10 nF); therefore, if any increases in soft start are desired, this should be done using the C_{SS} capacitor. The approximate total startup time is given by:

EQUATION 4-5:

$$T_{SS} = 1ms + 85k\Omega \times C_{SS}$$

5.0 COMPONENT SELECTION

5.1 Inductor

The MIC2253 is designed to work with a 2.2 µH inductor. This is due to the unavoidable “right half plane zero” effect for the continuous current boost converter topology. The frequency at which the right half plane zero occurs can be calculated as follows:

EQUATION 5-1:

$$f_{RHPZ} = \frac{{V_{IN}}^2}{V_{OUT} \times L \times I_{OUT} \times 2\pi}$$

The right half plane zero has the undesirable effect of increasing gain, while decreasing phase. This requires that the loop gain is rolled off before this has significant effect on the total loop response. This can be accomplished by either reducing inductance (increasing RHPZ frequency) or increasing the output capacitor value (decreasing loop gain).

5.2 Output Capacitor

Output capacitor selection is a trade-off between performance, size, and cost. Increasing output capacitance will lead to an improved transient response, but also an increase in size and cost. X5R or X7R dielectric ceramic capacitors are recommended for designs with the MIC2253.

The output capacitor sets the frequency of the dominant pole and zero in the power stage. The zero is given by:

EQUATION 5-2:

$$f_Z = \frac{1}{C_{OUT} \times R_{ESR} \times 2\pi}$$

Where:

R_{ESR} = The equivalent series resistance of the output capacitor.

For ceramic capacitors, the ESR is very small. This puts the zero at a very high frequency where it can be ignored. Fortunately, the MIC2253 is current mode in operation which reduces the need for this output capacitor zero when compensating the feedback loop.

The frequency of the pole caused by the output capacitor is given by:

EQUATION 5-3:

$$f_P = \frac{I_{OUT}}{C_{OUT} \times V_{OUT} \times 2\pi}$$

5.3 Diode Selection

The MIC2253 requires an external diode for operation. A Schottky diode is recommended for most applications due to their lower forward voltage drop and reverse recovery time. Make sure that the diode selected can deliver the peak inductor current and the maximum reverse voltage is rated greater than the output voltage.

5.4 Input Capacitor

A minimum 2.2 µF ceramic capacitor with an X5R or X7R dielectric is recommended for designing with the MIC2253. Increasing input capacitance will improve performance and greater noise immunity on the source. The input capacitor should be as close as possible to the inductor and the MIC2253, with short traces for good noise performance.

5.5 Compensation

The COMP pin is connected to the output of the voltage error amplifier. The voltage error amplifier is a transconductance amplifier. Adding a series RC to ground adds a zero at:

EQUATION 5-4:

$$f_{ZERO} = \frac{1}{2\pi \times R2 \times C4}$$

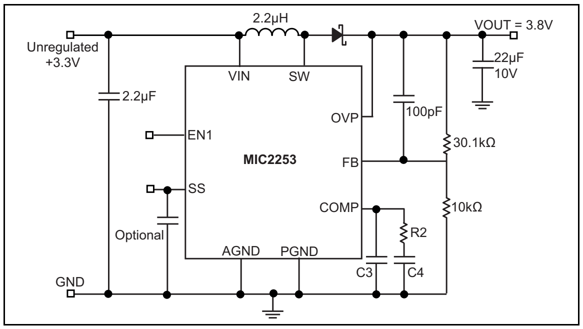


FIGURE 5-1: Typical Compensation Circuit.

The resistor should be set to approximately 600Ω. The capacitor typically ranges from 10 nF to 100 nF.

Adding an optional capacitor from the COMP pin to ground adds a pole at approximately:

EQUATION 5-5:

$$f_{POLE} = \frac{1}{2\pi \times R2 \times C3}$$

This capacitor typically is 100 pF. Generally, an RC to ground is all that is needed. The RC should be placed as close as possible to the COMP pin. The capacitor should be a ceramic with a X5R, X7R, or COG dielectric. Refer to the MIC2253 evaluation board user's guide document for component location.

5.6 Feedback Resistors

The feedback pin (FB) provides the control path to the control the output. The FB pin is used to compare the output to an internal reference. Output voltages are adjusted by selecting the appropriate feedback network values. The desired output voltage can be calculated as follows:

EQUATION 5-6:

$$V_{OUT} = V_{REF} \times \left(\frac{R_{TOP}}{R_{BOT}} + 1\right)$$

Where:

V_{REF} = 1.245V

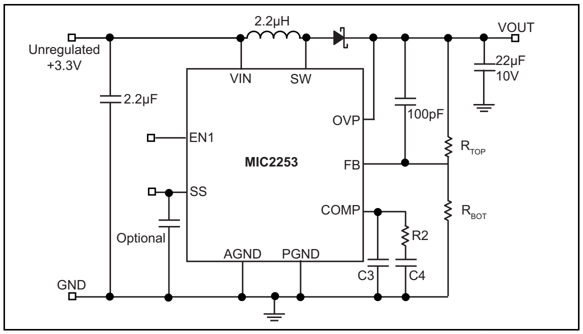
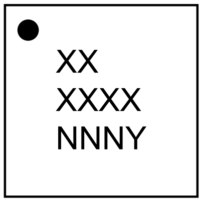


FIGURE 5-2: Output Voltage Setting Resistors.

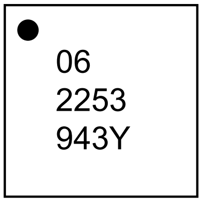
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

12-Lead DFN*



Example



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).

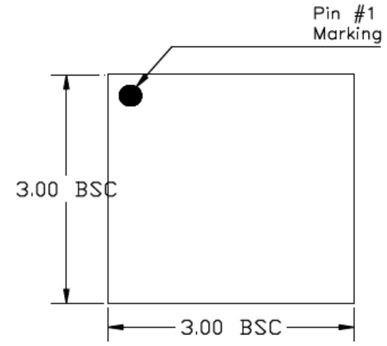
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

Underbar (_) and/or Overbar (‾) symbol may not be to scale.

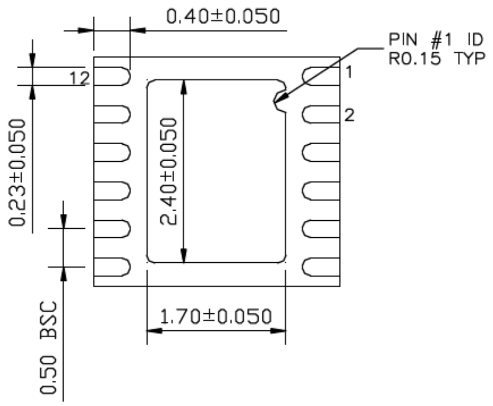
12-Lead 3 mm x 3 mm DFN Package Outline & Recommended Land Pattern

TITLE
12 LEAD DFN 3x3mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

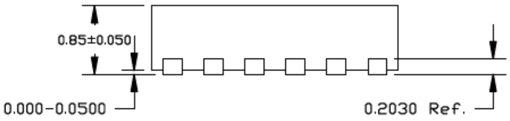
DRAWING #	DFN33-12LD-PL-1	**UNIT**	MM



TOP VIEW
NOTE: 1, 2, 3



BOTTOM VIEW
NOTE: 1, 2, 3

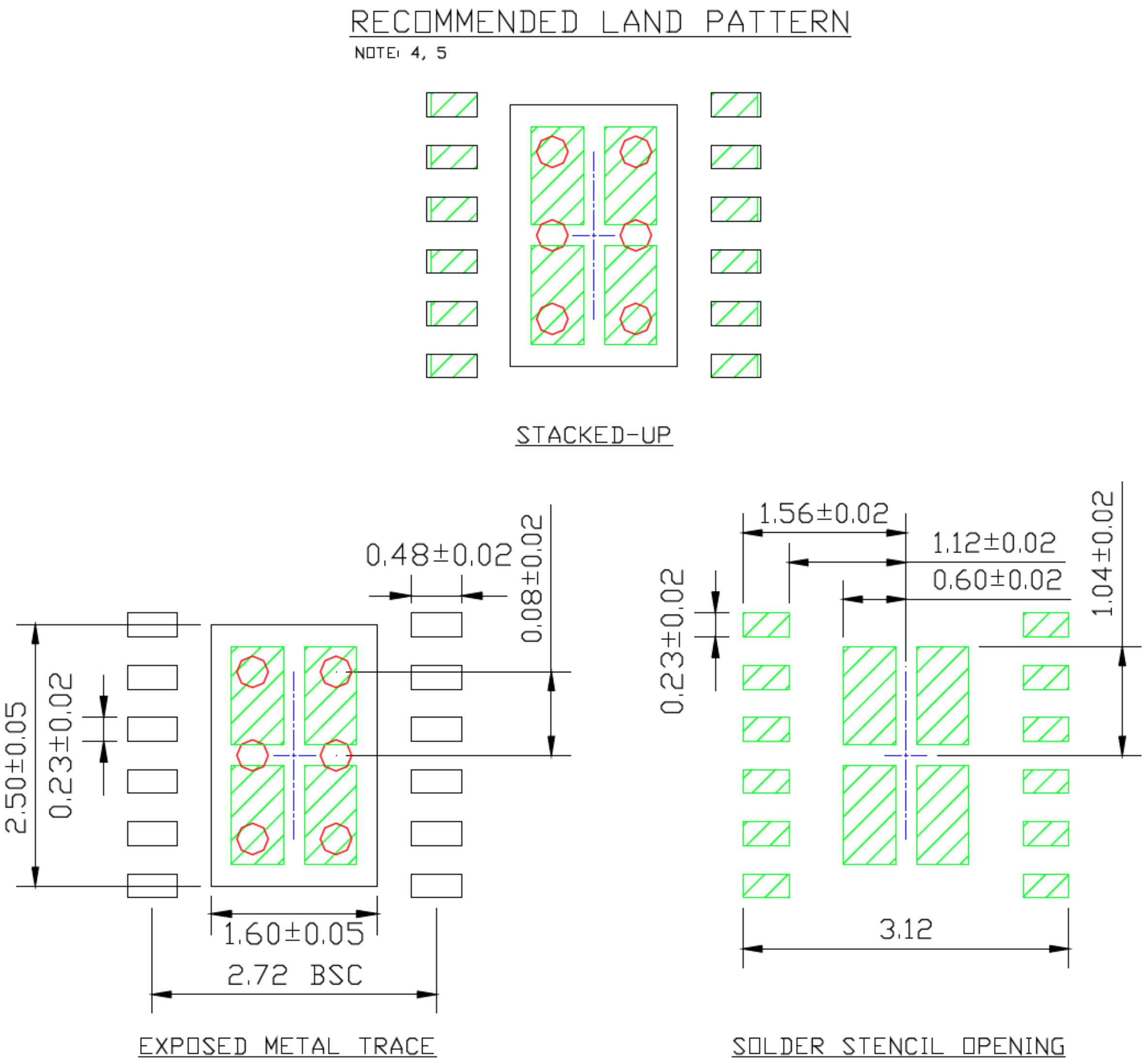


SIDE VIEW
NOTE: 1, 2, 3

NOTE:
1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076 MM 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 0.30–0.35 MM 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 0.50x0.95 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.

POD-Land Pattern drawing # DFN33-12LD-PL-1



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 (September 2018)

- Converted Micrel document MIC2253 to Microchip data sheet template DS2000xxxxA.
- Minor grammatical text changes throughout.
- Added Figure 5-1 and Figure 5-2.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

Device	**-XX**	**X**	**XX**	**-XX**
Part No.	Feature	Junction Temp. Range	Package	Media Type

Device:	MIC2253:		High Current 1 MHz High Efficiency Boost Regulator with OVP and Soft-Start
Feature:	06	=	6V Overvoltage Protection and Undervoltage Lockout
Junction Temperature Range:	Y	=	–40°C to +125°C, Industrial, RoHS-Compliant
Package:	ML	=	12-Lead 3 mm x 3 mm x 0.9 mm DFN
Media Type:	TR	=	5,000/Reel

Examples:

a) MIC2253-06YML-TR:	MIC2253, 6V Overvoltage Protection and Undervoltage Lockout, –40°C to +125°C Temperature Range, 12-Lead DFN, 5,000/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 specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip’s Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

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