



# MIC2619

## 1.2MHz PWM Boost Converter with OVP

### General Description

The MIC2619 is a 1.2MHz pulse width modulated (PWM) step-up switching regulator that is optimized for low power, high output voltage applications. With a maximum output voltage of 35V, and a switch current of over 350mA, the MIC2619 can easily supply most high voltage bias applications, such as TV tuners.

The MIC2619 implements a constant frequency 1.2MHz PWM current-mode control scheme. The high frequency PWM operation saves board space by reducing external component sizes. The additional benefit of the constant frequency PWM control scheme as opposed to variable frequency control schemes is lower output noise and smaller input ripple injected back to the battery source. The MIC2619 has programmable overvoltage protection to ensure output protection in case of fault condition.

The MIC2619 is available in a low profile Thin SOT-23 6-pin package. The MIC2619 has a junction temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

All support documentation can be found on Micrel's web site at: [www.micrel.com](http://www.micrel.com).

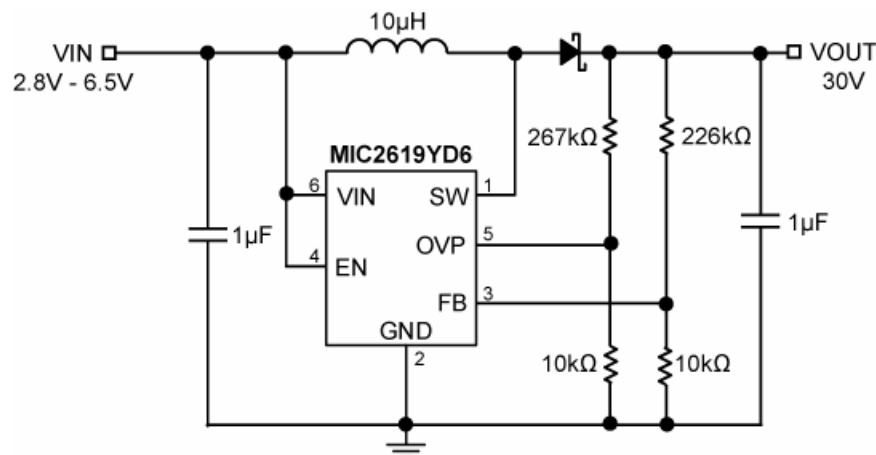
### Features

- 2.8V to 6.5V Input Voltage
- 350mA Switch Current
- Output Voltage up to 35V
- 1.2MHz PWM Operation
- 1.265V Feedback Voltage
- Programmable Over-Voltage Protection (OVP)
- $<1\%$  Line Regulation
- $<1\mu\text{A}$  Shutdown Current
- Over-Temperature Protection
- Under-Voltage Lock Out (UVLO)
- Low Profile Thin SOT-23-6 Package
- $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  Junction Temperature Range

### Applications

- Bias Supply Applications:
  - Tuner Varactor Bias
  - High Voltage Bias Supplies
  - Avalanche Photo Diode
  - High Voltage Display Bias
- DSL/Broadband applications
- Constant Current Power Supplies

### Typical Application



1.2MHz Boost Converter with OVP in Thin SOT-23-6

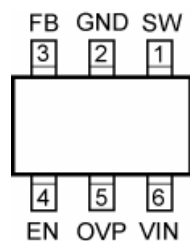
## Ordering Information

Part Number	Marking <sup>(1)</sup>	Oversvoltage Protection	Junction Temp. Range	Package	Lead Finish
MIC2619YD6	<u>2</u> 619	Programmable	-40°C to +125°C	Thin SOT-23-6	Lead Free

**Note:**

1. Under bar( ) symbol may not be to scale.

## Pin Configuration



6-Pin TSOT-23 (YD6)

## Pin Description

Pin Number	Pin Name	Pin Function
1	SW	Switch Node (Input): Internal power bipolar collector.
2	GND	Ground.
3	FB	Feedback (Input): Output voltage sense node. Connect external resistor network to set output voltage. Nominal feedback voltage is 1.265V.
4	EN	Enable (Input): Logic high enables regulator. Logic low shuts down regulator. Do not leave floating.
5	OVP	Over-Voltage Protection (Input): Programmable to 35V, adjustable through resistor divider network.
6	VIN	Supply (Input): 2.8V to 6.5V for internal circuitry. Requires a minimum 1.0μF ceramic capacitor.

**Absolute Maximum Ratings<sup>(1)</sup>**

Supply Voltage ( $V_{IN}$ ).....	7V
Switch Voltage ( $V_{SW}$ ).....	-0.3V to 40V
Enable Pin Voltage ( $V_{EN}$ ).....	-0.3 to $V_{IN}$
Feedback Voltage ( $V_{FB}$ ), ( $V_{OVP}$ ).....	6V
Ambient Storage Temperature ( $T_S$ ).....	-65°C to +150°C
ESD Rating <sup>(3)</sup> .....	2kV

**Operating Ratings<sup>(2)</sup>**

Supply Voltage ( $V_{IN}$ ).....	2.8V to 6.5V
Output Voltage ( $V_{OUT}$ ).....	$V_{IN}$ to 35V
Junction Temperature Range ( $T_J$ ).....	-40°C to +125°C
Package Thermal Impedance Thin SOT-23-6 ( $\theta_{JA}$ ).....	177°C/W

**Electrical Characteristics<sup>(4)</sup>**

$T_A = 25^\circ\text{C}$ ,  $V_{IN} = V_{EN} = 3.6\text{V}$ ,  $V_{OUT} = 10\text{V}$ ,  $I_{OUT} = 10\text{mA}$ , unless otherwise noted. **Bold** values indicate  $-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ .

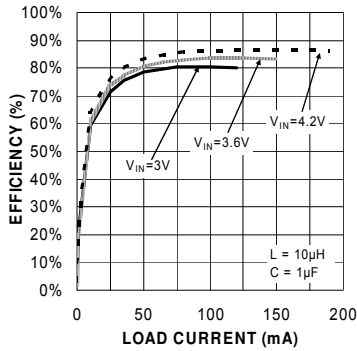
Parameter	Condition	Min	Typ	Max	Units
Supply Voltage Range		<b>2.8</b>		<b>6.5</b>	V
Under Voltage Lockout		1.8	2.1	2.4	V
Quiescent Current	$V_{FB} > 1.265\text{V}$ , (not switching)		2.1	5	mA
Shutdown Current	$V_{EN} = 0\text{V}$		0.04	1	$\mu\text{A}$
Feedback Voltage		1.227	1.265	1.303	V
Feedback Input Current	$V_{FB} = 1.265\text{V}$		-450		nA
Line Regulation	$2.8\text{V} \leq V_{IN} \leq 6.5\text{V}$		0.2	1	%
Load Regulation	$5\text{mA} \leq I_{OUT} \leq 20\text{mA}$		0.3		%
Maximum Duty Cycle		85	90		%
Switch Current Limit	$V_{IN} = 3.6\text{V}^{(5)}$	350			mA
Switch Saturation Voltage	$V_{IN} = 3.6\text{V}$ , $I_{SW} = 300\text{mA}$		400		mV
Switch Leakage Current	$V_{EN} = 0\text{V}$ , $V_{SW} = 10\text{V}$		0.01	1	$\mu\text{A}$
Enable Threshold	TURN ON	<b>1.5</b>			V
	TURN OFF			<b>0.4</b>	
Enable Pin Current	$V_{EN} = 6.5\text{V}$		14	40	$\mu\text{A}$
Oscillator Frequency			1.2		MHz
Overshoot Protection		1.202	1.265	1.328	V
OVP Input Current	$V_{OVP} = 1.265\text{V}$		-200		nA
Overtemperature Threshold Shutdown			150		$^\circ\text{C}$
	Hysteresis		10		$^\circ\text{C}$

**Notes:**

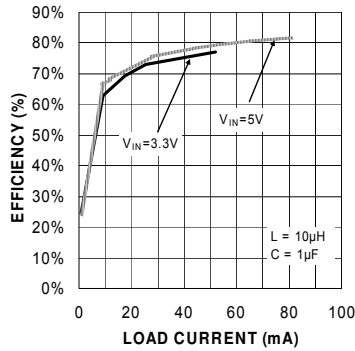
1. Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device outside of its operating ratings. The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_J(\text{max})$ , the junction-to-ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.
2. This device is not guaranteed to operate beyond its specified operating ratings.
3. Devices are inherently ESD sensitive. Handling precautions required. Human body model: 1.5k $\Omega$  in series with 100pF.
4. Specification for packaged product only.
5. Guaranteed by design.

# Typical Characteristics

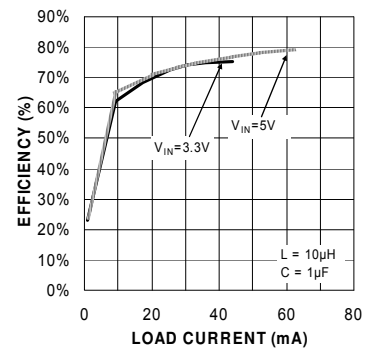
**Efficiency  $V_{OUT} = 5V$**



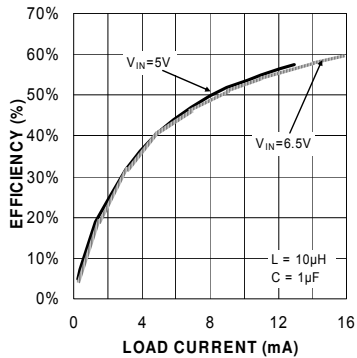
**Efficiency  $V_{OUT} = 10V$**



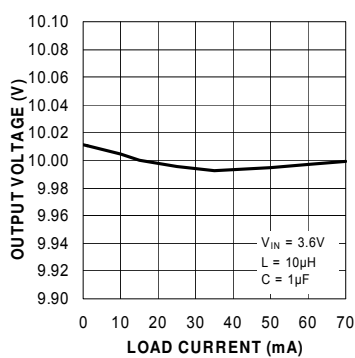
**Efficiency  $V_{OUT} = 12V$**



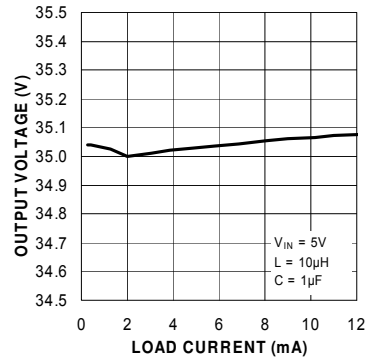
**Efficiency  $V_{OUT} = 35V$**



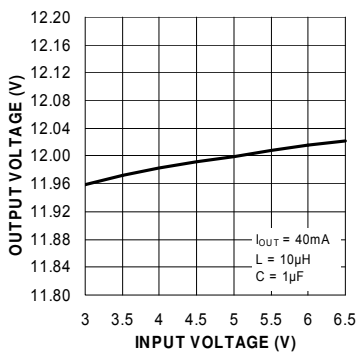
**Load Regulation ( $V_{OUT}=10V$ )**



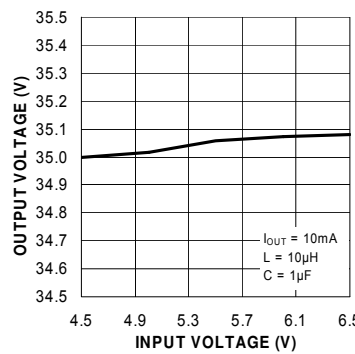
**Load Regulation ( $V_{OUT}=35V$ )**



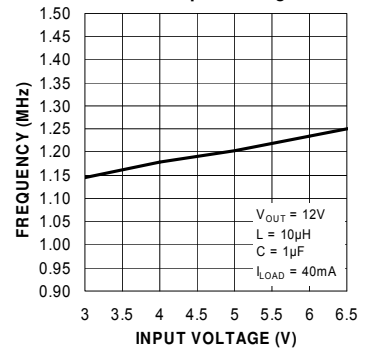
**Line Regulation ( $V_{OUT}=12V$ )**



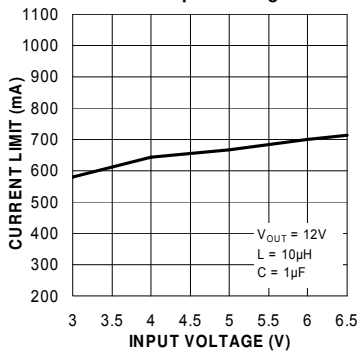
**Line Regulation ( $V_{OUT}=35V$ )**



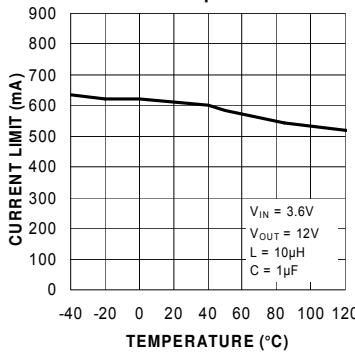
**Frequency vs. Input Voltage**



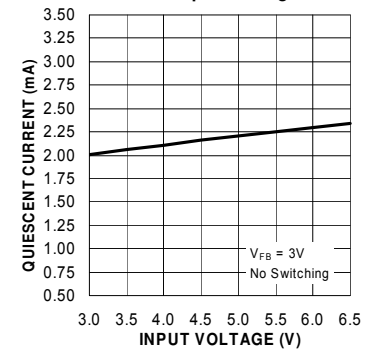
**Switch Current Limit vs. Input Voltage**



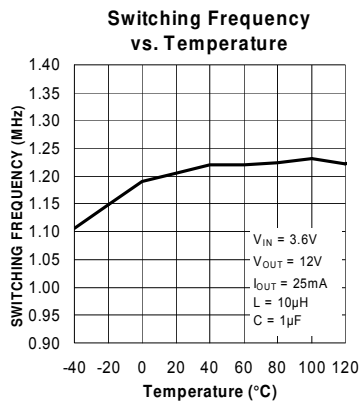
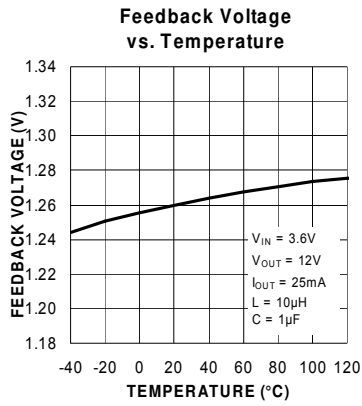
**Switch Current Limit vs. Temperature**



**Quiescent Current vs. Input Voltage**

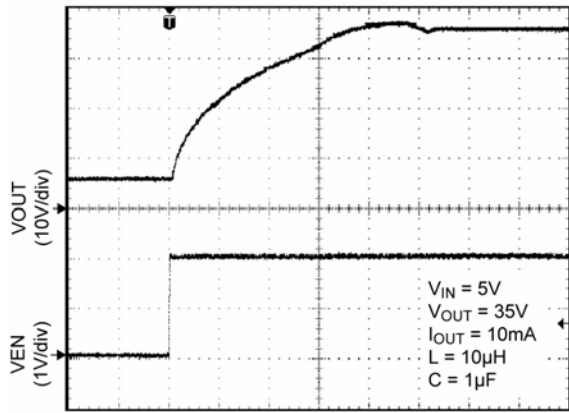


## Typical Characteristics (Continued)



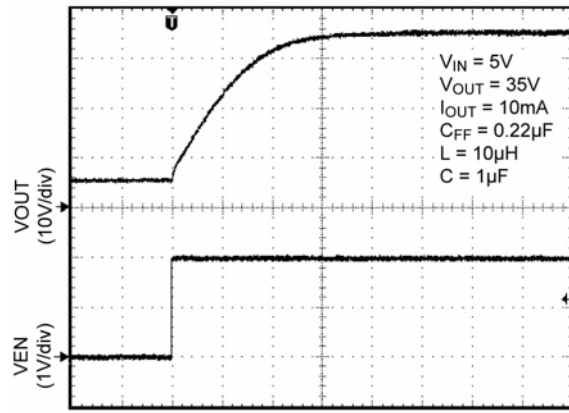
# Functional Characteristics

**Enable Turn-On**



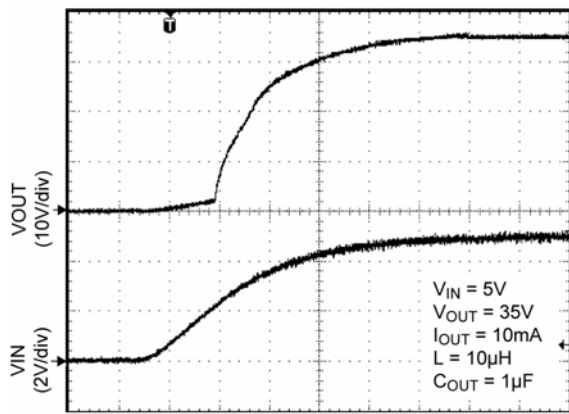
Time (400µs/div)

**Enable Turn-On with Softstart**



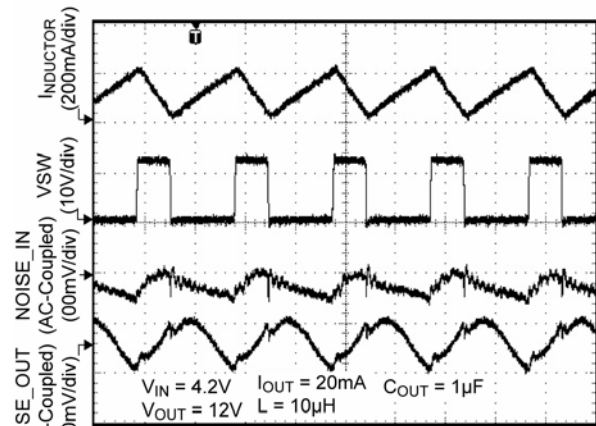
Time (4ms/div)

**Input Turn-On**



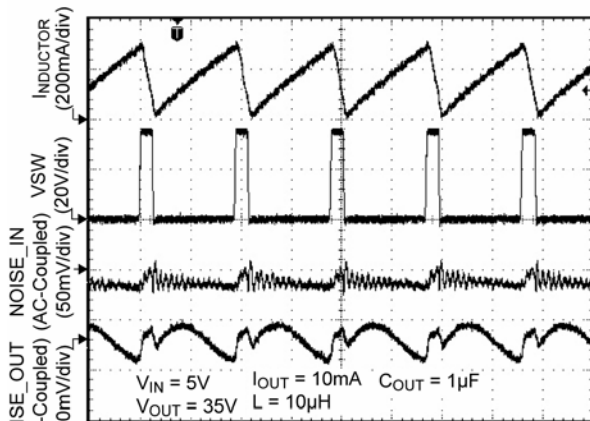
Time (2ms/div)

**Switching Waveform - Continuous**



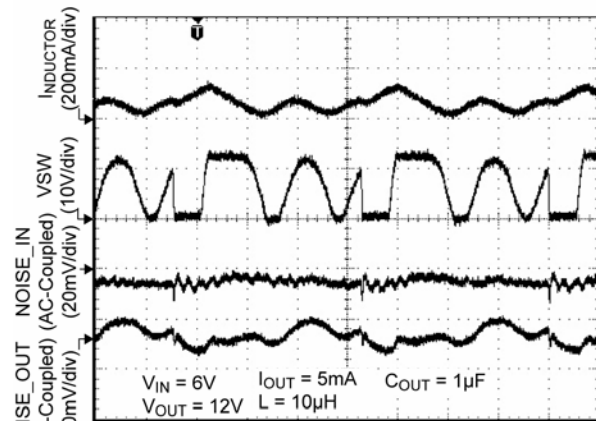
Time (400ns/div)

**Switching Waveform - Continuous**



Time (400ns/div)

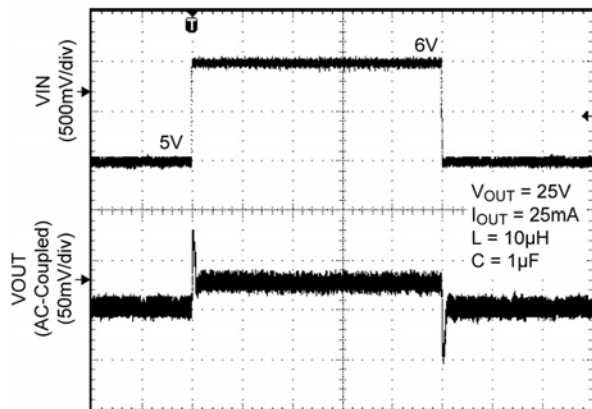
**Switching Waveform - Discontinuous**



Time (200ns/div)

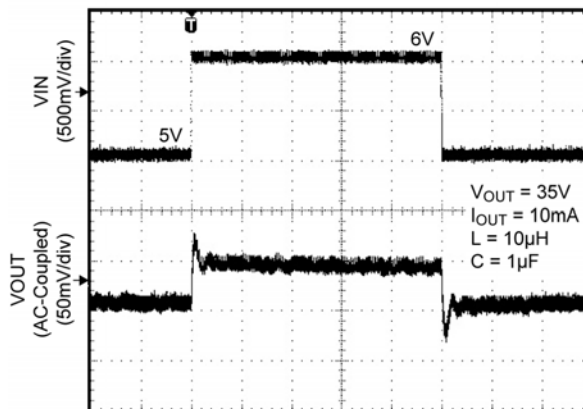
### Functional Characteristics (Continued)

Line Transient



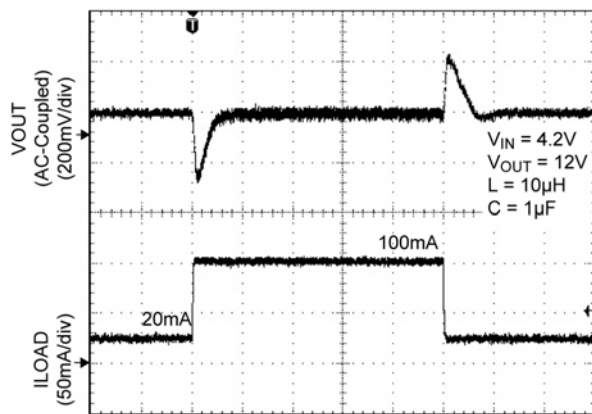
Time (1ms/div)

Line Transient



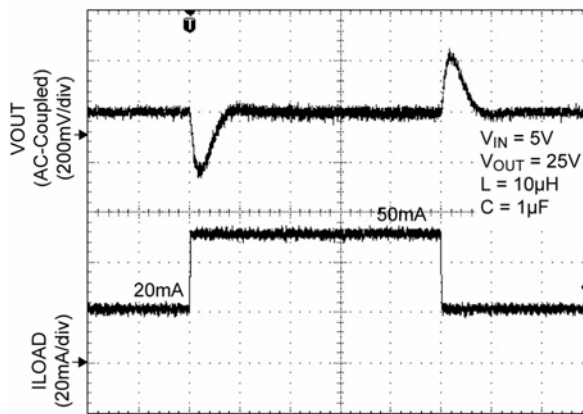
Time (1ms/div)

Load Transient



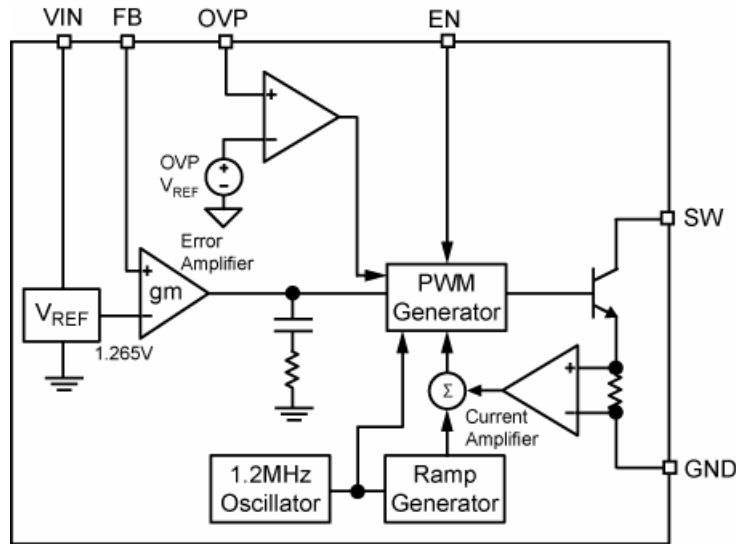
Time (100µs/div)

Load Transient



Time (100µs/div)

## Functional Diagram



MIC2619 Block Diagram

## Functional Description

The MIC2619 is a constant frequency, PWM current mode boost regulator. It is composed of an oscillator, slope compensation ramp generator, current amplifier,  $g_m$  error amplifier, PWM generator, and bipolar output transistor. The oscillator generates a 1.2MHz clock which triggers the PWM generator to turn on the output transistor and resets the slope compensation ramp generator. The current amplifier is used to measure switch current by amplifying the voltage signal from the internal sense resistor. The output of the current amplifier is summed with the output of the slope compensation ramp generator. This summed current-loop signal is then fed to one of the inputs of the PWM generator.

The  $g_m$  error amplifier measures the feedback voltage through the external feedback resistors and amplifies the error between the detected signal and the 1.265V 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 generator. When the current-loop signal exceeds the voltage loop signal, the PWM generator turns off the bipolar output transistor. The next clock period initiates the next switching cycle, maintaining the constant frequency current-mode PWM control.

### VIN

VIN provides power to the control and reference circuitry as well as the switch mode regulator MOSFETs. Due to the high speed switching, a  $1\mu\text{F}$  capacitor is recommended as close as possible to the VIN and GND pin.

### EN

The enable pin provides a logic level control of the output. In the off state, supply current of the device is greatly reduced (typically  $<0.1\mu\text{A}$ ). Also, in the off state, the output drive is placed in a "tri-stated" condition, where the bipolar output transistor is in an "off" state or non-conducting state.

### OVP

The OVP pin provides over-voltage protection on the output of the MIC2619. When the OVP circuit is tripped, the output voltage remains at the set OVP voltage. Because the OVP circuit operates at a lower frequency than the feedback circuit, output ripple will be higher while in an OVP state. OVP requires a resistor divider network to the output and GND to set the OVP voltage. If the output voltage overshoots the set OVP voltage, then the MIC2619 OVP circuit will shut off the switch; saving itself and other sensitive circuitry downstream. The accuracy of the OVP pin is  $\pm 5\%$  and therefore should be set above the output voltage to ensure noise or other variations will not cause a false triggering of the OVP circuit.



**FB**

The feedback pin provides the control path to control the output. FB requires a resistor divider network to the output and GND to set the output voltage.

**SW**

The switching pin connects directly to one end of the inductor to VIN and the anode of the Schottky diode to the output. Due to the high switching speed and high

voltage associated with this pin, the switch node should be routed away from sensitive nodes.

**GND**

The ground pin is the ground path for high current PWM mode. The current loop for the power ground should be kept as small as possible.

## Application Information

### DC-to-DC PWM Boost Conversion

The MIC2619 is a constant-frequency boost converter. It can convert a low DC input voltage to a higher DC output voltage. Figure 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 (D1). The Functional Characteristics show Input Voltage ripple, Output Voltage ripple, SW Voltage, and Inductor Current for 10mA load current. Regulation is achieved by modulating the pulse width i.e., pulse-width modulation (PWM).

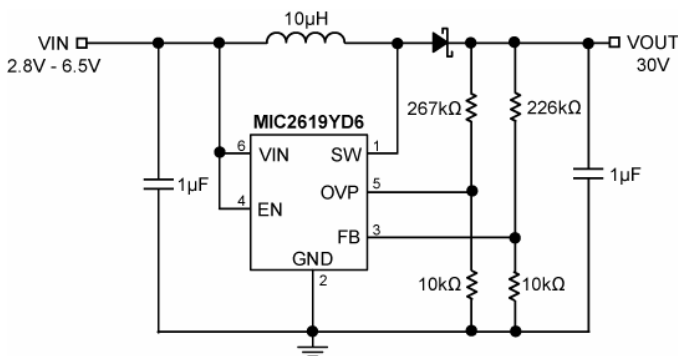


Figure 1. Typical Application Circuit

### Duty Cycle Considerations

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

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

However at light loads, the inductor will completely discharge before the end of a switching cycle. The current in the inductor reaches 0A before the end of the switching cycle. This is known as discontinuous conduction mode (DCM). DCM occurs when:

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

Where

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

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

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

The duty cycle required for voltage conversion should be less than the maximum duty cycle of 85%. 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.

### Input Capacitors

A 1µF ceramic capacitor is recommended on the VIN pin for bypassing. Increasing input capacitance will improve performance and provide greater noise immunity. The input capacitor should be as close as possible to the inductor and the MIC2619, with short traces for good noise performance.

X5R or X7R dielectrics are recommended for the input capacitor. Y5V dielectrics lose most of their capacitance over temperature and are therefore not recommended. Also, tantalum and electrolytic capacitors alone are not recommended because of their reduced RMS current handling, reliability, and ESR increases.

### Output Capacitors

Output capacitor selection is also a trade-off between performance, size, and cost. The minimum recommended output capacitor is 1µF. Increasing output capacitance will lead to an improved transient response but also an increase in size and cost. X5R or X7R dielectrics are recommended for the output capacitor. Y5V dielectrics lose most of their capacitance over temperature and are therefore not recommended.

### Inductor

Inductor selection will be determined by the following (not necessarily in order of importance);

- Inductance
- Rated current value
- Size requirements
- DC resistance (DCR)

The MIC2619 was designed for use with a 10µH inductor. Proper selection should ensure the inductor can handle the maximum average and peak currents required by the load. Maximum current ratings of the inductor are generally given in two methods; permissible DC current and saturation current. Permissible DC current can be rated either for a 40°C temperature rise or a 10 to 20% loss in inductance. Ensure the inductor selected can handle the maximum operating current. When saturation current is specified, make sure that there is enough margin so that the peak current will not

saturate the inductor. Peak current can be calculated as follows:

$$I_{PEAK} = \left[ I_{OUT} + V_{OUT} \left( \frac{1 - V_{OUT} \cdot V_{IN}}{2 \times f \times L} \right) \right]$$

As shown by the previous calculation, the peak inductor current is inversely proportional to the switching frequency and the inductance; the lower the switching frequency or the inductance the higher the peak current. As input voltage increases the peak current also increases.

The size of the inductor depends on the requirements of the application.

DC resistance (DCR) is also important. While DCR is inversely proportional to size, DCR can represent a significant efficiency loss. Refer to the Efficiency Considerations.

To maintain stability, increasing inductor size will have to be met with an increase in output capacitance. 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:

$$\text{Frequency} = \frac{V_{IN}^2}{V_{OUT} \cdot L \cdot I_{OUT} \cdot 2\pi}$$

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).

**Diode Selection**

The MIC2619 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. Ensure the diode selected can deliver the peak inductor current and the maximum reverse voltage is rated greater than the output voltage.

**Soft-start**

Feed-forward capacitors can be used to provide soft-start for the MIC2619. Figure 2 shows a typical circuit for soft-start applications. Typically a 0.22nF feed-forward capacitor will yield 5ms in rise time.

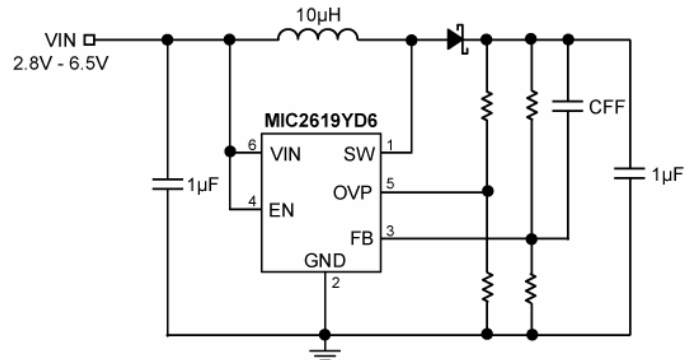


Figure 2. Soft-start Circuit

**Feedback resistors**

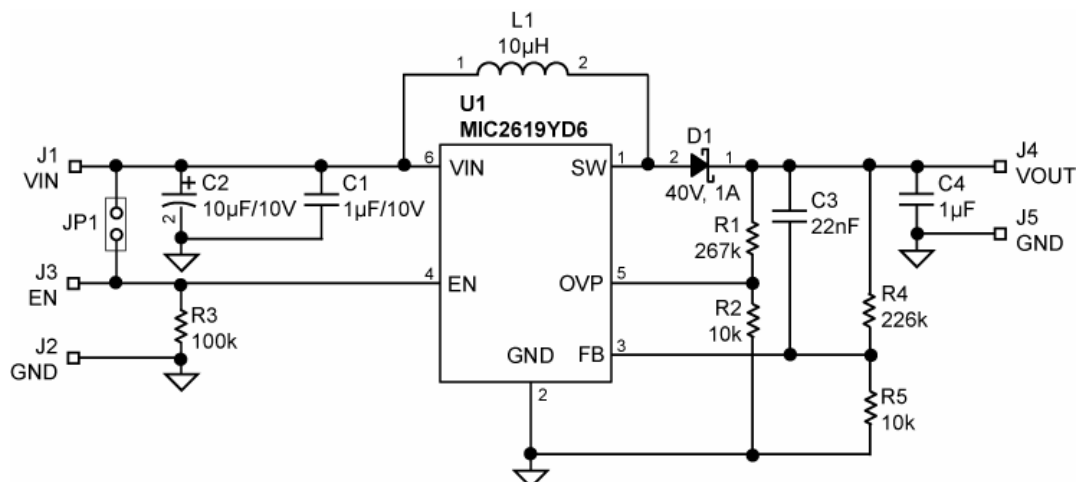
The MIC2619 utilizes a feedback pin to compare the output to an internal reference. The output voltage is adjusted by selecting the appropriate feedback resistor network values. Using the evaluation board schematic as a reference, the desired output voltage can be calculated as follows:

$$V_{OUT} = V_{REF} \cdot \left( \frac{R_4}{R_5} + 1 \right)$$

Where  $V_{REF}$  is equal to 1.265V. Over-voltage Protection uses the same equation as the feedback pin.

$$V_{OVP} = V_{REF} \cdot \left( \frac{R_1}{R_2} + 1 \right)$$

# MIC2619 Evaluation Board Schematic



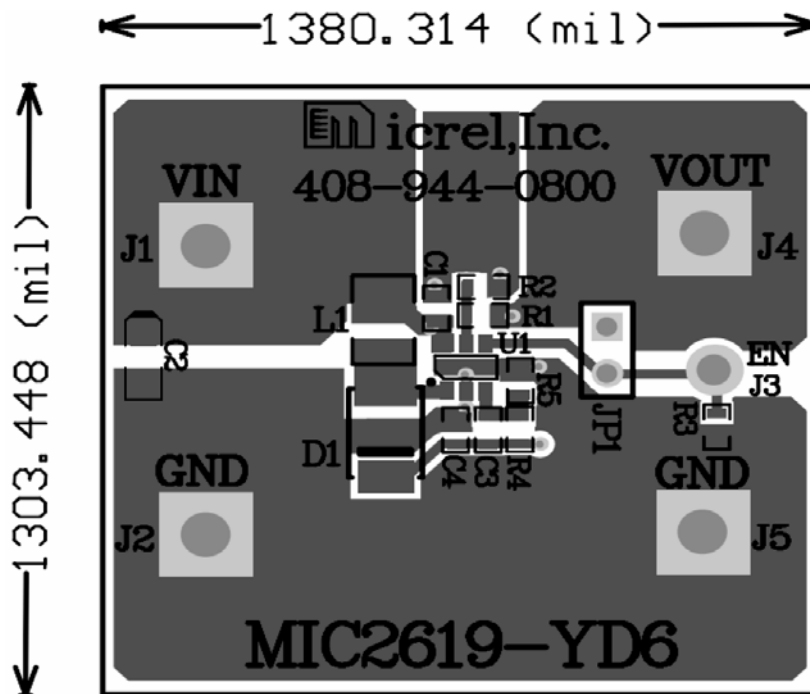
## Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1	C1608X5R1A105K	TDK <sup>(1)</sup>	Capacitor, 1.0µF, 10V, X5R, 0603 size	1
	GRM185R61A105KE36D	Murata <sup>(2)</sup>	Capacitor, 1.0µF, 10V, X5R, 0603 size	
	0603ZD105KT2A	AVX <sup>(3)</sup>	Capacitor, 1.0µF, 10V, X5R, 0603 size	
C2	TAJA106M010R	AVX	Capacitor, 10.0µF, 10V, A Case	1
C3	C1608X7R11H223K	TDK	Capacitor, 22nF, 50V, X7R, 0603 size	1
	GRM188R71H223KA01D	Murata	Capacitor, 22nF, 50V, X7R, 0603 size	
	06035C223JAT2A	AVX	Capacitor, 22nF, 50V, X7R, 0603 size	
C4	08055D105MAT2A	AVX	Capacitor, 1.0µF, 50V, X5R, 0805 size	1
	GRM21BR71H105KA12L	Murata	Capacitor, 1.0µF, 50V, X5R, 0805 size	
	CL21B105KBFNNNE	Samsung <sup>(4)</sup>	Capacitor, 1.0µF, 50V, X7R, 0805 size	
D1	SK14	MCC <sup>(5)</sup>	Schottky Diode, 1A, 40V	1
	B140/B	Diode, Inc. <sup>(6)</sup>	Schottky Diode, 1A, 40V	
L1	C1G22L100MNE	Samsung	Inductor, 10.0µH, 0.8A, 2.5 x 2.0 x 1.0mm	1
	VLF3012ST-100MR59	TDK	Inductor, 10.0µH, 0.59A, 2.8 x 3.0 x 1.2mm	
	LQH32PN100MN0L	Murata	Inductor, 10.0µH, 0.7A, 3.2 x 2.5 x 1.55mm	
R1	CRCW0603267KFKEA	Vishay <sup>(7)</sup>	Resistor, 267kΩ, 1%, 1/16W, 0603 size	1
R2, R5	CRCW060310K0FKEA	Vishay	Resistor, 10kΩ, 1%, 1/16W, 0603 size	2
R3	CRCW0603100KFKEA	Vishay	Resistor, 100kΩ, 1%, 1/16W, 0603 size	1
R4	CRCW0603226KFKEA	Vishay	Resistor, 226kΩ, 1%, 1/16W, 0603 size	1
U1	MIC2619YD6	Micrel, Inc. <sup>(8)</sup>	1.2MHz PWM Boost Converter with OVP	1

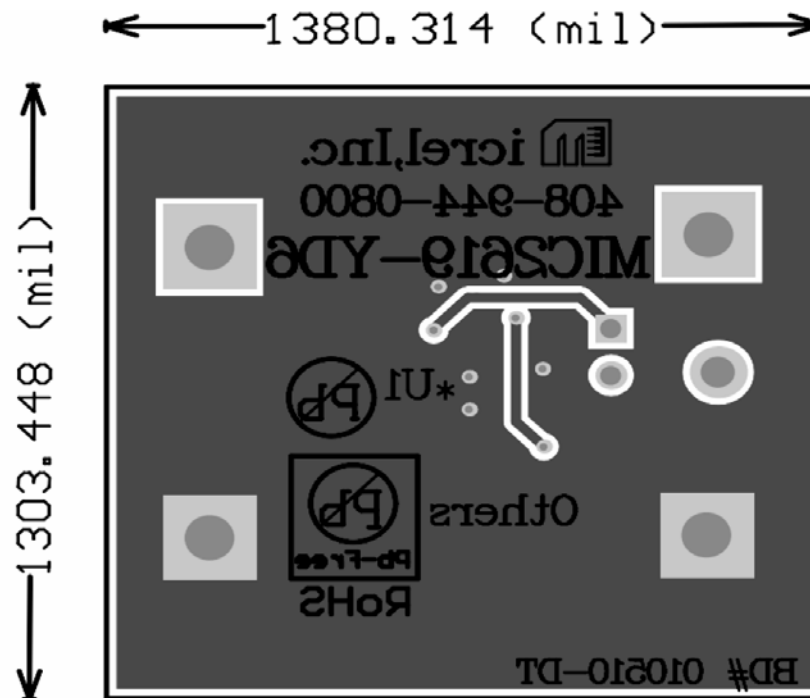
### Notes:

1. TDK: [www.tdk.com](http://www.tdk.com)
2. Murata: [www.murata.com](http://www.murata.com)
3. AVX: [www.avx.com](http://www.avx.com)
4. Samsung: [www.sem.samsung.com](http://www.sem.samsung.com)
5. MCC: [www.mccsemi.com](http://www.mccsemi.com)
6. Diode, Inc.: [www.diodes.com](http://www.diodes.com)
7. Vishay: [www.vishay.com](http://www.vishay.com)
8. Micrel, Inc.: [www.micrel.com](http://www.micrel.com)

### Recommended Layout

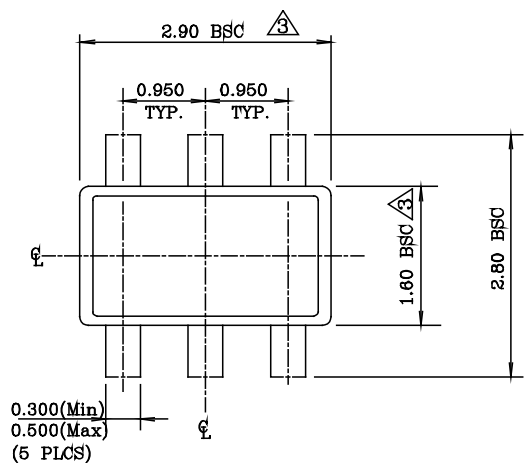


Top Layout



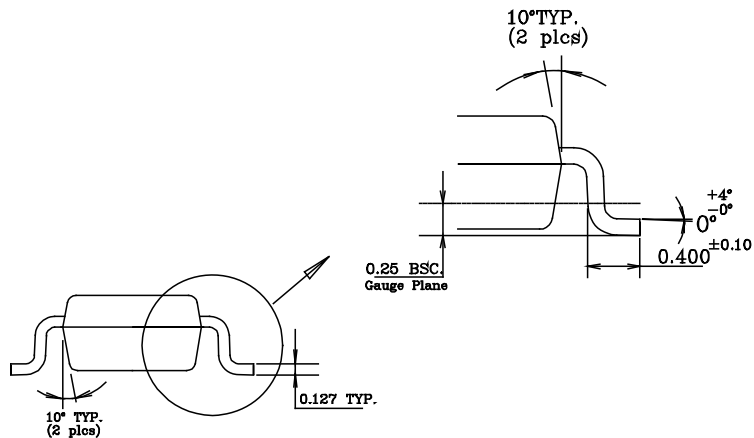
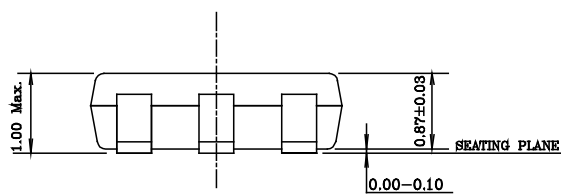
Bottom Layout

# Package Information



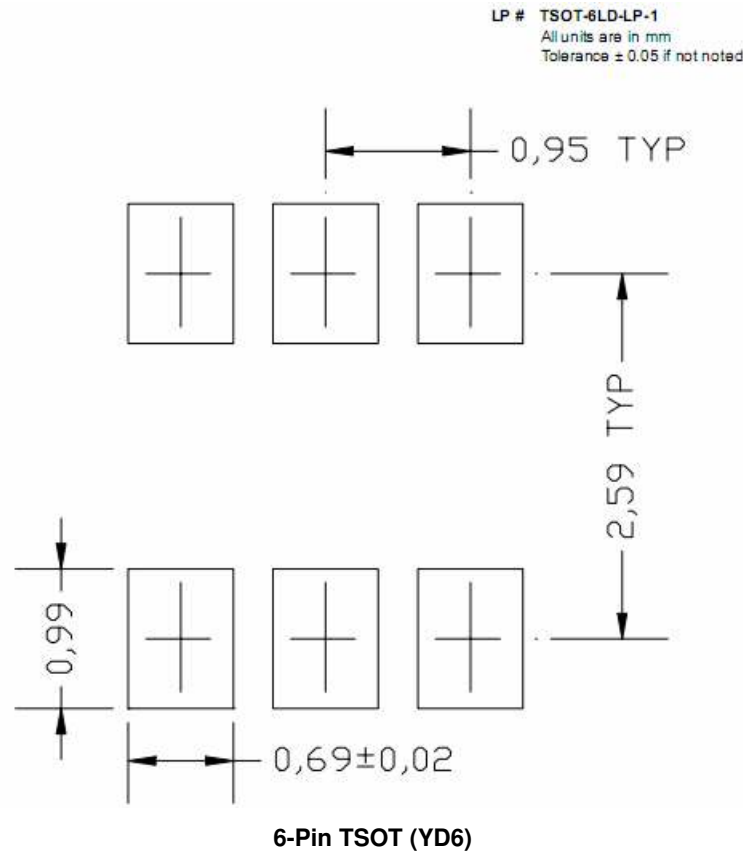
**NOTE:**

1. Dimensions and tolerances are as per ANSI Y14.5M, 1994.
2. Die is facing up for mold. Die is facing down for trim/form, ie. reverse trim/form.
- $\Delta 3$  Dimensions are exclusive of mold flash and gate burr.
4. The footlength measuring is based on the gauge plane method.
5. All specification comply to Jedec Spec M0193 Issue C.
6. All dimensions are in millimeters.



**6-Pin TSOT (YD6)**

## Recommended Land Pattern



**MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA**  
 TEL +1 (408) 944-0800 FAX +1 (408) 474-1000 WEB <http://www.micrel.com>

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