MIC4680

1A 200 kHz SuperSwitcher™ Buck Regulator

Features

- SOIC-8 Package with Up to 1.3A Output Current
- All Surface Mount Solution
- Only Four External Components Required
- Fixed 200 kHz Operation
- 3.3V, 5V, and Adjustable Output Versions
- Internally Compensated with Fast Transient Response
- Wide 4V to 34V Operating Input Voltage Range
- Less than 2 µA Typical Shutdown Mode Current
- Up to 90% Efficiency
- Thermal Shutdown
- Overcurrent Protection

Applications

- Simple 1A High-Efficiency Step-Down Regulator
- Replacement TO-220 and TO-263 Designs
- Efficient Pre-Regulator (5V to 2.5V, 12V to 3.3V, etc.)
- On-Card Switching Regulators
- Positive-to-Negative Converter (Inverting Buck-Boost)
- Simple Battery Charger
- Negative Boost Converter
- Higher Output Current Regulator using External FET

General Description

The MIC4680 SuperSwitcher™ is an easy-to-use fixed or adjustable output voltage step-down (buck) switch-mode voltage regulator. The 200 kHz MIC4680 achieves up to 1.3A of continuous output current over a wide input range in a 8-lead SOIC.

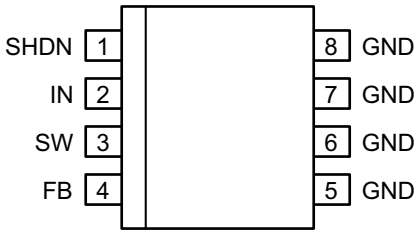
The MIC4680 is available in 3.3V and 5V fixed output versions or adjustable output down to 1.25V.

The MIC4680 has an input voltage range of 4V to 34V, with excellent line, load, and transient response. The regulator performs cycle-by-cycle current limiting and thermal shutdown for protection under fault conditions. In shutdown mode, the regulator draws less than 2 µA of standby current.

The MIC4680 SuperSwitcher regulator requires a minimum number of external components and can operate using a standard series of inductors and capacitors. Frequency compensation is provided internally for fast transient response and ease of use.

Package Type

MIC4680
8-Lead SOIC (M)
(Top View)



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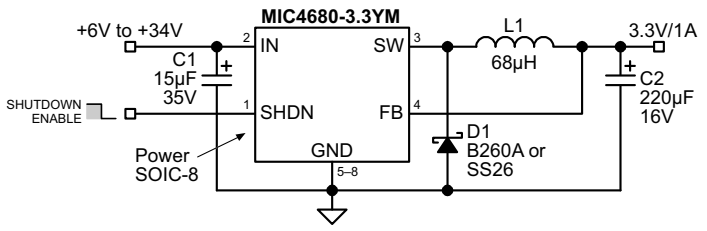
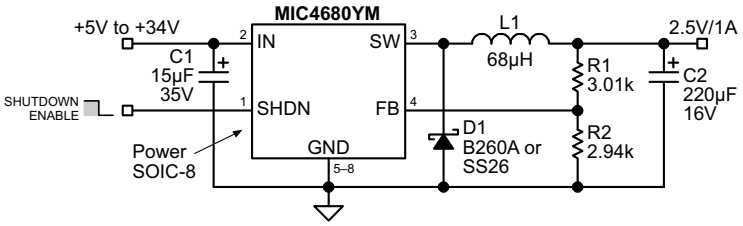
Typical Application Circuits

Fixed Regulator Circuit

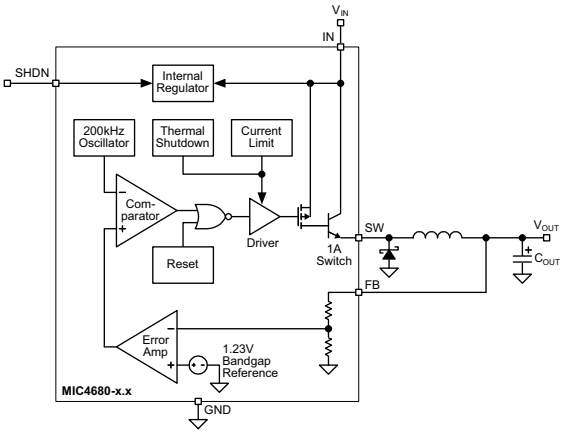


Adjustable Regulator Circuit

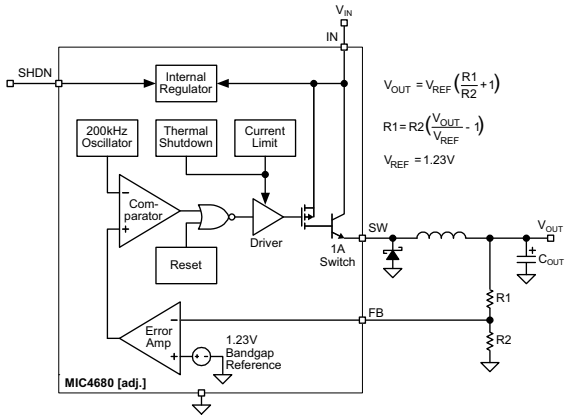


Functional Block Diagrams

Fixed Version



Adjustable Version



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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}; Note 1) ..... +38V
Shutdown Voltage (V_{SHDN}) ..... –0.3V to +38V
Steady-State Output Switch Voltage (V_{SW}) ..... –1V
Feedback Voltage (Adjustable Version; V_{FB}) ..... +12V
ESD Rating ..... Note 2

Operating Ratings ‡

Supply Voltage (V_{IN}; Note 3) ..... +4V to +34V

† 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 rating.

Note 1: Absolute maximum rating is intended for voltage transients only, prolonged DC operation is not recommended.

2: Devices are ESD sensitive. Handling precautions are recommended.

3: $V_{IN(MIN)} = V_{OUT} + 2.5V$ or 4V, whichever is greater.

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: V_{IN} = 12V; I_{LOAD} = 500 mA; T_J = +25°C, **bold** values valid for –40°C to +125°C, unless noted. (Note 1)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
MIC4680 Adjustable Voltage Version						
Feedback Voltage	V_{FB}	1.217	1.230	1.243	V	±1%
		1.205	—	**1.255**		±1%
		1.193	1.230	1.267		8V ≤ V_{IN} ≤ 34V, 0.1A ≤ I_{LOAD} ≤ 1A, V_{OUT} = 5V
		1.180	—	**1.280**		
Maximum Duty Cycle	DC_{MAX}	93	97	—	%	V_{FB} = 1.0V
Output Leakage Current	I_{OZ}	—	50	500	µA	V_{IN} = 34V, V_{SHDN} = 5V, V_{SW} = 0V
		—	4	20	mA	V_{IN} = 34V, V_{SHDN} = 5V, V_{SW} = –1V
Quiescent Current	I_Q	—	7	12	mA	V_{FB} = 1.5V
MIC4680-3.3						
Output Voltage	V_{OUT}	3.266	3.3	3.333	V	±1%
		3.201	—	**3.399**		±3%
		3.168	3.3	3.432		6V ≤ V_{IN} ≤ 34V, 0.1A ≤ I_{LOAD} ≤ 1A
		3.135	—	**3.465**		
Maximum Duty Cycle	DC_{MAX}	93	97	—	%	V_{FB} = 2.5V
Output Leakage Current	I_{OZ}	—	50	500	µA	V_{IN} = 34V, V_{SHDN} = 5V, V_{SW} = 0V
		—	4	20	mA	V_{IN} = 34V, V_{SHDN} = 5V, V_{SW} = –1V

Note 1: Test at T_A = +85°C, ensured by design, and characterized to T_J = +125°C.

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ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: V_{IN} = 12V; I_{LOAD} = 500 mA; T_J = +25°C, **bold** values valid for –40°C to +125°C, unless noted. (Note 1)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Quiescent Current	I_Q	—	7	12	mA	V_{FB} = 4.0V
MIC4680-5.0						
Output Voltage	V_{OUT}	4.950	5.0	5.05	V	±1%
		4.85	—	**5.15**		±3%
		4.800	5.0	5.200		8V ≤ V_{IN} ≤ 34V, 0.1A ≤ I_{LOAD} ≤ 1A
		4.750	—	**5.250**		
Maximum Duty Cycle	DC_{MAX}	93	97	—	%	V_{FB} = 4.0V
Output Leakage Current	I_{OZ}	—	50	500	µA	V_{IN} = 34V, V_{SHDN} = 5V, V_{SW} = 0V
		—	4	20	mA	V_{IN} = 34V, V_{SHDN} = 5V, V_{SW} = –1V
Quiescent Current	I_Q	—	7	12	mA	V_{FB} = 6.0V
MIC4680-3.3 and MIC4680-5.0						
Frequency Fold Back	—	30	50	100	kHz	—
Oscillator Frequency	f_{OSC}	180	200	220	kHz	—
Saturation Voltage	V_{SAT}	—	1.4	**1.8**	V	I_{OUT} = 1A
Short-Circuit Current Limit	I_{SC}	1.3	1.8	2.5	A	V_{FB} = 0V, see Figure 1-1
Standby Quiescent Current	I_{STBY}	—	1.5	—	µA	V_{SHDN} = V_{IN}
		—	30	100	µA	V_{SHDN} = 5V (regulator off)
Shutdown Input Logic Level	V_{SHDN}	2	1.6	—	V	Regulator off
		—	1.0	0.8		Regulator on
Shutdown Input Current	I_{SHDN}	–10	–0.5	10	µA	V_{SHDN} = 5V (regulator off)
		–10	–1.5	10		V_{SHDN} = 0V (regulator on)
Thermal Shutdown	T_{SHDN}	—	160	—	°C	—

Note 1: Test at T_A = +85°C, ensured by design, and characterized to T_J = +125°C.

Test Circuit

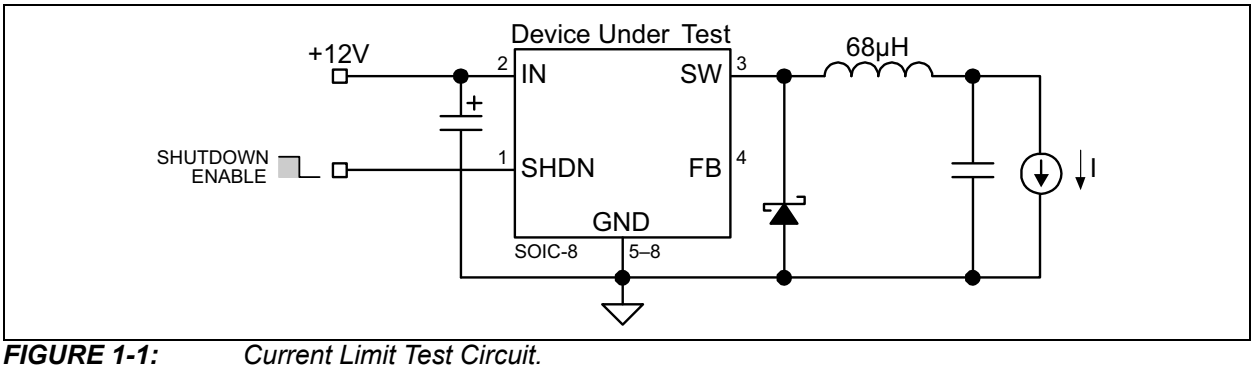

FIGURE 1-1: *Current Limit Test Circuit.*

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Shutdown Input Behavior

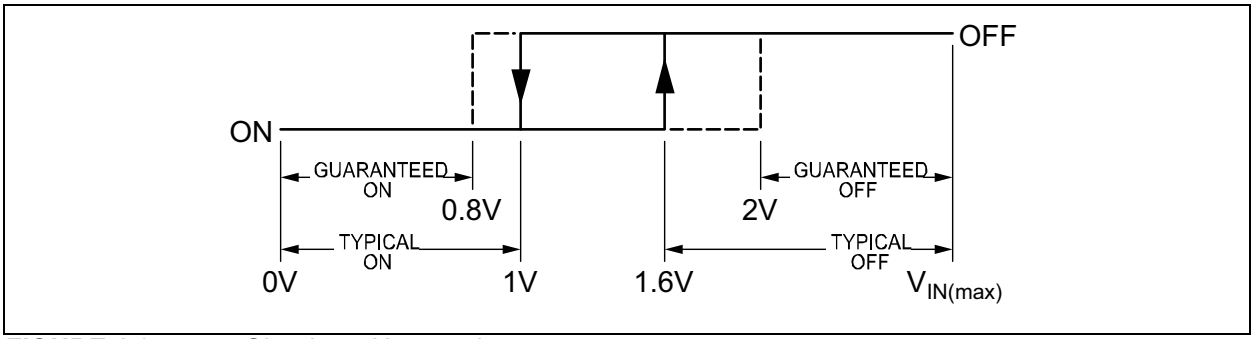

FIGURE 1-2: *Shutdown Hysteresis.*

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Maximum Junction Temperature Range	$T_{J(MAX)}$	–40	—	+125	°C	—
Operating Temperature Range	T_J	–40	—	+125	°C	—
Storage Temperature Range	T_S	–65	—	+150	°C	—
Package Thermal Resistance						
Thermal Resistance, SOIC 8-Lead	θ_{JA}	—	63	—	°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.

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2.0 TYPICAL OPERATING CHARACTERISTICS

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.

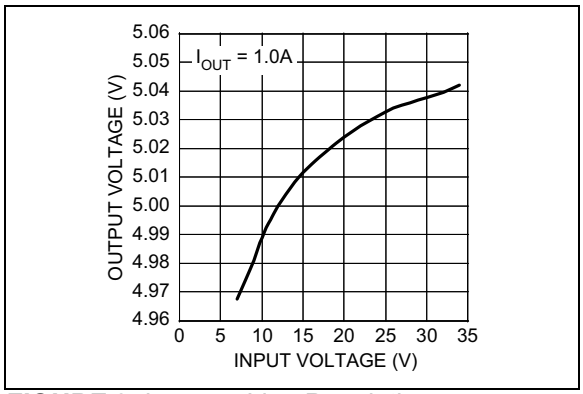

FIGURE 2-1: *Line Regulation.*

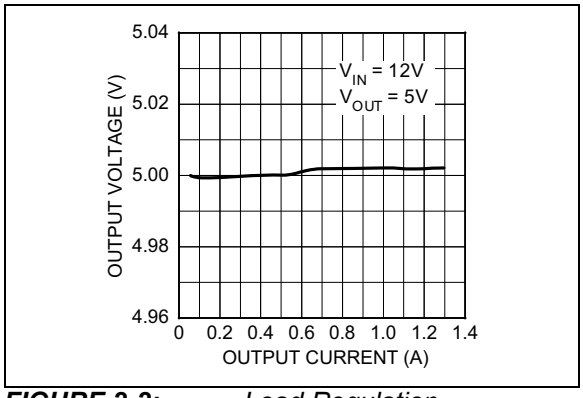

FIGURE 2-2: *Load Regulation.*

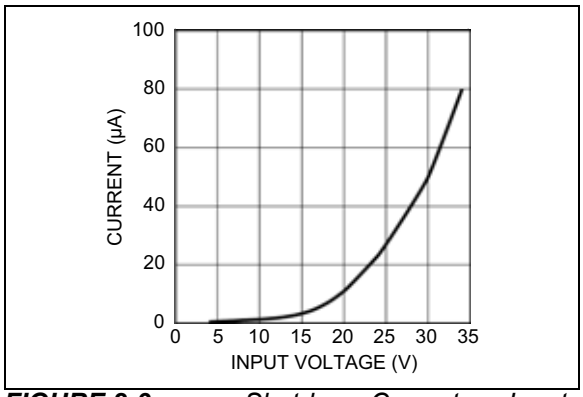

FIGURE 2-3: *Shutdown Current vs. Input Voltage.*

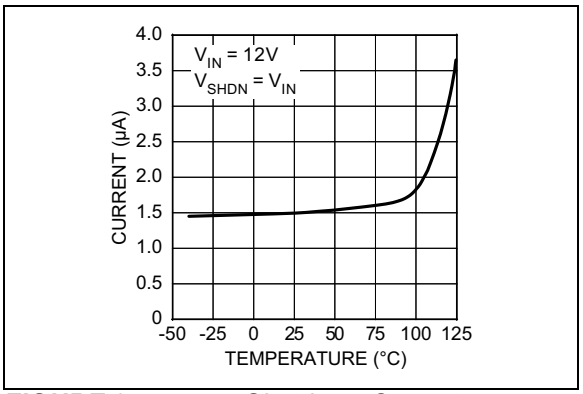

FIGURE 2-4: *Shutdown Current vs. Temperature.*

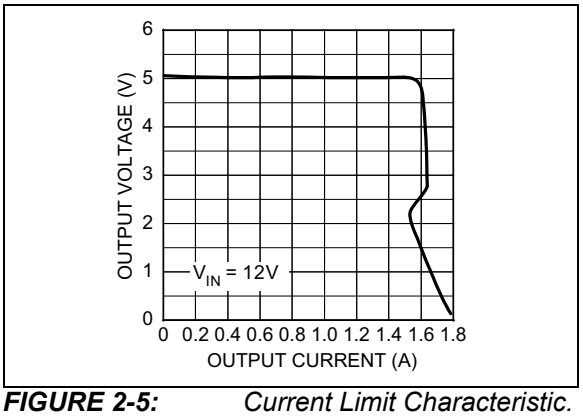

FIGURE 2-5: *Current Limit Characteristic.*

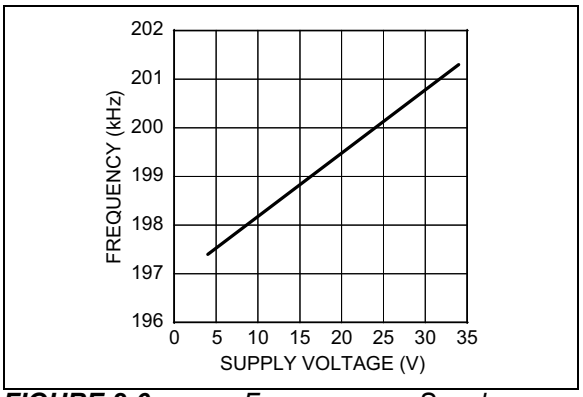

FIGURE 2-6: *Frequency vs. Supply Voltage.*

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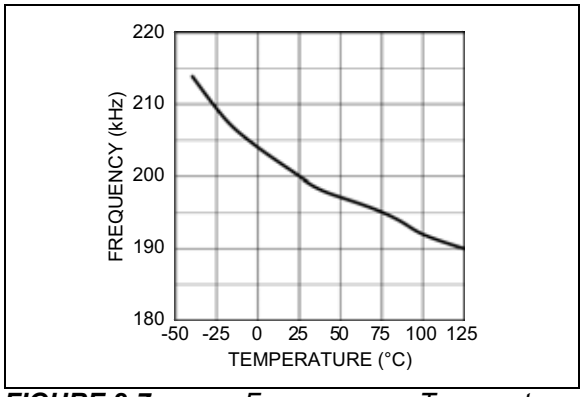

FIGURE 2-7: *Frequency vs. Temperature.*

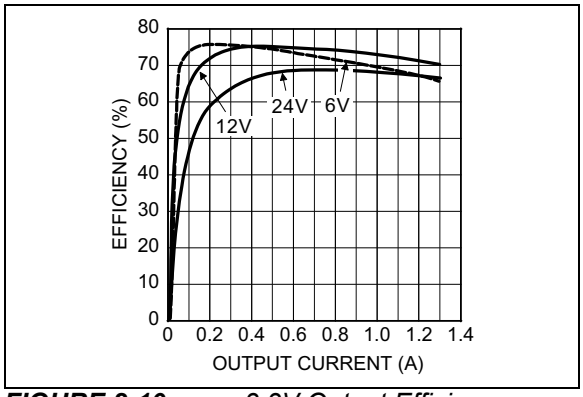

FIGURE 2-10: *3.3V Output Efficiency.*

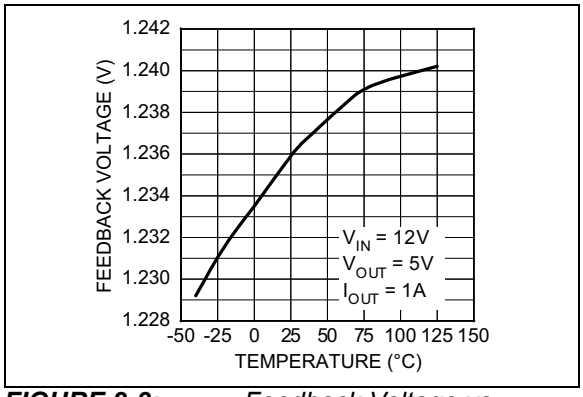

FIGURE 2-8: *Feedback Voltage vs. Temperature.*

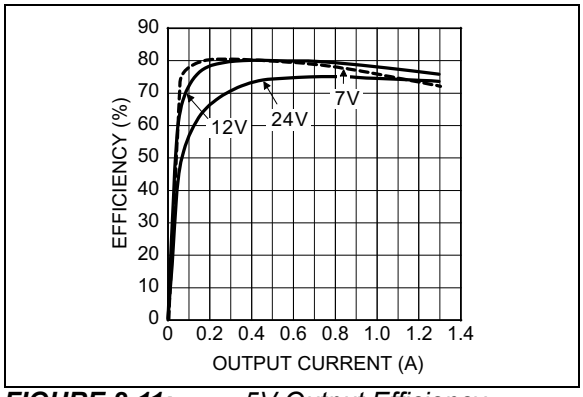

FIGURE 2-11: *5V Output Efficiency.*

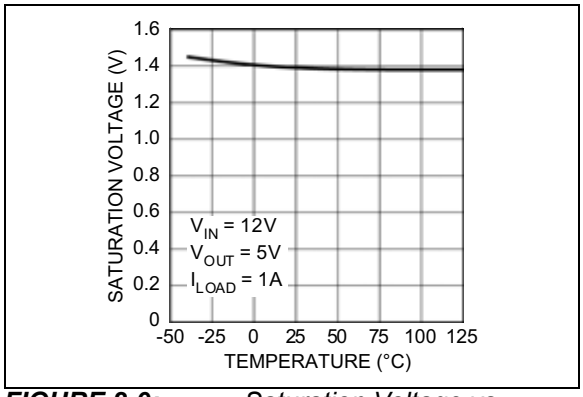

FIGURE 2-9: *Saturation Voltage vs. Temperature.*

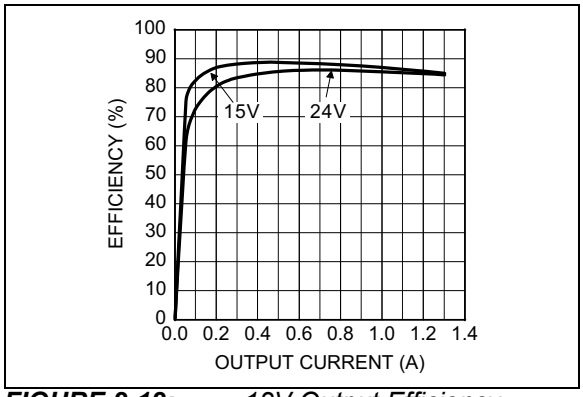

FIGURE 2-12: *12V Output Efficiency.*

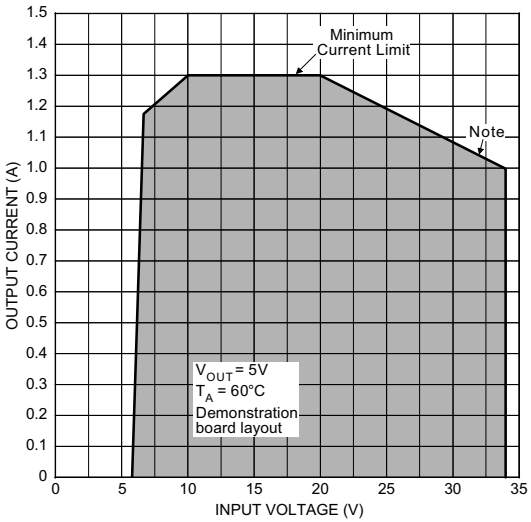

FIGURE 2-13: *Safe Operating Area.*

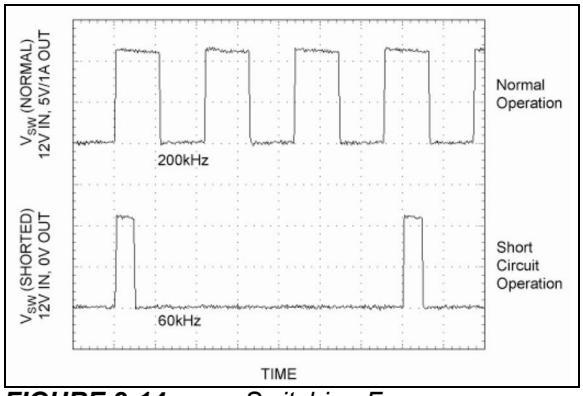

FIGURE 2-14: *Switching Frequency Foldback.*

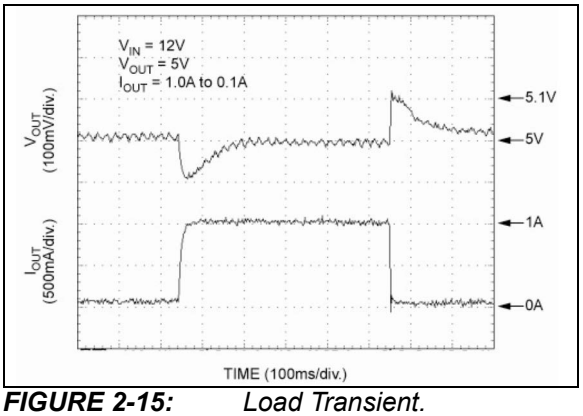

FIGURE 2-15: *Load Transient.*

2.1 Frequency Foldback

The MIC4680 folds the switching frequency back during a hard short-circuit condition to reduce the energy per cycle and protect the device.

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2.2 Bode Plots

The following bode plots show that the MIC4680 is stable over all conditions using a 68 µF inductor (L) and a 220 µF output capacitor (C_{OUT}). To ensure stability, it is a good practice to maintain a phase margin of greater than 35°.

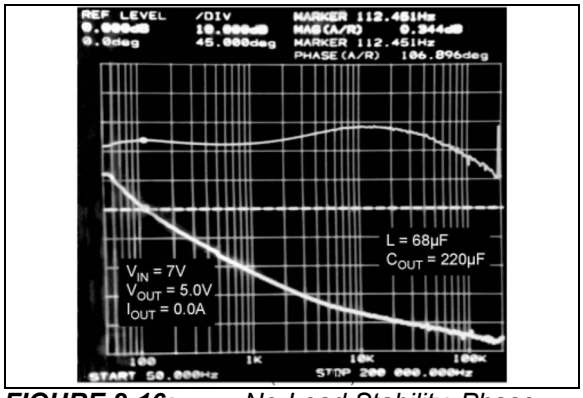

FIGURE 2-16: *No-Load Stability, Phase Margin = 106°.*

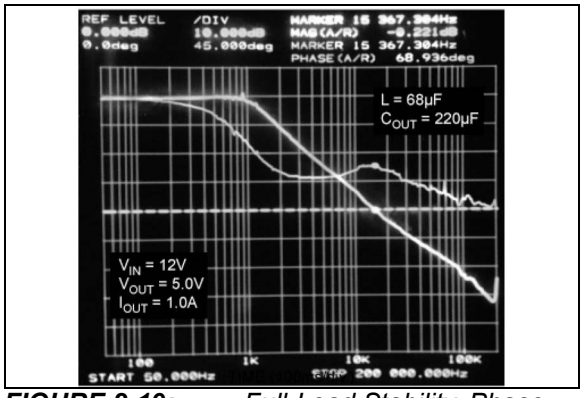

FIGURE 2-19: *Full-Load Stability, Phase Margin = 69°.*

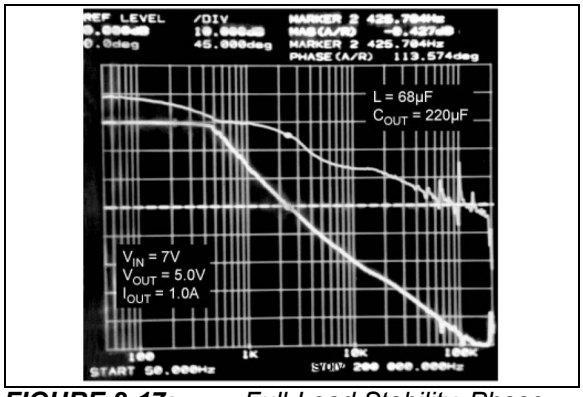

FIGURE 2-17: *Full-Load Stability, Phase Margin = 114°.*

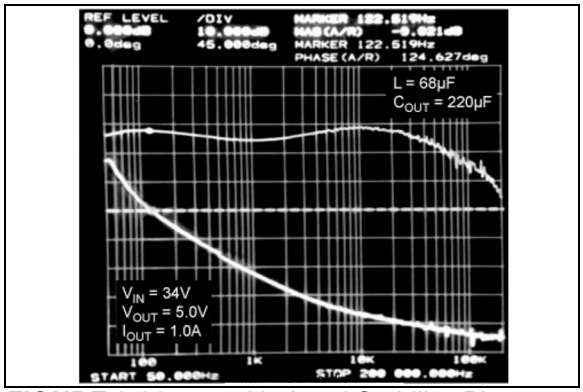

FIGURE 2-20: *No-Load Stability, Phase Margin = 125°.*

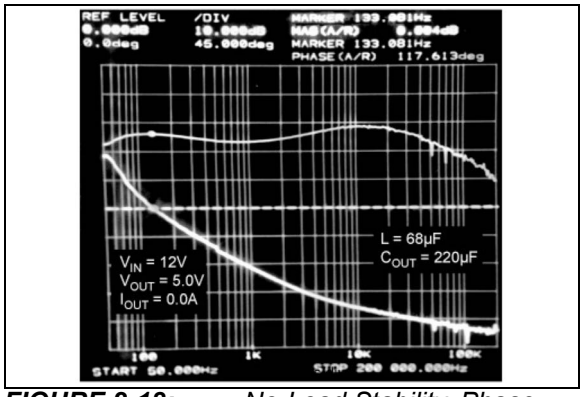

FIGURE 2-18: *No-Load Stability, Phase Margin = 117°.*

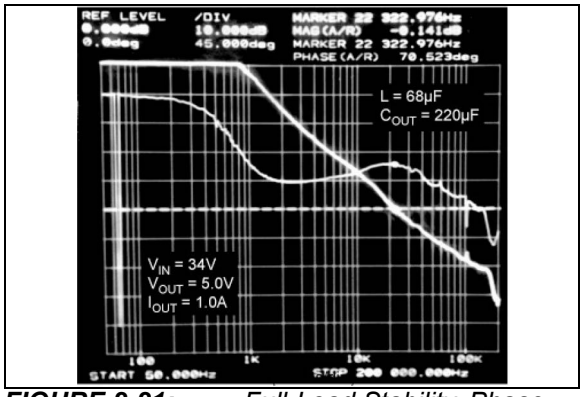

FIGURE 2-21: *Full-Load Stability, Phase Margin = 71°.*

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	SHDN	Shutdown (Input): Logic low enables regulator. Logic high (>1.6V) shuts down regulator.
2	VIN	Supply Voltage (Input): Unregulated +4V to +34V supply voltage.
3	SW	Switch (Output): Emitter of NPN output switch. Connect to external storage inductor and Schottky diode.
4	FB	Feedback (Input): Connect to output on fixed output voltage versions, or to 1.23V tap of voltage-divider network for adjustable version.
5, 6, 7, 8	GND	Ground.

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4.0 FUNCTIONAL DESCRIPTION

The MIC4680 is a variable duty cycle switch-mode regulator with an internal power switch. Refer to the Functional Block Diagrams.

4.1 Supply Voltage

The MIC4680 operates from a +4V to +34V unregulated input. Highest efficiency operation is from a supply voltage around +15V. See Figure 2-10 through Figure 2-12.

4.2 Enable/Shutdown

The shutdown (SHDN) input is TTL compatible. Ground the input if unused. A logic low enables the regulator. A logic high shuts down the internal regulator which reduces the current to typically 1.5 µA when V_{SHDN} = V_{IN} = 12V and 30 µA when V_{SHDN} = 5V. See Figure 1-2.

4.3 Feedback

Fixed-voltage versions of the regulator have an internal resistive divider from the feedback (FB) pin. Connect FB directly to the output voltage.

Adjustable versions require an external resistive voltage divider from the output voltage to ground, center tapped to the FB pin. See Table 5-1 for recommended resistor values.

4.4 Duty Cycle Control

A fixed-gain error amplifier compares the feedback signal with a 1.23V bandgap voltage reference. The resulting error amplifier output voltage is compared to a 200 kHz sawtooth waveform to produce a voltage-controlled variable duty cycle output.

A higher feedback voltage increases the error amplifier output voltage. A higher error amplifier voltage (comparator inverting input) causes the comparator to detect only the peaks of the sawtooth, reducing the duty cycle of the comparator output. A lower feedback voltage increases the duty cycle. The MIC4680 uses a voltage mode control architecture.

4.5 Output Switching

When the internal switch is on, an increasing current flows from the supply V_{IN}, through external storage inductor L1, to output capacitor C_{OUT} and the load. Energy is stored in the inductor as the current increases with time.

When the internal switch is turned off, the collapse of the magnetic field in L1 forces current to flow through fast recovery diode D1, charging C_{OUT}.

4.6 Output Capacitor

External output capacitor C_{OUT} provides stabilization and reduces ripple. See the Bode Plots for additional information.

4.7 Return Paths

During the ON portion of the cycle, the output capacitor and load currents return to the supply ground. During the OFF portion of the cycle, current is being supplied to the output capacitor and load by storage inductor L1, which means that D1 is part of the high-current return path.

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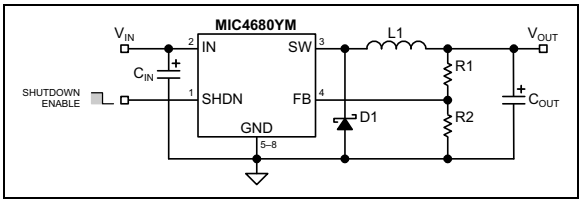
5.0 APPLICATIONS INFORMATION

5.1 Adjustable Regulators



Adjustable regulators require a 1.23V feedback signal. Recommended voltage-divider resistor values for common output voltages are included in Table 5-1.

For other voltages, the resistor values can be determined using the following formulas.

EQUATION 5-1:

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

EQUATION 5-2:

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

$$R2 = \frac{R1}{V_{OUT}/V_{REF} - 1}$$

Where:
V_{REF} = 1.23V

TABLE 5-1: RECOMMENDED COMPONENTS FOR COMMON OUTPUT VOLTAGES

V_{OUT}	R1[1,2]	R2[1,2]	C_{IN}	D1	L1	C_{OUT}
1.8V	3.01 kΩ	6.495 kΩ	15 µF 35V T495X156K035ATE 200	2A 60V Schottky B260A Vishay-Diode, Inc or SS26 General Semiconductor	68 µH 1.5A Coiltronics UP2B-680 or Sumida CDRH125-680MC[3] or Sumida CDRH124-680MC[3]	220 µF 10V T495X227K010ATE 060
2.5V	3.01 kΩ	2.915 kΩ				
3.3V	3.01 kΩ	1.788 kΩ				
5.0V	3.01 kΩ	982Ω				
6.0V	3.01 kΩ	776Ω				

Note 1: All resistors 1%.
2: Nearest available resistor values.
3: Shielded magnetics for low-RFI applications.

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5.2 Thermal Considerations

The MIC4680 SuperSwitcher features the power SOIC-8. This package has a standard 8-pin small-outline package profile but with much higher power dissipation than a standard SOIC-8. The MIC4680 SuperSwitcher is the first DC-to-DC converter to take full advantage of this package.

The reason that the power SOIC-8 has higher power dissipation (lower thermal resistance) is that pins 5 though 8 and the die-attach paddle are a single piece of metal. The die is attached to the paddle with thermally conductive adhesive. This provides a low thermal resistance path from the junction of the die to the ground pins. This design significantly improves package power dissipation by allowing excellent heat transfer through the ground leads to the printed circuit board.

One of the limitation of the maximum output current on any MIC4680 design is the junction-to-ambient thermal resistance (θ_{JA}) of the design (package and ground plane).Examining θ_{JA} in more detail:

EQUATION 5-3:

$$\theta_{JA} = \theta_{JC} + \theta_{CA}$$

Where:
θ_{JC} = Junction-to-case thermal resistance.
θ_{CA} = Case-to-ambient thermal resistance.

θ_{JC} is a relatively constant 20°C/W for a power SOIC-8.

θ_{CA} is dependent on layout and is primarily governed by the connection of pins 5 though 8 to the ground plane. The purpose of the ground plane is to function as a heat sink.

θ_{JA} is ideally 63°C/W but will vary depending on the size of the ground plane to which the power SOIC-8 is attached.

5.3 Determining Ground-Plane Heat-Sink Area

There are two methods of determining the minimum ground plane area required by the MIC4680.

5.3.1 QUICK METHOD

Make sure that MIC4680 pins 5 though 8 are connected to a ground plane with a minimum area of 6cm^2. This ground plane should be as close to the MIC4680 as possible. The area maybe distributed in any shape around the package or on any PCB layer as long as there is good thermal contact to pins 5 though 8. This ground plane area is more than sufficient for most designs.

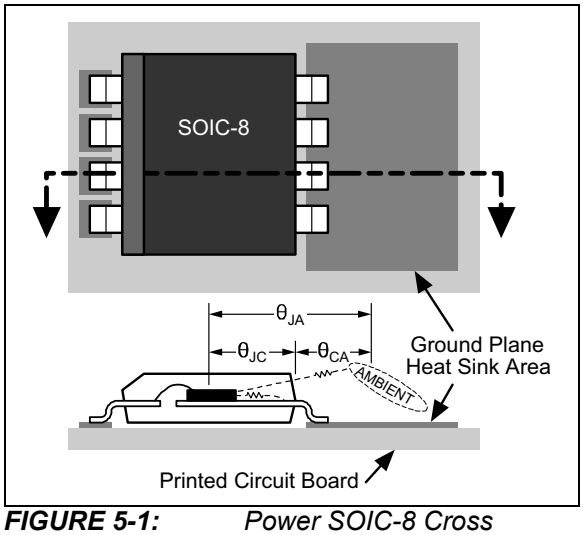

FIGURE 5-1: *Power SOIC-8 Cross Section.*

5.3.2 MINIMUM COPPER/MAXIMUM CURRENT METHOD

Using Figure 5-2, for a given input voltage range, determine the minimum ground-plane heat-sink area required for the application's maximum output current. Figure 5-2 assumes a constant die temperature of 75°C above ambient.

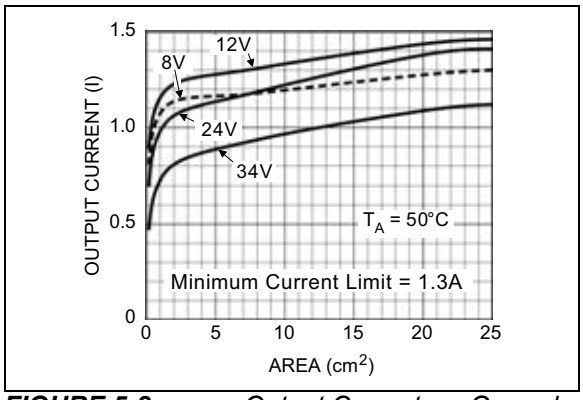

FIGURE 5-2: *Output Current vs. Ground Plane Area.*

When designing with the MIC4680, it is a good practice to connect pins 5 through 8 to the largest ground plane that is practical for the specific design.

5.4 Checking the Maximum Junction Temperature

For this example, with an output power (P_{OUT}) of 5W, (5V output at 1A maximum with V_{IN} = 12V) and 65°C maximum ambient temperature, what is the maximum junction temperature?

Referring to Figure 2-11, read the efficiency (η) for 1A output current at V_{IN} = 12V or perform you own measurement.

η = 79%

The efficiency is used to determine how much of the output power (P_{OUT}) is dissipated in the regulator circuit (P_D).

EQUATION 5-4:

$$P_D = \frac{P_{OUT}}{\eta} - P_{OUT}$$

$$P_D = \frac{5\text{W}}{0.79} - 5\text{W} = 1.33W$$

Calculate the worst-case junction temperature:

EQUATION 5-5:

$$T_J = P_{D(IC)} \times \theta_{JC} + (T_C - T_A) + T_{A(MAX)}$$

Where:
T_J = Junction temperature.
$P_{D(IC)}$ = The MIC4680 power dissipation.
θ_{JC} = Junction-to-case thermal resistance (approx. 20°C/W for the MIC4680).
T_C = Pin temperature measurement taken at the entry point of pin 6 or 7 into the plastic package at the ambient temperature at which T_C is measured.
T_A = Ambient temperature at which T_C is measured.
$T_{A(MAX)}$ = Maximum ambient operating temperature for the specific design.

Calculating the maximum junction temperature given a maximum ambient temperature of 65°C:

EQUATION 5-6:

$$T_J = 1.064 \times 20°\text{C/W} + (45°C - 25°C) + 65°C$$

$$T_J = 106.3°C$$

This value is less than the allowable maximum operating junction temperature of 125°C as listed in the Operating Ratings ‡. Typical thermal shutdown is 160°C and is listed in the Electrical Characteristics table.

5.5 Increasing the Maximum Output Current

The maximum output current at high input voltages can be increased for a given board layout. The additional three components shown in Figure 5-3 will reduce the overall loss in the MIC4680 by about 20% at high V_{IN} and high I_{OUT}.

Even higher output current can be achieved by using the MIC4680 to switch an external FET. See Figure 5-7 for a 5A supply with current limiting.

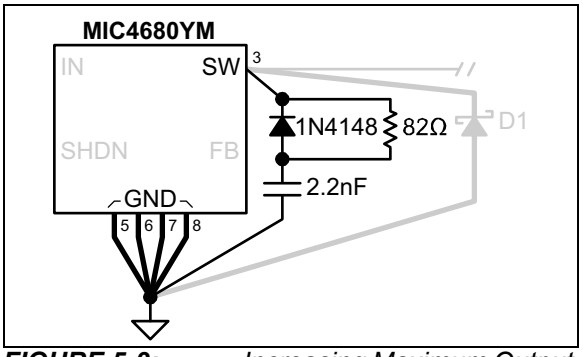

FIGURE 5-3: *Increasing Maximum Output Current at High Input Voltages.*

5.6 Layout Considerations

Layout is very important when designing any switching regulator. Rapidly changing switching currents through the printed circuit board traces and stray inductance can generate voltage transients which can cause problems.

To minimize stray inductance and ground loops, keep trace lengths, indicated by the heavy lines in Figure 5-4, as short as possible. For example, keep D1 close to Pin 3 and Pins 5 through 8, keep L1 away from sensitive node FB, and keep C_{IN} close to Pin 2 and Pins 5 though 8. See Thermal Considerations for ground plane layout.

The feedback pin should be kept as far way from the switching elements (usually L1 and D1) as possible.

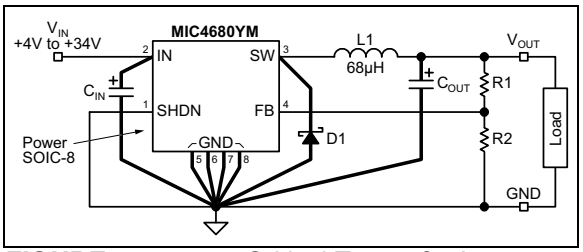

FIGURE 5-4: *Critical Traces for Layout.*

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5.7 Application Circuits

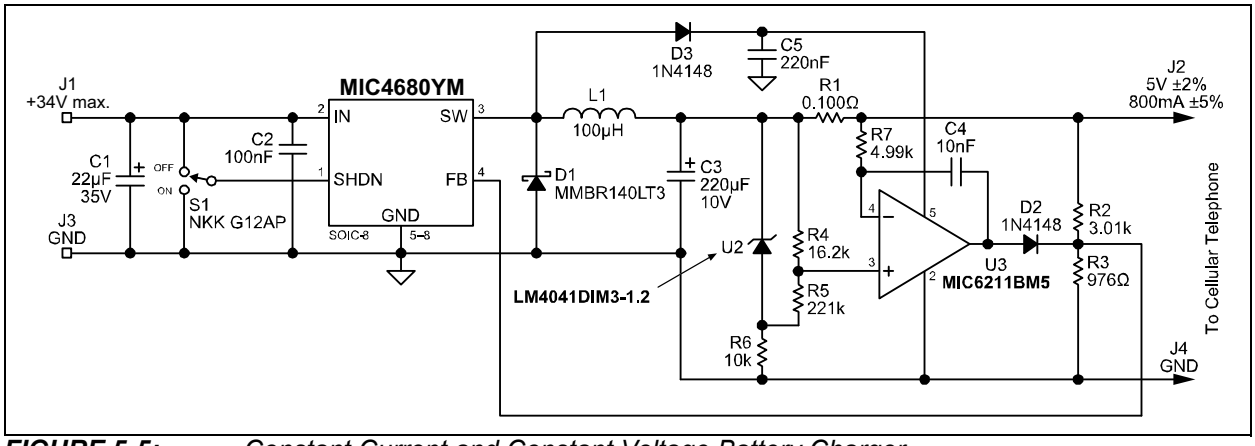


FIGURE 5-5: *Constant Current and Constant Voltage Battery Charger.*

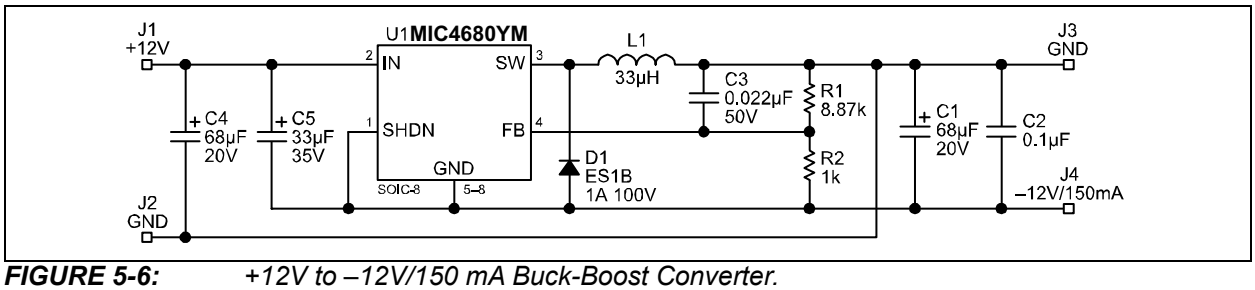


FIGURE 5-6: *+12V to –12V/150 mA Buck-Boost Converter.*

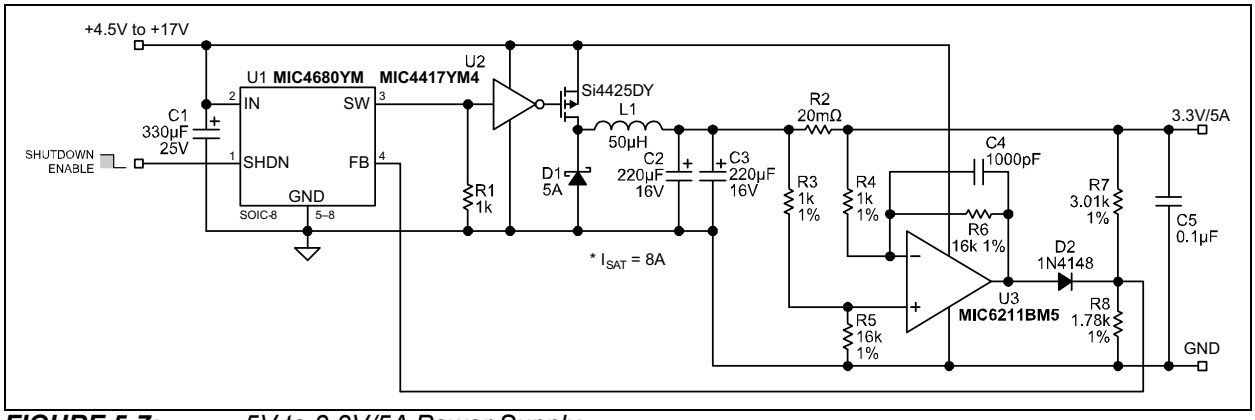
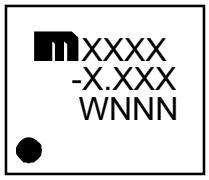


FIGURE 5-7: *5V to 3.3V/5A Power Supply.*

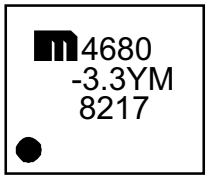
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

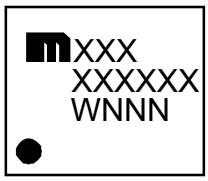
8-Lead SOIC*
(Fixed)



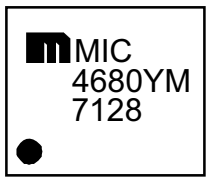
Example



8-Lead SOIC*
(Adjustable)



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.	

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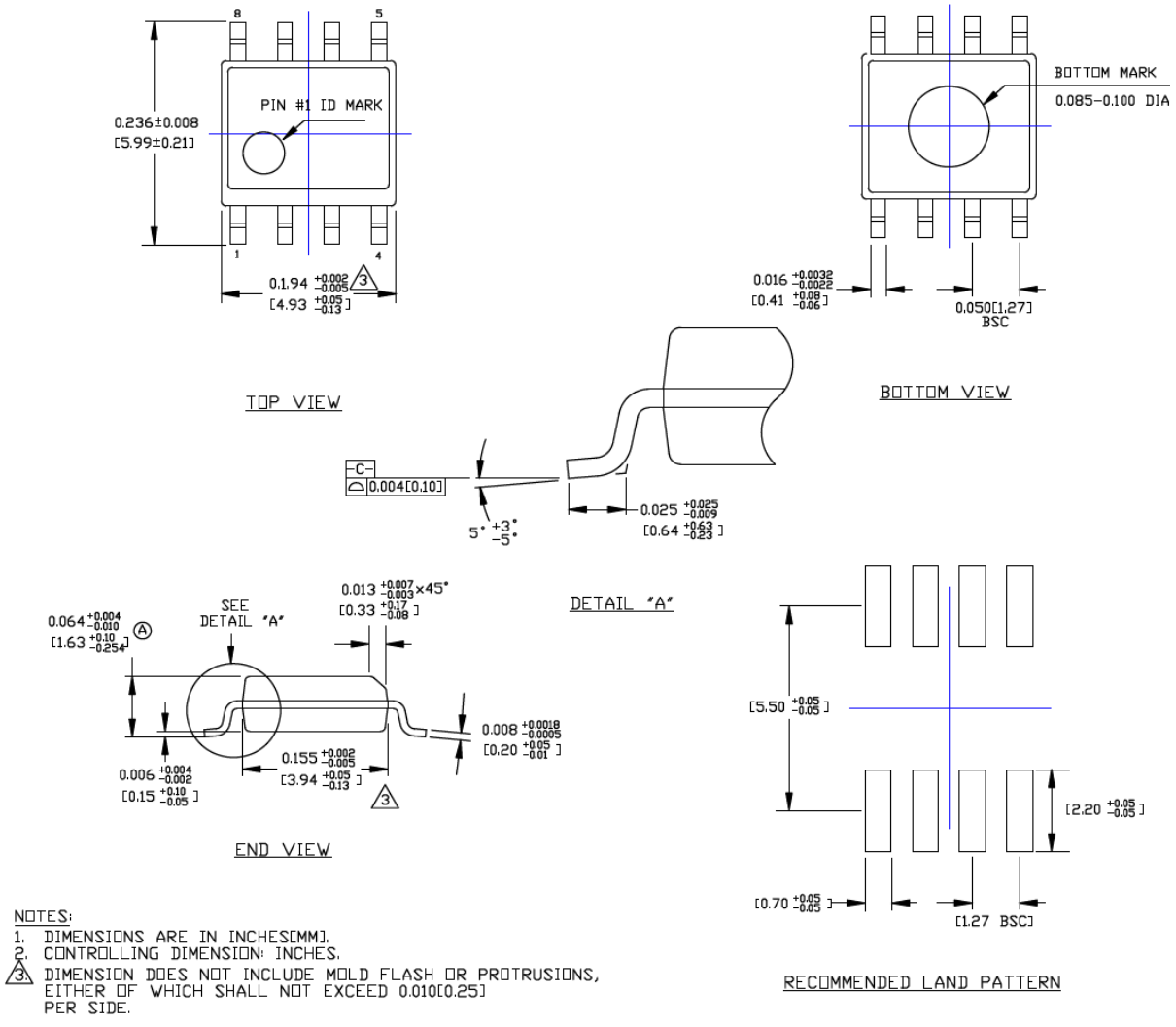
8-Lead SOIC Package Outline and Recommended Land Pattern

TITLE
8 LEAD SOICN PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	SOICN-8LD-PL-1	UNIT	INCH [MM]



NOTES:
1. DIMENSIONS ARE IN INCHES[MM].
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSION DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS, EITHER OF WHICH SHALL NOT EXCEED 0.010[0.25] PER SIDE.

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

NOTES:

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APPENDIX A: REVISION HISTORY

Revision A (November 2021)

- Converted Micrel document MIC4680 to Microchip data sheet template DS20006623A.
- Minor grammatical text changes throughout.

NOTES:

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PRODUCT IDENTIFICATION SYSTEM

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

Device	-X.X	X	X	-XX
Part No.	Output Voltage	Temperature Range	Package	Media Type

Device:	MIC4680:	1A 200 kHz SuperSwitcher™ Buck Regulator
Output Voltage:	<blank>=	Adjustable
	3.3 =	3.3V
	5.0 =	5.0V
Temperature Range:	Y =	–40°C to +125°C
Package:	M =	8-Lead SOIC
Media Type:	<blank>=	95/Tube
	TR =	2,500/Reel

Examples:

a) MIC4680YM: MIC4680, Adjustable Output Voltage, –40°C to +125°C Temp. Range, 8-Lead SOIC, 95/Tube

b) MIC4680-3.3YM-TR: MIC4608, 3.3V Output Voltage, –40°C to +125°C Temp. Range, 8-Lead SOIC, 2,500/Reel

c) MIC4680-5.0YM-TR: MIC4680, 5.0V Output Voltage, –40°C to +125°C Temp. Range, 8-Lead SOIC, 2,500/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.

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