



MIC2142

Micropower Boost Converter

General Description

The MIC2142 is a micropower boost switching regulator housed in a SOT23-5 package. The input voltage range is between 2.2V to 16V, making the device suitable for one-cell Li Ion and 3 to 4-cell alkaline/NiCad/NiMH applications. The output voltage of the MIC2142 can be adjusted up to 22V.

The MIC2142 is well suited for portable, space-sensitive applications. It features a low quiescent current of 85 μ A, and a typical shutdown current of 0.1 μ A. Its 330kHz operation allows small surface mount external components to be used. The MIC2142 is capable of efficiencies over 85% in a small board area.

The MIC2142 can be configured to efficiently power a variety of loads. It is capable of providing a few mA output for supplying low power bias voltages; it is also capable of providing the 80mA needed to drive 4 white LEDs.

The MIC2142 is available in a SOT23-5 package with an ambient operating temperature range from -40°C to $+85^{\circ}\text{C}$.

Data sheets and support documentation can be found on Micrel's web site at www.micrel.com.

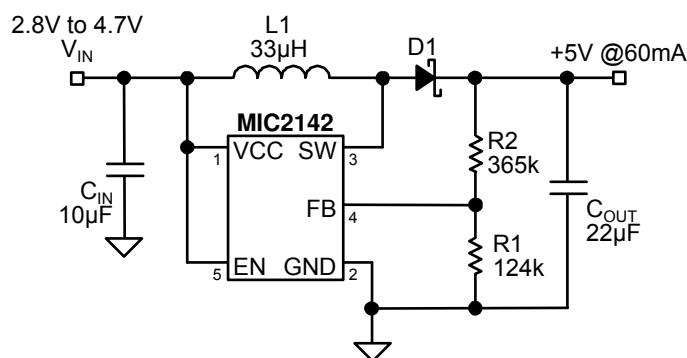
Features

- 2.2V to 16V input voltage
- Up to 22V output voltage
- 330kHz switching frequency
- 0.1 μ A shutdown current
- 85 μ A quiescent current
- Implements low-power boost, SEPIC, or flyback
- SOT23-5 package

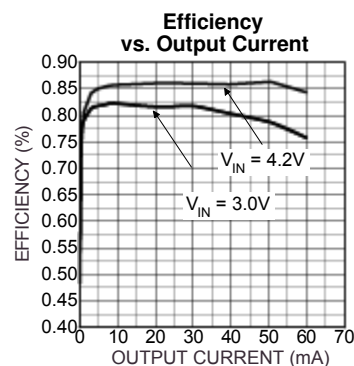
Applications

- LCD bias supply
- White LED driver
- 12V Flash memory supply
- Local 3V to 5V conversion

Typical Application



Typical Configuration



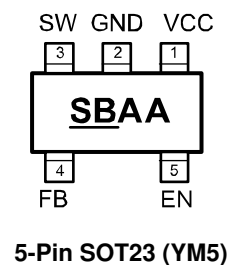
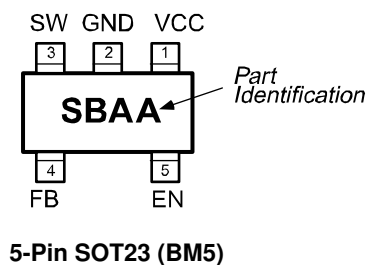
Efficiency vs. Output Current

Ordering Information

Part Number		Marking*		Voltage	Ambient Temperature Range	Package
Standard	Pb-Free	Standard	Pb-Free			
MIC2142BM5	MIC2142YM5	SBAA	<u>SBAA</u>	Adj.	−40° to +85°C	5-Pin SOT23

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

Pin Configuration



Pin Description

Pin Number	Pin Name	Pin Function
1	VCC	Chip Supply: +2.2V to +16V.
2	GND	Ground: Return for internal circuitry and internal MOSFET (switch) source.
3	SW	Switch Node (Input): Internal MOSFET drain; 22V maximum.
4	FB	Feedback (Input): Output voltage sense node.
5	EN	Shutdown: Device shuts down to 0.1μA typical supply current.

Absolute Maximum Ratings⁽¹⁾

Supply Voltage (V_{CC}).....	18V
Switch Voltage (V_{SW}).....	24V
Enable Pin Voltage (V_{EN}) ⁽³⁾	18V
Feedback Voltage (V_{FB}) Adjustable Version.....	8V
Ambient Storage Temperature (T_s).....	–65°C to +150°C
ESD Rating ⁽⁴⁾	

Operating Ratings⁽²⁾

Supply Voltage (V_{CC}).....	2.2V to 16V
Enable Pin Voltage (V_{EN}) ⁽³⁾	0V to 16V
Switch Voltage (V_{SW}).....	22V
Ambient Temperature (T_A).....	–40°C to +85°C
Junction Temperature Range (T_J).....	–40°C to +125°C
Package Thermal Impedance SOT23-5 (θ_{JA}).....	220°C/W

Electrical Characteristics

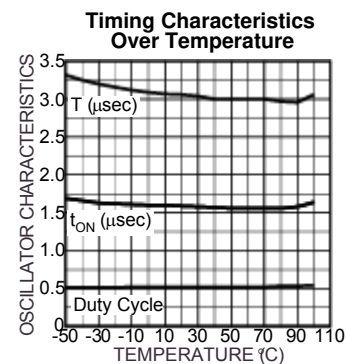
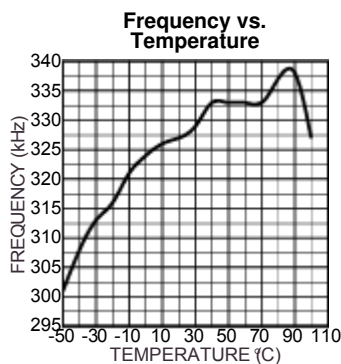
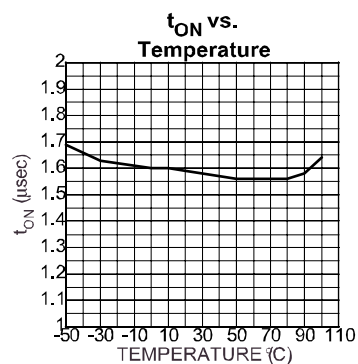
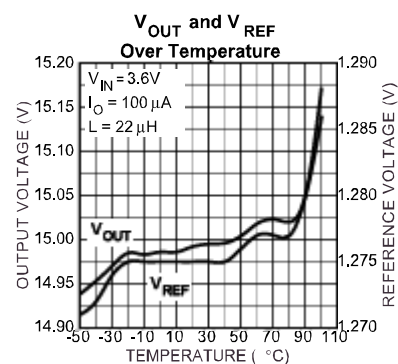
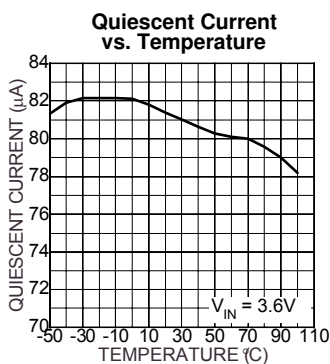
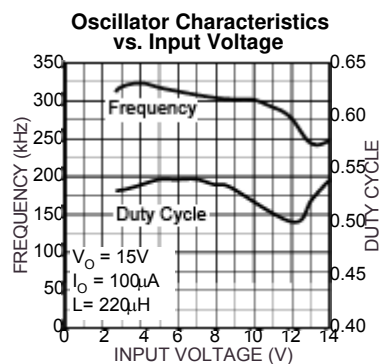
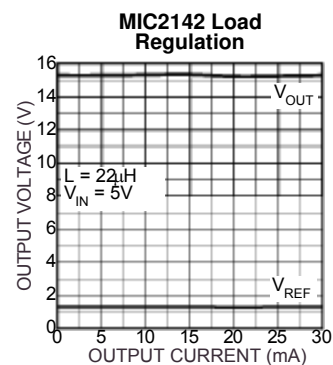
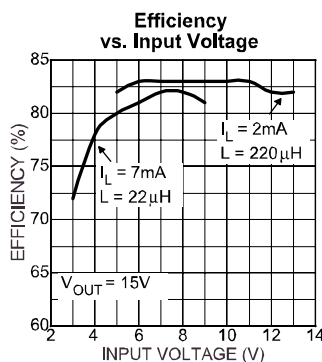
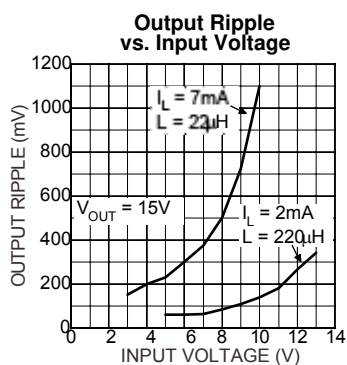
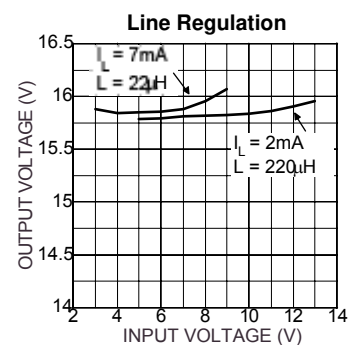
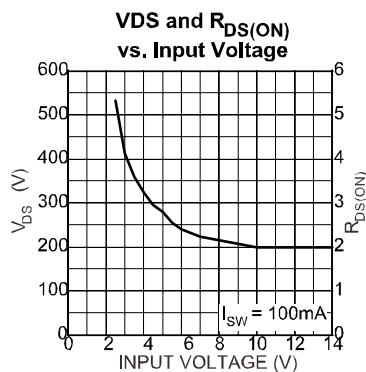
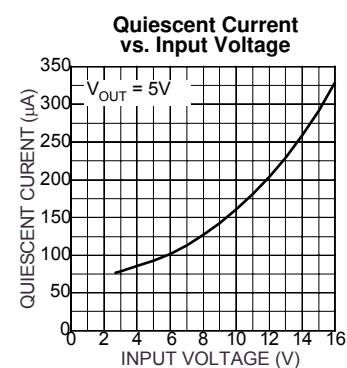
$V_{CC} = 3.6V$; $V_{OUT} = 5V$; $I_{OUT} = 200mA$; $T_A = 25^\circ C$, **bold** values indicate $-40^\circ C \leq T_J \leq +125^\circ C$, unless noted.

Parameter	Condition	Min	Typ	Max	Units
Input Voltage		2.2		16	V
Quiescent Current	$V_{EN} = ON$, $V_{FB} = 2.2V$ (adjustable)		85	125	μA
	$V_{EN} = ON$, $V_{OUT(NOMINAL)} + 1V$ (MIC2142-5.0)		85	125	μA
	$V_{EN} = OFF$ (shutdown)		0.1	2	μA
Feedback Voltage (V_{FB})	($\pm 2\%$)	1.254	1.28	1.306	V
	($\pm 3\%$)	1.241		1.312	V
Comparator Hysteresis			18		mV
Feedback Input Bias Current, Note 5	adjustable		30		nA
	fixed		20		μA
Enable Input Voltage	V_{IH} (turn on)	$0.6V_{CC}$	$0.55V_{CC}$		V
	V_{IL} (turn off)		1.1	0.8	V
Enable Input Current		–1	0.01	1	μA
Load Regulation	$200\mu A \leq I_{OUT} \leq 20mA$		0.2		% V_{OUT}
Line Regulation	$2.2V \leq V_{CC} \leq 16V$; $I_{OUT} = 4mA$ (adjustable)		0.25		%/V
	$2.2V \leq V_{CC} \leq 4.5V$; $I_{OUT} = 4mA$ (MIC2142-5.0)		0.25		%/V
SW on Resistance	$I_{SW} = 100mA$, $V_{CC} = 2.5V$		5		Ω
Switch Leakage Current	$V_{EN} = OFF$, $V_{SW} = 12V$		0.05	1	μA
Oscillator Frequency		295	330	365	kHz
Duty Cycle		50	57	65	%

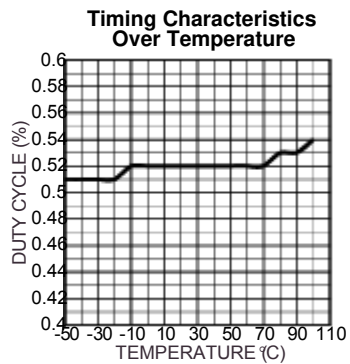
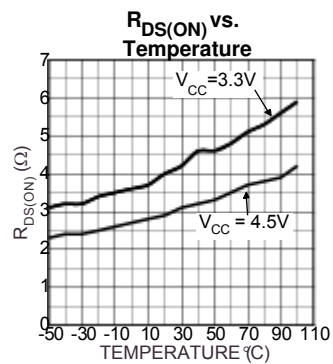
Notes:

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, $T_{J(Max)}$, the junction-to-ambient thermal resistance, θ_{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. The θ_{JA} of the power SOT23-5 is 220°C/W mounted on a PC board.
2. The device is not guaranteed to function outside its operating rating.
3. V_{EN} must be $\leq V_{IN}$.
4. Devices are ESD sensitive. Handling precautions recommended.
5. The maximum suggested value of the programming resistor, whose series resistance is measured from feedback to ground, is 124k Ω . Use of larger resistor values can cause errors in the output voltage due to the feedback input bias current.

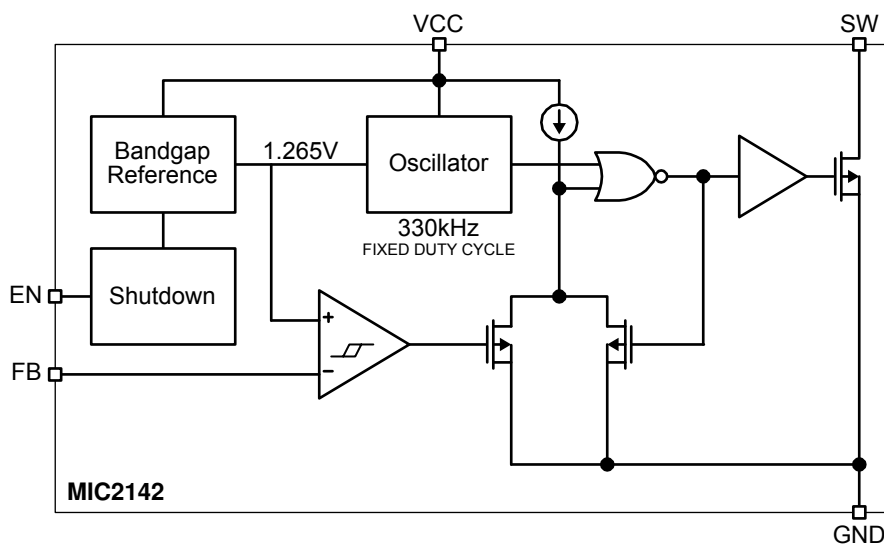
Typical Characteristics



Typical Characteristics (cont.)



Functional Diagram



Functional Description

This MIC2142 is a fixed duty cycle, constant frequency, gated oscillator, micropower, switch-mode power supply controller. Quiescent current for the MIC2142 is only 85 μ A in the switch off state, and since a MOSFET output switch is used, additional switch drive current is minimized. Efficiencies above 85% throughout most operating conditions can be realized.

A functional block diagram is shown above and typical schematic is shown on page 1. Regulation is performed by a hysteretic comparator, which regulates the output voltage by gating the internal oscillator. The internal oscillator operates at a fixed 57% duty cycle and 330kHz frequency. For the fixed output versions, the output is divided down internally and then compared to the internal V_{REF} input. An external resistive divider is used for the adjustable version.

The comparator has hysteresis built into it, which determines the amount of low frequency ripple that will be present on the output. Once the feedback input to the comparator exceeds the control voltage by 18mV, the high frequency oscillator drive is removed from the output switch. As the feedback input to the comparator returns to the reference voltage level, the comparator is reset and the high frequency oscillator is again gated to the output switch. The 18mV of hysteresis seen at the comparator will be multiplied by the ratio of the output voltage to the reference voltage. For a five volt output this ratio would be 4, corresponding to a ripple voltage of 72mV at the output.

The maximum output voltage is limited by the voltage capability of the output switch. Output voltages up to 22V can be achieved with a standard boost circuit. Higher output voltages can be realized with a flyback configuration.

Application Information

Pre-designed circuit information is at the end of this section.

Component Selection

Resistive Divider (Adjustable Version)

The external resistive divider should divide the output voltage down to the nominal reference voltage. Current drawn through this resistor string should be limited in order to limit the effect on the overall efficiency. The maximum value of the resistor string is limited by the feedback input bias current and the potential for noise being coupled into the feedback pin. A resistor string on the order of 2MΩ limits the additional load on the output to 20μA for a 20V output. In addition, the feedback input bias current error would add a nominal 60mV error to the expected output. Equation 1 can be used for determining the values for R2 and R1.

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

Boost Inductor

Maximum power is delivered to the load when the oscillator is gated on 100% of the time. Total output power and circuit efficiency must be considered when determining the maximum inductor value. The largest inductor possible is preferable in order to minimize the peak current and output ripple. Efficiency can vary from 80% to 90% depending upon input voltage, output voltage, load current, inductor, and output diode.

Equation 2 solves for the output current capability for a given inductor value and expected efficiency. Figures 7 through 12 show estimates for maximum output current assuming the minimum duty and maximum frequency and 80% efficiency. To determine the necessary inductance; find the intersection between the output voltage and current, and then select the value of the inductor curve just above the intersection. If the efficiency is expected to be different than the 85% used for the graph, Equation 2 can then be used to better determine the maximum output capability.

The peak inductor/switch current can be calculated from Equation 3 or read from the graph in Figure 13. The peak current shown in the graph in Figure 13 is derived assuming a max duty cycle and a minimum frequency. The selected inductor and diode peak current capability must be greater than this. The peak current seen by the inductor is calculated at the maximum input voltage. A wide ranging input voltage will result in a higher worst case peak current in the inductor than a narrow input range.

$$(2) \quad I_{O(max)} = \frac{(V_{IN(min)} t_{ON})^2}{2L_{MAX} T_S} \times \frac{1}{\frac{V_O}{eff} - V_{IN(min)}}$$

$$(3) \quad I_{PK} = \frac{t_{ON(max)} V_{IN(max)}}{L_{MIN}}$$

Table 1 lists common inductors suitable for most applications. Due to the internal transistor peak current limitation at low input voltages, inductor values less than 10μH are not recommended. Table 6 lists minimum inductor sizes versus input and output voltage. In low-cost, low-peak-current applications, RF-type leaded inductors may be sufficient. All inductors listed in Table 5 can be found within the selection of CR32- or LQH4C-series inductors from either Sumida or MuRata.

Manufacturer	Series	Device Type
MuRata	LC4/C3/C1HQ	surface mount
Sumida	CR32	surface mount
J.W. Miller	78F	axial leaded
Coilcraft	90	axial leaded

Table 1. Inductor Examples

Boost Output Diode

Speed, forward voltage, and reverse current are very important in selecting the output diode. In the boost configuration the average diode current is the same as the average load current and the peak is the same as the inductor and switch current. The peak current is the same as the peak inductor current and can be derived from Equation 3 or the graph in Figure 13. Care must be taken to make sure that the peak current is evaluated at the maximum input voltage.

The BAT54 and BAT85 series are low current Schottky diodes available from "On Semiconductor" and "Phillips" respectively. They are suitable for peak repetitive currents of 300mA or less with good reverse current characteristics. For applications that are cost driven, the 1N4148 or equivalent will provide sufficient switching speed with greater forward drop and reduced cost. Other acceptable diodes are On Semiconductor's MBR0530 or Vishay's B0530, although they can have reverse currents that exceed 1 mA at very high junction temperatures. Table 2 summarizes some typical performance characteristics of various suitable diodes.

Diode	75°C V _{FWD} at 100mA	25°C V _{FWD} at 100mA	Room Temp. Leakage at 15V	75°C Leakage at 15V	Package
MBR0530	0.275V	0.325V	2.5μA	90μA	SOD123 SMT
1N4148	0.6V (175°C)	0.95V	25nA (20V)	0.2μA (20V)	leaded and SMT
BAT54	0.4V (85°C)	0.45V	10nA (25V)	1μA (20V)	SMT
BAT85	0.54V (85°C)	0.56V	0.4μA	2μA (85°C)	DO-34 leaded

Table 2. Diode Examples

Output Capacitor

Due to the limited availability of tantalum capacitors, ceramic capacitors and inexpensive electrolytics may be preferred. Selection of the capacitor value will depend upon the peak inductor current and inductor size. MuRata offers the GRM series with up to 10μF @ 25V with a Y5V temperature coefficient in a 1210 surface mount package. Low cost applications can use the M-series leaded electrolytic capacitor from Panasonic. In general, ceramic, electrolytic, or tantalum values ranging from 1μF to 22μF can be used for the output capacitor.

Manufacturer	Series	Type	Package
MuRata	GRM	ceramic Y5V	surface mount
Vishay	594	tantalum	surface mount
Panasonic	M-series	Electrolytic	leaded

Table 3. Capacitor Examples

Design Example

Given a design requirement of 12V output and 1mA load with a minimum input voltage of 2.5V, Equation 2 can be used to calculate to maximum inductance or it can be read from the graph in Figure 7. Once the maximum inductance has been determined the peak current can be determined using Equation 3 or the graph in Figure 13.

$$V_{OUT} = 12V$$

$$I_{OUT} = 5mA$$

$$V_{IN} = 2.5V \text{ to } 4.7V$$

$$F_{max} = 360kHz$$

$$\eta = 0.8 = \text{efficiency}$$

$$D_{nom} = 0.55$$

$$T_{S(min)} = \frac{1}{F_{max}} = \frac{1}{360kHz} = 2.78\mu sec$$

$$t_{ON(min)} = \frac{D_{nom}}{f_{max}} = \frac{0.55}{360kHz} = 1.53\mu sec$$

$$L_{max} = \frac{V_{IN(min)}^2 \times t_{ON(min)}^2}{I_{O(max)} \times 2 \times T_{S(min)}} \times \frac{1}{\frac{V_O}{\eta} - V_{IN(min)}}$$

$$L_{max} = \frac{2.5^2 \times 1.53\mu sec^2}{5mA \times 2 \times 2.78\mu sec} \times \frac{1}{\frac{12}{0.8} - 2.5} = 42\mu H$$

Select 39μH ±10%.

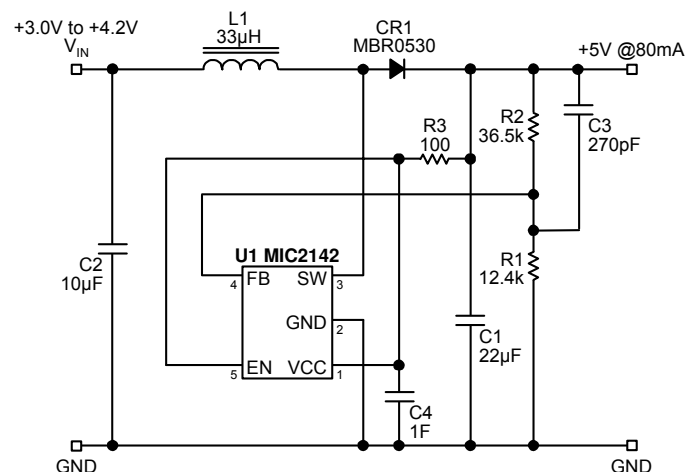
$$t_{ON(max)} = \frac{1.1 \times D_{nom}}{F_{min}} = \frac{1.1 \times 0.55}{300kHz} = 2\mu sec$$

$$I_{peak} = \frac{t_{ON(max)} \times V_{IN(max)}}{L_{min}} = \frac{2.0\mu sec \times 4.7V}{35\mu H} = 270mA$$

Bootstrap Configuration

For input voltages below 4.5V the bootstrap configuration can increase the output power capability of the MIC2142. Figure 2 shows the bootstrap configuration where the output voltage is used to bias the MIC2142. This improves the power capability of the MIC2142 by increasing the gate drive voltage hence the peak current capability of the internal switch. This allows the use of a smaller inductor which increases the output power capability. Table 4 also summarizes the various configurations and power capabilities using the bootstrap configuration. This bootstrap configuration is limited to output voltage of 16V or less.

Figure 1 shows how a resistor (R3) can be added to reduce the ripple seen at the V_{CC} pin when in the bootstrap configuration. Reducing the ripple at the V_{CC} pin can improve output ripple in some applications.

Figure 1. Bootstrap V_{CC} with V_{CC} Low Pass Filter

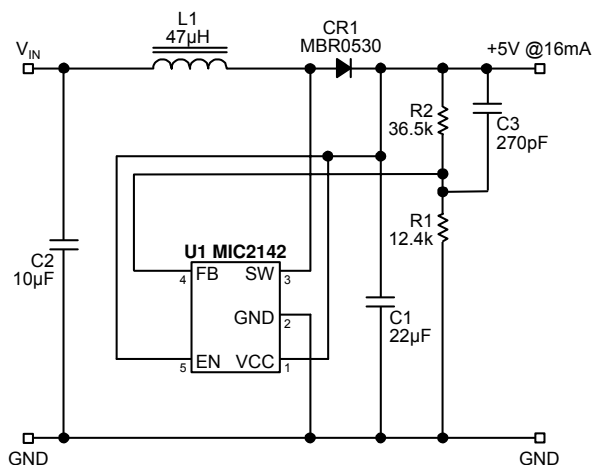


Figure 2. Bootstrap Configuration

For additional pre-designed circuits, see Table 4.

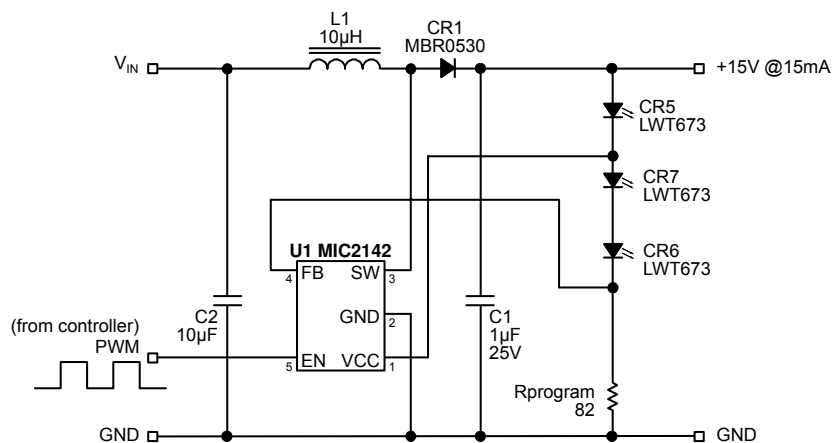


Figure 3. Series White LED Driver with PWM Dimming Control

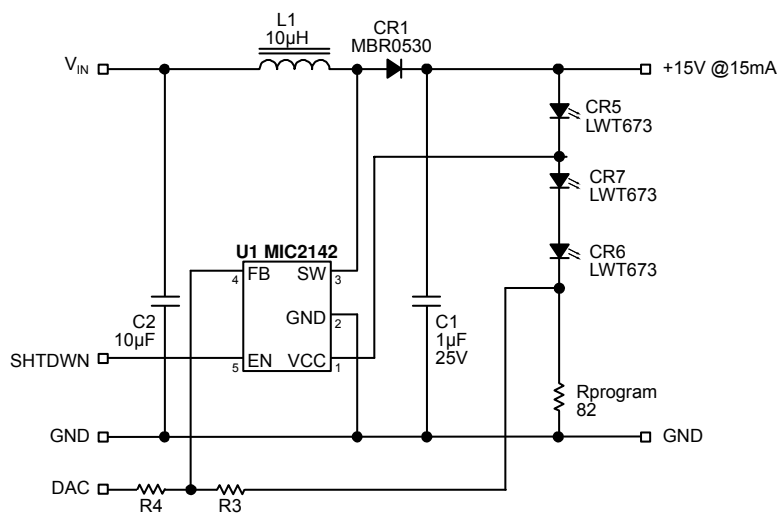


Figure 4. Series White LED Driver with Analog Dimming Control

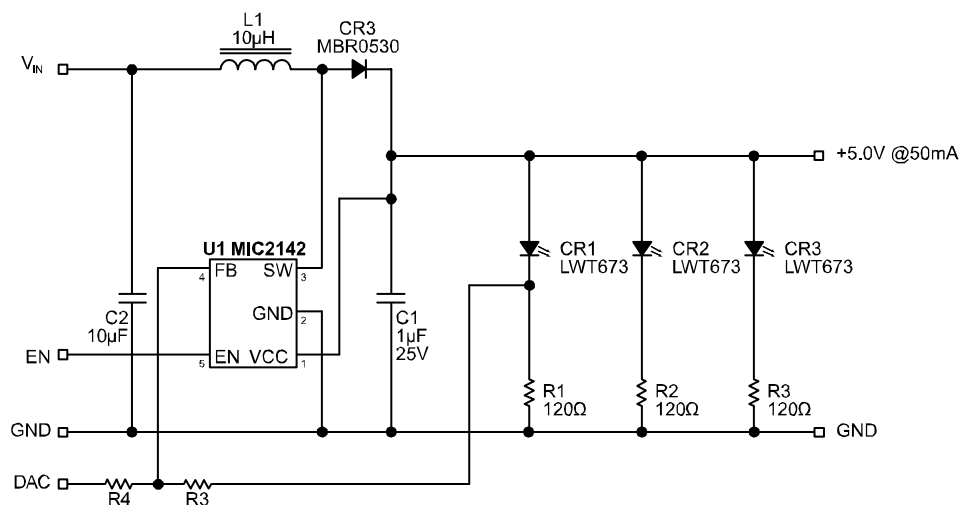


Figure 5. Parallel White LED Driver with Analog Dimming Control

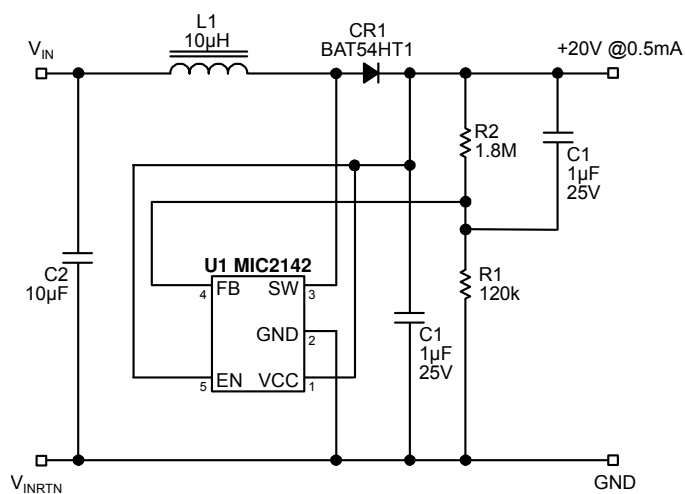


Figure 6. Handheld LCD Supply

V _{IN(min)}	V _{IN(max)}	V _{OUT}	I _{OUT(max)}	L1	I _{PK} @ V _{IN(max)}	CR1
2.5V	3.0V	3.3V	40mA 23mA 10mA	47μH 85μH 180μH	129mA 74mA 34VmA	BAT54 BAT54 BAT54
2.5V	4.5V	5V boot strapped boot strapped	16.5mA 7.8mA 51 77	47μH 100μH 15 10	193mA 91mA 605 908	BAT54 BAT54 MBR0530 MBR
2.5	11.5 4.7	12 boot strapped boot strapped	1.8 2.25 15 22	47 100 15 10	493 232 632 950	MBR BAT MBR MBR
2.5	14.5 4.7	15 boot strapped boot strapped	3.7 1.7 17.4 8	47 100 10 22	622 292 950 430	MBR BAT MBR MBR
2.5 2.5	4.7 4.7	20 20	2.7 1.5	47 82	202 110	BAT BAT
3.0	4.7	5 boot strapped boot strapped	40 70 100	33 18 12	287 525 800	BAT MBR MBR
3.0	8.5 4.7 4.7	9 boot strapped boot strapped	15 28 40	33 18 12	520 525 800	MBR MBR MBR
3.0 3.0 3.0	14.5 4.7 4.7	15 boot strapped boot strapped	7.8 14 21	33 18 12	886 525 800	MBR MBR MBR
3.0	4.7	20	5.6	33	287	BAT
5.0	8.5	9	70 23 10	27 82 180	635 209 95	MBR BAT BAT
5.0	11.5	12	43 14 6	27 82 180	860 283 129	MBR BAT BAT
5.0	14.5 9	15	30 10 30	27 82 27	1083 357 672	MBR MBR MBR
5.0	8.0	20	8	68	237	BAT
9	11.5	12	118 66 30	56 100 220	414 232 105	MBR BAT BAT
9	14	15	70 40 18	56 100 220	504 282 128	MBR BAT BAT
9	14	20	20 10 6	120 220 390	235 128 72	BAT BAT BAT
12	14	15	156 71 27	68 150 390	415 182 72	MBR BAT BAT
12	14	20	35	150	188	BAT

Table 4. Typical Maximum Power Configuration

V_{IN}	V_{OUT}	I_{OUT}	L_1	CR1	I_{PEAK}	Configuration
3.3V±5%	5V	70mA	18μH	MBR0530	400	Bootstrap
	9V	30mA	18μH	MBR0530	400	Bootstrap
	12V	20mA	18μH	MBR0530	400	Bootstrap
	15V	15mA	18μH	MBR0530	400	Bootstrap
5V±5%	20V	6mA	33μH	BAT54	214	Bootstrap
	9V	70mA	27μH	MBR0530	370	
	12V	40mA	27μH	MBR0530	370	
	15V	30mA	27μH	MBR0530	370	
12V±5%	20V	8mA	68μH	BAT54	148	
	15V	158	68	MBR0530	350	
15V±5%	20V	35	150	BAT54	160	
	20V	50	220	BAT54	1140	

Table 5. Typical Maximum Power Configurations for Regulated Inputs

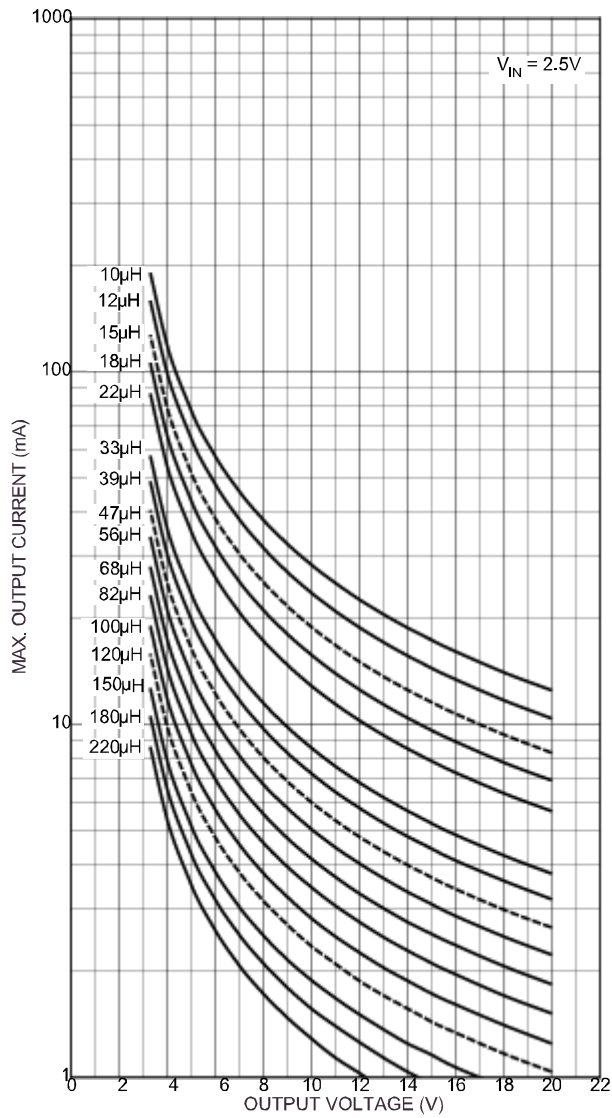
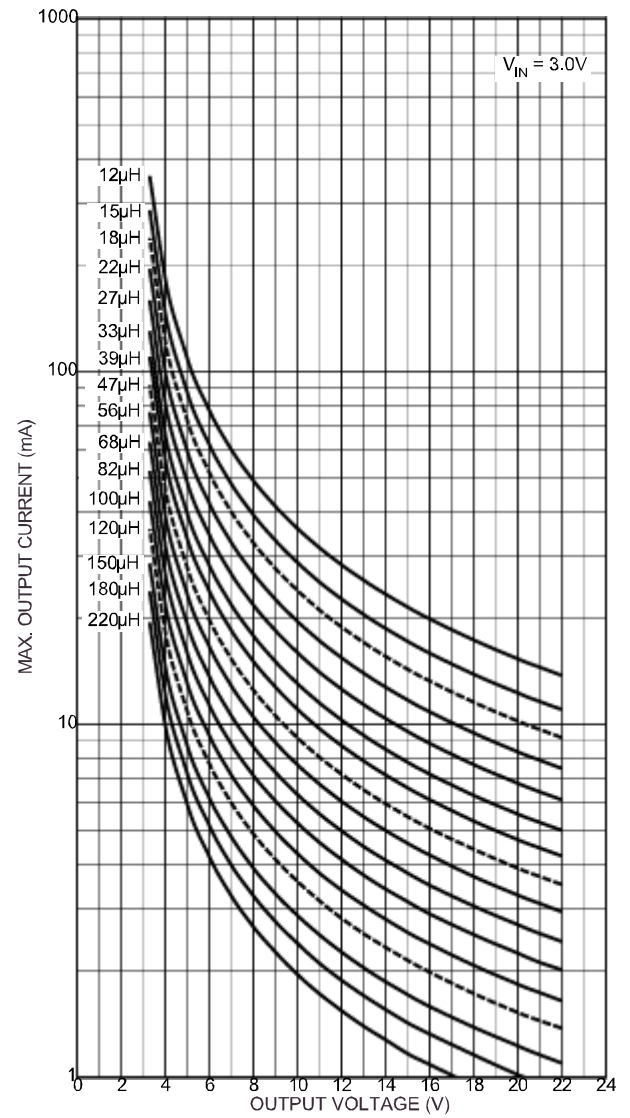
	$V_{OUT} = 16V \text{ to } 22V$	$V_{OUT} < 16V \text{ (bootstapped)}$	$V_{OUT} < 16V \text{ (bootstapped)}$
	85°C	85°C	40°C
$V_{IN} \text{ (V)}$	$L_{MIN} \text{ (}\mu\text{H)}$	$L_{MIN} \text{ (}\mu\text{H)}$	$L_{MIN} \text{ (}\mu\text{H)}$
2.5	47	47 (15)	47 (10)
3	33	33 (18)	33 (12)
3.5	47	27 (22)	27 (15)
4	56	27 (22)	22 (18)
5	68	27	22
6	82	33	22
7	100	39	27
8	100	47	33
9	120	56	33
10	150	56	39
11	150	68	47
12	150	68	47
13	180	82	56
14	180	82	56
15	220	82	56
16	220	100	68

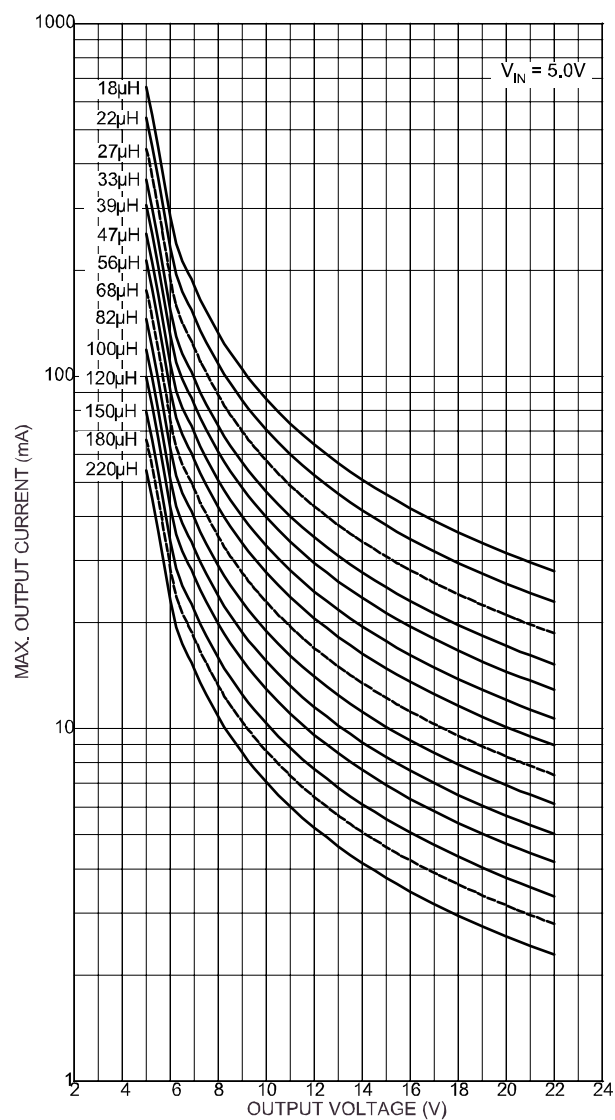
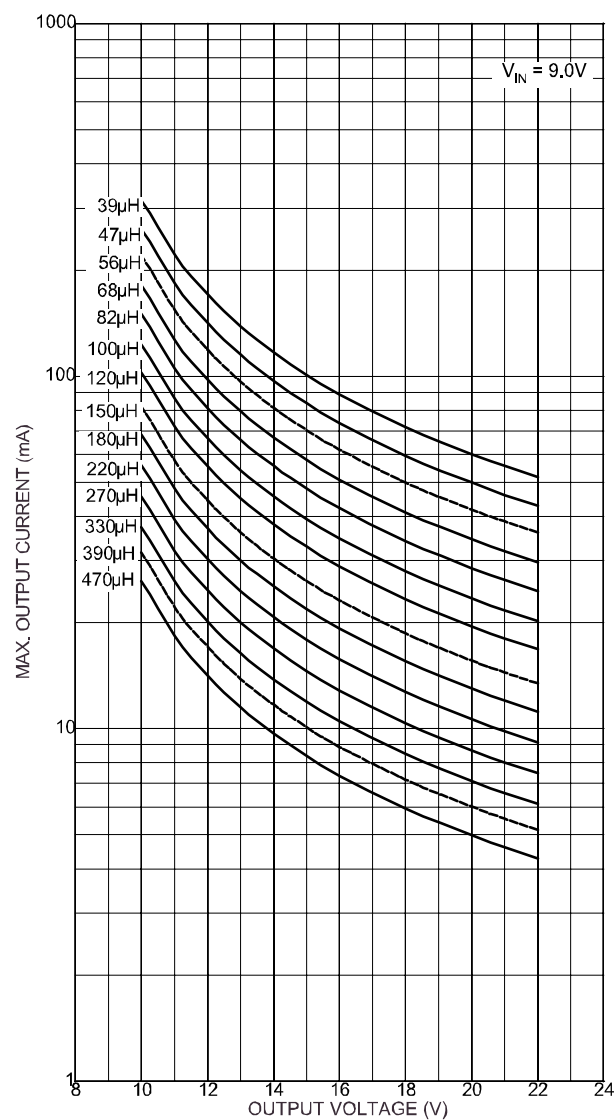
Table 6. Minimum Inductance

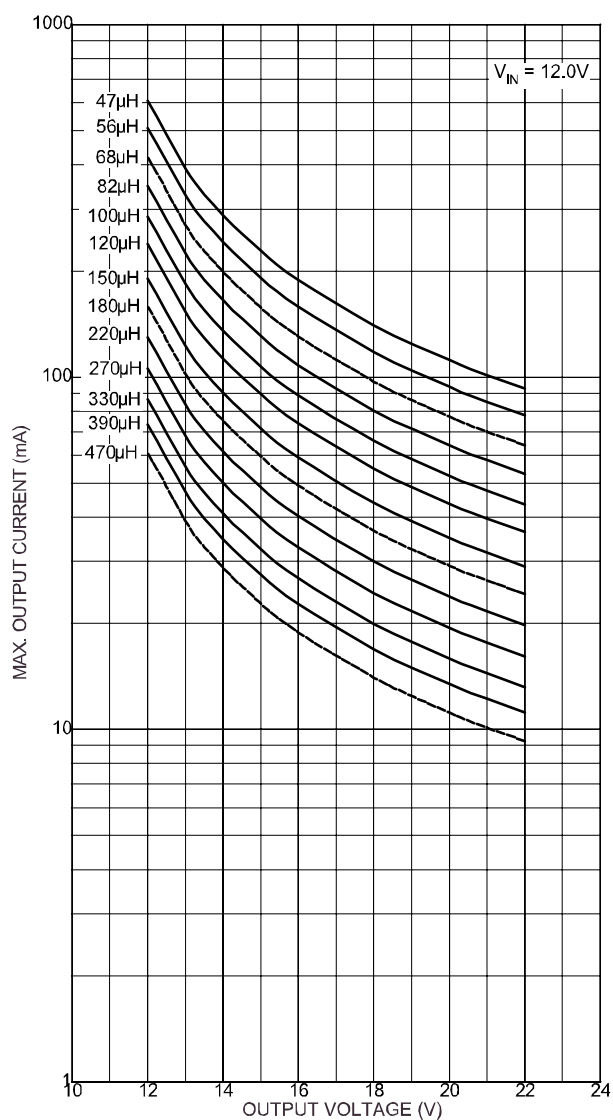
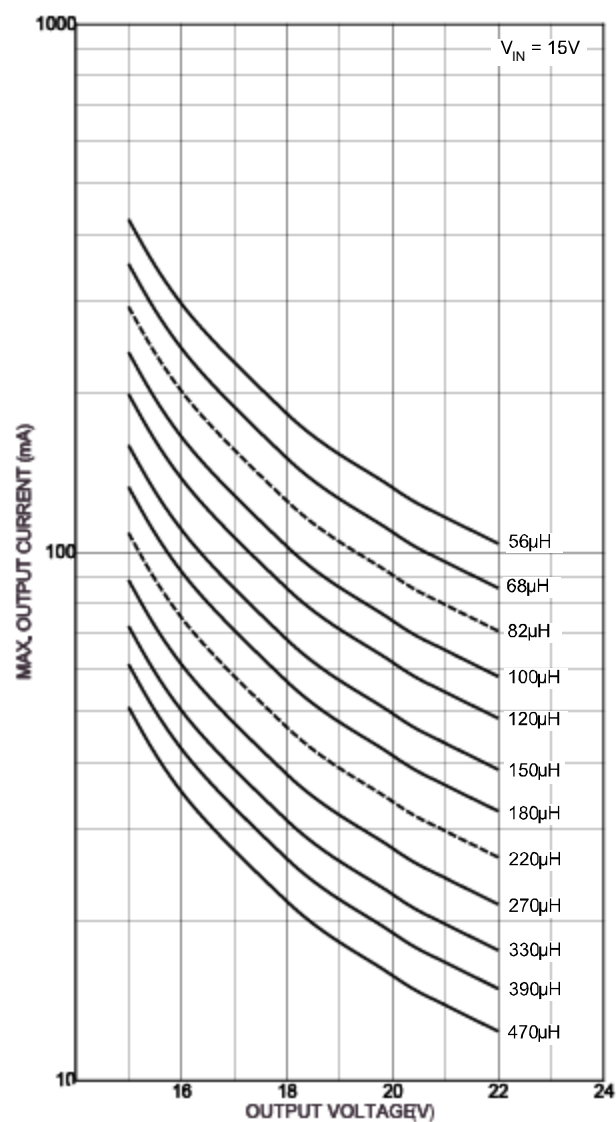
Manufacturer	Web Address
MuRata	www.murata.com
Sumida	www.sumida.com
Coilcraft	www.coilcraft.com
J.W. Miller	www.jwmiller.com
Micrel	www.micre.com
Vishay	www.vishay.com
Panasonic	www.panasonic.com

Table 7. Component Supplier Websites

Inductor Selection Guides

Figure 7. Inductor Selection for $V_{IN} = 2.5V$ Figure 8. Inductor Selection for $V_{IN} = 3.0V$

**Figure 9. Inductor Selection for $V_{IN} = 5V$** **Figure 10. Inductor Selection for $V_{IN} = 9V$**

Figure 11. Inductor Selection for $V_{IN} = 12V$ Figure 8. Inductor Selection for $V_{IN} = 15V$

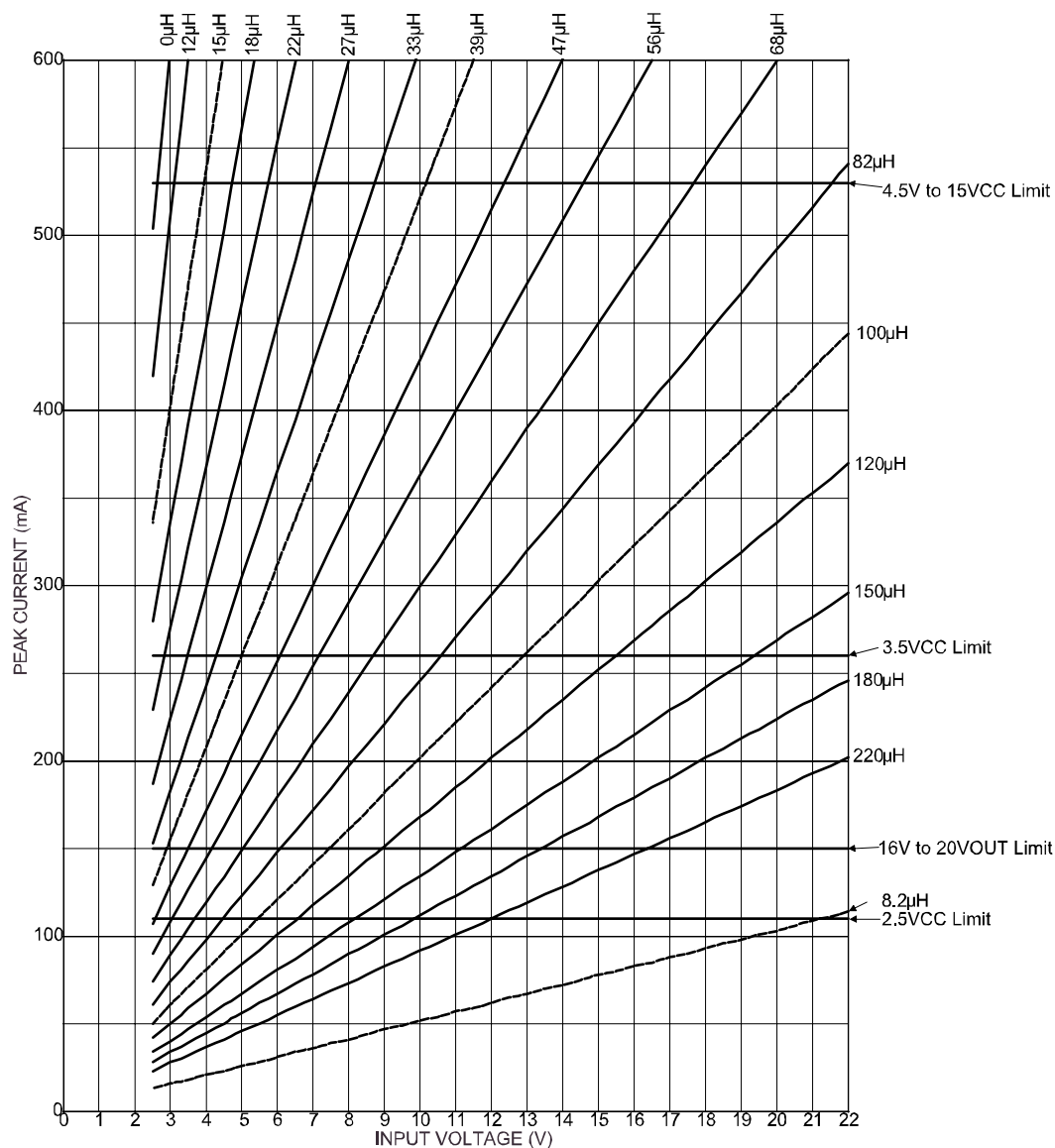
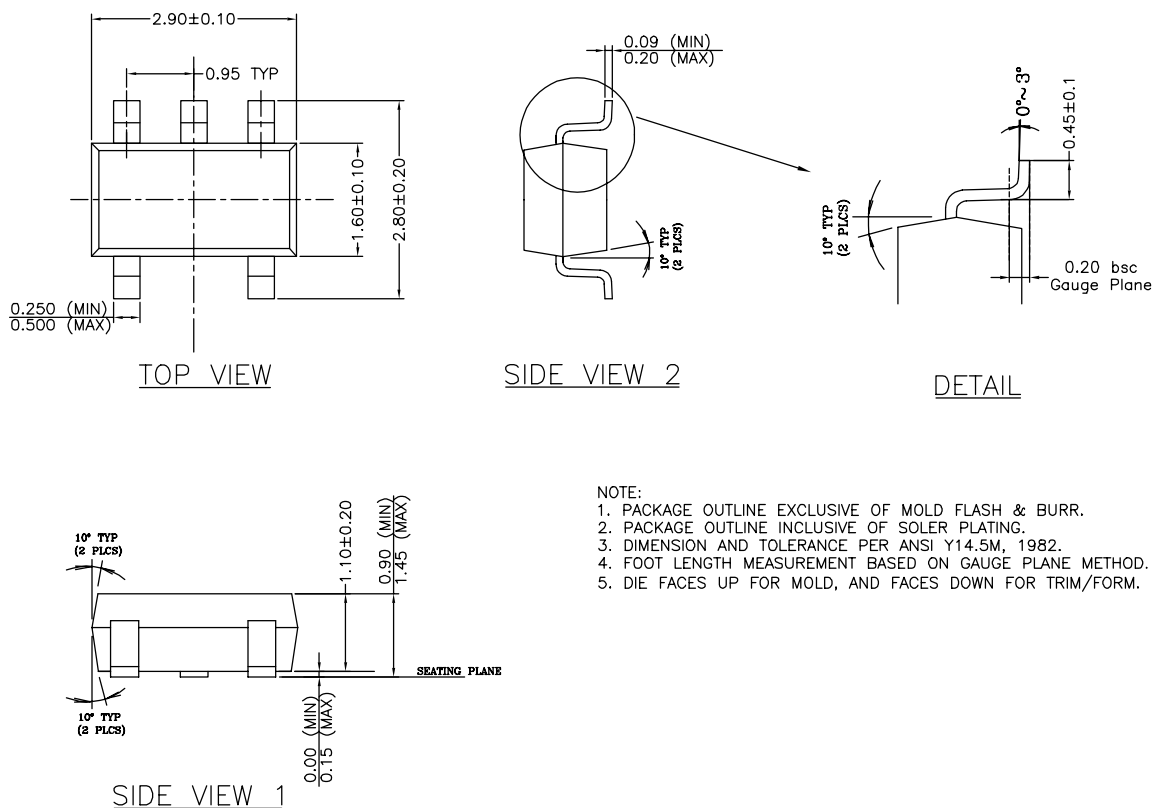


Figure 13. Peak Inductor Current vs. Input Voltage

Package Information



- 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.

5-Pin SOT23 (M5)

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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