The Infinite Bandwidth Company™

MIC2142

Micropower Boost Converter

Preliminary Information

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 85µA, and a typical shutdown current of 0.1µA. It's 330kHz operation allows small surface mount external components to be used. The MIC2142 is capable of efficiences 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°C

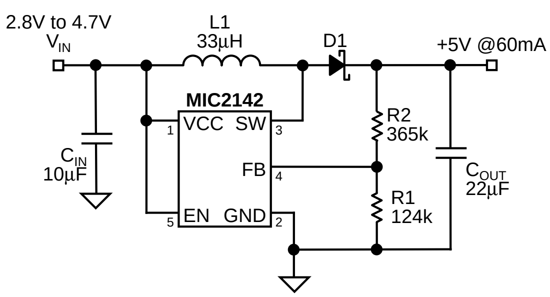
Features

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

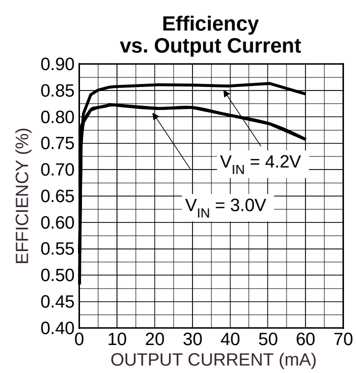
Applications

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

Typical Application



Typical Configuration



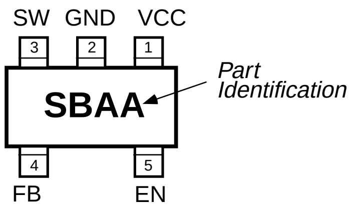
Efficiency vs. Output Current

Micrel, Inc. • 1849 Fortune Drive • San Jose, CA 95131 • USA • tel + 1 (408) 944-0800 • fax + 1 (408) 944-0970 • http://www.micrel.com

Ordering Information

Part Number	Voltage	Ambient Temp. Range	Package
MIC2142BM5	Adj	–40°C to +85°C	SOT23-5

Pin Configuration



SOT23-5 (BM5)

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 (Note 1)

Supply voltage (V_{CC}) 18V
Switch voltage (V_{SW}) 24V
Enable pin voltage (V_{EN}) **Note 3** 18V
Feedback Voltage (V_{FB})
Adjustable version 8V
Ambient Storage Temperature (T_S) .... –65°C to +150°C

Operating Ratings (Note 2)

Supply Voltage (V_{CC}) .... 2.2V to 16V
Enable pin voltage (V_{EN}) **Note 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
θ_{JA} SOT23-5 .... 220°C/W

Electrical Characteristics

V_{CC} =3.6V, V_{OUT} = 5V, I_{OUT} = 20mA, T_A=25°C; unless otherwise specified. **Bold** values indicate 25°C ≤ T_J ≤ 125°C.

Parameter	Condition	Min	Typ	Max	Units
Input Voltage		2.2		16	V
Quiescent Current	V_{EN} = ON , V_{FB} = 2.2V		85	**125**	µA
	V_{EN} = OFF (shutdown)		0.1	**2**	µA
Feedback Voltage (V_{FB})	(±2%)	1.254	1.28	1.306	V
	(±3%)	**1.241**		**1.312**	V
Comparator Hysteresis			18		mV
Feedback Input Bias Current **Note 4**			30		nA
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	200µA ≤ I_{OUT} ≤ 20mA		0.2		%V_{OUT}
Line Regulation	2.2V ≤ V_{CC} ≤ 16V; I_{OUT} = 4mA		0.25		%/V
SW on Resistance	I_{SW} = 100mA, V_{CC} = 2.5V		5		Ω
	I_{SW} = 100mA, V_{CC} = 12V		2		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	%

Note 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.

Note 2: The device is not guaranteed to function outside its operating rating.

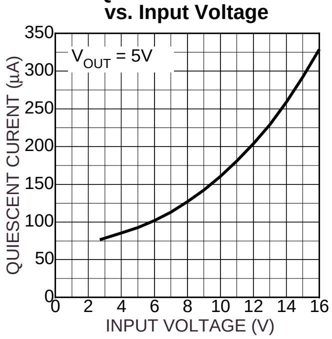
Note 3: V_{EN} must be ≤ V_{IN}

Note 4: The maximum suggested value of the programming resistor, whose series resistance is measured from feedback to ground, is 124kΩ. Use of larger resistor values can cause errors in the output voltage due to the feedback input bias current.

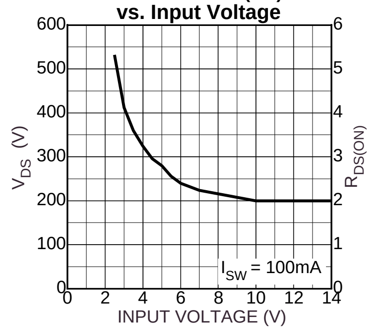
Note 5: Devices are ESD sensitive, handling precautions required.

Typical Characteristics

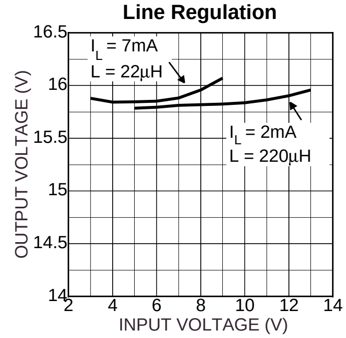
Quiescent Current vs. Input Voltage



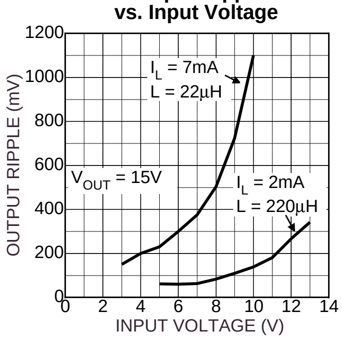
VDS and $R_{DS(ON)}$ vs. Input Voltage



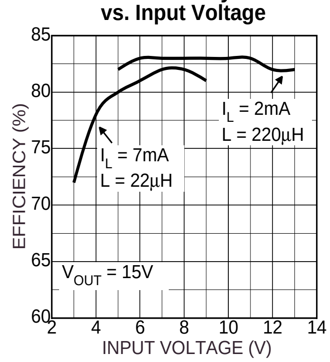
Line Regulation



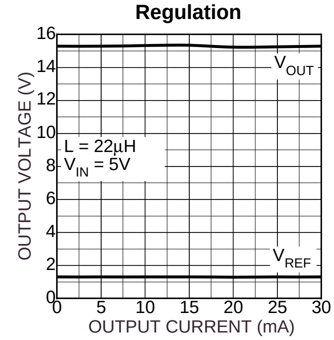
Output Ripple vs. Input Voltage



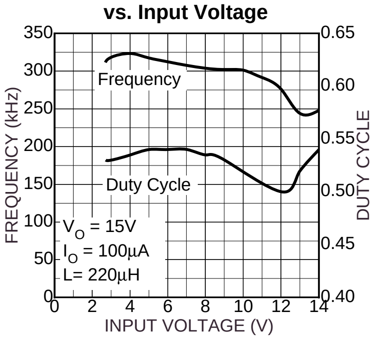
Efficiency vs. Input Voltage



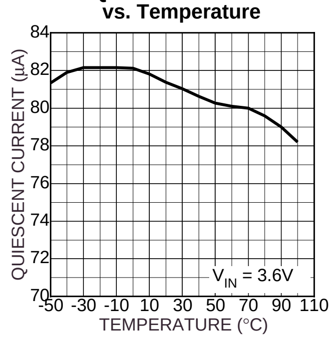
MIC2142 Load Regulation



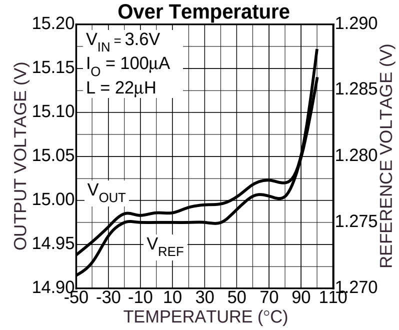
Oscillator Characteristics vs. Input Voltage



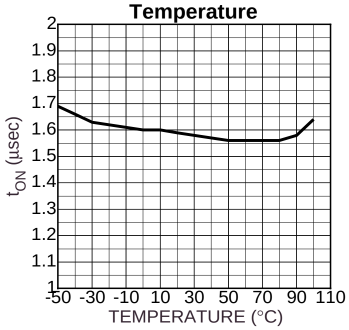
Quiescent Current vs. Temperature



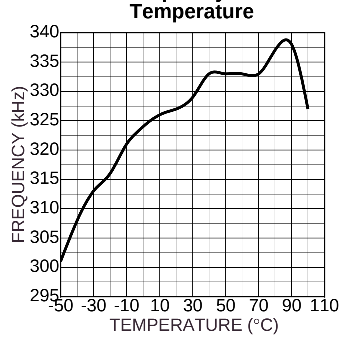
V_{OUT} and V_{REF} Over Temperature



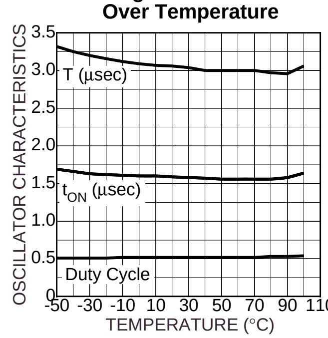
t_{ON} vs. Temperature

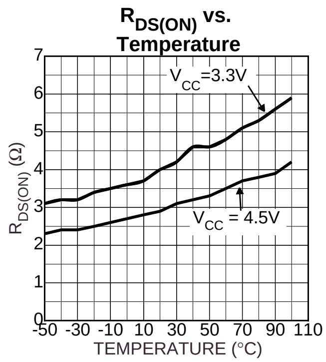


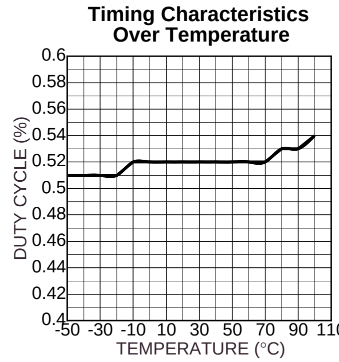
Frequency vs. Temperature



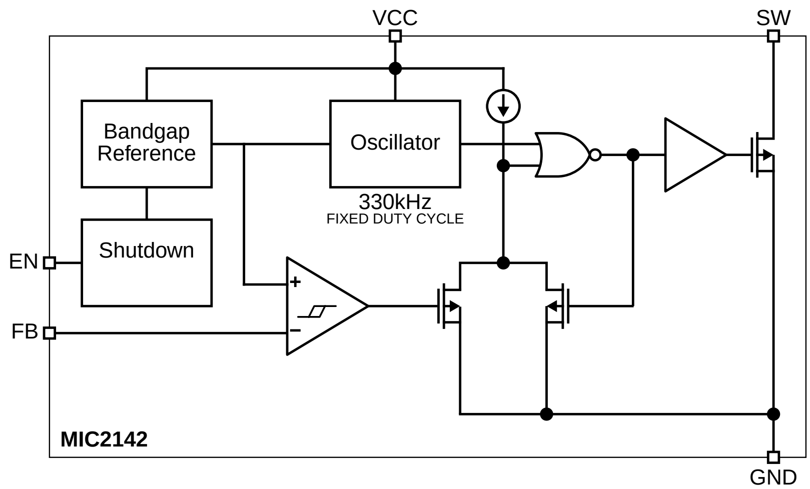
Timing Characteristics Over Temperature




RDS(ON) vs.
Temperature
VCC=3.3V
VCC = 4.5V
RDS(ON) (Ω)
TEMPERATURE (°C)
0
1
2
3
4
5
6
7
-50 -30 -10 10 30 50 70 90 110


Timing Characteristics
Over Temperature
DUTY CYCLE (%)
TEMPERATURE (°C)
0.4
0.42
0.44
0.46
0.48
0.5
0.52
0.54
0.56
0.58
0.6
-50 -30 -10 10 30 50 70 90 110

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 85µA 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 use 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

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

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

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

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 recommmended. Table 6 lists minimum inductor sizes versus input and output voltage. In low-cost, low-peak-current applications, RF-type leaded inductors may 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	LQH1C/3C/4C	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 Shottky 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	0.54 (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 electrolyics 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 10uF @ 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 an miniumum 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 to 4.7V

F_{max} = 360kHz

η = 0.8 = 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 impoves 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 booststrap 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.

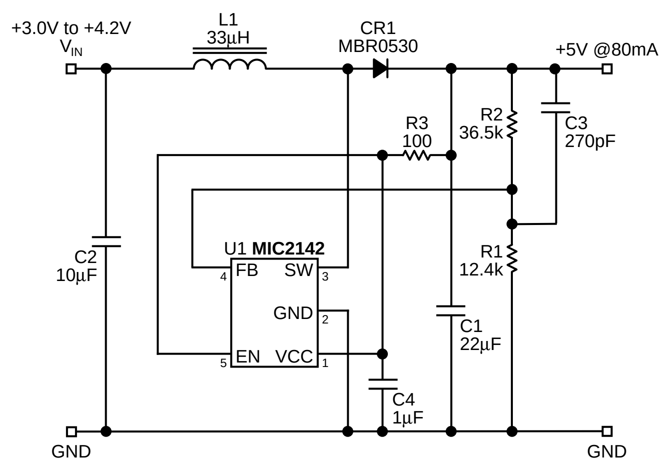


Figure 1. Bootstrap V_{CC} with V_{CC} Low Pass Filter

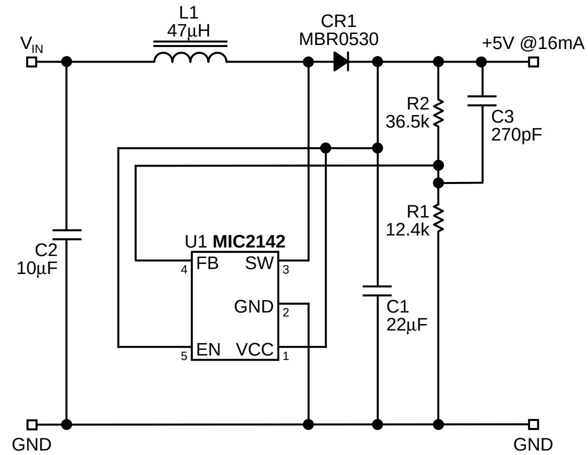


Figure 2. Booststrap Configuration

For additional predesigned circuits, see Table 4.

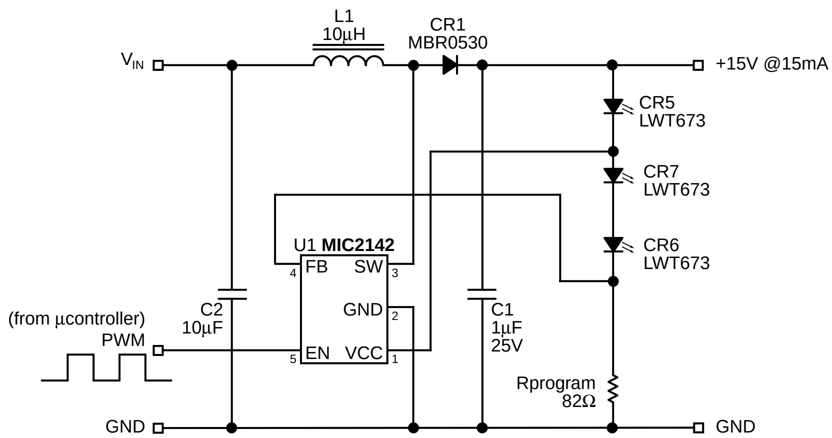


Figure 3. Series White LED Driver with PWM Dimming Control

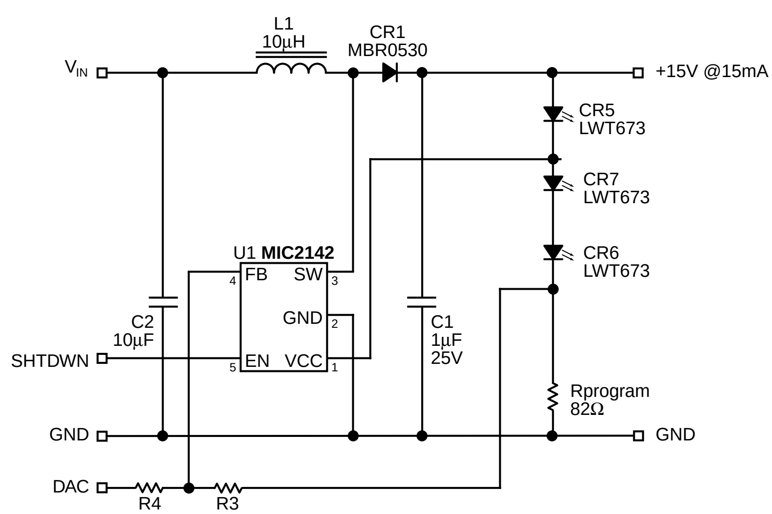


Figure 4. Series White LED Driver with Analog Dimming Control

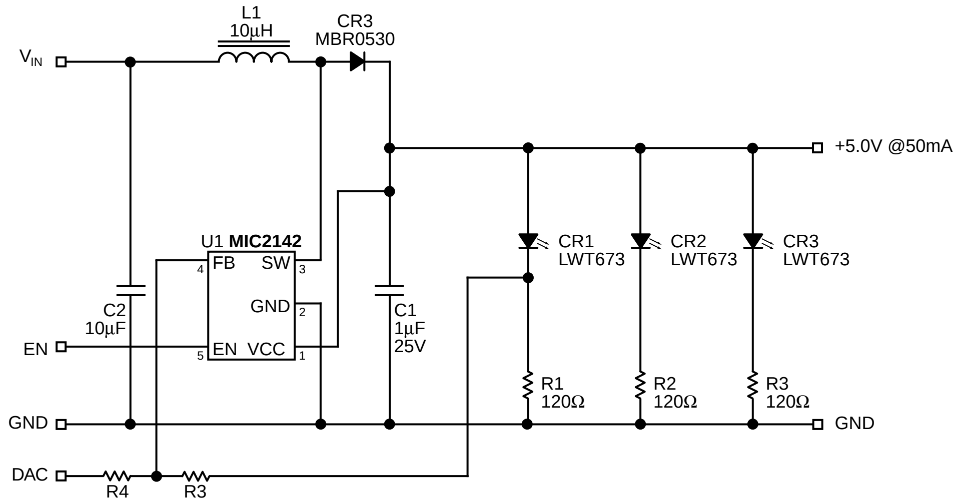


Figure 5. Parallel White LED Driver with Analog Dimming Control

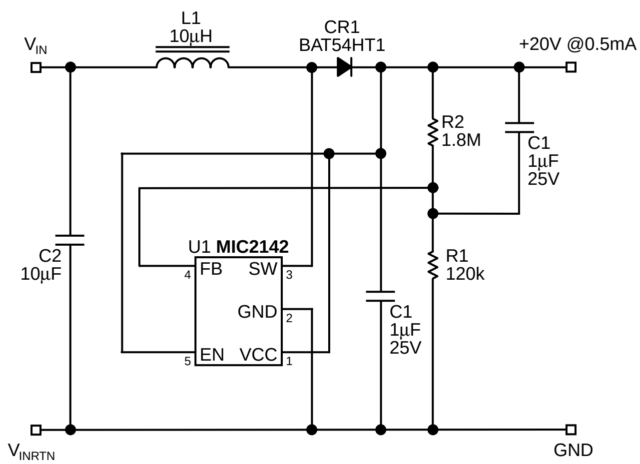


Figure 6. Handheld LCD Supply

Predesigned Circuit Values

$V_{IN(min)}$	$V_{IN(max)}$	V_{OUT}	$I_{OUT(max)}$	L1	I_{PK} @ $V_{IN(max)}$	CR1
2.5V	3.0V	3.3V	40mA	47µH	129mA	BAT54
			23mA	85µH	74mA	BAT54
			10mA	180µH	34VmA	BAT54
2.5V	4.5V	5V	16.5mA	47µH	193mA	BAT54
			7.8mA	100µH	91mA	BAT54
		boot strapped	51	15	605	MBR0530
		boot strapped	77	10	908	MBR
2.5	11.5	12	4.8	47	493	MBR
			2.25	100	232	BAT
	4.7	boot strapped	15	15	632	MBR
		boot strapped	22	10	950	MBR
2.5	14.5	15	3.7	47	622	MBR
			1.7	100	292	BAT
	4.7	boot strapped	17.4	10	950	MBR
		boot strapped	8	22	430	MBR
2.5	4.7	20	2.7	47	202	BAT
2.5	4.7	20	1.5	82	110	BAT
3.0	4.7	5	40	33	287	BAT
		boot strapped	70	18	525	MBR
		boot strapped	100	12	800	MBR
3.0	8.5	9	15	33	520	MBR
	4.7	boot strapped	28	18	525	MBR
	4.7	boot strapped	40	12	800	MBR
3.0	14.5	15	7.8	33	886	MBR
3.0	4.7	boot strapped	14	18	525	MBR
3.0	4.7	boot strapped	21	12	800	MBR
3.0	4.7	20	5.6	33	287	BAT
5.0	8.5	9	70	27	635	MBR
			23	82	209	BAT
			10	180	95	BAT
5.0	11.5	12	43	27	860	MBR
			14	82	283	BAT
			6	180	129	BAT
5.0	14.5	15	30	27	1083	MBR
			10	82	357	MBR
	9		30	27	672	MBR
5.0	8.0	20	8	68	237	BAT
9	11.5	12	118	56	414	MBR
			66	100	232	BAT
			30	220	105	BAT
9	14	15	70	56	504	MBR
			40	100	282	BAT
			18	220	128	BAT
9	14	20	20	120	235	BAT
			10	220	128	BAT
			6	390	72	BAT
12	14	15	156	68	415	MBR
			71	150	182	BAT
			27	390	72	BAT
12	14	20	35	150	188	BAT

Table 4. Typical Maximum Power Configuration

V_{IN}	V_{OUT}	I_{OUT}	L1	CR1	I_{PEAK}	Configuration
3.3V±5%	5V 9V 12V 15V 20V	70mA 30mA 20mA 15mA 6mA	18µH 18µH 18µH 18µH 33µH	MBR0530 MBR0530 MBR0530 MBR0530 BAT54	400 400 400 400 214	Bootstrap Bootstrap Bootstrap Bootstrap
5V±5%	9V 12V 15V 20V	70mA 40mA 30mA 8.0mA	27µH 27µH 27µH 68µH	MBR0530 MBR0530 MBR0530 BAT54	370 370 370 148	
12V±5%	15V 20V	158 35	68 150	MBR0350 BAT54	350 160	
15V±5%	20V	50	220	BAT54	1140	

Table 5. Typical Maximum Power Configurations for Regulated Inputs

	V_{OUT} = 16V to 22V	V_{OUT} < 16V (boostraped)	V_{OUT} < 16 (boostraped)
	85C	85C	40C
V_{IN} (V)	L_{MIN} (µH)	L_{MIN} (µH)	L_{MIN} (µH)
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.micrel.com
Vishay	www.vishay.com
Panasonic	www.panasonic.com

Table 7. Component Supplier Websites

Inductor Selection Guides

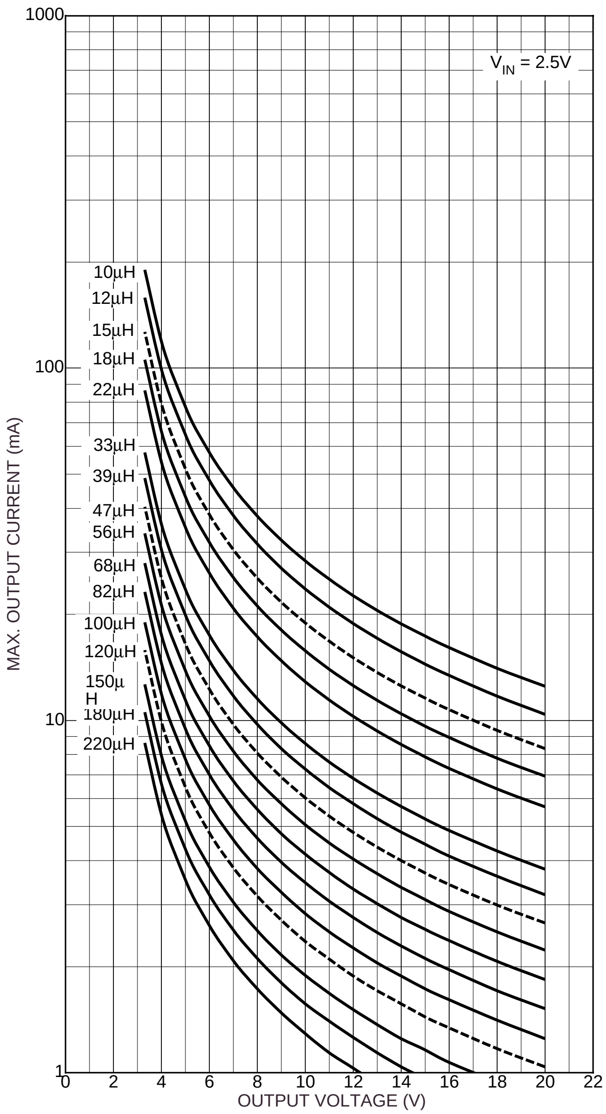


Figure 7. Inductor Selection for V_{IN} = 2.5V

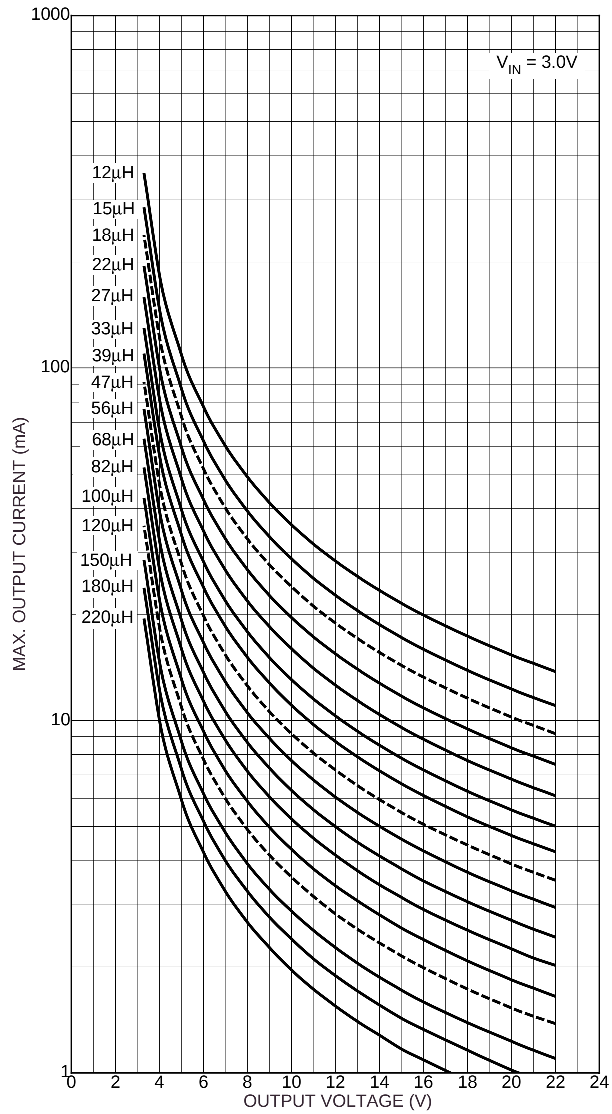


Figure 8. Inductor Selection for V_{IN} = 3.0V

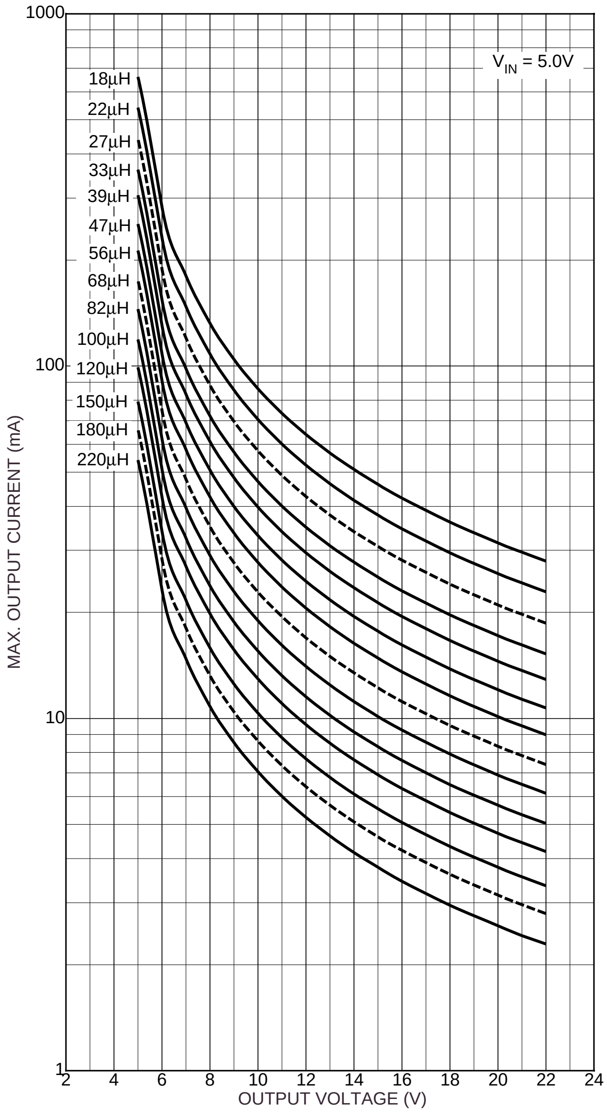


Figure 9. Inductor Selection for V_{IN} = 5V

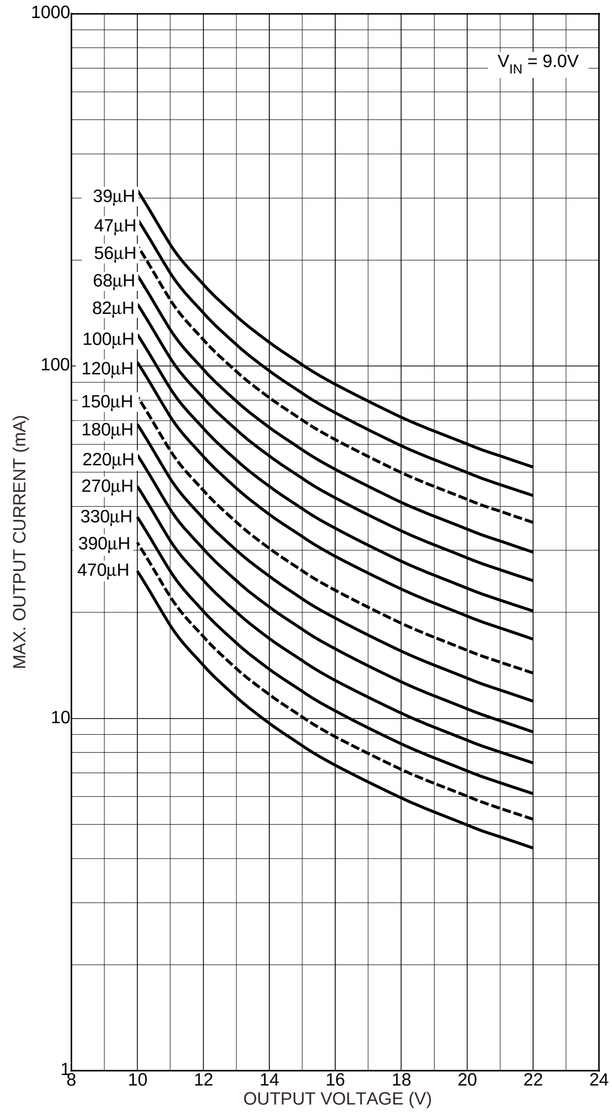


Figure 10. Inductor Selection for V_{IN} = 9V

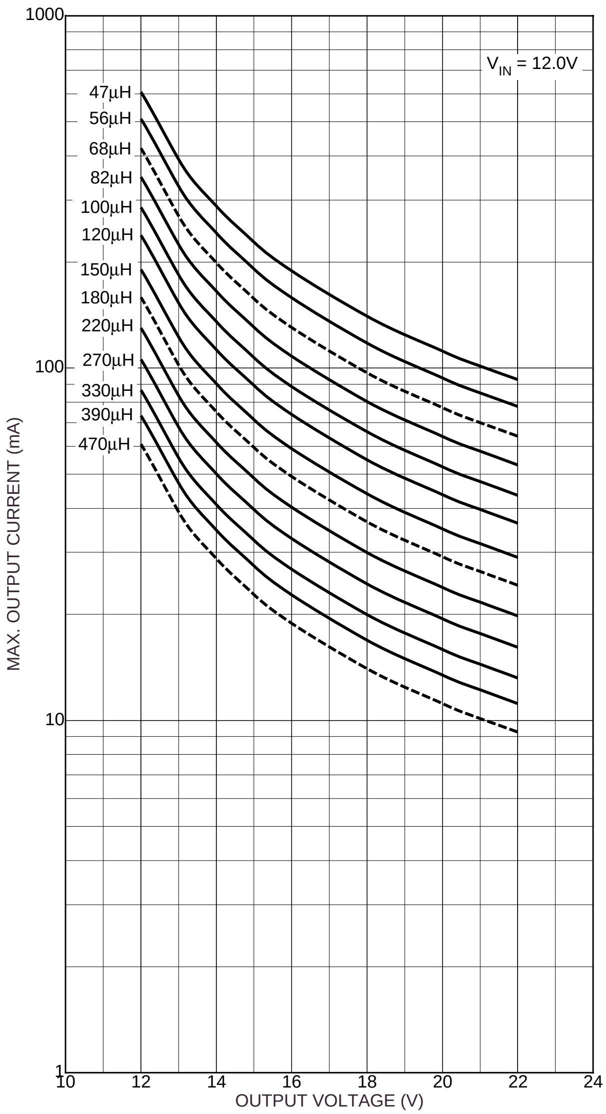


Figure 11. Inductor Selection for V_{IN} = 12V

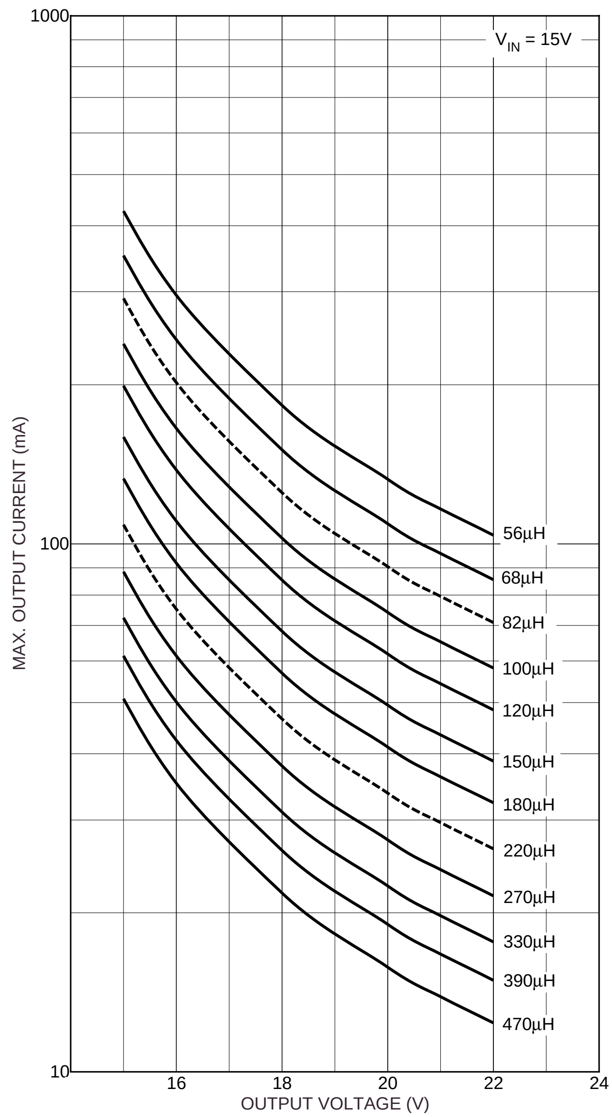


Figure 12. Inductor Selection for V_{IN} = 15V

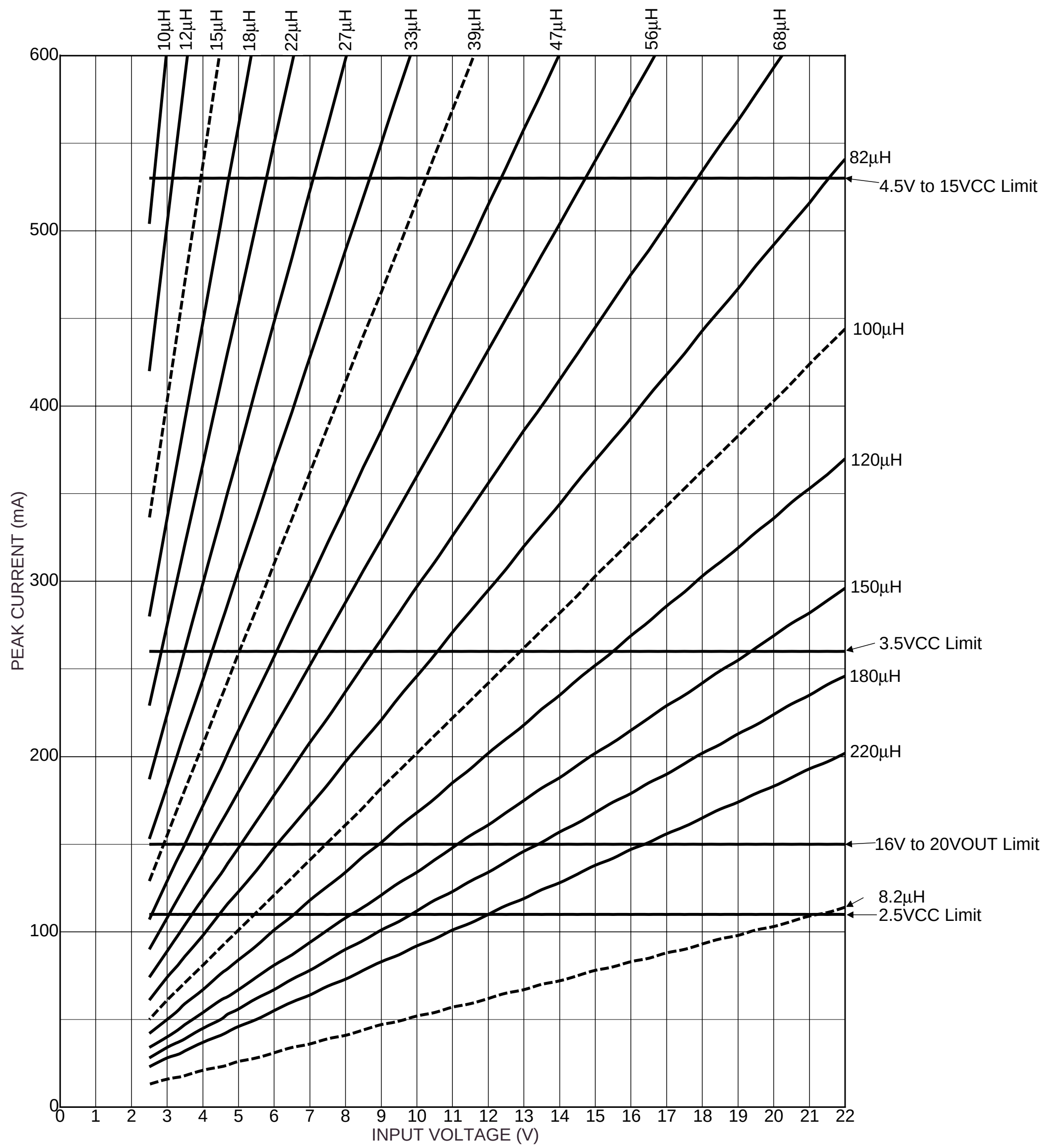
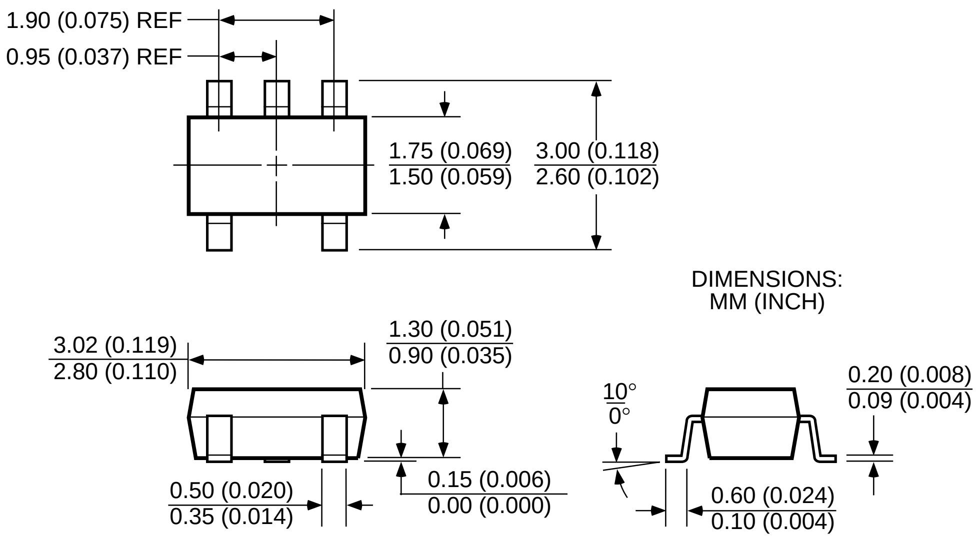


Figure 13. Peak Inductor Current vs. Input Voltage

Package Information



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