



60mA 1.5x High-Efficiency White LED Charge Pumps

MAX1912/MAX1913

General Description

The MAX1912/MAX1913* power LEDs with a regulated output voltage or current (up to 60mA) from an unregulated input supply (2.7V to 5.3V). These are complete DC-DC converters requiring only four small ceramic capacitors and no inductors. Input ripple is minimized by a unique regulation scheme that maintains a fixed 750kHz switching frequency over a wide load range. Also included are logic-level shutdown and soft-start to reduce input current surges at startup.

The MAX1912 has a reduced feedback (SET) threshold of 200mV for minimum loss when operating as a current source. The MAX1913 has a 1.25V SET threshold for best accuracy in voltage-feedback applications. Connecting SET to IN on the MAX1913 selects a preset 5.0V output voltage. Contact factory for current-sense thresholds other than 200mV or preset output voltages other than 5.0V

Features

- ◆ High-Efficiency 1.5x Charge Pumps
- ◆ Low Input Ripple with 750kHz Operation
- ◆ 200mV Current-Sense Threshold Reduces Power Loss
- ◆ Current- or Voltage-Regulated Charge Pump
- ◆ 60mA Output Current
- ◆ No Inductors Required
- ◆ Small Ceramic Capacitors
- ◆ Regulated $\pm 3\%$ Output Voltage
- ◆ Load Disconnected in Shutdown
- ◆ 1 μ A Shutdown Current
- ◆ Small 10-Pin μ MAX Package

Applications

- Backlight White LED Biasing
- Cellular Phones
- PDA's
- Digital Still Cameras
- MP3 Players
- Backup-Battery Boost Converters

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX1912EUB	-40°C to +85°C	10 μ MAX
MAX1913EUB50*	-40°C to +85°C	10 μ MAX

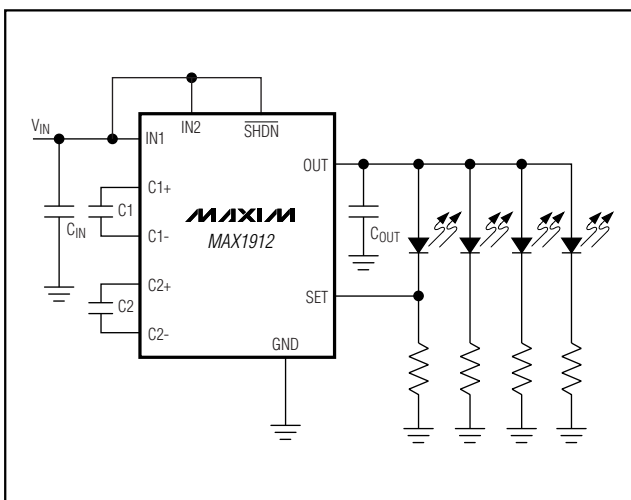
*Future product—contact factory for availability.

Selector Guide

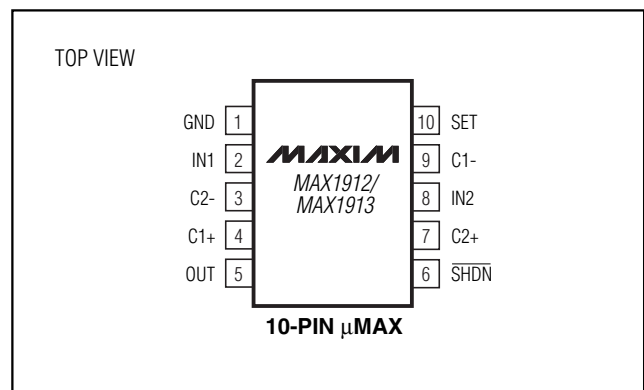
PART	MODE	VSET	VOUT
MAX1912EUB	1.5x	200mV	Adjustable Current
MAX1913EUB50*	1.5x	1.25V	5.0V or Adjustable

*Future product—contact factory for availability.

Typical Operating Circuit



Pin Configuration



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ABSOLUTE MAXIMUM RATINGS

IN1, IN2, OUT, $\overline{\text{SHDN}}$, SET to GND -0.3V, +6V
 C1-, C2-, to GND -0.3V, $V_{\text{IN}} + 1\text{V}$
 C1+, C2+ to GND -0.3V, greater of $V_{\text{OUT}} + 1\text{V}$ or $V_{\text{IN}} + 1\text{V}$
 OUT Short-Circuit to GND Continuous

Continuous Power Dissipation
 10-Pin μMAX (derate 5.6 mW/°C above +70°C) 444mW
 Operating Temperature Range -40°C to +85°C
 Storage Temperature Range -65°C to +150°C
 Lead Temperature (soldering, 10s) +300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

($V_{\text{IN}} = 3.6\text{V}$, $\text{GND} = 0$, $\overline{\text{SHDN}} = \text{SET} = \text{IN}$, $C_{\text{IN}} = 2.2\mu\text{F}$, $C_1 = C_2 = 0.47\mu\text{F}$, $C_{\text{OUT}} = 2.2\mu\text{F}$, $T_{\text{A}} = 0^\circ\text{C}$ to $+85^\circ\text{C}$. Typical values are at $T_{\text{A}} = +25^\circ\text{C}$, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Operating Range		2.7		5.3	V
Undervoltage Lockout Threshold	Both rising and falling edges	2.2		2.5	V
Undervoltage Lockout Hysteresis			35		mV
MAX1912 SET Regulation Point	$0 < I_{\text{LOAD}} < 60\text{mA}$	0.19	0.2	0.21	V
MAX1912 Current Regulation	Output current change for $3\text{V} < V_{\text{OUT}} < 5\text{V}$		0.5		%/V
Maximum Output Current		60			mA
No Load Input Current	$V_{\text{IN}} = 3.6\text{V}$		1.5	2.5	mA
Supply Current in Shutdown	$V_{\text{IN}} = 5.3\text{V}$, $V_{\text{OUT}} = 0$, $\overline{\text{SHDN}} = 0$		0.1	10	μA
Output Leakage Current in Shutdown	$V_{\text{IN}} = 3.6\text{V}$, $\overline{\text{SHDN}} = 0$		0.1	10	μA
Switching Frequency	$V_{\text{IN}} = 3.6\text{V}$	625	750	875	kHz
Switching Frequency Temperature Coefficient	$f = 750\text{kHz}$		250		ppm/°C
SET Input Current			1	100	nA
$\overline{\text{SHDN}}$ Input Current	$\overline{\text{SHDN}} = 0$ or 5.5V			1	μA
$\overline{\text{SHDN}}$ Input Voltage Low	$2.7\text{V} < V_{\text{IN}} < 5.3\text{V}$			0.4	V
$\overline{\text{SHDN}}$ Input Voltage High	$2.7\text{V} < V_{\text{IN}} < 5.3\text{V}$	1.6			V
Thermal-Shutdown Threshold	Rising temperature, 15°C hysteresis typical		160		°C

ELECTRICAL CHARACTERISTICS

($V_{\text{IN}} = 3.6\text{V}$, $\text{GND} = 0$, $\overline{\text{SHDN}} = \text{SET} = \text{IN}$, $C_{\text{IN}} = 2.2\mu\text{F}$, $C_1 = C_2 = 0.47\mu\text{F}$, $C_{\text{OUT}} = 2.2\mu\text{F}$, $T_{\text{A}} = -40^\circ\text{C}$ to $+85^\circ\text{C}$, unless otherwise noted.) (Note 1)

PARAMETER	CONDITIONS	MIN	MAX	UNITS
Input Voltage Operating Range		2.7	5.3	V
Undervoltage Lockout Threshold	Both rising and falling edges	2.2	2.5	V
Maximum Output Current		60		mA
Supply Current in Shutdown	$V_{\text{IN}} = 5.3\text{V}$, $V_{\text{OUT}} = 0$, $\overline{\text{SHDN}} = 0$		10	μA

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ELECTRICAL CHARACTERISTICS (continued)

($V_{IN} = 3.6V$, $GND = 0$, $\overline{SHDN} = SET = IN$, $C_{IN} = 2.2\mu F$, $C_1 = C_2 = 0.47\mu F$, $C_{OUT} = 2.2\mu F$, $T_A = -40^\circ C$ to $+85^\circ C$, unless otherwise noted.) (Note 1)

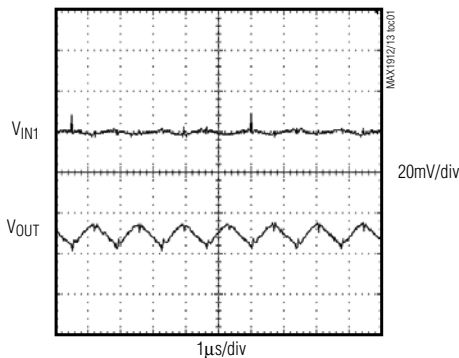
PARAMETER	CONDITIONS	MIN	MAX	UNITS
Output Leakage Current in Shutdown	$V_{IN} = 3.6V$, $\overline{SHDN} = 0$		10	μA
MAX1912 SET Regulation Point	$0 < I_{LOAD} < 60mA$	0.19	0.21	V
SET Input Current			100	nA
\overline{SHDN} Input Current	$\overline{SHDN} = 0$ or $5.5V$		1	μA
\overline{SHDN} Input Voltage Low	$2.7V < V_{IN} < 5.3V$		0.4	V
\overline{SHDN} Input Voltage High	$2.7V < V_{IN} < 5.3V$	1.6		V

Note 1: Limits to $-40^\circ C$ are guaranteed by design, not production tested.

Typical Operating Characteristics

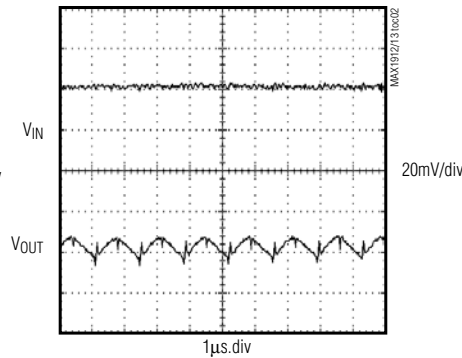
($T_A = +25^\circ C$, unless otherwise noted.)

INPUT AND OUTPUT VOLTAGE RIPPLE



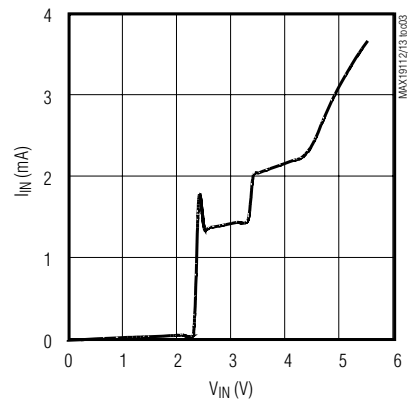
$C_{IN} = 10\mu F$, $C_{OUT} = 4.7\mu F$
MAX1912 DRIVING 4 LEDES (60mA)
 $V_{IN} = 3.3V$

INPUT AND OUTPUT VOLTAGE RIPPLE WITH ADDITIONAL INPUT FILTER

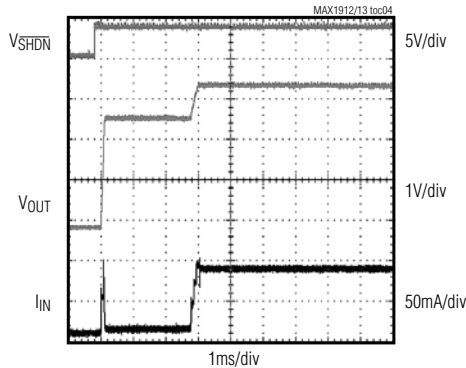


MAX1912 DRIVING 4 LEDES (60mA)
 $10\mu F - 1\Omega - 10\mu F$ INPUT FILTER, $C_{OUT} = 4.7\mu F$
 $V_{IN} = 3.3V$

QUIESCENT CURRENT vs. INPUT VOLTAGE

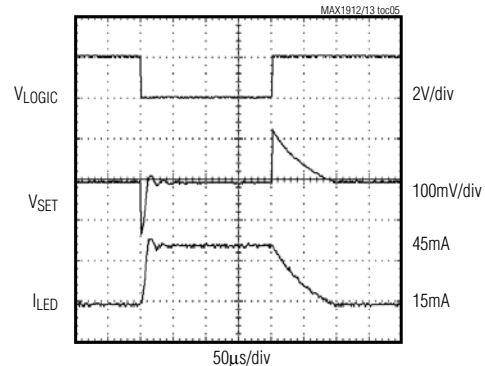


STARTUP INPUT CURRENT AND OUTPUT VOLTAGE



CIRCUIT OF FIGURE 2
 $R_1 = R_2 = R_3 = 15\Omega$
 $C_{IN} = 10\mu F$, $C_{OUT} = 2.2\mu F$
 $V_{IN} = 3.3V$

INTENSITY CHANGE STEP RESPONSE



CIRCUIT OF FIGURE 10
 $R_A = 22k\Omega$, $R_B = 1.5k\Omega$, $R_L = 4.7\Omega$
 $C_{IN} = 10\mu F$, $C_{OUT} = 4.7\mu F$
 $V_{LOGIC(HIGH)} = 2V$

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Pin Description

PIN	NAME	FUNCTION
1	GND	Ground
2	IN1	Supply Voltage Input. Connect to IN2. Bypass to GND with a 2.2 μ F ceramic capacitor.
3	C2-	Transfer Capacitor 2 Connection, Negative Side
4	C1+	Transfer Capacitor 1 Connection, Positive Side
5	OUT	Output. Bypass to GND with a 2.2 μ F ceramic capacitor.
6	$\overline{\text{SHDN}}$	Shutdown Input. Drive low to turn off the device and disconnect the load from the input. OUT is high impedance in shutdown. Drive high or connect to IN for normal operation.
7	C2+	Transfer Capacitor 2 Connection, Positive Side
8	IN2	Supply Voltage Input. Connect to IN1.
9	C1-	Transfer Capacitor 1 Connection, Negative Side
10	SET	SET programs the output voltage with a resistive-divider from OUT (MAX1913), or programs output current with a resistor from SET to GND (MAX1912). For the MAX1913, when SET is connected to IN, V_{OUT} is internally set to 5V.

Detailed Description

The MAX1912/MAX1913 are complete charge-pump boost converters requiring only four small ceramic capacitors. They employ a 750kHz fixed-frequency 50% duty-cycle clock. The MAX1912/MAX1913 use a 1.5x charge-pump mode. This operation has two phases (see Figure 1), charge and transfer. In charge phase, transfer capacitors C1 and C2 charge in series from the input voltage. In transfer phase, C1 and C2 are configured in parallel and connected from OUT to IN, transferring charge to C_{OUT} . If this system were allowed to operate unregulated and unloaded, it would generate an output voltage 1.5 times the input voltage.

Output Regulation

The output voltage is regulated by controlling the rate at which the transfer capacitors are charged. The switching frequency and duty cycle are constant, so the output noise spectrum is predictable. Input and output ripple are much smaller in value than with other regulating charge-pump topologies because the charge transferred per cycle is only the amount required to supply the output load.

Soft-Start

The MAX1912/MAX1913 include soft-start circuitry to limit inrush current at turn-on. When starting up with the output voltage at zero, the output capacitor is charged through a ramped current source, directly from the input with no charge-pump action until the output voltage is near the input voltage. If the output is shorted to ground, the part remains in this mode without damage until the short is removed.

Once the output capacitor is charged to the input voltage, the charge-pumping action begins. Startup surge current is minimized by ramping up charge on the transfer capacitors. As soon as regulation is reached, soft-start ends and the part operates normally. If the SET voltage reaches regulation within 2048 clock cycles (typically 2.7ms), the part begins to run in normal mode. If the SET voltage is not reached by 2048 cycles, the soft-start sequence is repeated. The devices will continue to repeat the soft-start sequence until the SET voltage reaches the regulation point.

Shutdown Mode

When driven low, $\overline{\text{SHDN}}$ turns off the charge pump. This reduces the quiescent current to approximately 0.1 μ A. The output is high impedance in shutdown. Drive $\overline{\text{SHDN}}$ high or connect to IN for normal operation.

Thermal Shutdown

The MAX1912/MAX1913 shut down when their die temperature reaches +160°C. Normal operation continues after the die cools by 15°C. This prevents damage if an excessive load is applied or the output is shorted to ground.

Design Procedure

Setting Output Current (MAX1912)

The MAX1912 has a SET voltage threshold of 0.2V, used for LED current regulation (Figure 2). The current through the resistor and LED is:

$$I_{\text{LED}} = 0.2/R$$

If additional matching LEDs with ballast resistors are connected to the output as in Figure 2, the current

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through each additional LED is the same as that in the regulated LED.

In Figure 2, total LED current depends somewhat on LED matching. Figure 3 shows a connection that regulates the average of all the LED currents to reduce the impact of mismatched LEDs. Figure 4's circuit improves LED current matching by raising the ballast resistance while maintaining a 200mV V_{SET} . The increased ballast resistance tolerates wider LED mismatch but reduces efficiency and raises the minimum input voltage required for regulation.

Yet another method of biasing LEDs is shown in Figure 5. In this case, the current through the complete parallel combination of LEDs is set by R_4 . R_1 , R_2 , and R_3 are only used to compensate for LED variations. This method of biasing is useful for parallel LED arrays that do not allow connection to individual LEDs.

Setting Output Voltage (MAX1913)

The MAX1913 has a SET voltage threshold of 1.25V. The output voltage is set by connecting a resistor voltage divider as shown in Figure 6. The output voltage is adjustable from 3V to 5V. To set the output voltage, select a value for R_2 that is less than 50k Ω , then solve for R_1 using the following equation:

$$R_1 = R_2 \left(\frac{V_{OUT}}{1.25} - 1 \right)$$

If SET is connected to the input, the output voltage is 5V (Figure 7). Other parts with internally set voltages from 3V to 5V in 100mV steps are available by special order.

Capacitor Selection

Use low-ESR ceramic capacitors. Recommended values are 0.47 μ F for the transfer capacitors, 2.2 μ F to 10 μ F for the input capacitor, and 2.2 μ F to 4.7 μ F for the output capacitor. To ensure stability over a wide temperature range, ceramic capacitors with an X7R dielectric are recommended. Place these capacitors as close to the IC as possible. Increasing the value of the input and output capacitors further reduces input and output ripple. With a 10 μ F input capacitor and a 4.7 μ F output capacitor, input ripple is less than 5mV peak-to-peak and output ripple is less than 15mV peak-to-peak for 60mA of output current. A constant 750kHz switching frequency and fixed 50% duty cycle create input and output ripple with a predictable frequency spectrum.

Decoupling the input with a 1 Ω resistor (as shown in Figures 2–10) will improve stability when operating from low-impedance sources such as high-current laboratory

bench power supplies. This resistor may be omitted when operating from higher impedance sources such as lithium or alkaline batteries.

For some designs, such as an LED driver, input ripple is more important than output ripple. Input ripple depends on the source supply's impedance. Adding a lowpass filter to the input further reduces ripple. Figure 8 shows a C-R-C filter used to reduce input ripple to less than 1mV when driving a 60mA load.

Applications Information

Adjusting LED Intensity

Figure 9 shows a circuit using a DAC to set the LED intensity. Maximum intensity occurs when the output of the DAC is zero. R_L may be initially estimated from the maximum load current:

$$R_L \approx 0.2 / I_L(\text{MAX})$$

Use this as a starting point to calculate R_A and R_B from the formula below. The total load current at different DAC output voltages is determined by:

$$I_L = \frac{0.2}{R_L} - \frac{(V_{DAC} - 0.2) \times R_B}{R_L \times R_A}$$

Figure 10 uses a digital input for two-level dimming control. The LEDs are brightest when a logic low input ($V_{LOGIC} = 0$) is applied, and dimmed with a logic high input. The total LED current is determined by:

$$I_L = \frac{0.2}{R_L} - \frac{(V_{LOGIC} - 0.2) \times R_B}{R_L \times R_A}$$

PC Board Layout

The MAX1912/MAX1913 are high-frequency switched-capacitor voltage regulators. For best circuit performance, use a ground plane and keep C_{IN} , C_{OUT} , C_1 , C_2 , and feedback resistors (if used) close to the device. If using external feedback, keep the feedback node as small as possible by positioning the feedback resistors very close to SET.

Chip Information

TRANSISTOR COUNT: 2500

PROCESS: BiCMOS

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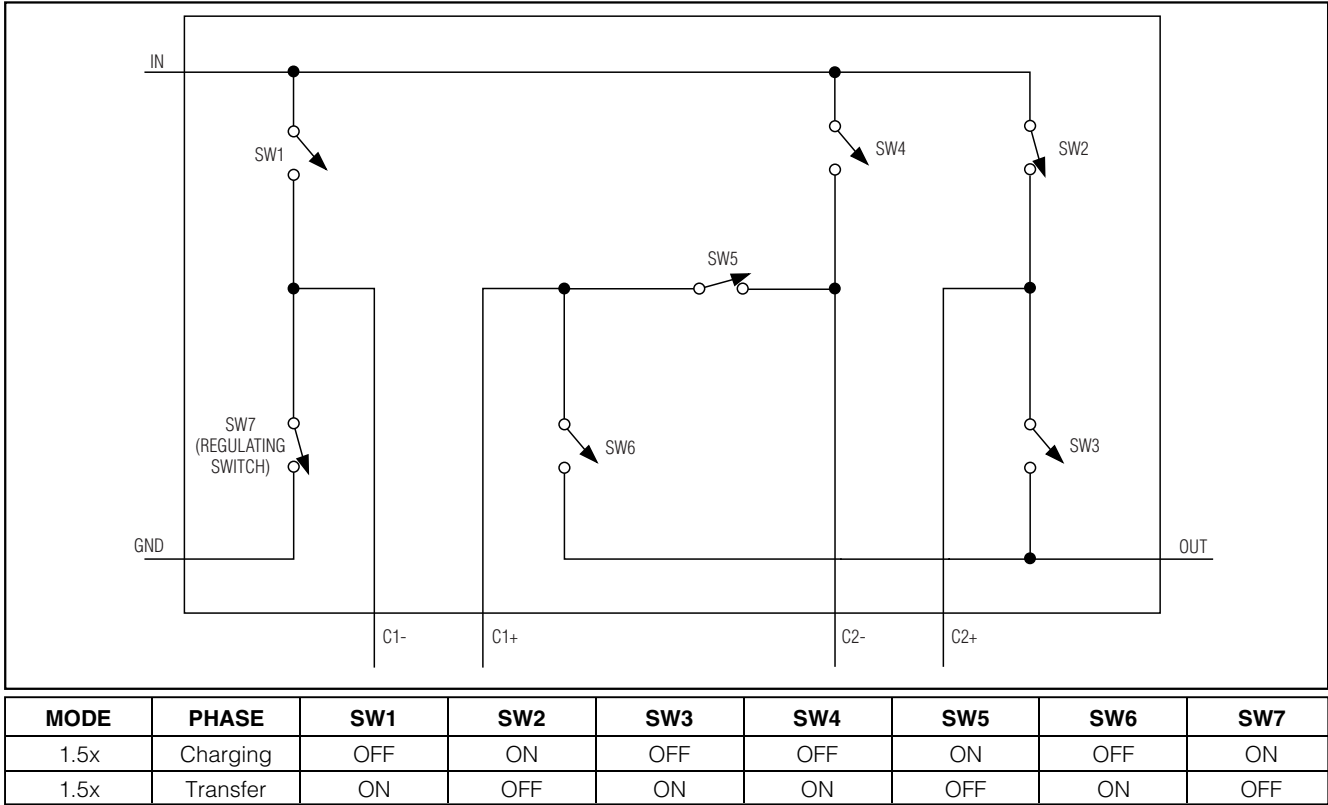


Figure 1. Functional Charge-Pump Switch Diagram (Switches Shown for Charging Phase)

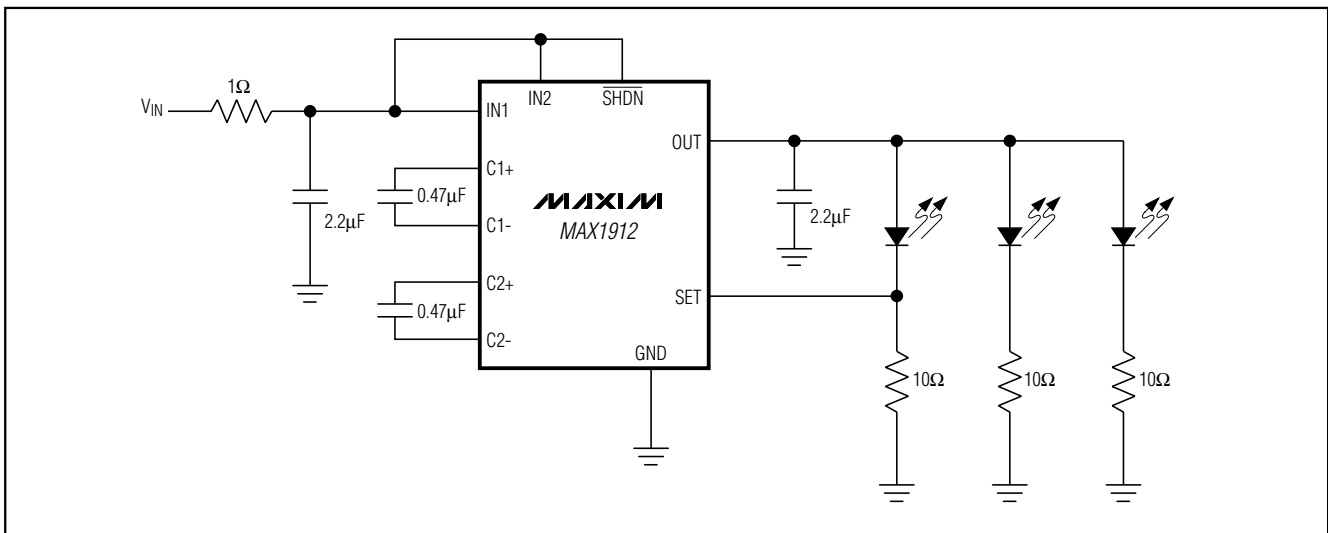


Figure 2. LED Biasing with the MAX1912

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MAX1912/MAX1913

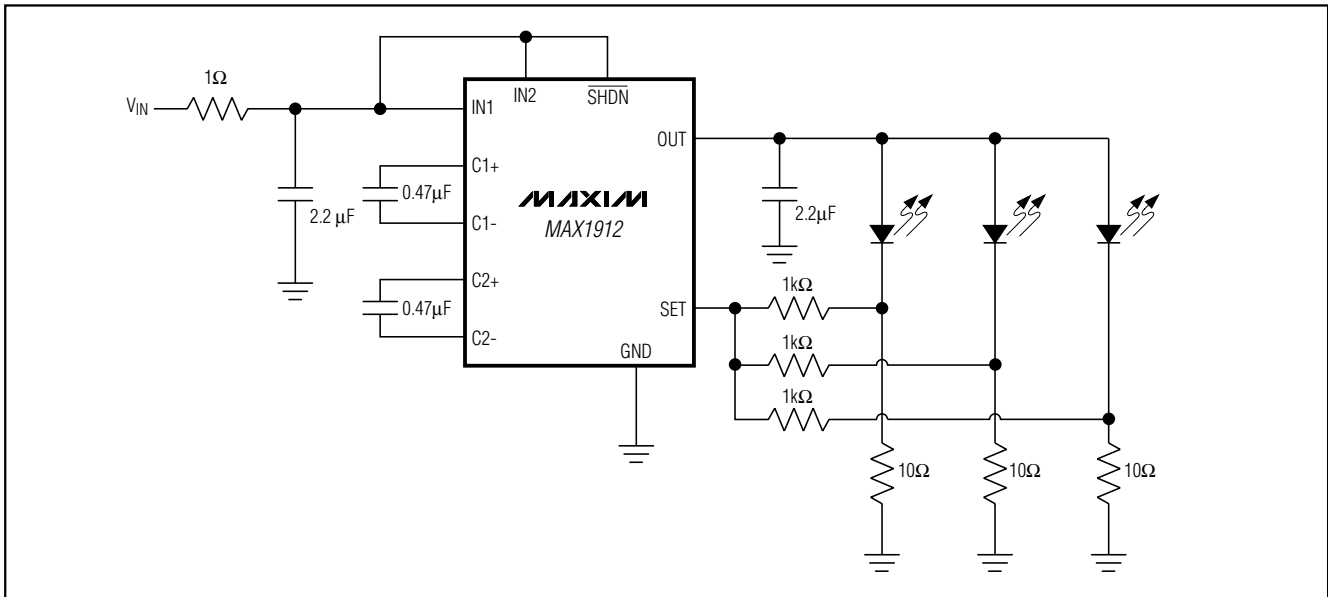


Figure 3. The MAX1912 Regulating Average Current Through LEDs

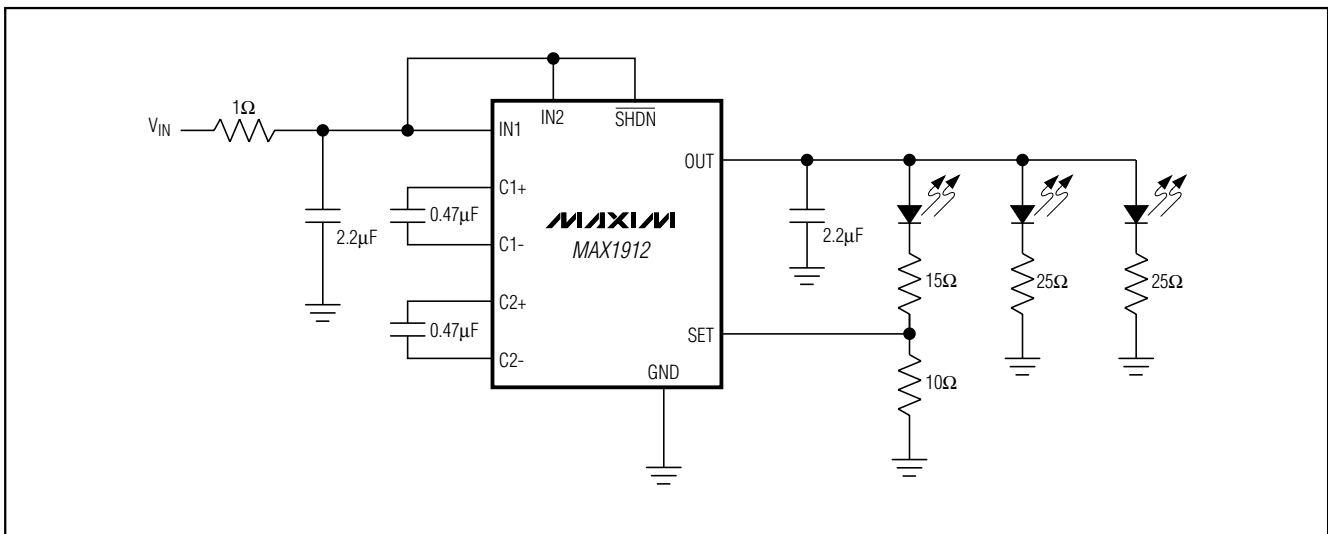


Figure 4. Alternate Method of Biasing to Improve LED-to-LED Matching

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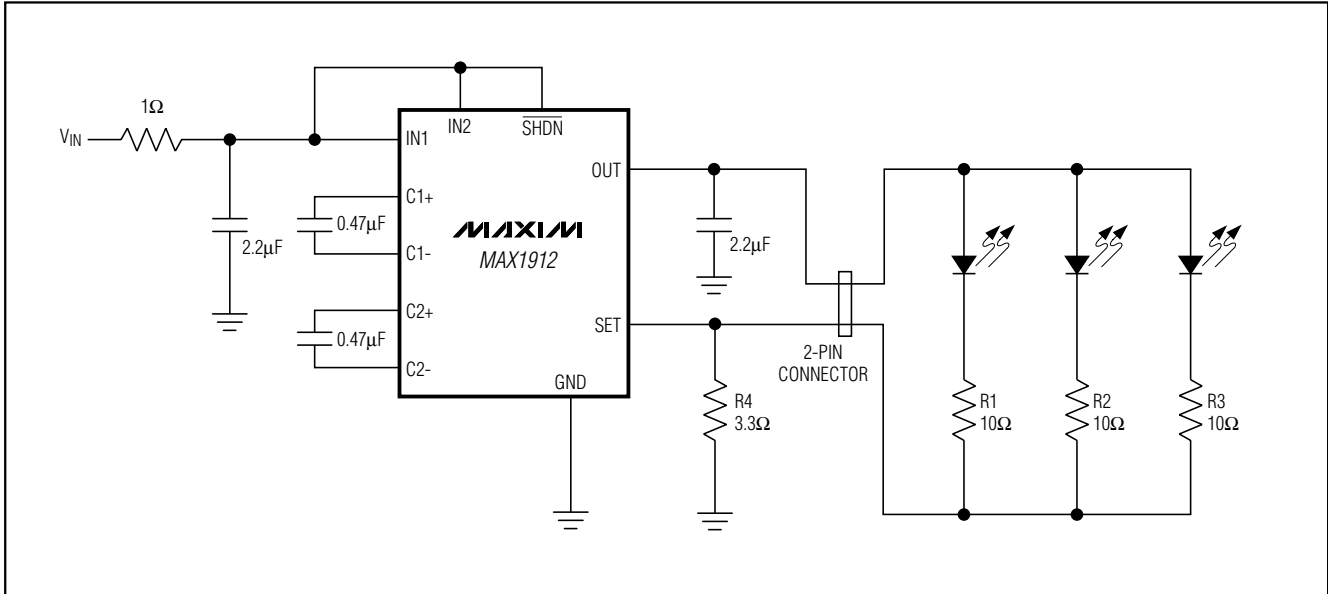


Figure 5. Alternate Method of Biasing LEDs Controls Total Current; Suitable When the LED Array Must Be Biased with Only Two Connections

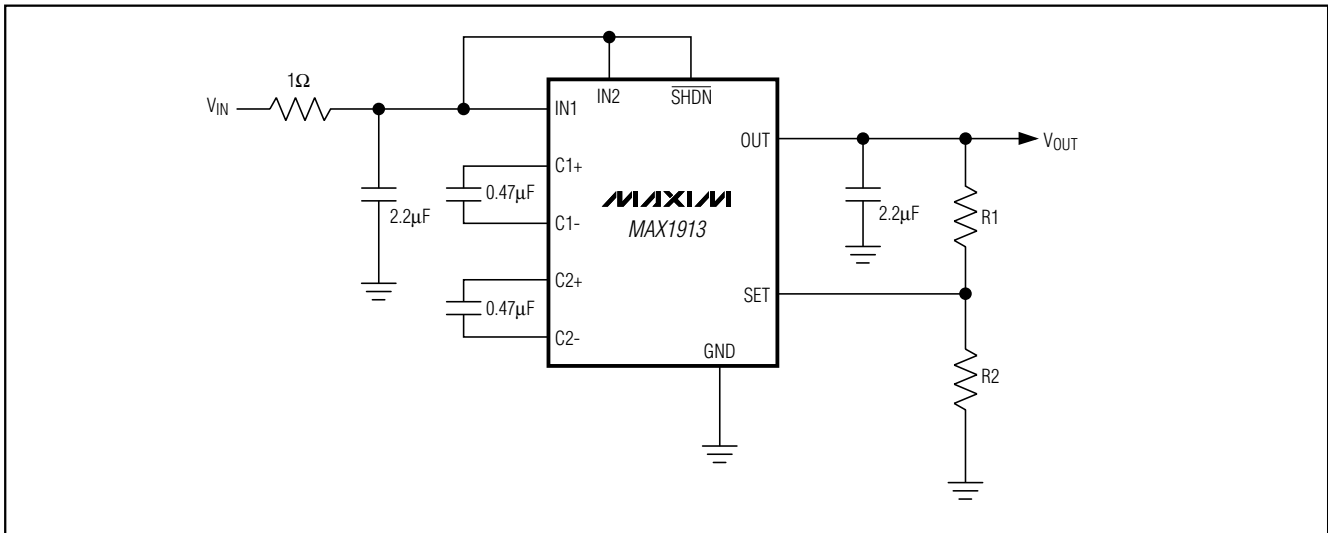


Figure 6. Output Voltage Set with a Resistor-Divider

60mA 1.5x High-Efficiency White LED Charge Pumps

MAX1912/MAX1913

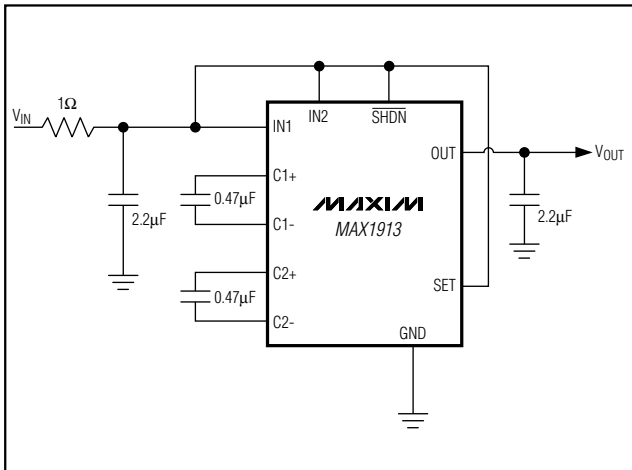


Figure 7. Output Voltage Internally Set to 5V

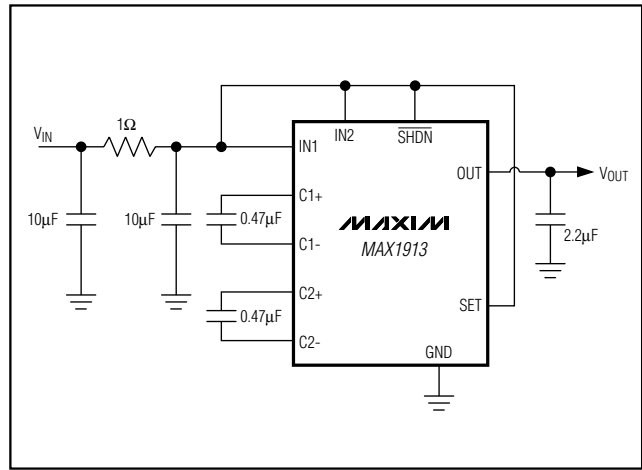


Figure 8. C-R-C Filter Reduces Ripple On the Input

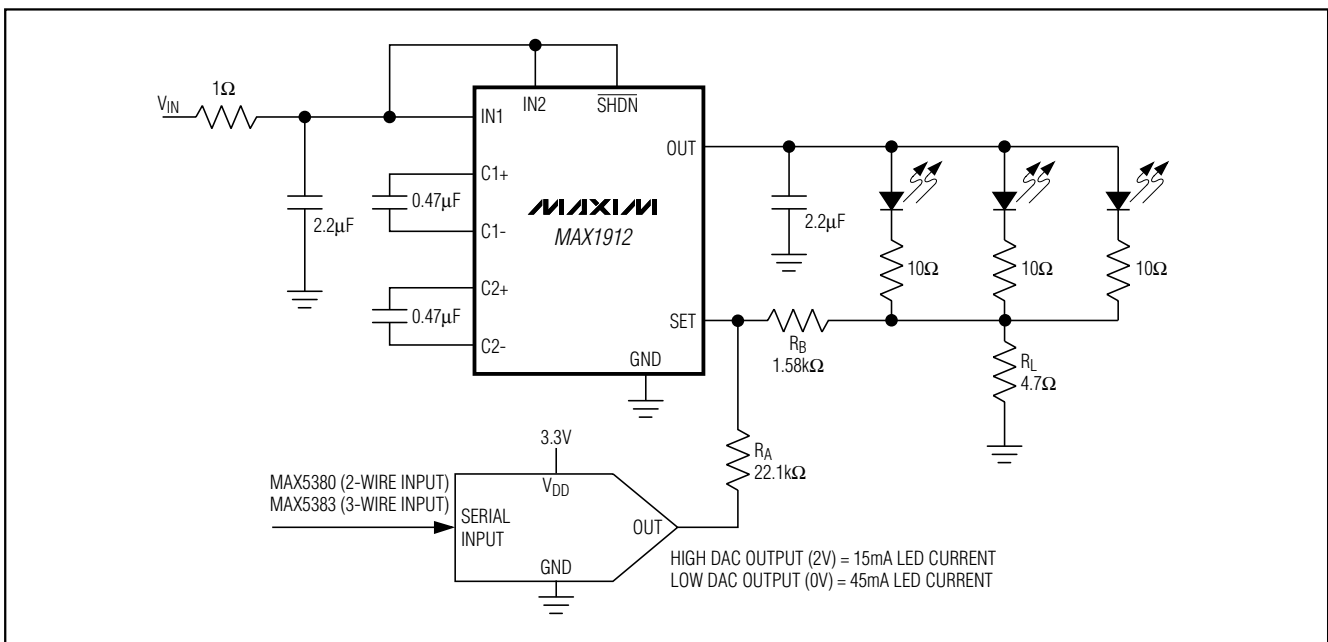


Figure 9. Circuit with SOT DAC for Intensity Control

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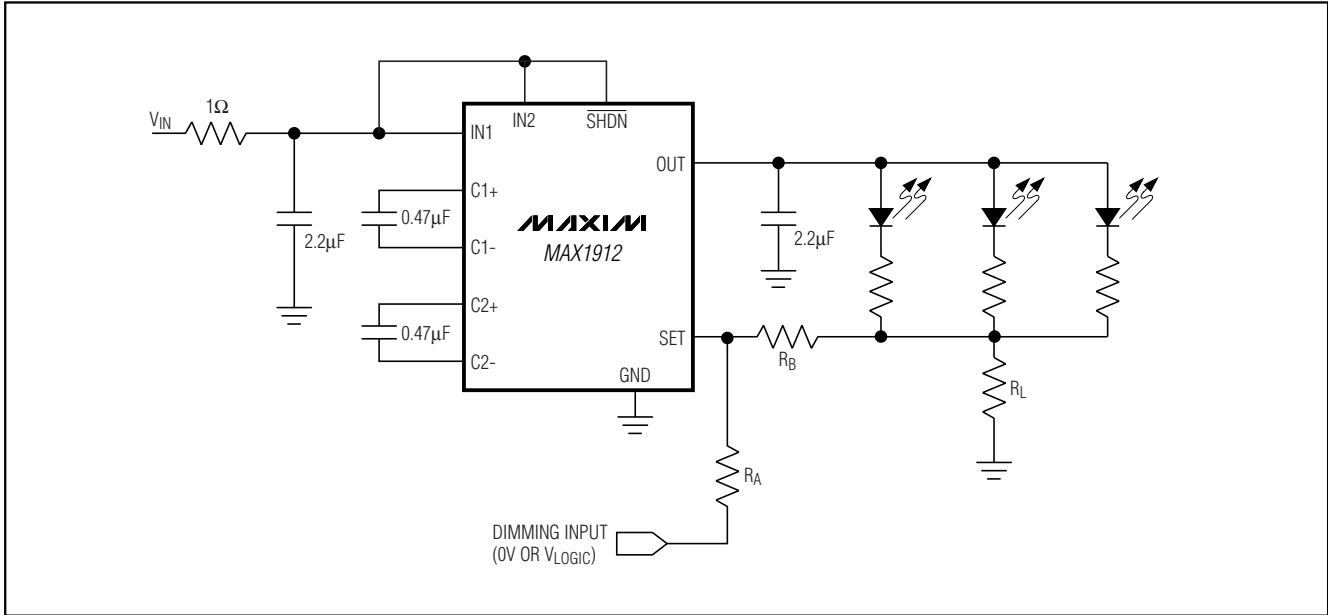
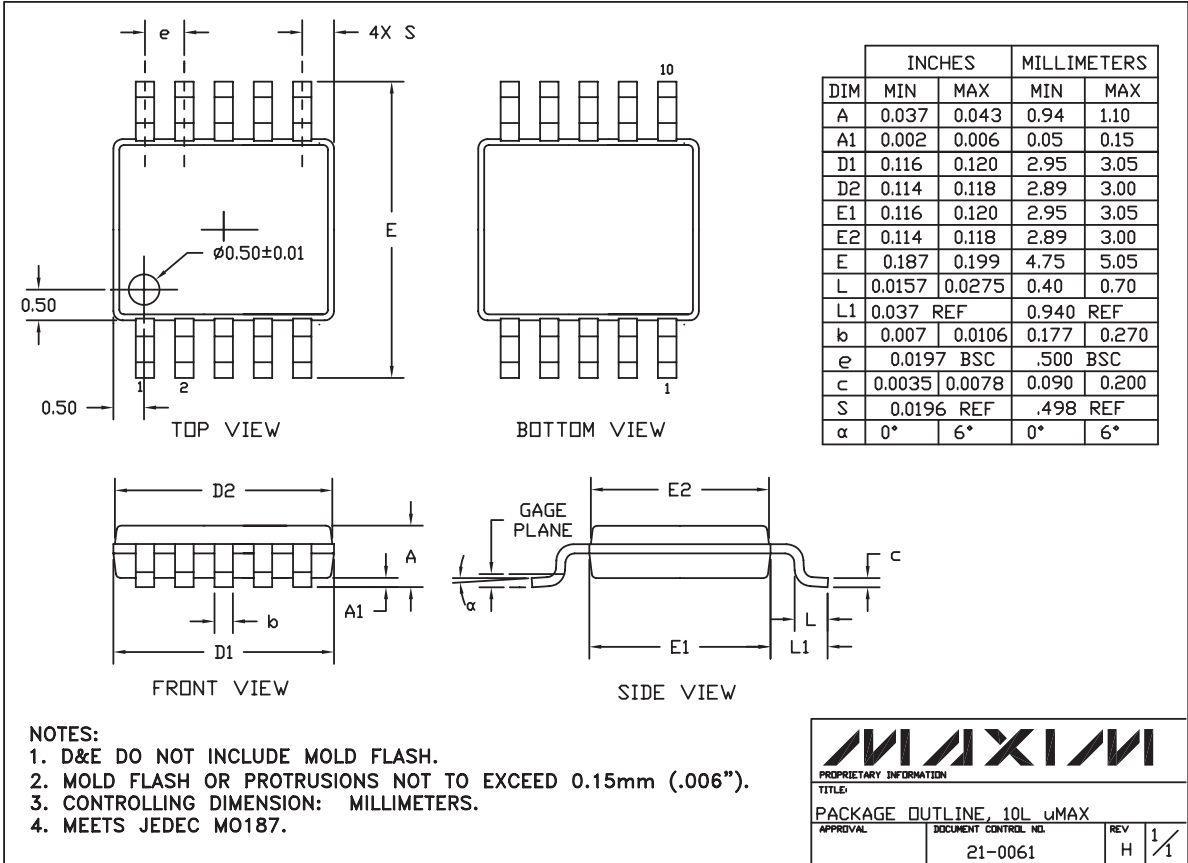


Figure 10. Using Digital Logic Input for Intensity Control

60mA 1.5x High-Efficiency White LED Charge Pumps

Package Information

MAX1912/MAX1913



10LUMAX.EPS

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