Charge Pump White LED Driver

Features

- 3.0V to 6.5V input voltage range
- Two mode operation; 1x and 1.5x
- Fixed 4.5V output with initial accuracy of ± 2%
- Supports 150mA (@4V) continuous output current
- High efficiency at both high and low input voltages
- Low external parts count, requires no inductor
- PWM brightness control via the ENA pin
- 650 kHz switching frequency
- Low shutdown current of <1µA
- Soft start prevents excessive inrush current
- Over temperature and over current protection
- Low output ripple (<1%), low EMI
- Input protection provides superior ESD rating, requiring only standard handling precautions
- TDFN-8 or MSOP-8 package
- Optional RoHS compliant lead free packageing

Applications

- Drive white LEDs to backlight color LCDs
- Drive white or RGB LEDs for camera flash
- Cellular phones
- MP3 players
- PDAs, GPS

Product Description

The CM9153 is an efficient 1.5x switched capacitor (charge pump) regulator ideal for white LED applications. It has a regulated 4.5V, 120mA output, capable of driving up to six parallel white LEDs. With a typical operating input voltage range from 3.0V to 6.0V, the CM9153 can be operated from a single cell Li-Ion battery.

It features an efficient, 1.5x charge pump circuit that uses only two 1.0µF ceramic bucket capacitors and two small capacitors for VIN and VOUT. The LED brightness can be adjusted by applying a PWM signal on the ENA pin.

The CM9153 output voltage is regulated to 4.5V, ± 5% over the line and load ranges. Up 150mA of output current is available. A proprietary design architecture (patent pending) maintains high efficiency (> 80%), at both below 3.2 V_{IN}, resulting in longer battery life, and above 5.25 V_{IN}, when an adapter is plugged in, keeping the part cool. It offers low output voltage ripple, typically less than 50mV. Internal over-temperature and over-current management provide short circuit protection.

The CM9153 is packaged in either a space-saving 8-lead TDFN or 8-lead MSOP package. It can operate over the industrial temperature range of –25°C to 85°C.

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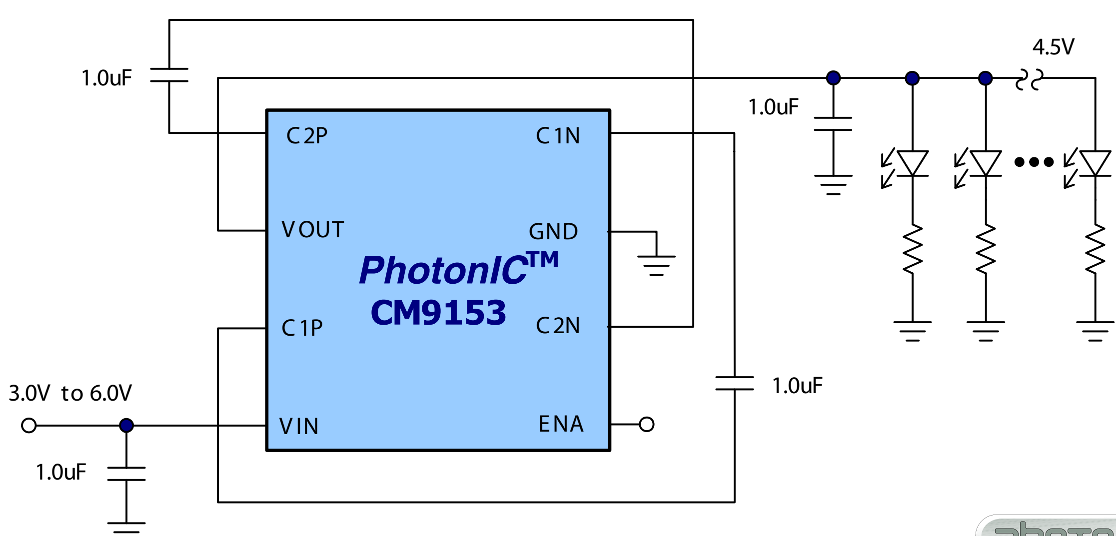
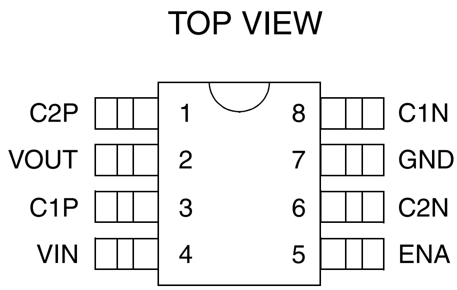
Typical Application

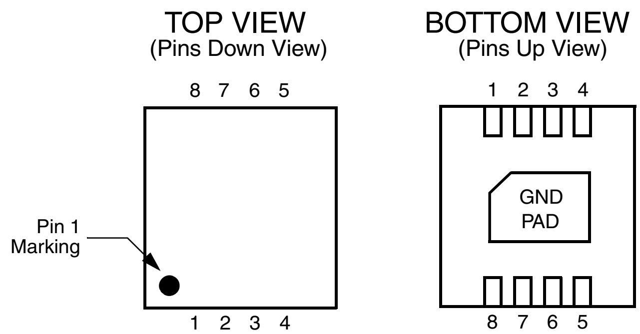


Package Pinout

PACKAGE / PINOUT DIAGRAM



CM9153-01MR
8 Lead MSOP Package



CM9153-01DE
8 Lead TDFN Package

Note: This drawing is not to scale.

Ordering Information

PART NUMBERING INFORMATION

Leads	Package	Lead-free Finish	
		Ordering Part Number[1]	Part Marking
8	TDFN	CM9153-01DE	
8	MSOP	CM9153-01MR	

Note 1: Parts are shipped in Tape & Reel form unless otherwise specified.

Specifications

ABSOLUTE MAXIMUM RATINGS

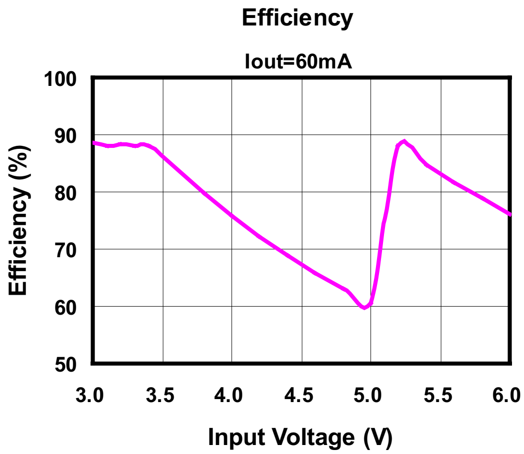
PARAMETER	RATING	UNITS
ESD Protection (HBM)	± 2	kV
VIN to GND	[GND - 0.3] to +6.5	V
Pin Voltages V_{OUT} to GND C1P, C1N to GND C2P, C2N to GND	 [GND - 0.3] to +6.0 [GND - 0.3] to +4.5 [GND - 0.3] to +4.5	 V V V
Storage Temperature Range	-65 to +150	°C
Operating Temperature Range	-40 to +85	°C
Lead Temperature (Soldering, 10s)	300	°C

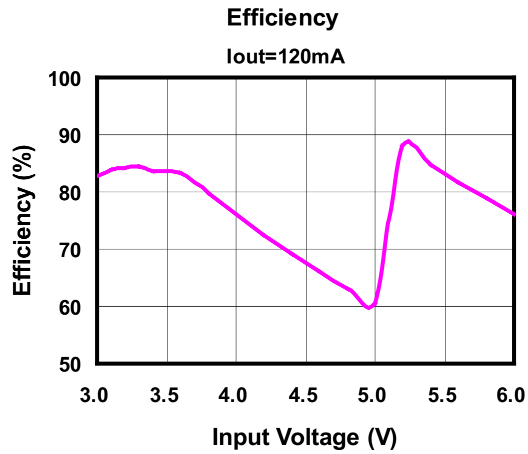
Specifications (cont'd)

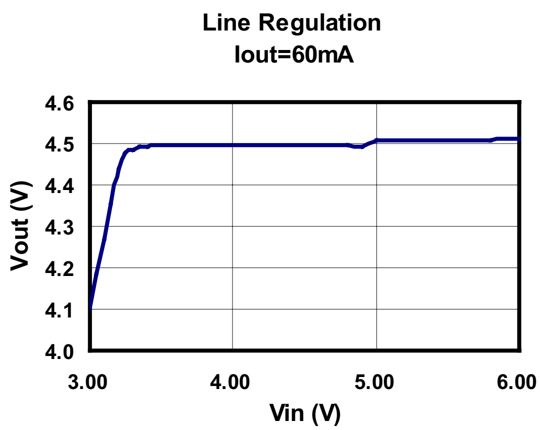
ELECTRICAL OPERATING CHARACTERISTICS						
SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	VIN Supply Voltage		3.0		6.0	V
I_{SD}	Shut-Down Supply Current	ENA = 0		1		µA
I_Q	Quiescent Current			1600	2500	µA
charge pump Circuit						
$V_{R\ LOAD}$	Load Regulation	Fs = 650 kHz, Iout = 0 mA to 120 mA, Vin = 3.2V to 6.5V Iout = 0 mA to 90 mA, Vin = 3.0V to 3.2V	4.2 4.0	4.5 4.1	4.7 4.2	V V
$V_{R\ LIN}$	Line Regulation	Iout = 60 mA, Vin = 3.2V to 6.5V Vin = 3.0V to 3.2V	4.4 4.0	4.5 4.1	4.6 4.3	V V
I_{OUT}	Output Current	Vout = 4.5V Vout = 4.0V			120 150	mA mA
V_{OUTR}	Output Ripple Voltage	Iout = 60 mA		50		mV
fs	Switching Frequency			650		kHz
CLK						
	High Level Input Voltage		1.2			V
	Low Level Input Voltage				0.6	V
ENA						
V_{IH}	High Level Input Voltage		1.3			V
V_{IL}	Low Level Input Voltage				0.4	V
Protection						
I_{LIM}	Over-current Limit			400	600	mA
T_{JSD}	Over-temperature Limit			135		°C
T_{HYS}	Over-temperature Hysteresis			15		°C

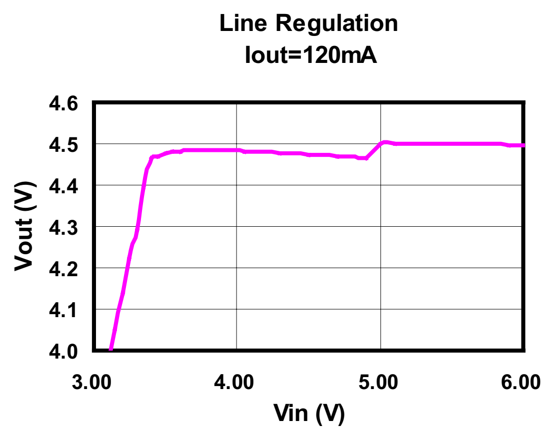
Typical Performance Curves

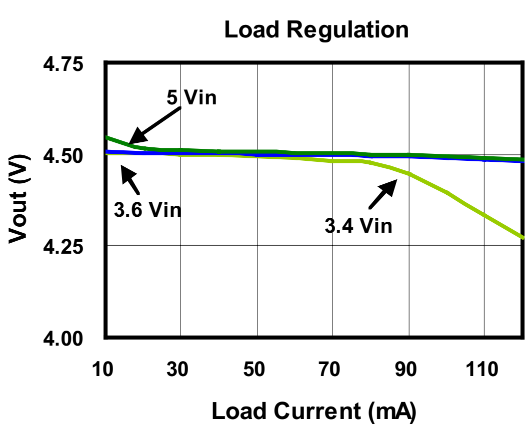
$C_{IN}=C_{OUT}=C1=C2=1.0\mu F$, $T_A=25$ °C, unless specified

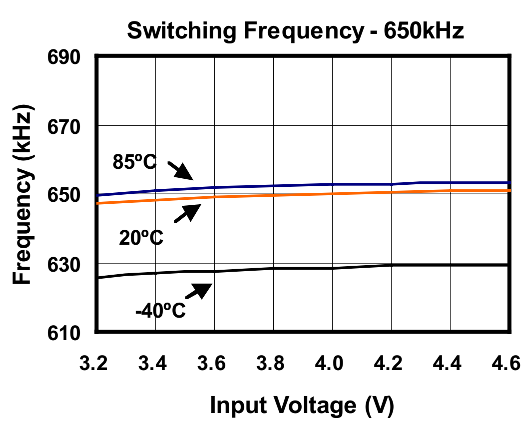






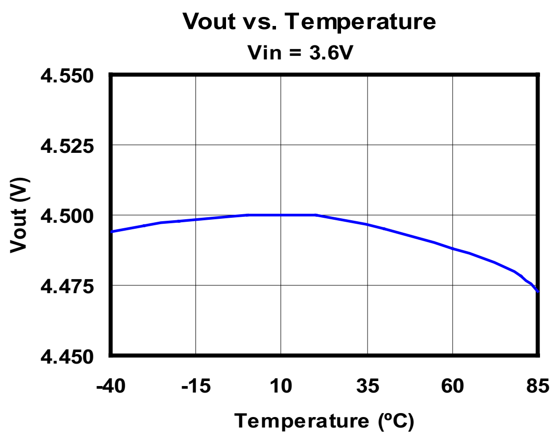


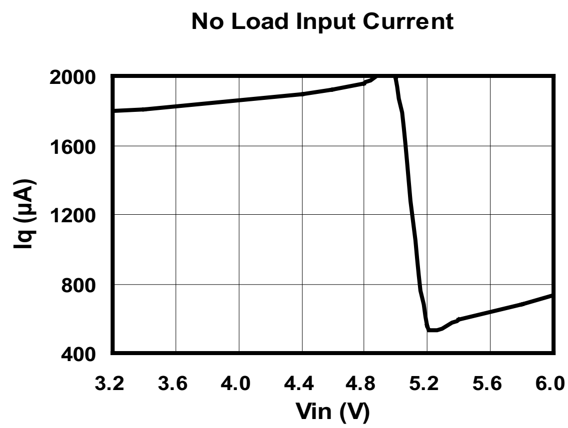


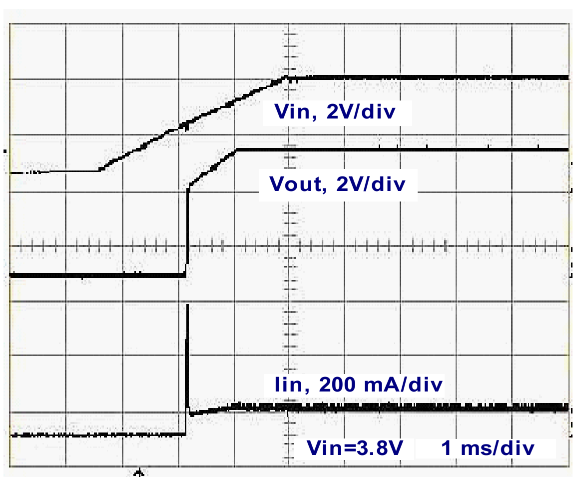


Typical Performance Curves (cont'd)

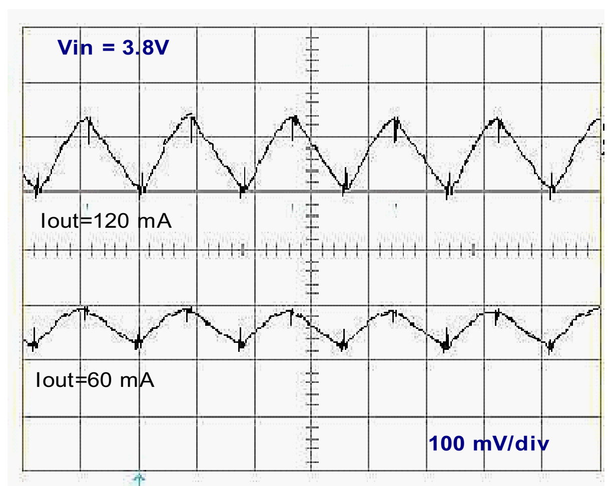
$C_{IN}=C_{OUT}=C1=C2=1.0\mu F$, $T_A=25°C$, unless specified





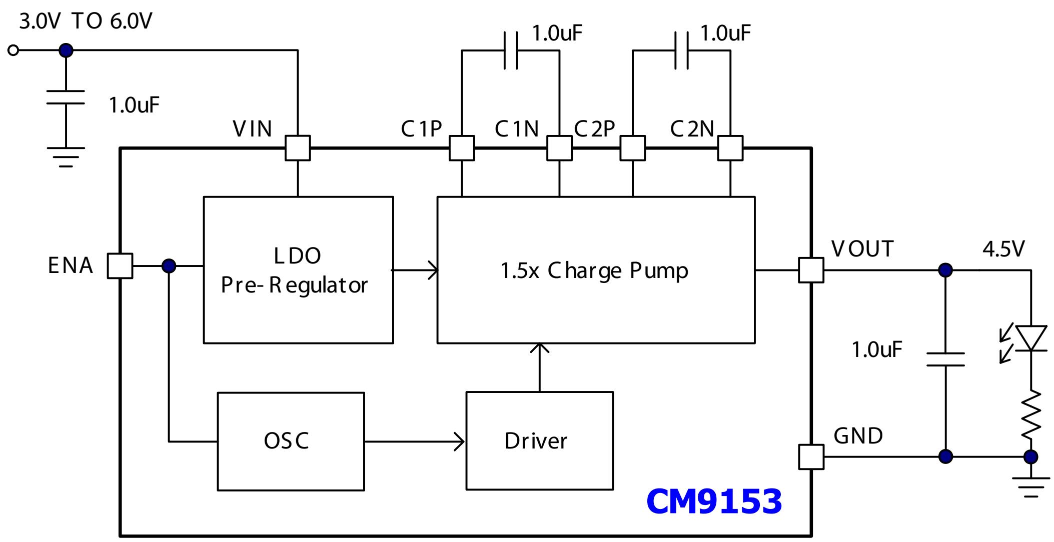


Startup



Output Ripple

Functional Block Diagram



Pin Descriptions

PIN DESCRIPTIONS		
LEAD(s)	**NAME**	**DESCRIPTION**
1	C2P	This pin is the plus side of charge pump bucket capacitor C2. Connect a 1.0μF ceramic capacitor between C2N and C2P.
2	VOUT	The regulated 4.5V output voltage pin. This pin requires a 1.0μF or larger ceramic capacitor to ground. This pin connects to the anodes of the LEDs.
3	C1P	This pin is the plus side of charge pump bucket capacitor C1. Connect a 1.0μF ceramic capacitor with a voltage rating of 10 V or greater between C1N and C1P.
4	VIN	Positive supply voltage input pin. This voltage should be between 3.0V and 6V. This pin requires a 1.0μF or larger ceramic capacitor to ground.
5	ENA	Enable pin, active high. By applying a PWM signal to this pin, the LED brightness can be controlled.
6	C2N	This pin is the minus side of charge pump bucket capacitor C2. Connect a 1.0μF ceramic capacitor between C2N and C2P.
7	GND	Ground pin.
8	C1N	This pin is the minus side of charge pump bucket capacitor C1. Connect a 1.0μF ceramic capacitor between C1N and C1P.

Application Information

The CM9153 is a switched capacitor, charge pump voltage converter ideally suited for driving white LEDs to backlight or sidelight LCD color displays for portable devices, such as cellular phones, PDAs, and any application where small space and efficiency are critical. The CM9153 charge pump is the perfect driver for such portable applications by providing efficiency, compact overall size, low system cost and minimal EMI.

The CM9153 contains a linear low dropout (LDO) regulator followed by a 1.5x fractional charge pump that converts the nominal lithium-ion (Li-Ion) or lithium polymer battery voltage levels (3.6V) by a gain of 1.5 and regulates the converted voltage to 4.5V, ± 5%, enough to drive the forward voltage drop of white LEDs. The CM9153 requires only two external switched, or bucket, capacitors, plus an input and an output capacitor resulting in a compact, low profile design. In many applications, all these can conveniently be the same value, 1.0µF, commonly available in a compact 0805 surface mount package.

The CM9153 is intended for white LED applications, but it can drive most all types of LEDs with a forward voltage drop of less than 4V.

The LED current is determined by its series resistor, R_{LED}, and is approximately:

$$I_{LED} = \frac{4.5V - V_{FWD\_LED}}{R_{LED}}$$

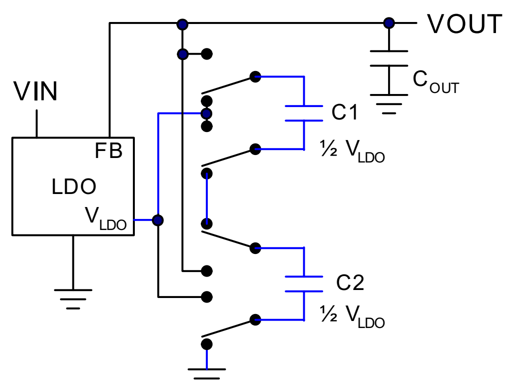
Typical white LEDs have a forward voltage drop, V_{FWD_LED}, of 3.5V to 3.7V. Like all single junction devices, white LEDs often have poorly matched forward voltages. If the LEDs were put in parallel without a series resistor, the current in the paralleled branches would vary, resulting in non-uniform brightness. R_{LED}, in addition to setting the current, compensates for this variation by functioning as a ballast resistor, providing negative feedback for each paralleled LED.

CM9153 Operation

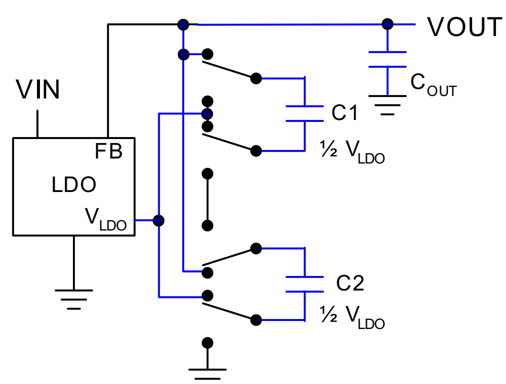
When a voltage exceeding the undervoltage lockout threshold (UVLO) is applied to the VIN pin, the CM9153 initiates a softstart cycle, typically lasting 100µS. Softstart limits the inrush current while the output capacitors are charged during the power-up of the device.

The input voltage, VIN, passes through an LDO preregulator that compares the output voltage to a precision bandgap reference. After the LDO, the charge pump boosts the LDO voltage by 1.5 times. A feedback circuit to the LDO monitors the output voltage, and when the output voltage reaches 4.5V, the LDO output will operate at about 3V, regulating the device output at 1.5 x 3V = 4.5V.

The charge pump uses two phases from the oscillator to drive internal switches that are connected to the bucket capacitors, C1 and C2, as shown in Figure 1. In the first switch position, the bucket capacitors are connected in series and each are charged from the LDO to a voltage of $V_{LDO}/2$. The next phase changes the switch positions so that C1 and C2 are put in parallel, and places them on top of V_{LDO}. The resulting voltage across C_{OUT} is then; $V_{LDO}+1/2V_{LDO} = 1.5 \times V_{LDO}$.



Charge C1 and C2 to ½ V_{LDO}



Transfer ½ V_{LDO} charge to top of V_{LDO}

Figure 1. Switch Operation

Application Information (cont'd)

When the input voltage is greater than the output voltage, the CM9153 senses this condition and if the input voltage rises above 5V, the charge pump automatically disables, removing the voltage gain stage and the output is then provided directly through the LDO, regulated at 4.5V. This increases the efficiency and minimizes chip heating in this operating condition.

The CM9153 has over temperature and over current protection circuitry to limit device stress and failure during short circuit conditions. An overcurrent condition will limit the output current (approximately 400 mA ~ 600 mA) and will cause the output voltage to drop, until automatically resetting after removal of the excessive current. Over-temperature protection disables the IC when the junction is about 135 °C, and automatically turns on the IC when the junction temperature drops by approximately 15 °C.

Efficiency

A conventional charge pump with a fixed gain of 2x will usually develop more voltage than is needed to drive paralleled white LEDs from Li-Ion sources. This excessive gain develops a higher internal voltage, reducing system efficiency and increasing battery drain in portable devices. A fractional charge pump with a gain of 1.5x is better suited for driving white LEDs in these applications.

The CM9153 charge pump automatically switches between 2 conversion gains, 1x and 1.5x, allowing high efficiency levels over a wide operating input voltage range. The 1x mode allows the regulated LDO voltage to pass directly through to the output when sufficient input voltage is available whereas the 1.5x charge pump is enabled only when the battery input is too low to sustain the output load.

At nominal loads, the switching losses and quiescent current are negligible. If these losses are ignored for simplicity, the efficiency, η, for an ideal 1.5x charge pump can be expressed as the output power divided by the input power:

$$\eta \approx \frac{P_{OUT}}{P_{IN}}$$

For an ideal 1.5x charge pump, I_{IN} 1.5 x I_{OUT}, and the efficiency may be expressed as:

$$\frac{P_{OUT}}{P_{IN}} \approx \left(\frac{V_{OUT} \times I_{OUT}}{V_{IN} \times 1.5 \times I_{OUT}}\right) = \frac{V_{OUT}}{1.5 \times V_{IN}}$$

$$V_{OUT} = 4.5V, \qquad \therefore \ \eta \approx \frac{4.5V}{1.5 \times V_{IN}}$$

The ideal 2x charge pump can be similarly expressed:

$$\frac{P_{OUT}}{P_{IN}} \approx \frac{4.5V}{2.0 \times V_{IN}}$$

In 1x mode, when the input voltage is above the output voltage, the part functions as a linear regulator and the ideal efficiency is simply V_{OUT}/V_{IN}.

The typical conversion efficiency plots for these modes, with some losses, are shown in Figure 2.

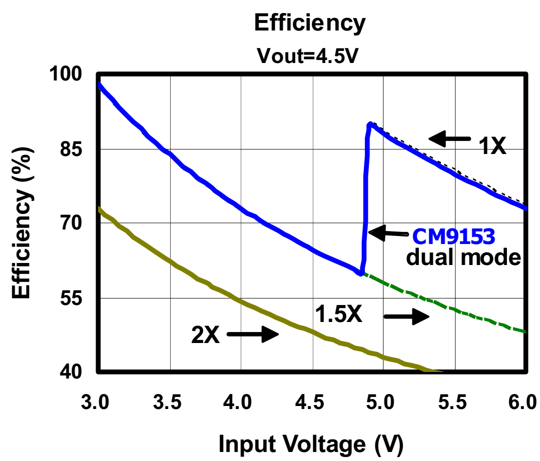


Figure 2. Ideal efficiency curves

As can be seen, the CM9153, with 1x and 1.5x modes, has better efficiency in this application than a fixed 2x charge pump. At low battery voltages, the higher efficiency of the charge pump's 1.5x gain reduces battery drain. At higher input voltages, above 4.9V typically seen when the system is running off an AC adapter, the CM9153, operating in the 1x mode, has better efficiency than single mode 1.5x or 2x charge pumps, lowering the power dissipation for cooler circuit operation and long life.

Application Information (cont'd)

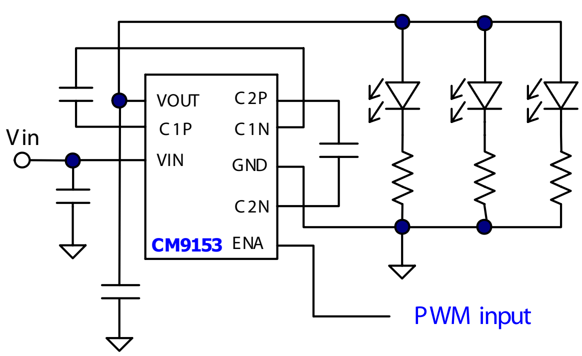
CM9153 Design Examples

Capacitor Selection

The external bucket capacitors will affect the output impedance of the converter, so surface mount, low ESR ceramic capacitors are recommended. Tantalum and Aluminum capacitors should not be used because their ESR is too high. The ceramic dielectric must be stable over the operating temperature and voltage range. As a result, X7R or X5R type dielectric is recommended. In noise sensitive applications, output ripple can be further reduced by increasing the capacitance of the output capacitor. Reflected input ripple current depends on the impedance of the VIN source, which includes the PCB traces. Increasing the input capacitor will reduce this ripple. The input capacitor also affects the output voltage ripple. All the capacitors should be located close to the device for best performance.

LED Brightness Control

Changes in ambient light often require the backlight display intensity to be adjusted, usually to conserve battery life. There are simple solutions to lowering the LED brightness when using the CM9153.



PWM Brightness Control, Lowered Quiescent Current

A PWM signal can be used to control the brightness, which is more efficient than other solutions that dissipate the unwanted LED current in the series resistors. It also maintains the white LED color fidelity by avoiding color temperature variations that come with bias current changes. The LED intensity is determined by the PWM duty cycle, which can vary from 0% to 100%.

In the configuration shown in Figure , the brightness is controlled by the PWM signal applied to ENA. Decreased Duty Cycle will lower the LED brightness, See Figure 3 and Figure 4.

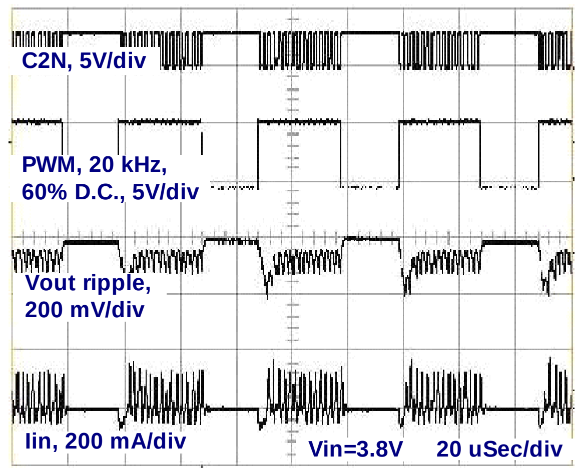


Figure 3. High Brightness Waveforms

The recommended PWM frequency is between 100 Hz and 20 kHz. If a frequency of less then 100 Hz is used, flicker might be seen in the LEDs. The frequency should also be greater than the refresh rate of the TFT display. Higher frequencies will cause a loss of brightness control linearity. In addition, higher frequency can cause chromaticity shifts because the fixed rise and fall times of the PWM signal will shift the forward current.

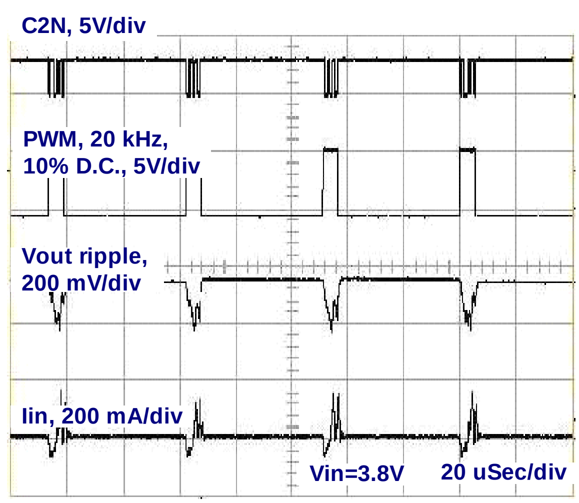


Figure 4. Low Brightness Waveforms

Application Information (cont'd)

Camera Flash Application

Many smart phones and PDAs include a digital camera. These compact cameras typically utilize a white LED flash to illuminate the picture subject in low light conditions. The CM9153 is easily adapted to such an application. Figure 6 is a typical application using the CM9153 as a white LED flash driver, which is ideal for this application because it is capable of driving up to 120 mA continuous current, or 200mA of pulse current, from a Li-ion battery. The One-shot is used to create a single pulse of a set duration to the ENA pin of the CM9153.

The Flash LED modules shown here contain three matched white LEDs with a common anode and separated cathodes. The series resistor is chosen based on the forward drop of the module LEDs (typically 3.3V to 3.6V at the peak pulse current) and the number of parallel modules being driven.

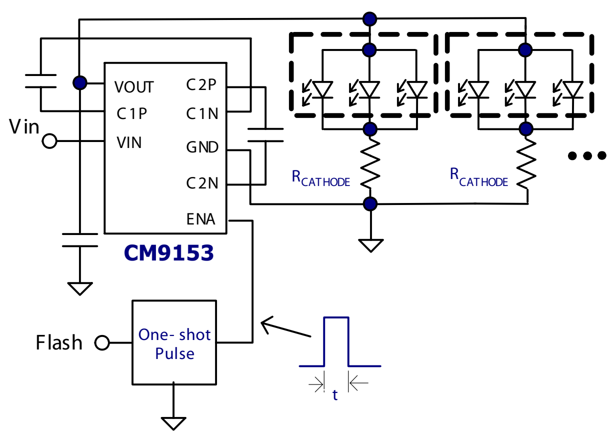


Figure 6, Camera Flash Application

Layout Guide

The charge pump is rapidly charging and discharging its external capacitors, so external traces to the capacitors should be made as wide and short as allowable to minimize inductance and high frequency ringing. The four capacitors should be located as close as practical to the charge pump, particularly C1 and C2, which have the highest dv/dt. Connect ground and power traces to the capacitors through short, low impedance paths. Use a solid ground plane, ideally on the backside of the PCB, which it should carry only ground potential. Connect the ground side of C_{IN}, C_{OUT} and the chip GND as close as practical. For best thermal performance, the exposed backside lead frame should be soldered to the PCB.

Mechanical Details

TDFN-08 Mechanical Specifications

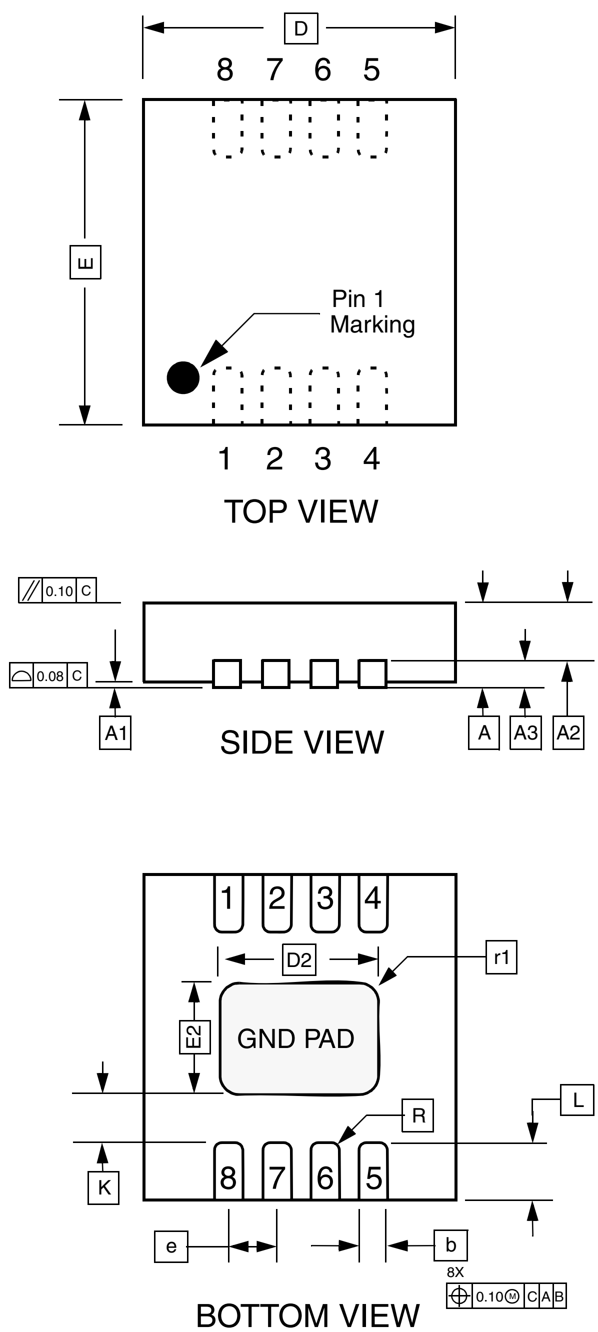
The CM9153 is supplied in an 8-lead TDFN package. Dimensions are presented below.

For complete information on the TDFN-08, see the California Micro Devices TDFN Package Information document.

PACKAGE DIMENSIONS						
Package	TDFN					
JEDEC No.	MO-229 (Var. VCCD-3)⁼					
Leads	8					
Dim.	**Millimeters**			**Inches**		
	Min	**Nom**	**Max**	**Min**	**Nom**	**Max**
A	0.70	0.75	0.80	0.028	0.030	0.031
A1	0.00	0.02	0.05	0.000	0.001	0.002
A2	0.55	0.65	0.80	0.022	0.026	0.031
A3		0.20			0.008	
b	0.18	0.25	0.30	0.007	0.010	0.012
D		2.00			0.079	
D2	0.88	0.98	1.08	0.035	0.039	0.043
E		2.00			0.079	
E2	0.46	0.56	0.66	0.018	0.022	0.026
e		0.50			0.020	
K	0.20			0.008		
L	0.20	0.30	0.45	0.008	0.012	0.018
L2			0.13			0.005
R		0.075			0.003	
r1		0.075			0.003	
# per tube	NA					
# per tape and reel	3000 pieces					
Controlling dimension: millimeters						

⁼This package is compliant with JEDEC standard MO-229, variation VCCD-3 with exception of the "D2" and "E2" dimensions as called out in the table above and the "r1" dimension which is not specified in the MO-229 standard.

Mechanical Package Diagrams



Package Dimensions for 8-Lead TDFN

Mechanical Details (cont'd)

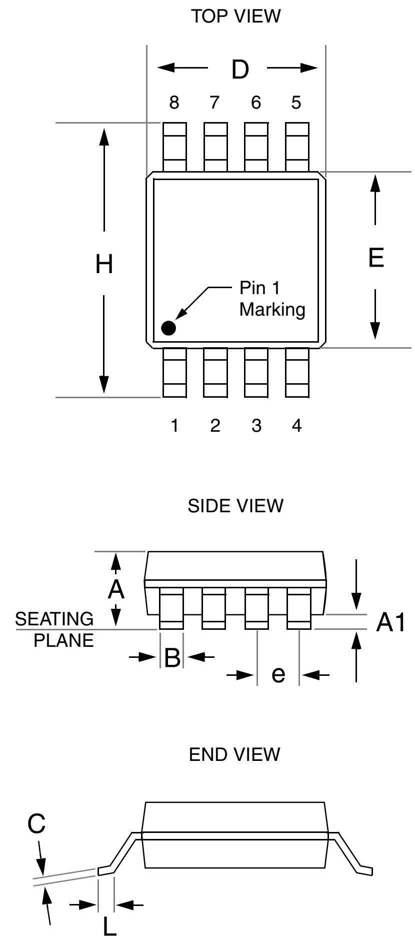
MSOP-8 Mechanical Specifications:

The CM9153-01MR is supplied in a 8-pin MSOP package. Dimensions are presented below.

For complete information on the MSOP-8, see the California Micro Devices MSOP Package Information document.

PACKAGE DIMENSIONS				
Package	MSOP			
Pins	8			
Dimensions	**Millimeters**		**Inches**	
	Min	**Max**	**Min**	**Max**
A	0.87	1.17	0.034	0.046
A1	0.05	0.25	0.002	0.010
B	0.30 (typ)		0.012 (typ)	
C	0.18		0.007	
D	2.90	3.10	0.114	0.122
E	2.90	3.10	0.114	0.122
e	0.65 BSC		0.025 BSC	
H	4.90 BSC		0.193 BSC	
L	0.43	0.64	0.017	0.025
# per tape and reel	4000 pieces			
Controlling dimension: inches				

Mechanical Package Diagrams



Package Dimensions for MSOP-8