DESCRIPTION

The A8440 is a complete backlight display solution that is designed to independently control LEDs. The A8440 is a charge pump WLED driver capable of driving up to 4 LEDs with 30mA each LED. Its four tightly regulated current sources ensure excellent LED current and brightness matching. LED driver current is programmed by an external resistor.

The A8440 operates over an input voltage range from 3V to 5.5V, optimized for WLED applications powered by Li-Ion battery, requiring only for low cost ceramic capacitors.

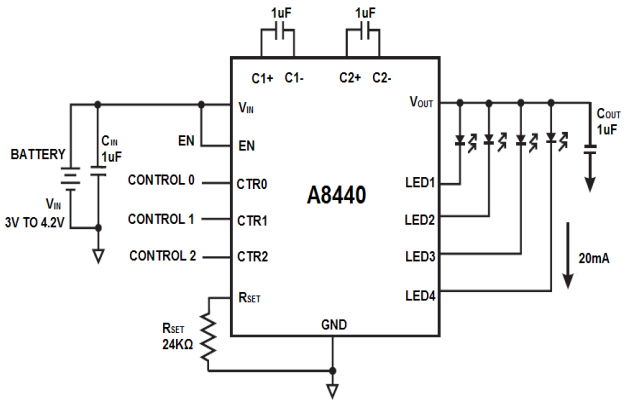
The A8440 provides excellent efficiency by operating the charge pump in a gain of 1 or 1.5. Maximum efficiency is achieved over Li-Ion battery voltage range by selecting the proper gain based on the LED forward voltage requirements.

The A8440 has a fixed 1MHz switching frequency, consuming less than 1uA of supply current when shutdown.

The A8440 LED dimming can be accomplished by several methods including using a DC voltage to set the R_{SET} pin current, applying a PW signal on the control signals, or adding a switched resistor in parallel with R_{SET}. The enable input pin allows the A8440 to be placed in power-down mode.

The A8440 is available in 16pin TQFN (3x3mm) QFN16 (4x4mm) package.

Typical Application



FEATURES

- Individually Current Regulation for Up to 4 LEDs
- Input Voltage Range: 2.7Vto 5.5V
- Wide Current Range, up to 30mA per LED
- 3-bit Digital Output Control
- 3% Maximum Tolerance Current Matching
- 1x and 1.5x mode Operating with Automatic Switchover
- High Available Total LED Current 120mA (4 x 30mA)
- Peak Efficiency : 90%
- Fixed Frequency 1MHz
- Power-Saving Shutdown mode of 1uA
- Open LED Protection
- Soft-Start Over-Current-Protection and Current Limiting
- Available in TQFN-16 (3x3mm) and QFN16 (4x4mm) Package

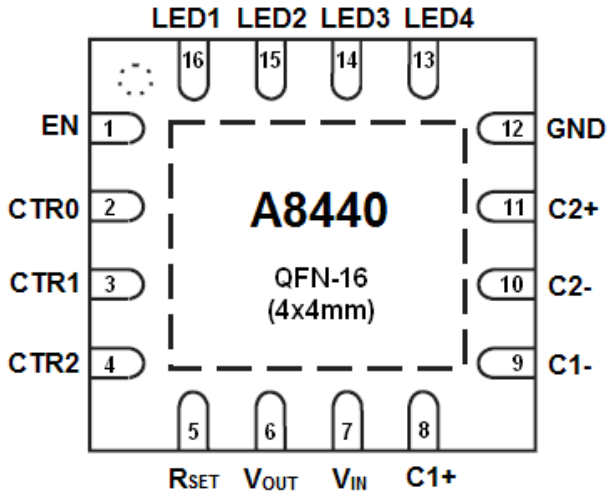
APPLICATION

- Portable Devices, Mobile Phone, DVR, Smart Phone...etc.
- Hand-held Devices, PDA, PMP, MP3, DSC...etc.
- White LED Backlight Application
- LED Modules

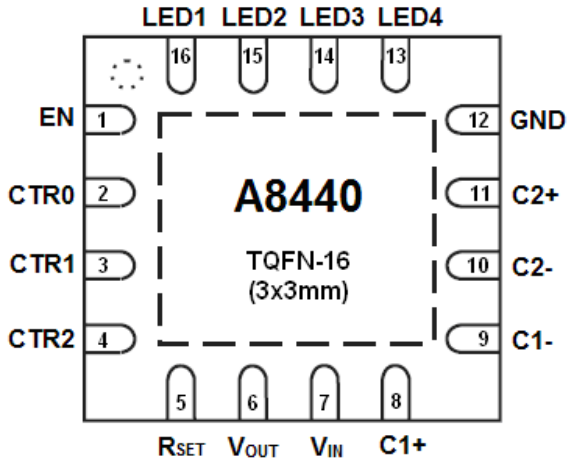
ORDERING INFORMATION

Package Type	Part Number	
TQFN16(3x3mm)	TQ16	A8440TQ16R
		A8440TQ16VR
QFN16 (4x4mm)	Q16	A8440Q16R
		A8440Q16VR
Note	R: Tape & Reel V: Green Package	
AiT provides all Pb free products Suffix " V " means Green Package		

PIN DESCRIPTION



Top View



Top View

Pin #	Pin Name	Function
1	EN	Enable Input Active High
2	CTR0	Digital Control Input 0
3	CTR1	Digital Control Input 1
4	CTR2	Digital Control Input 2
5	R_{SET}	Set LED Output Current by the Current Sourced out of the R_{SET} pin
6	V_{OUT}	Output Pin, Charge Pump output connected to the LED anodes
7	V_{IN}	Input Pin, Supply Voltage
8	C1+	Bucket Capacitor 1 Terminal
9	C1-	Bucket Capacitor 1 Terminal
10	C2-	Bucket Capacitor 2 Terminal
11	C2+	Bucket Capacitor 2 Terminal
12	GND	Ground Pin
13	LED4	LED4 Cathode Terminal
14	LED3	LED3 Cathode Terminal
15	LED2	LED2 Cathode Terminal
16	LED1	LED1 Cathode Terminal

ABSOLUTE MAXIMUM RATINGS

V_{IN}, LEDx, V_{OUT} Voltage	-0.3V ~ 7.0V
EN, CTRx Voltage	-0.3V ~ V_{IN} (V)
R_{SET} Voltage	-0.3V ~ V_{IN} (V)
R_{SET} Current	±1mA
Storage Temperature Range	-65°C ~ +150°C
Lead Temperature (Soldering, 10s)	+300°C
Operating Temperature Range	-40°C ~ +85°C
ESD Ratings	
Human Body Model (HBM)	2kV
Machine Model (MM) (Note1)	200V
I_{LED} per LED pin	0 to 30uA
Thermal Resistance (Junction to Ambient) (θ_{JA})	68°C/W
Power Dissipation (P_D=@T_A=25°C)	1.47W

Stresses above 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 Electrical Characteristics are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note1: Machine models are with 200pF capacitor discharged directly into each pin.

THERMAL INFORMATION

Parameter	Symbol	Package	Max	Unit
Thermal Resistance (Junction to Ambient)	θ_{JA}	TQFN 3*3 mm	34	°C/W
		QFN 4*4 mm	25	
Power Dissipation, P_D@T_A=25°C	P_D	TQFN 3*3 mm	2.9	W
		QFN 4*4 mm	4.0	

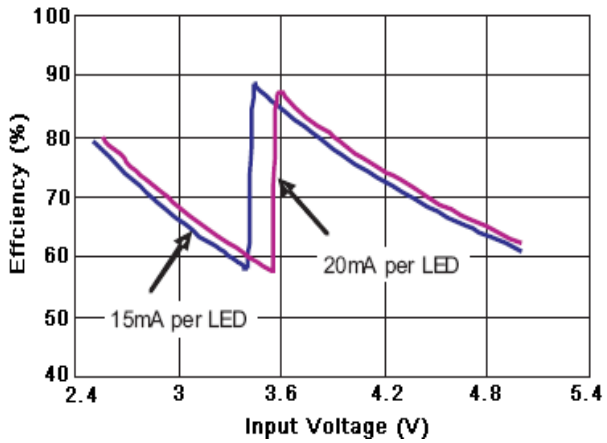
ELECTRICAL CHARACTERISTICS

V_{IN}=3.5V, T_A=25°C, C_{IN}=C_O=1uA, unless otherwise specified.

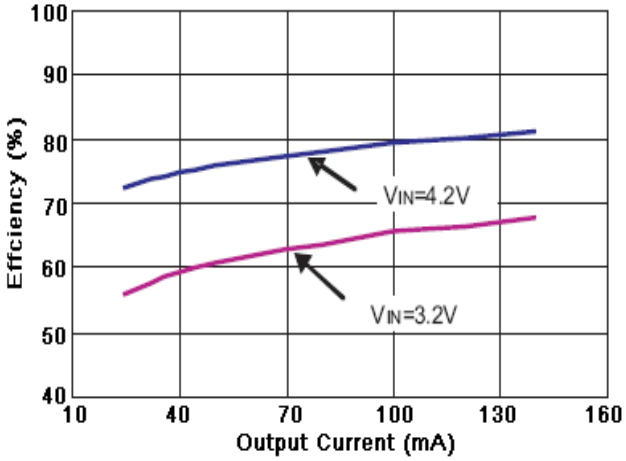
Parameter	Symbol	Conditions		Min	Typ	Max	Unit
V_{IN} at mode Transition from 1x to 1.5x	$V_{IN-Transition}$	I_{LED}=15mA I_{LED}=20mA			3.45 3.60		V
R_{SET} Regulated Voltage	V_{RSET}			1.19	1.23	1.25	V
Programmed LED Current	I_{LED}	R_{SET} =90KΩ			5.0		mA
		R_{SET}=29.3KΩ			15.0		mA
		R_{SET}=14.7KΩ			30.0		mA
LED Current Accuracy	$I_{LED-ACC}$			5		5	%
LED Channel Matching	$I_{LED-DEV}$	(I_{LED} - I_{LEDAVG}) / I_{LEDAVG}		3		3	%
Quiescent Current	Iq	V_{EN}=0V Shutdown Mode			0.05	1	uA
		1x Mode, No Load			0.6	1.2	mA
		1.5x Mode, No Load			2.5	5	mA
Output Resistance (Open Loop)	R_{OUT}	1x Mode, I_{OUT}=100mA			1.7		Ω
		1.5x Mode, I_{OUT}=100mA			4.3		Ω
Charge Pump Frequency	f_{OSC}				1.0		MHz
1x to 1.5x Mode Transition Dropout Delay	$T_{DROPOUT}$				10		us
Input Leakage Current	I_{EN-CTR}	ON Inputs EN, CTR0, 1 & 2				1	uA
Detect Threshold	V_{EN-CTR}	On Inputs EN, CTR0, 1 & 2	High	1.5			V
			Low			0.4	V
Input Voltage Range	V_{IN}			2.7		5.5	V

ELECTRICAL CHARACTERISTICS

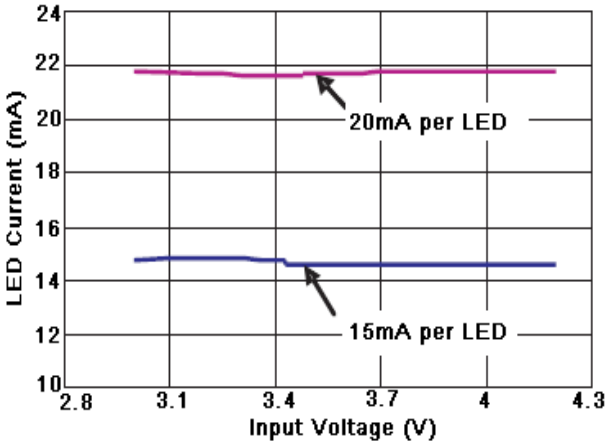
1. Efficiency vs. Input Voltage (4 LEDs)



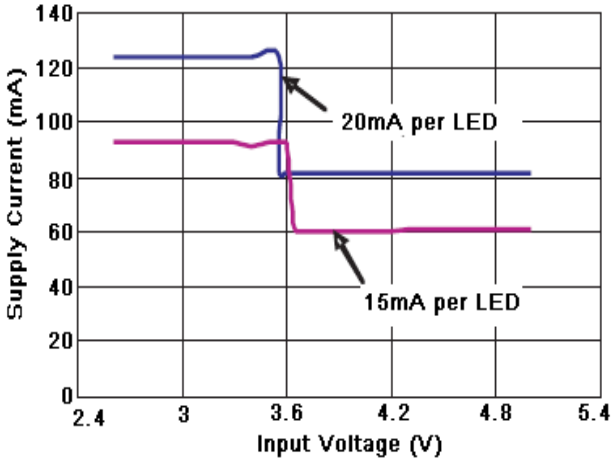
2. Efficiency vs. Output Current (4 LEDs)



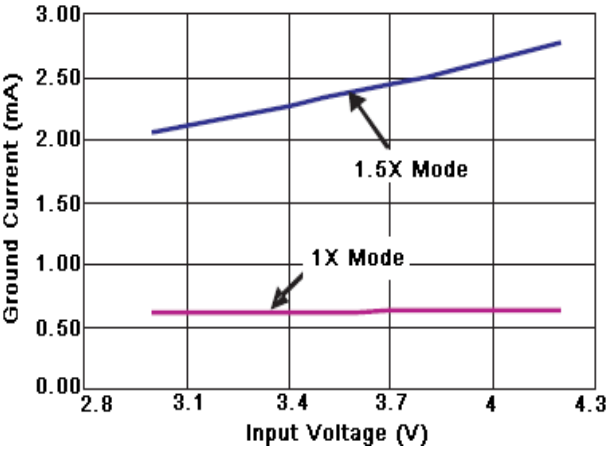
3. LED Current vs. Input Voltage (4 LEDs)



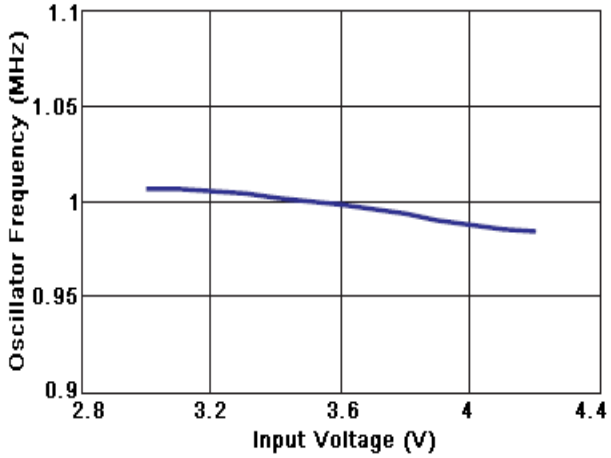
4. Supply Current vs. Input Voltage (4 LEDs)



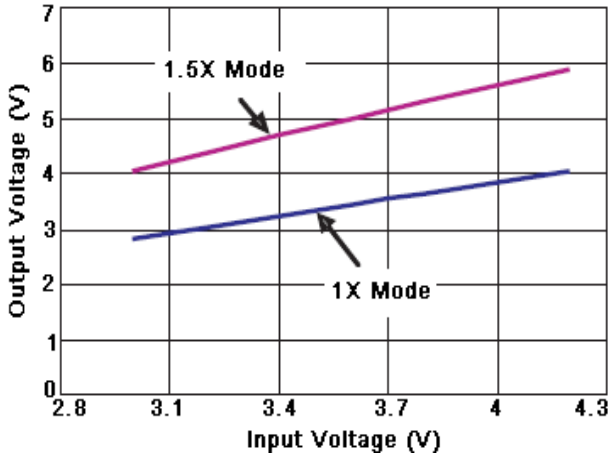
5. Ground Current vs. Input Voltage



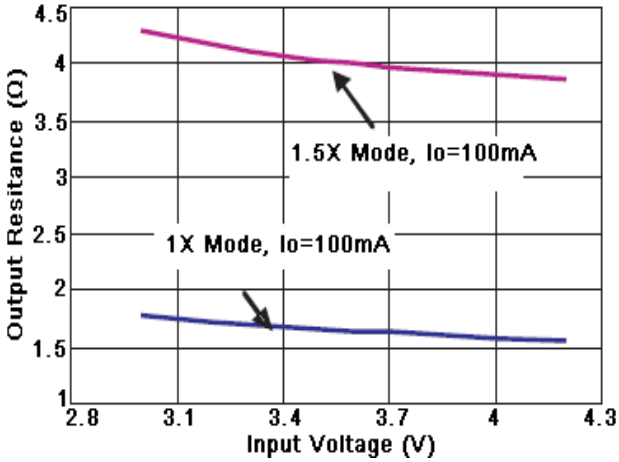
6. Oscillator Frequency vs. Input Voltage



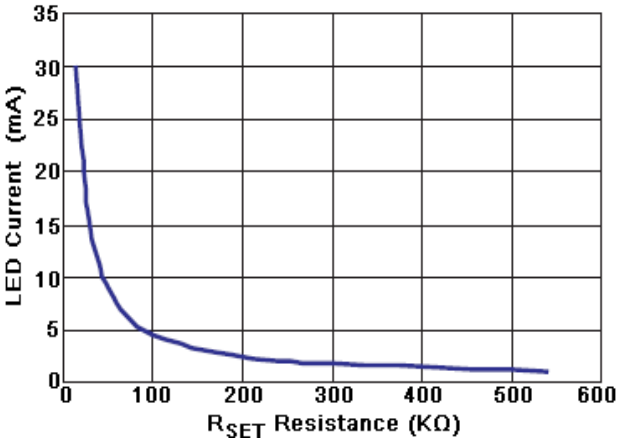
7. Output Voltage vs. Input Voltage



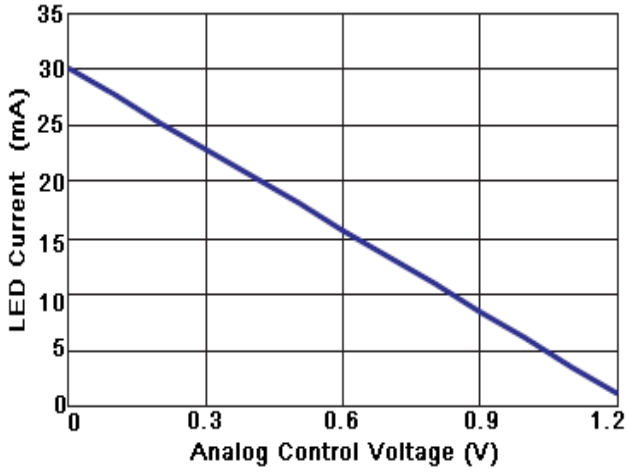
8. Output Resistance vs. Input Voltage



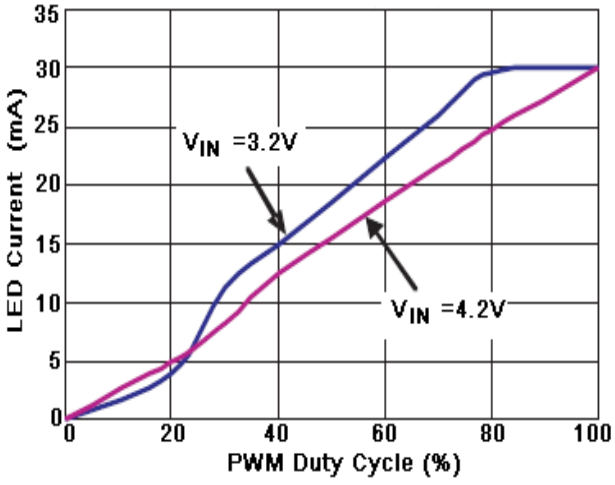
9. LED Current Setting Using the External Resistor R_{SET}
LED Current vs. R_{SET} Resistance



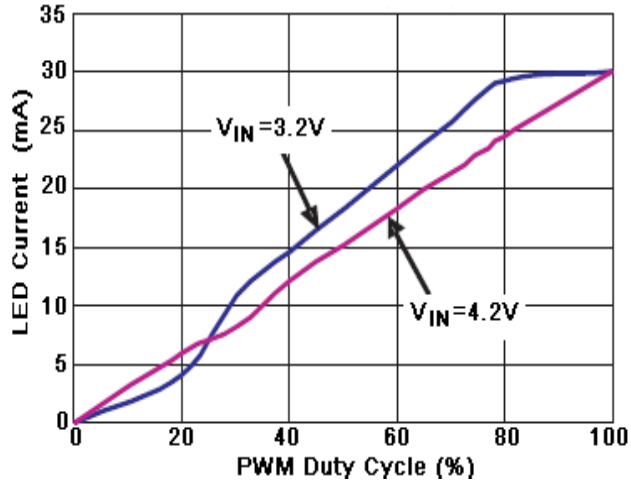
10. LED Current Setting Using a DC Voltage to R_{SET} Pin
LED Current vs. Analog Control Voltage



11. LED Current Setting Using a PWM Signal to EN Pin
LED Current vs. Duty Cycle @ f=100Hz

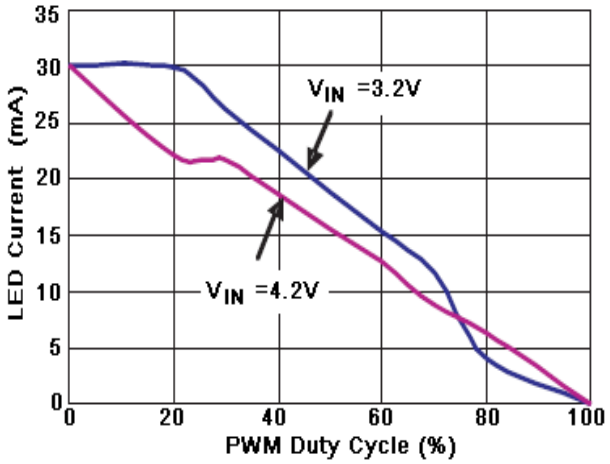


LED Current vs Duty Cycle @ f=1KHz

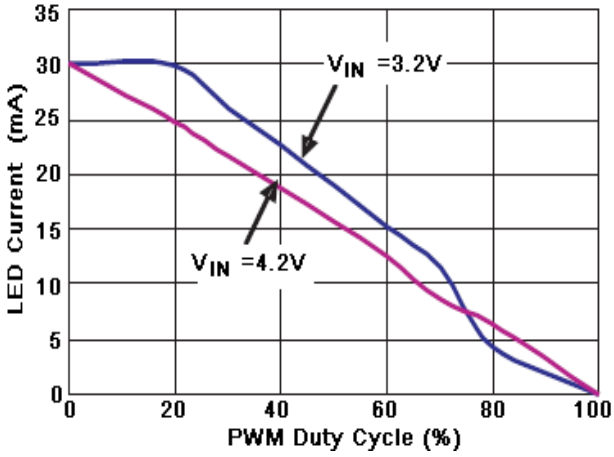


12. LED Current Setting Using a PWM Signal to CTR0 Pin

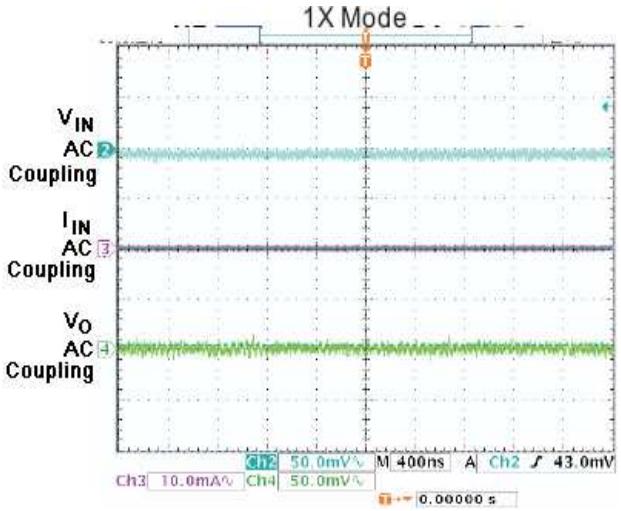
LED Current vs Duty Cycle @ f=100HZ

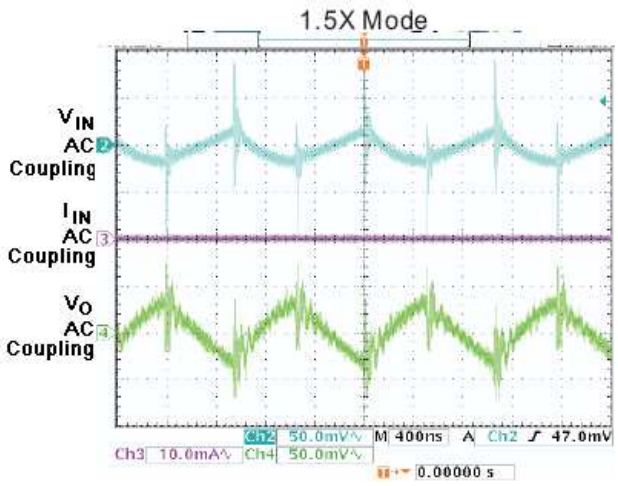


LED Current vs Duty Cycle @ f=1KHZ

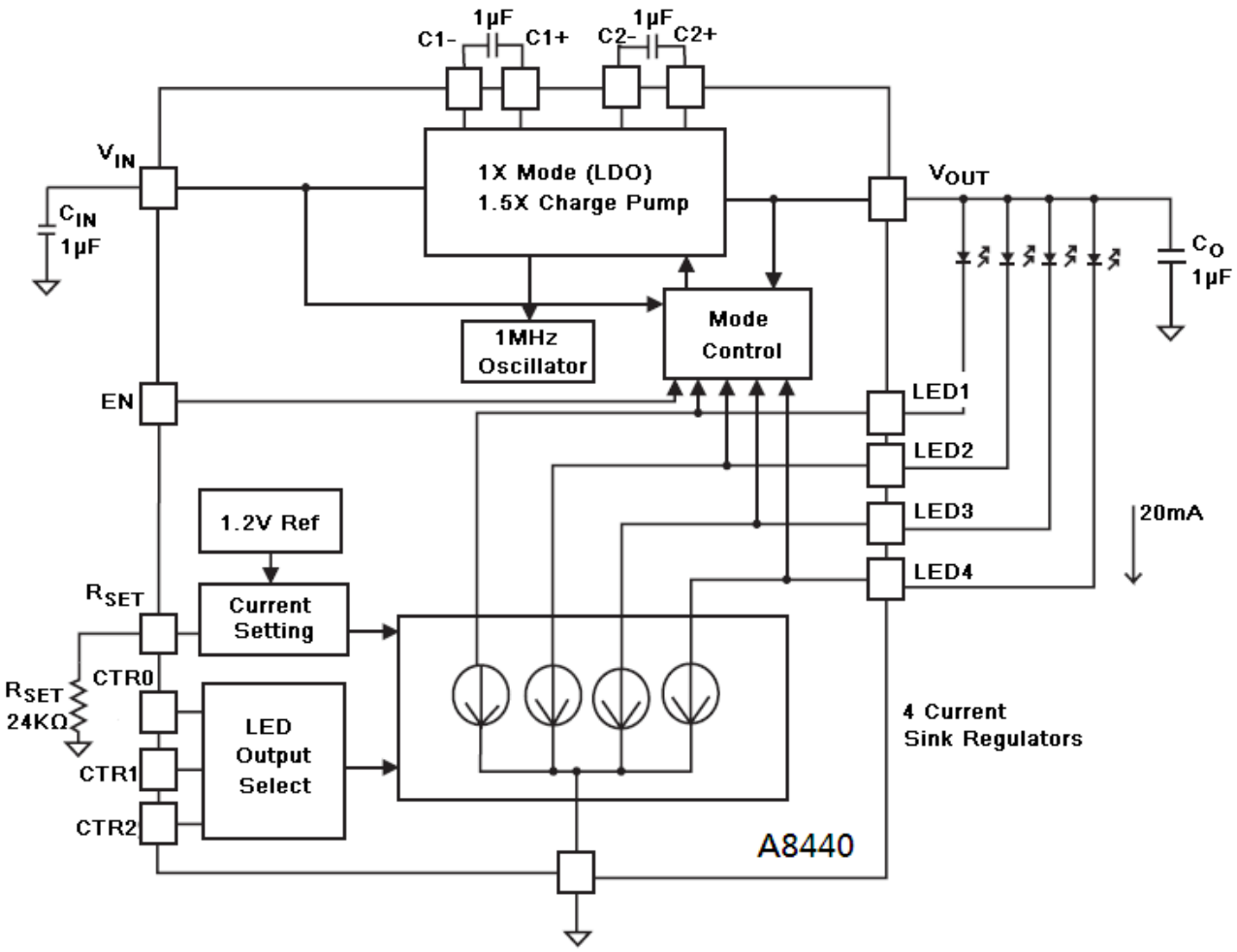


13. Output Ripple





BLOCK DIAGRAM



DETAILED INFORMATION

As shown in the block diagram, the main components within the A8440 include a fractional charge pump, mode selection circuit, output selection logic, LED current setting detection circuit, and 4 current sense circuits.

The fractional charge pump multiplies the input voltage a multiple of 1X and 1.5X times the input voltage. The charge pump switches at a fixed 1MHz when the mode is 1.5X. The charge pump does not switch during 1X mode, saving power and improving efficiency.

The mode selection circuit automatically selects the mode as 1X or 1.5X based on circuit conditions such as LED voltage, input voltage and load current. 1X is the more efficient mode than 1.5X mode.

LED Enable Logic Selection

Table 1 shows the output selection logic control over the LED outputs for on and off functions with 8 different output states.

Table 1: LED Enable Logic Selection

Control Lines			LED Outputs			
CTR2	CTR1	CTR0	LED4	LED3	LD2	LED1
0	0	0	-	-	-	ON
0	0	1	-	-	ON	-
0	1	0	-	ON	-	-
0	1	1	ON	-	-	-
1	0	0	-	-	ON	ON
1	0	1	-	ON	ON	ON
1	1	0	ON	ON	ON	ON
1	1	1	-	-	-	-

The current set and detection circuit uses an external resistor and a 1.20V reference to program the LED current. 4 current regulating circuits sink matched currents from the LEDs. LEDs with matched forward voltage will produce the best possible matched currents. For best matching performance it is recommended that the V_F between LEDs be under 250mV.

The unused LED channels can be turned off by CTR0, CTR1 and CTR2, and connecting the respective LED pins to V_{OUT} pin, in which case, the corresponding LED driver sink current is only about 20 A.

Methods for Setting LED Current

There are 4 methods for setting and adjusting the LED current outlined here. The methods are:

1) LED Current Setting with an External Resistor R

2) Analog Reference V (LED Current Setting with a DC Voltage to RSET Pin)

3) PWM Input at CTR0 (LED Current Setting with a PWM Signal to CTRx Pin)

4) PWM Input at EN (LED Current Setting with a PWM Signal to EN Pin)

1) LED Current Setting with an External Resistor R

The most basic means of setting the LED current is connecting a resistor from R to GND, as shown in the application circuit on Page 1. The resistor R establishes the reference current needed for a constant LED current. Values of R for a fixed LED current are given in Table 2, "Typical R Resistance vs. LED Current".

Table 2: R Resistance Selection

I_{LED}(mA)	R_{SET}(kΩ)	Standard Value (kΩ)	Value % Difference
30	14.7	14.7	0..0%
20	21.8	22.0	0.9%
15	29.3	29.4	0.3%
10	44.1	44.2	0.2%
9	49.4	49.9	1.0%
8	55.7	56.0	0.5%
7	64.2	63.4	0.3%
6	75.0	75.0	0.0%
5	90.0	88.7	-0.3%
4	114.2	115.0	0.7%
3	156.5	158.0	0.9%
2	238.0	237.0	-0.4%
1	540.0	536.0	-0.7%

2) Analog Reference V (LED Current Setting with a DC Voltage to RSET Pin)

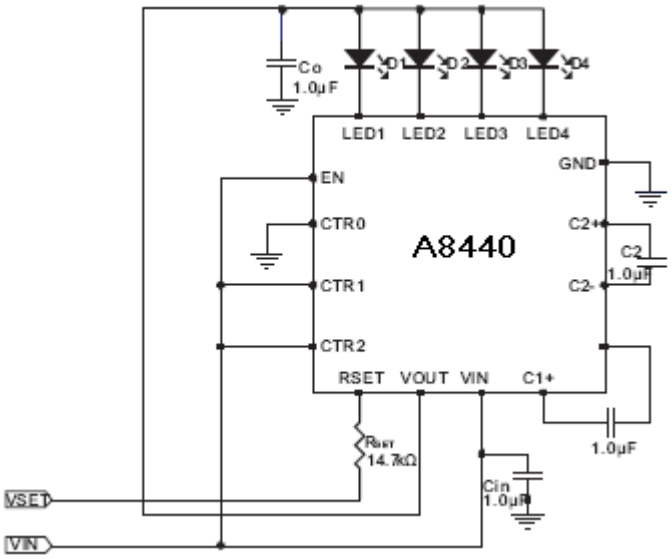
Analog Reference V is for setting the LED current to control brightness. An example circuit is shown in Figure 1, employing a 14.7k resistor and an analog input DC voltage, V , which varies from 1.2V to 0V to control LED current from 1mA to 30mA. Table 3 shows the resulting output. If necessary, the analog V voltage can be sourced from a voltage higher than 1.20V, but the source must be divided down so that the V mode will not exceed 1.20V. For lower current and higher resolution applications, a larger resistor may

be used instead. PWM applications are also possible with this circuit by application of RC filtering (Consult with PAM for detail application support).

Table 3: Analog Voltage for LED Current Control

V_{SET}(V)	I_{LED}(mA)	V_{SET}(V)	I_{LED}(mA)
0.0	30.0	0.7	13.3
0.1	27.7	0.8	10.9
0.2	25.3	0.9	8.4
0.3	22.9	1.0	6.0
0.4	20.5	1.1	3.6
0.5	18.1	1.2	1.1
0.6	15.7		

Figure 1: Analog Voltage for LED Current Control



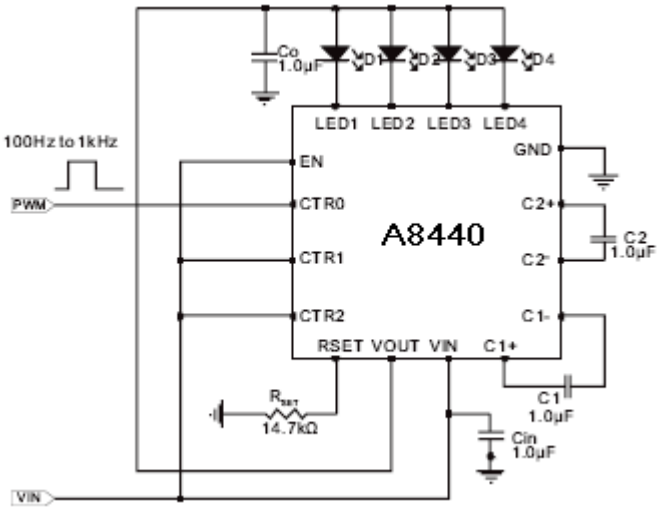
3) PWM Input at CTR0 (LED Current Setting with a PWM Signal to CTRx Pin)

In circuit in Figure 2 four LEDs are turned on and off by a PWM signal on the CTR0. A resistor R is used to set the on state current and the average LED current is then proportional to the percentage of on-time when the CTR0 pin is logic low. Average LED current is approximately equal to:

$$I_{AVG} = (t_{ON} * I_{LED\_ON}) / (t_{ON} + t_{OFF})$$

It is recommended that PWM frequency is between 100Hz and 1kHz. Due to start up delay and ramp up time, frequency >1kHz will result in error in the average value of ILED Frequency <100Hz can cause the LEDs to blink visibly.

Figure 2: PWM Signal at CTR0 pin for LED Current Control



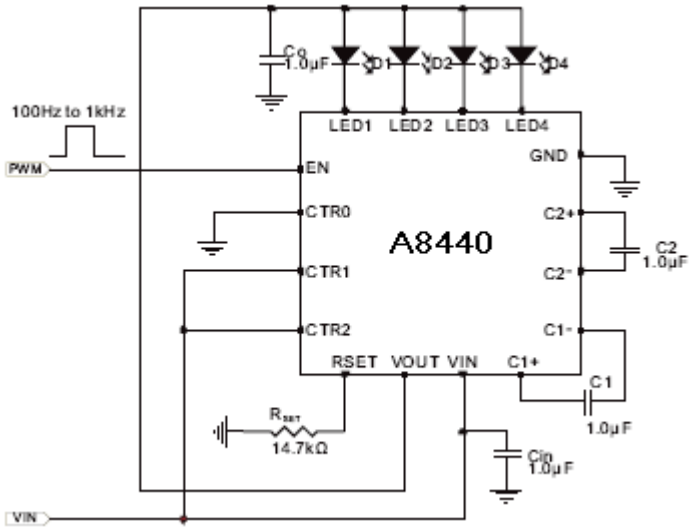
4) PWM Input at EN (LED Current Setting with a PWM Signal to EN Pin)

The four LEDs are turned on and off by applying a PWM signal to the EN pin in circuit in Figure 3. The circuit is the same as one in method 3, using a resistor R_{SET} to set the on state current and the average LED current proportional to the percentage of on-time when the EN pin is logic low. Average LED current is approximately equal to:

$$I_{AVG} = (t_{ON} * I_{LED\_ON}) / (t_{ON} + t_{OFF})$$

Similarly, it is recommended that PWM frequency is between 100Hz and 1kHz. Due to start up delay and ramp up time, frequency >1kHz will result in error in the average value of I_{LED}. Frequency <100Hz can cause the LEDs to blink visibly

Figure 3: PWM Signal at EN pin for LED Current Control

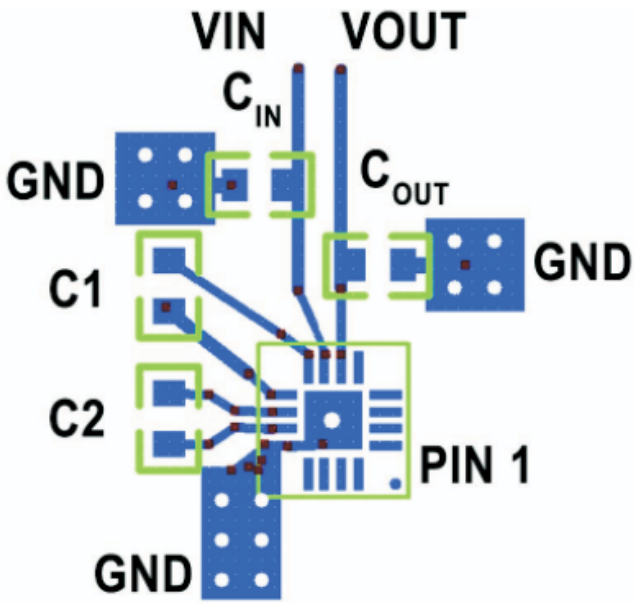


PCB Layout

When the driver is in the 1.5X charge pump mode, the 1MHz switching frequency operation requires to minimize the trace length and impedance to ground on all 4 capacitors. A ground plane should cover the area on the bottom side of the PCB opposite to the IC and the bypass capacitors. Capacitors C and Co should be short connected to ground with multiple vias as shown on Figure4.

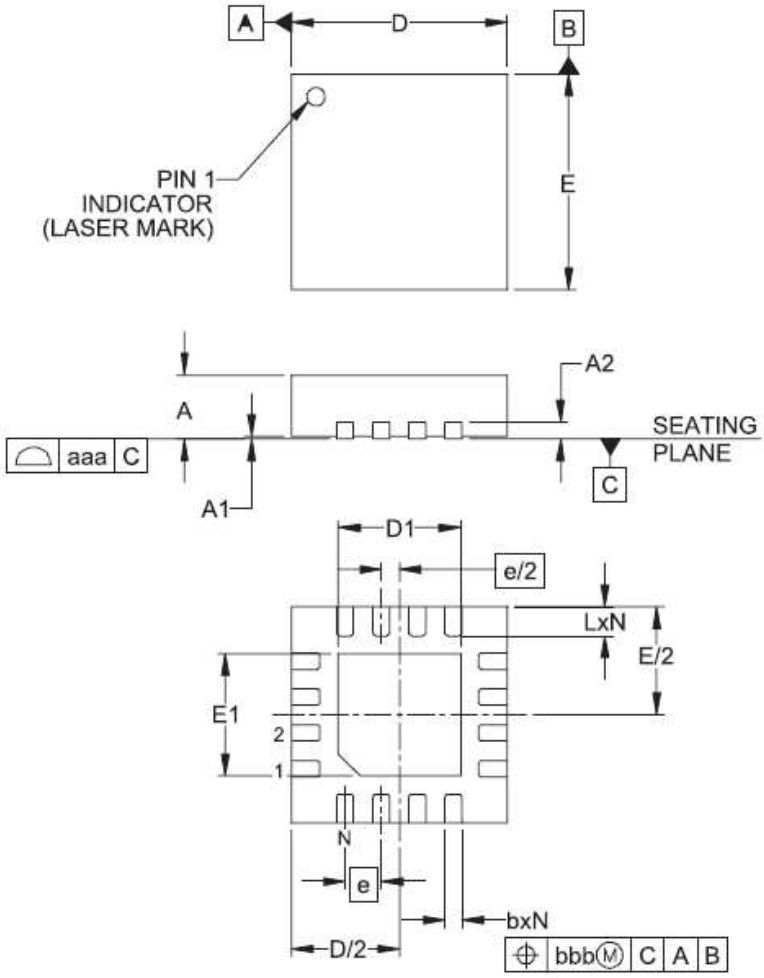
Square copper area matches the QFN 16 exposed pad (GND) which is connected by a trace to the pin 12 pad (GND). A large via (metalized hole) centered in the square pad provides a low impedance connection to the ground plane on the opposite side of the PCB and allows the heat dissipation of the LED driver to achieve excellent thermal performance.

Figure 4: PCB layout



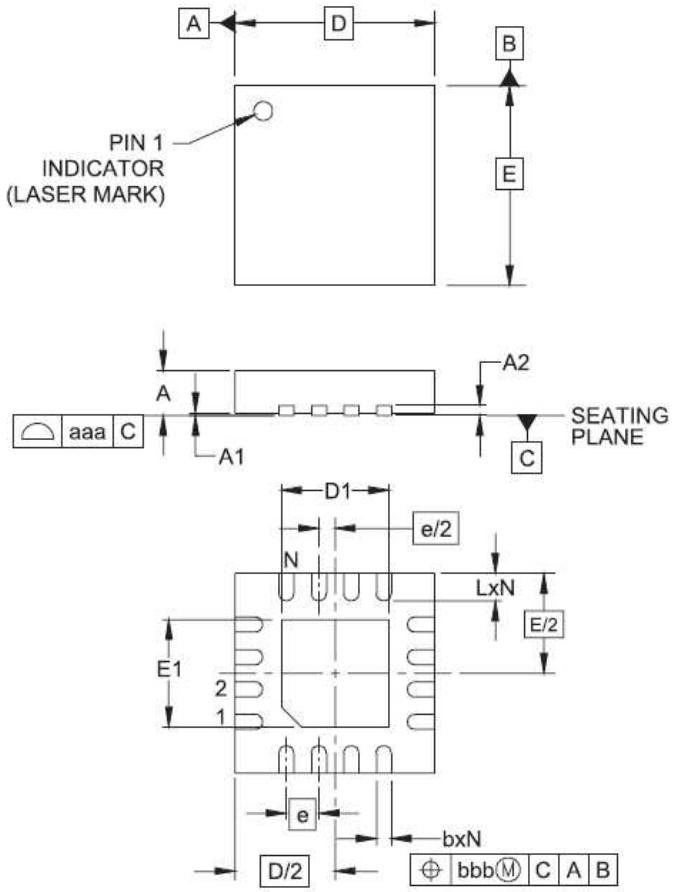
PACKAGE INFORMATION

Dimension in TQFN16 (Unit: mm)



SYMBOL	MIN	TYP	MAX
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A2		0.20	
b	0.18	0.25	0.30
D	2.90	3.00	3.10
D1	1.55	1.70	1.80
E	2.90	3.00	3.10
E1	1.55	1.70	1.80
e		0.50BSC	
L	0.30	0.40	0.50
N		16	
aaa		0.08	
bbb		0.10	

Dimension in TQFN16 (Unit: mm)



SYMBOL	MIN	TYP	MAX
A	0.80	0.90	1.00
A1	0.00	0.02	0.05
A2		0.20	
b	0.25	0.30	0.35
D	3.90	4.00	4.10
D1	2.00	2.15	2.25
E	3.90	4.00	4.10
E1	2.00	2.15	2.25
e		0.65BSC	
L	0.45	0.55	0.65
N		16	
aaa		0.08	
bbb		0.10	

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