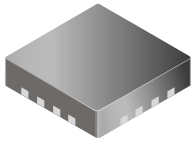
Ultracompact 6-Channel Backlight and Flash/Torch White LED Driver

Features and Benefits

- Proprietary adaptive control scheme (1×, 1.5×, 2×)
- 0.5% typical LED current matching
- 2 separate serial interfaces for dimming control
- Drives up to 6 white LEDs (4 display backlight, 2 flash/torch)
- 30 mA per LED channel for display backlight
- 100 mA per LED channel for flash/torch backlight
- 320 mA total output current capability
- Low EMI design and soft-start function
- Short circuit, overvoltage, thermal shutdown protection
- 0.75 mm very thin profile, 3 mm × 3 mm package

Package: 16 pin QFN/MLP (suffix ES)



Approximate Scale 1:1

Description

The A8530 high efficiency charge pump ICs offer a simple, low-cost white LED driver solution for driving four display backlight and two flash/torch/video mode white LEDs. Using a proprietary control scheme (1×, 1.5×, and 2×), the A8530 can deliver well-matched LED current while maintaining the highest efficiency and low EMI. The LED current is regulated over the entire range of Li+ battery voltage to provide uniform intensity.

LED brightness and on/off can be controlled for 4 display backlight LEDs and 2 flash/torch LEDs through 2 single-wire serial interface pins.

The A8530 is available in a very thin profile (0.75 mm nominal height) 3 mm× 3 mm QFN/MLP 16 pin package. Applications include:

- White LED backlights for cellular phones, PDAs
- Digital cameras, camcorders
- Other portable device white LED backlighting
- 320 mA WLED flash/torch

Typical Applications

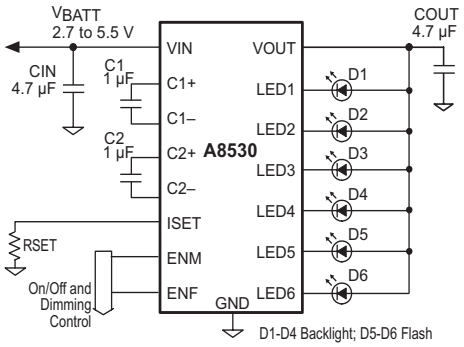


Figure 1. 4 × 30 mA backlight with 2 × 100 mA flash

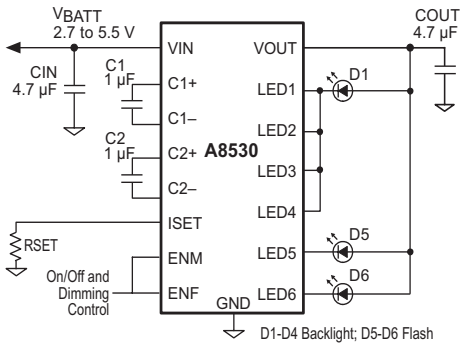


Figure 2. 3 × 100 mA flash

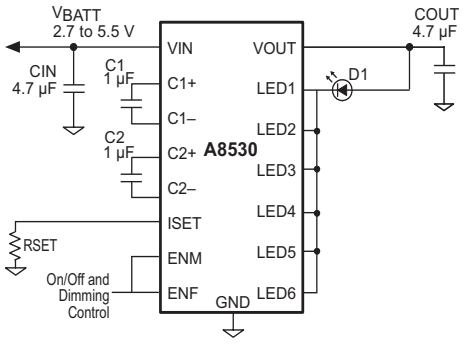


Figure 3. 320 mA flash

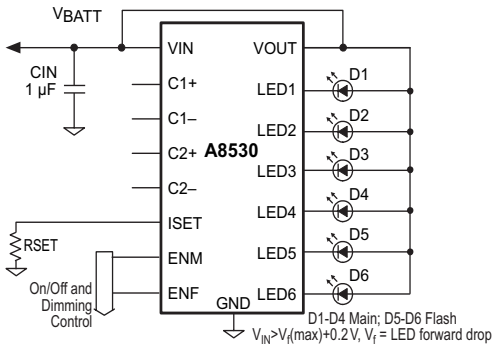
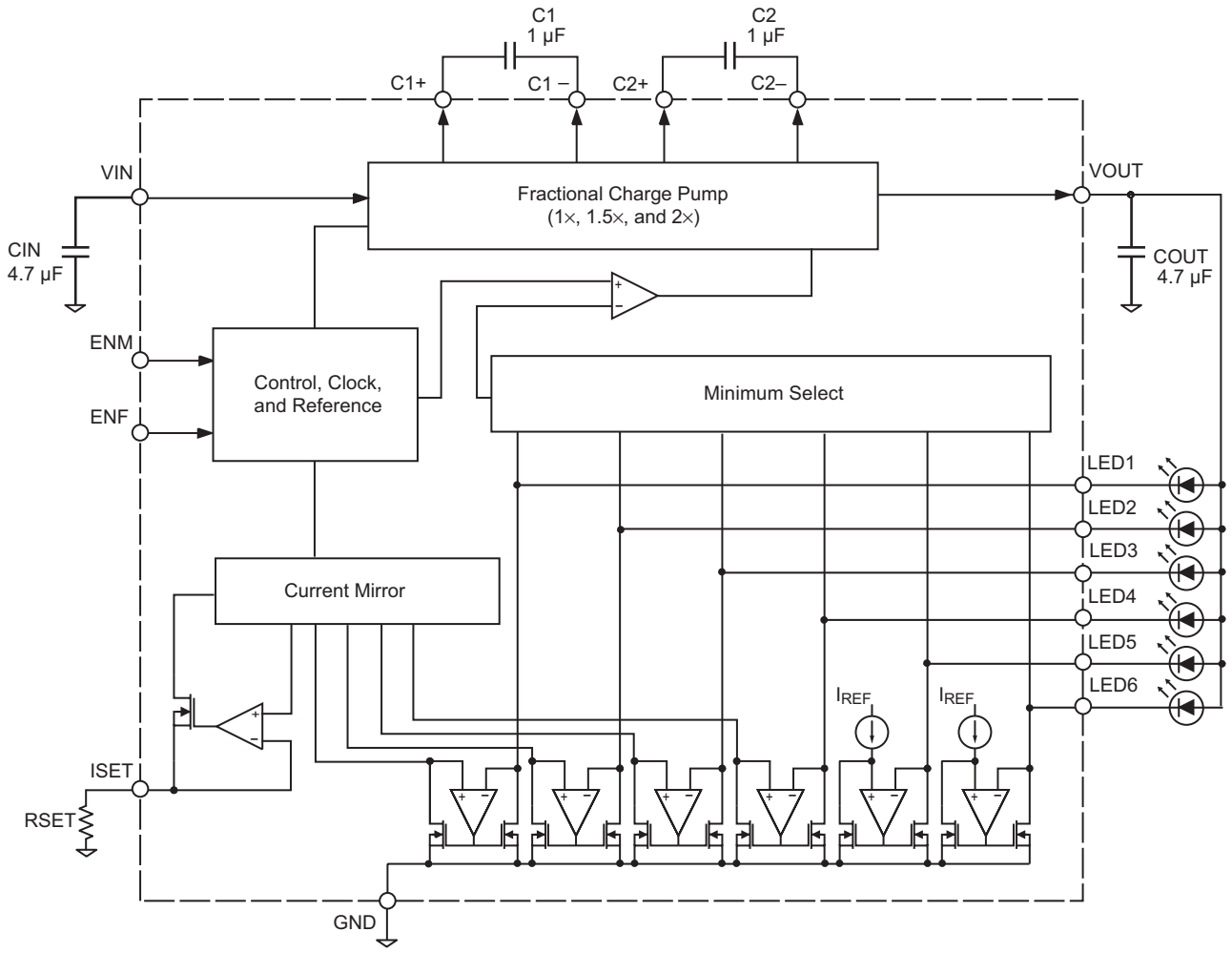


Figure 4. High efficiency current sink

Functional Block Diagram



Absolute Maximum Ratings

Input or Output Voltage
- VIN, VOUT, C1+, C1– , C2+, C2– to GND ..... **–0.3 to 6 V**
- All other pins ..... **–0.3 to V_{IN} + 0.3 V**

VOUT Short Circuit to GND ..... **Continuous**
Operating Ambient Temperature, T_A ..... **–40°C to 85°C**
Junction Temperature, $T_{J(max)}$ ..... **150°C**
Storage Temperature, T_S ..... **–55°C to 150°C**

Package Thermal Characteristics

Package Thermal Resistance, $R_{\theta JA}$ = 68 °C/W
(vendor data, on 4-layer PCB; unverified)

Device package is lead (Pb) free, with 100% matte tin leadframe plating.

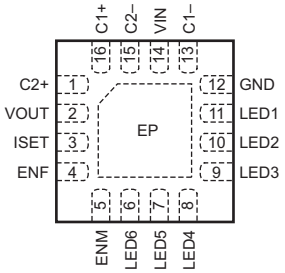
Use the following complete part number when ordering:

Part Number	Packaging*	Package Type
A8530EESTR-T	7-in. reel, 1500 pieces/reel	ES, 3 × 3 mm MLP-16

*Contact Allegro for additional packing options.

Pin-out Diagram

ES Package



(Top View)

Terminal List Table

Name	Number	Function
C1–	13	Negative terminal of capacitor C1. Connect capacitor C1 between C1+ and C1–.
C1+	16	Positive terminal of capacitor C1.
C2–	15	Negative terminal of capacitor C2
C2+	1	Positive terminal of capacitor C2. Connect capacitor C2 between C2+ and C2–.
ENF	4	Enable and dimming control input for flash/torch.
ENM	5	Enable and dimming control input for display backlight.
EP	–	Exposed metal pad on bottom side. Connect this to ground plane for better thermal performance.
GND	12	Ground.
ISET	3	Connect RSET resistor to ground to set desired constant current through backlight LEDs. $I_{LED(max)} = 220 \times 0.6\ V / R_{SET}$
LED1, LED2, LED3, and LED4	8, 9, 10, and 11	Current sink for display backlight LEDs. If not used, connect to VOUT, but do not leave open. If left open, the IC works in 2 × mode.
LED5 and LED6	6 and 7	Current sink for flash/torch LEDs. If not used, connect to VOUT, but do not leave open. If left open, the IC works in 2 × mode.
VIN	14	Power supply voltage input.
VOUT	2	Charge pump output voltage source for display backlight and flash/torch LED anodes. Connect a 4.7 µF capacitor, COUT, between VOUT and GND (see figures 1 through 4).

ELECTRICAL CHARACTERISTICS[a] VIN = ENM = 3.6 V, ENF = GND, C1 = C2 = 1 µF, CIN = COUT = 4.7 µF, RSET = 6.49 kΩ, T_A = –40°C to +85°C; typical values are at T_A = 25°C; unless otherwise noted

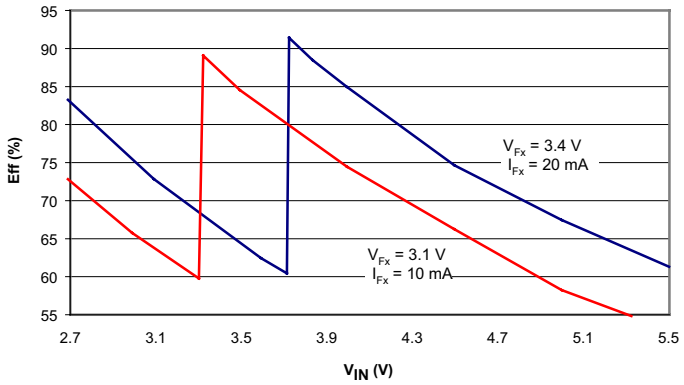
Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Input Voltage Range	V_{IN}		2.7	–	5.5	V
Undervoltage Lockout Threshold	V_{UVLO}	V_{IN} falling	2.25	2.45	2.60	V
UVLO Hysteresis Window	$V_{UVLOHYS}$		–	60	–	mV
Quiescent Current	I_Q	Switching in 1.5× or 2.0× mode; T_A = 25°C	–	6	–	mA
		ENF = ENM = GND; T_A = 25°C	–	0.1	2	µA
Soft-start Completion Time	t_{ss}		–	2.0	–	ms
ISET Bias Voltage	$V_{ISETBIAS}$		–	0.6	–	V
ISET Leakage in Shutdown	$V_{ISETLKG}$		–	0.01	1	µA
ISET Current Range	I_{SET}		40	–	140	µA
ISET to LEDx Current Ratio for LED1 through LED4	I_{LEDx}/I_{ISET}	100% setting, I_{SET} = 60 µA	–	220	–	A/A
100% Output Current for LED5 and LED6	$I_{LED56MAX}$	Default 100% setting when ENF is enabled	92	100	108	mA
I_{LED} Accuracy for LED1 through LED4[b]	$E_{ILED14ERR}$	ENF = GND, ENM = VIN	–	±1.6	–	%
LED Current Matching for LED1 through LED4[c]	ΔI_{LED14}	ENF = GND, ENM = VIN	–	±0.5	–	%
LED Current Matching for LED5 and LED6[c]	ΔI_{LED56}	ENF = VIN, ENM = GND, 100%	–	±0.5	–	%
Regulation Voltage at LEDx (1.5× and 2× modes)	V_{REG}	ENF = ENM = VIN	–	250	–	mV
1x mode to 1.5x or 1.5x to 2x mode transition voltage at LEDx	V_{trans}	V_{LEDx} falling	–	150	–	mV
Transition–Dropout Delta[d]	ΔV_{dr}	Measured as $V_{trans} - V_{dropout}$	–	40	–	mV
Open Loop Output Resistance[e]	R_{OUT}	1× mode $(V_{IN} - V_{OUT})/I_{OUT}$	–	1	–	Ω
		1.5× mode $(1.5 \times V_{IN} - V_{OUT})/I_{OUT}$	–	2.5	–	Ω
		2× mode $(2 \times V_{IN} - V_{OUT})/I_{OUT}$	–	5	–	Ω
LED Leakage in Shutdown	V_{LEDLKG}	ENF = ENM = GND, V_{IN} = 5.5 V	–	0.01	1	µA
Oscillator Frequency	f_{osc}		–	1	–	MHz
Output Overvoltage Protection (guaranteed by design)	V_{ovp}	Open circuit at any LED that is programmed to be in the ON state	–	–	6.0	V
ENF and ENM Input High Threshold	V_{IH}	Input high logic threshold	1.4	–	–	V
ENF and ENM Input Low Threshold	V_{IL}	Input low logic threshold	–	–	0.4	V
Input High Current	I_{IH}	V_{IH}=VIN	–	–	1	µA
Input Low Current	I_{IL}	V_{IL}= GND	–	–	1	µA
ENM and ENF Pulse Low Time (figure 6)	t_{LO}		0.5	–	250	µs
ENM and ENF Pulse High Time (figure 6)	t_{HI}		0.5	–	–	µs
ENM and ENF Initial Pulse High Time (figure 6)	t_{INIHI}	First ENM or ENF pulse after shutdown	50	–	–	µs
Shutdown or Dimming Reset Delay	t_{SHDN}	Falling edge of ENF and/or ENM	–	0.5	–	ms
Thermal Shutdown Threshold	T_{TSD}	20ºC hysteresis	–	165	–	ºC

[a]Specifications for the range T_A = –40°C to 85°C are guaranteed by design.
[b]I_{LED} accuracy is defined as $(I_{SET} \times 220 - I_{LEDAVG})/(I_{SET} \times 220)$.
[c]LED current matching is defined as $(I_{LEDx} - I_{LEDAVG})/I_{LEDAVG}$.
[d]Dropout voltage $V_{dropout}$ is defined as LEDx-to-GND voltage at which I_{LEDx} drops 10% below the value of I_{LEDx} when V_{LEDx} = 300 mV.
[e]The open loop output resistance, R_{OUT}, for 1.5× mode is measured when one of the LEDx pins is tied to ground or open (thus its voltage is always less than 80 mV).

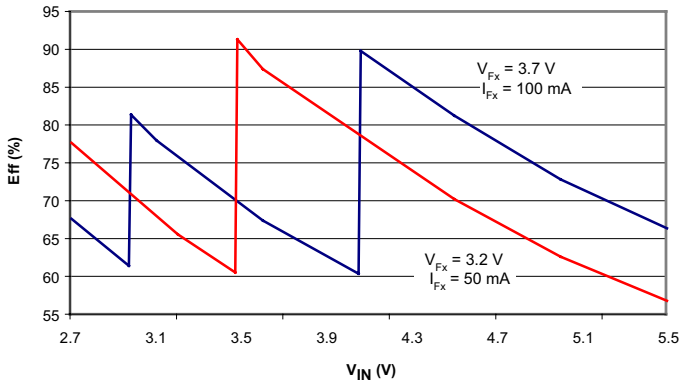
Performance Characteristics

Tests performed using application circuit shown in figure 1
T_A = 25°C, V_{IN} = 3.6 V (unless otherwise noted)

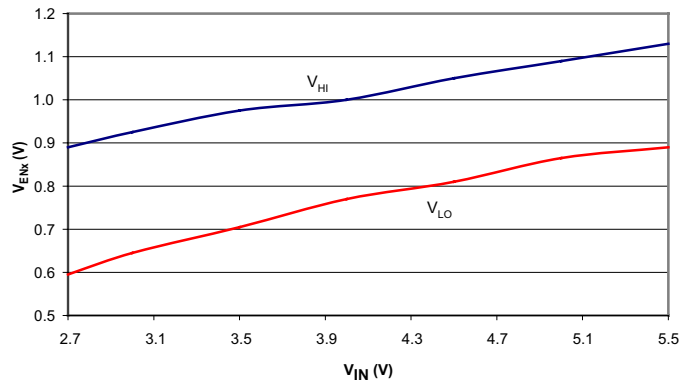
Efficiency versus Supply Voltage
for LED1 through LED4, in parallel



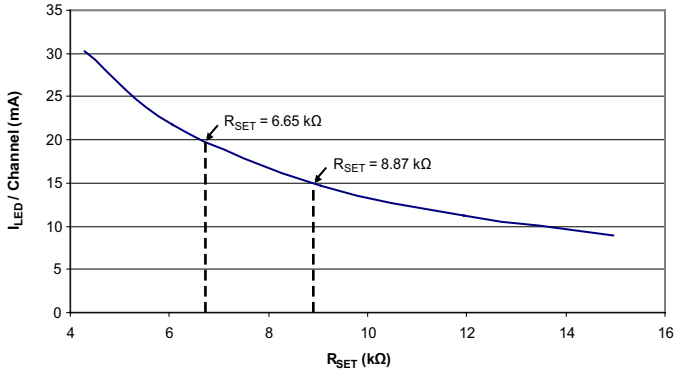
Efficiency versus Supply Voltage
for LED5 and LED6, in parallel



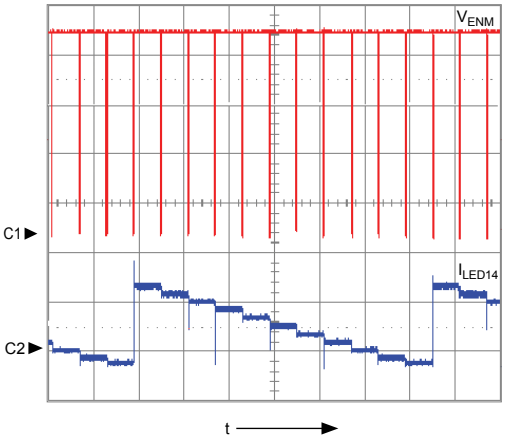
Logic Level



R_{SET} versus I_{LED}



Dimming on ENM
Enable Pulses versus Total Current, LED1 through LED4



Symbol	Parameter	Units/Division
C1	V_{ENM}	0.5 V
C2	I_{LED14}	50 mA
t	time	50 ms

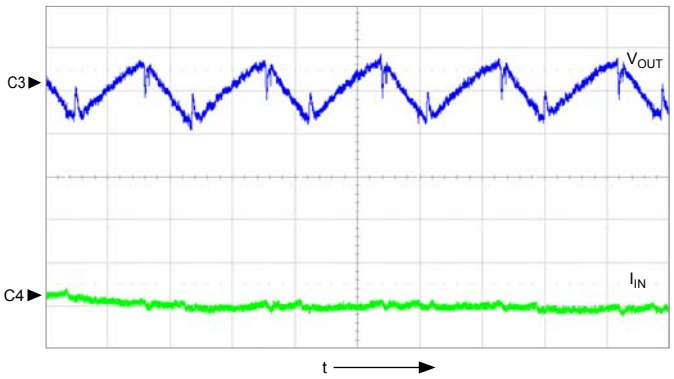
Performance Characteristics

Tests performed using application circuit shown in figure 1
T_A = 25°C, V_{IN} = 3.6 V (unless otherwise noted)

LED5-6 ON, 1.5× mode

V_{IN} = 3.2 V, I_{OUT} = 200 mA, V_F = 3.1 V

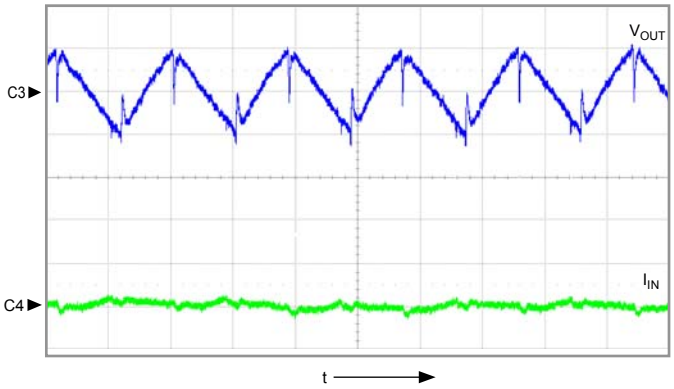
Symbol	Parameter	Units/Division
C3	V_{OUT} Ripple	20 mV
C4	I_{IN} Ripple	50 mA
t	time	500 ns



LED5-6 ON, 2× mode

V_{IN} = 2.7 V, I_{OUT} = 200 mA, V_F = 3.1 V

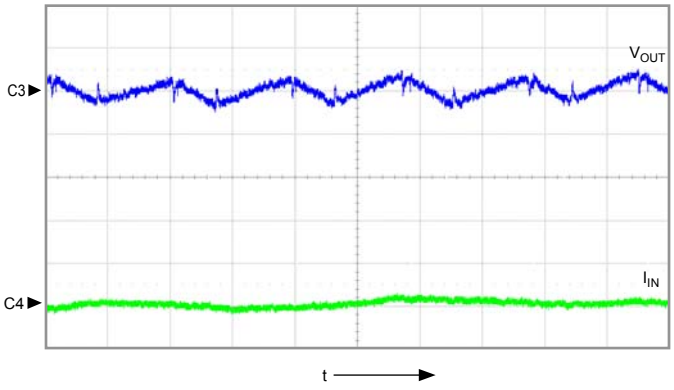
Symbol	Parameter	Units/Division
C3	V_{OUT} Ripple	20 mV
C4	I_{IN} Ripple	50 mA
t	time	500 ns



LED1-4 ON, 1.5× mode

V_{IN} = 3.6 V, I_{OUT} = 80 mA, V_F = 3.4 V

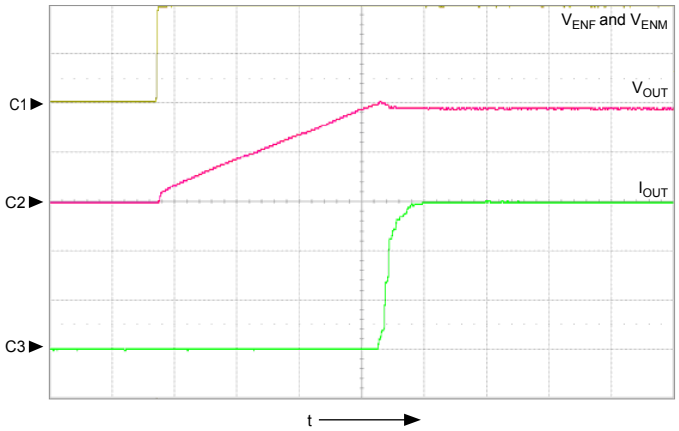
Symbol	Parameter	Units/Division
C3	V_{OUT} Ripple	20 mV
C4	I_{IN} Ripple	50 mA
t	time	500 ns



Performance Characteristics

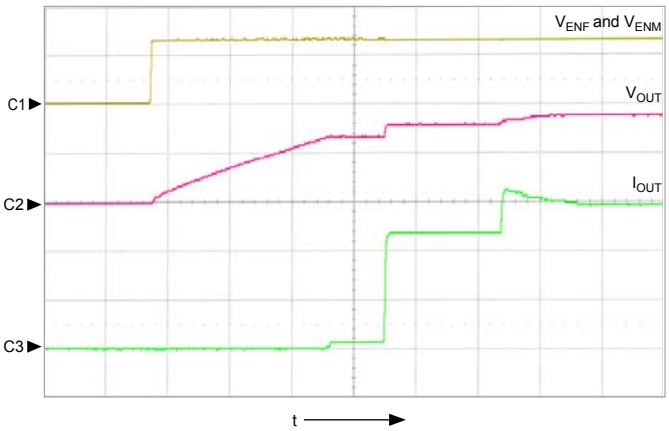
Tests performed using application circuit shown in figure 1
T_A = 25°C

Turn ON LED1-6 in 1X Mode
V_{IN} = 4.0 V, I_{OUT} = 280 mA



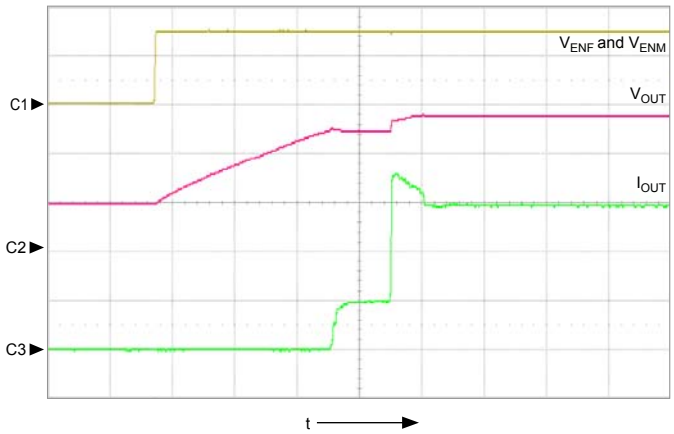
Symbol	Parameter	Units/Division
C1	V_{ENF} and V_{ENM}	2.00 V
C2	V_{OUT}	2.00 V
C3	I_{OUT}	100 mA
t	time	0.5 ms

Turn ON LED1-6 in 2X mode
V_{IN} = 2.7 V, I_{OUT} = 280 mA



Symbol	Parameter	Units/Division
C1	V_{ENF} and V_{ENM}	2.00 V
C2	V_{OUT}	2.00 V
C3	I_{OUT}	100 mA
t	time	0.5 ms

Turn ON LED1-6 in 1.5X Mode
V_{IN} = 3.0 V, I_{OUT} = 280 mA



Symbol	Parameter	Units/Division
C1	V_{ENF} and V_{ENM}	2.00 V
C2	V_{OUT}	2.00 V
C3	I_{OUT}	100 mA
t	time	0.5 ms

Application Information

Setting LED Current

Use the following formula to set the display backlight LED full current (100%) using RSET on LED1 through LED4. The maximum current through one LED should not exceed 30 mA:

$$R_{SET} = 0.6\ V \times 220 / I_{LEDx}$$

where R_{SET} is in Ω and I_{LEDx} in amperes.

The default flash/torch current on LED5 and LED6 is set internally to 100 mA per channel. When both the display backlight and the flash/torch LEDs are on, the maximum current output from LED1 through LED4 is 30 mA per channel. The output current of the flash/torch LEDs (LED5 and LED6) can be adjusted by serial dimming at the ENF pin within 1 ms after ENF is pulled high.

Transitions Between 1× and 1.5× or 2× Modes

The A8530 adaptively selects operating mode. When V_{IN} is sufficiently high to maintain V_{LEDx} > 150 mV, the A8350 operates in 1 × mode unless, as V_{IN} drops, the LED*x* nodes fall below the 150 mV threshold. When V_{LEDx} falls below 150 mV, the IC enters 1.5× mode.

When the A8530 switches from 1× to 2× mode, it first switches to 1.5× mode for a typical duration of 1 ms before entering 2× mode.

When operating in 1.5× mode, if $V_{OUT} < V_{IN}$, then the IC switches back to 1× mode every 130 ms, and then reenters 1.5× mode again if necessary.

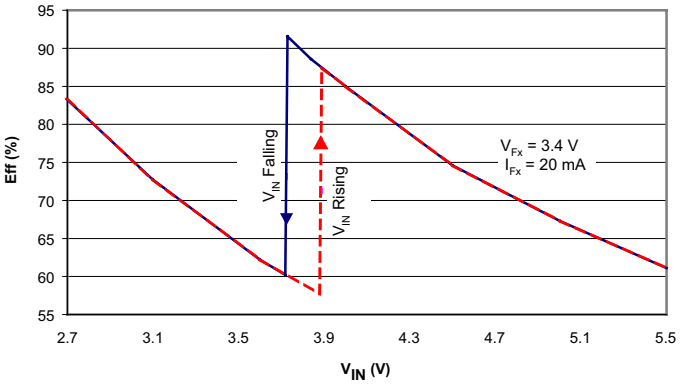


Figure 5. Mode change transitions

Transitions Between 1.5× and 2× Modes

The transition from 1.5× to 2× mode depends upon dropout conditions.

When operating in 2× mode, the IC switches back to 1.5× mode every 130 ms, and then reenters 2× mode again if necessary. Furthermore, when in 2× mode, whenever a channel disabling is sensed (that is, whenever ENM is held low for > 0.5 ms with ENF high, or vice versa), the IC automatically reverts to 1.5× mode, and then reenters 2× mode again if necessary.

Dimming

Display Backlight LED1 through LED4 Dimming The display backlight LEDs (LED1 through LED4) brightness and on/off can be controlled using digital input at the ENM pin. The ENM pin accepts one-wire serial pulse input to enable the A8350 and to set up to 11 dimming levels, from 100% down to 5%.

When ENM is initially pulled up from shutdown, after a soft-start, the current for the backlight LEDs is programmed to 100% of the setting current, which is determined by the current through the ISET pin. Each subsequent pulse reduces the LED current by 10%, and the 10th pulse reduces the current by 5%. The next pulse restores 100% (full) brightness. Figure 6 shows the timing diagram for ENM control.

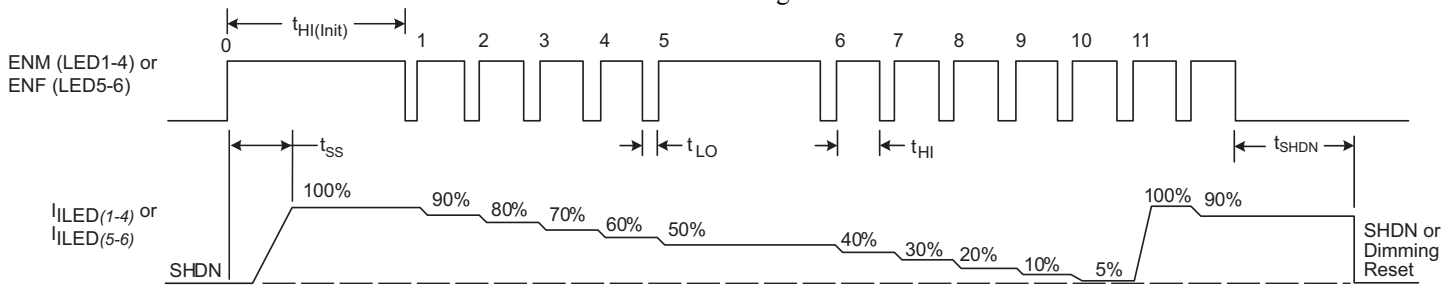


Figure 6. Single-Wire Serial Dimming Control; at pins ENF and ENM.

Flash/Torch LED5 and LED6 Operation The flash/torch LEDs (LED5 and LED6) brightness and on/off can be controlled using digital input at ENF pin. ENF accepts one-wire serial pulse input to enable the A8530 and to set up to 11 dimming levels, from 100 mA (the default 100% level) down to 5 mA.

When the ENF pin is initially pulled up from shutdown, after a soft-start (if the IC is not yet soft-started using the ENM pin), the current for LED5 and LED6 is, by default, programmed to 100 mA, corresponding to 100% of flash/torch brightness. Each subsequent pulse reduces the LED current by 10 mA, and the 10th pulse reduces the current by 5 mA. The next pulse then restores to 100 mA (full) output current per channel. Figure 6 shows the timing diagram for ENF.

Absolute Level Operation Some applications require dimming to a specific level, regardless of the present level of dimming. For example, if the IC should dim to 30%, this can be done with 7 steps, as shown in figure 6, irrespective of the dimming level in effect. This can be achieved by pulling corresponding ENx pin low for time greater than t_{SHDN} and then applying pulses as shown in figure 6 (7 for 30% dimming). If the pulses are applied within 2 to 3 ms, the display flicker is not visible. The procedure is shown in figure 7.

Shutdown

When the ENM pin is pulled low for 0.5 ms or longer, the display backlight channels are shut off and dimming is reset to 100% upon the next ENM going high edge. When the ENF pin is pulled low for 0.5 ms or longer, the brightness of the flash/torch channels is reset to 100 mA upon the next ENF going high edge. When both ENM and ENF are pulled low for 0.5 ms or longer, the A8530 enters the shutdown mode.

Short Circuit Protection

The A8530 is protected against short circuits on the output. When V_{OUT} is externally pulled below 1.2 V, the IC enters Short Circuit mode. The A8530 resumes normal operation when the short circuit is removed.

Symbol	Parameter	Units/Division
C1	V_{ENM}	2.00 V
C2	V_{OUT}	2.00 V
C3	I_{OUT}	50 mA
t	time	0.5 ms

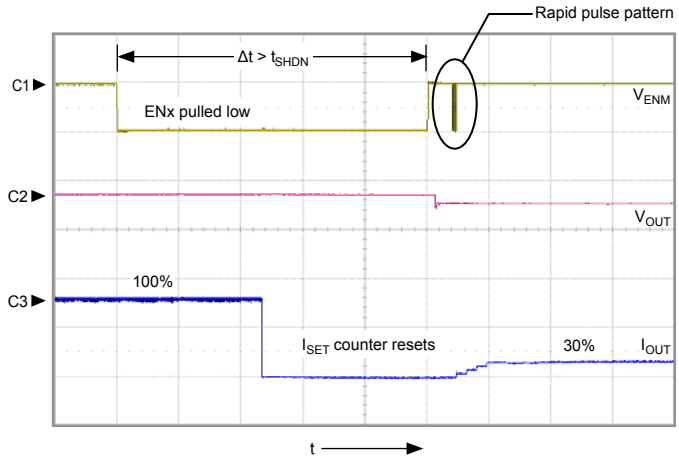


Figure 7. Absolute Dimming Level Setting. With ENM pulled low longer the t_{SHDN}, pulsing the corresponding EN*x* pin sets an absolute target level.

Overvoltage Protection

The A8530 is protected up to 4.9 V supply voltage, against accidental overvoltage caused by an open LED. When any LED opens, V_{OUT} will increase till 6 V. Remaining LEDs will continue to function normally. Normal operation will be resumed when the fault is removed.

LED Disconnection

Every LEDx pin has a disable subcircuit, as shown in figure 8. The A8530 compares the voltage on each LED pin, and if the voltage on the pin is greater than either $V_{OUT} - 0.4$ V or $V_{IN} - 0.4$ V, then the corresponding LED pin is disabled.

Thermal Shutdown

The IC is internally protected against overtemperature. The overtemperature limit is set to 165°C nominal. The IC shuts down when the junction temperature exceeds 165°C and automatically turns on again when the IC cools.

Component Selection

Ceramic capacitors with X5R or X7R dielectric are recommended for the input capacitor, CIN, the output capacitor, COUT, and the charge pump capacitors, C1 and C2.

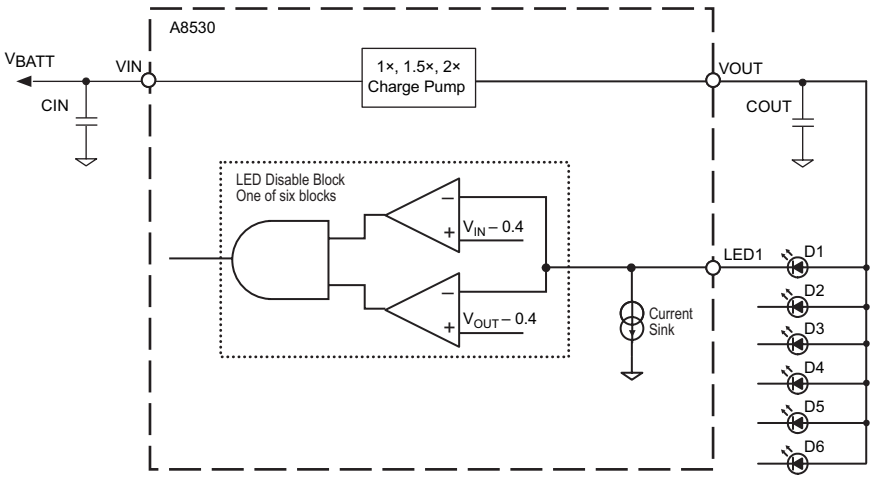


Figure 8. LED disable subcircuit. Subcircuit for one LED*x* pin shown. A similar block is connected to each LED*x* pin.

Package ES, 3 × 3 mm 16-Pin QFN/MLP