



# Charge Pump Driver for LCD LED Backlights

## Preliminary Technical Data

## ADM8845/6

### FEATURES

ADM8845 drives 6 White LEDs from a 2.6 V to 5.5 V (li-ion) input supply

ADM8846 drives 5 White LEDs from a 2.6 V to 5.5 V (li-ion) input supply

1x/1.5x/2x Fractional Charge Pump to maximise power efficiency

1% LED Current Matching

Low power shutdown mode

Package footprint only 9mm<sup>2</sup> (3mm x 3mm)

Package height only 0.9mm

Shutdown Function

Soft-start limiting inrush current

### APPLICATIONS

White LED Backlighting

Micro TFT color displays

Mobile phones

DSC

PDA's

### GENERAL DESCRIPTION

The ADM8845 provides the power required to drive up to 6 white LEDs, using charge pump technology. The ADM8846 provides the power required to drive up to 5 white LEDs, using charge pump technology. The LEDs are used for backlighting a color LCD display. To maximize power efficiency, a charge pump that can operate in either of a 1x, 1.5x or 2x mode is used. The Charge Pump automatically switches between 1x/1.5x/2x modes based on the input voltage, to maintain correct output levels at a high power efficiency.

Improved brightness matching of the LEDs is achieved by the use of a feedback pin to sense individual LED current with a maximum matching accuracy of 1% and LED to ISET maximum matching of 1%.

The ADM8845/6 provides two digital input control pins, CTRL1 and CTRL2. Which control the operation and the brightness of the LEDs.

The ADM8845 is configured with a main and a sub display options, the main display refers to 4 of the 6 LEDs (FB1 - FB4) and the sub display refers to the remaining 2 LEDs (FB5 - FB6), refer to Figure 2.

The ADM8845 provides the option to control the brightness of the LEDs with a Digital PWM signal. The duty cycle of the PWM signal determines the brightness of the backlight LEDs.

REV. PrE 06/03

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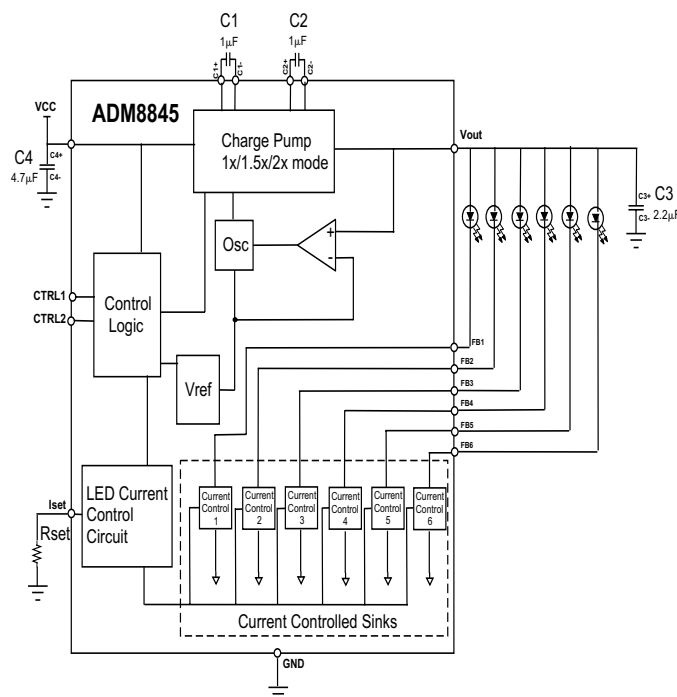


Figure 1. ADM8845 FUNCTIONAL BLOCK DIAGRAM

The ADM8846 controls the operation and brightness of all 5 LEDs together. The ADM8846 provides 3 built-in brightness levels for brightness control of the 6 LEDs.

The ADM8845/6 also allows the brightness of the LEDs to be controlled using a DC voltage, refer to page 8, Figure 10.

The ADM8845/6 also has soft-start circuitry to limit inrush current flow at power up.

The ADM8845/6 is fabricated using CMOS technology for minimal power consumption. The part is packaged in a 16-pin LFCSP package.

ADM8845/6

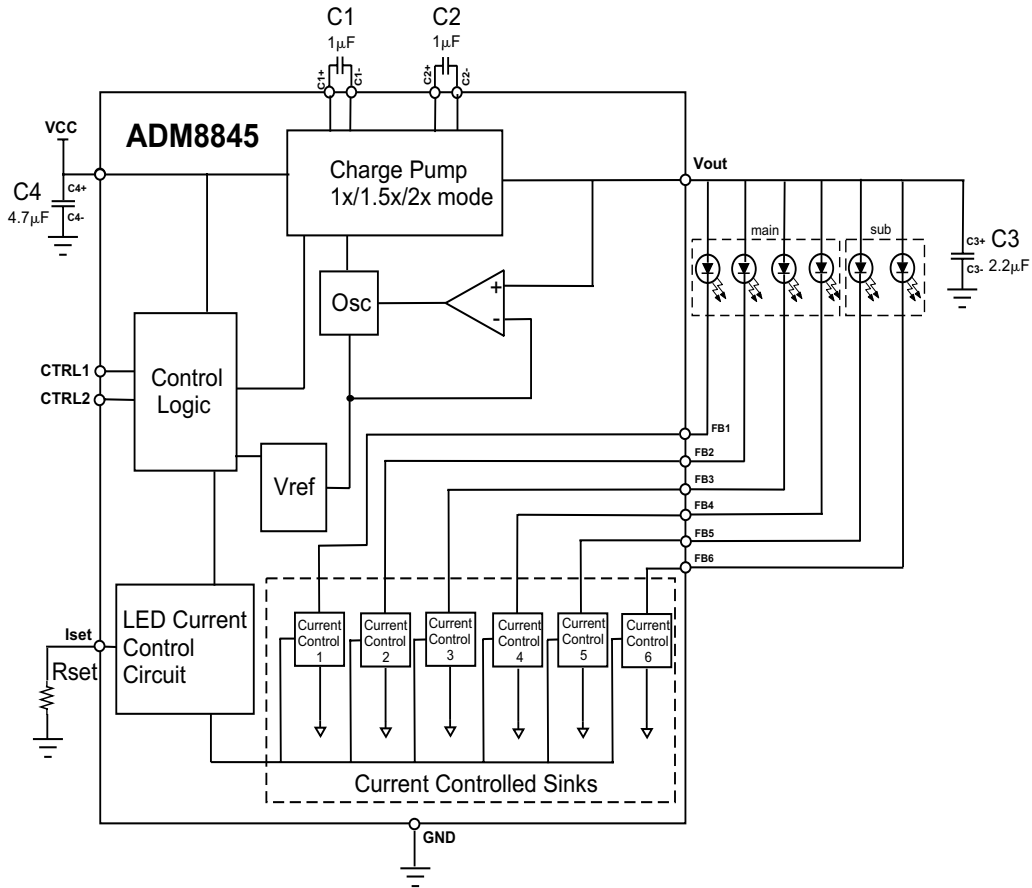


Figure 2. ADM8845 FUNCTIONAL BLOCK DIAGRAM

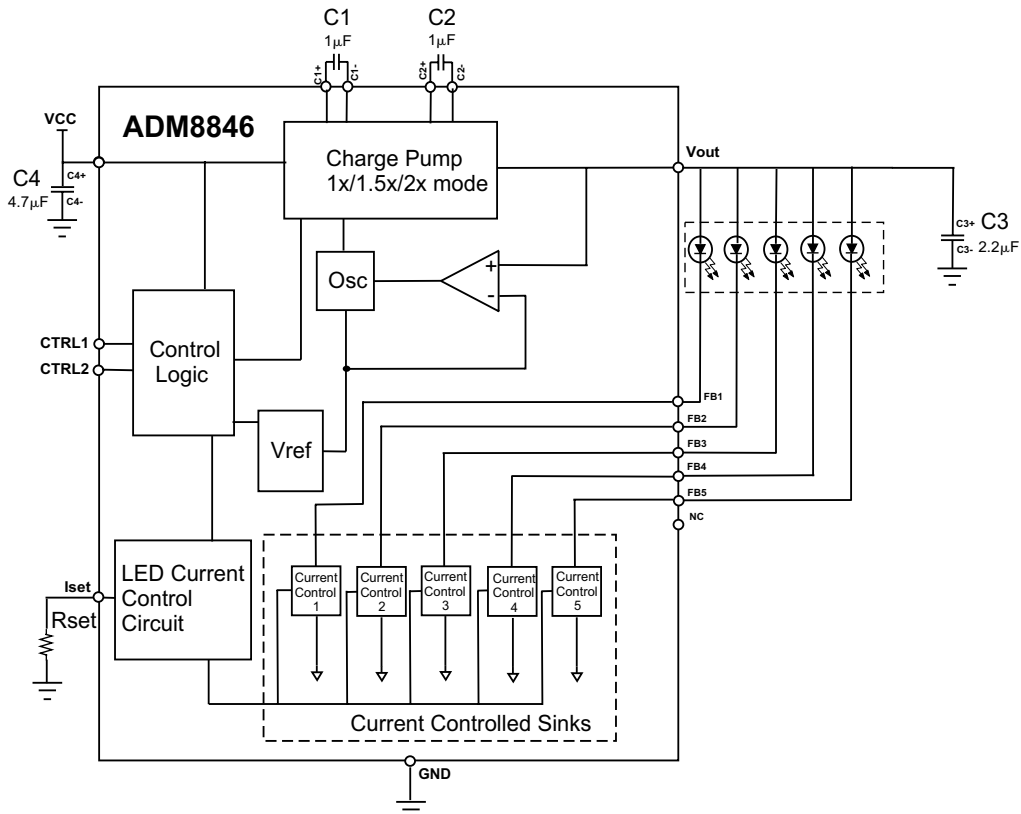


Figure 2. ADM8846 FUNCTIONAL BLOCK DIAGRAM

# PRELIMINARY TECHNICAL DATA

( $V_{CC} = 2.6V$  to  $5.5V$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$  unless otherwise noted )  
 $C1, C2 = 1.0\mu F$ ;  $C3 = 2.2\mu F$ ;

## ADM8845/6 - SPECIFICATIONS

PARAMETER	Min	Typ	Max	Units	Test Conditions
Input Voltage, $V_{CC}$	2.6		5.5	V	
Supply Current, $I_{CC}$		2.6		mA	All 6 LEDs Disconnected, $V_{CC} = 3.3V$ , $R_{SET} = 7.08k\Omega$ ADM8845: CTRL1 = 1, CTRL2 = 1, ADM8846: CTRL1 = 0, CTRL2 = 1.
Shutdown Current			5	$\mu A$	
Charge-Pump Frequency		1.5		MHz	
Charge Pump Mode Thresholds					
1.5x to 2x		3.33		V	
Accuracy			4	%	
2x to 1.5x		3.36		V	
Accuracy			4	%	
Hysteresis		30		mV	
1x to 1.5x		4.77		V	
Accuracy			4	%	
1.5x to 1x		4.81		V	
Accuracy			4	%	
Hysteresis		40		mV	
<b>Iset Pin</b>					
LED : LED Accuracy			1	%	$I_{LED} = 20mA$ , $V_{FB} = 0.4V$
LED : $I_{SET}$ Accuracy			1	%	$I_{LED} = 20mA$ , $V_{FB} = 0.4V$
Iset pin voltage		1.18		V	
$I_{LED}$ to $I_{SET}$ Ratio		120			
Min Compliance on FB pin		0.2	0.3	V	Iset = 20mA
Charge Pump Output Resistance			2.5	Ohm's	1.5x Mode
LED Current			6	Ohm's	2x Mode
LED Current			30	mA	
PWM	0.1		200	KHz	
<b>Digital Inputs</b>					
Input Hi	0.7 $V_{CC}$			V	
Input Low			0.3 $V_{CC}$	V	
Input Leakage Current			1	$\mu A$	
Charge Pump Power Efficiency		75		%	ADM8845: CTRL1 = 1, CTRL2 = 1, ADM8846: CTRL1 = 0, CTRL2 = 1, $V_{CC} = 3.3V$ , $I_{load} = 120mA$ $V_{f_{LED}} = 3.8V$
Vout Ripple		30		mV	$I_{LED} = 20mA$

\* Specifications are target values and are subject to change without notice.

### THERMAL CHARACTERISTICS

16-Lead LFCSP Package:

$\Theta_{JA} = 50^\circ C/Watt$

Note: If  $I_{LED} = 30mA$  per LED and all 6 LEDs are being used, then  $T_A = -40^\circ C$  to  $70^\circ C$

# PRELIMINARY TECHNICAL DATA

## ADM8845/6

### PIN FUNCTION DESCRIPTION

Pin		Mnemonic	Function
<b>ADM8845 ADM8846</b>			
1	4	VOUT	Charge Pump Output. A 2.2 $\mu$ F capacitor to ground is required on this pin.
2	2	C2+	Flying Capacitor 2 Positive Connection
3	3	I <sub>SET</sub>	Bias current set input. The current flowing through the R <sub>SET</sub> resistor I <sub>SET</sub> is gained up by 120 to give the I <sub>LED</sub> current. Connect a resistor R <sub>SET</sub> to GND to set the bias current as V <sub>SET</sub> /R <sub>SET</sub> . (Note: V <sub>set</sub> = 1.18V)
4	5	FB1	LED1 Cathode connection and Charge Pump Feedback. The current flowing in LED1 is 120 times the current flowing through R <sub>SET</sub> , I <sub>SET</sub> .
5	6	FB2	LED2 Cathode connection and Charge Pump Feedback. The current flowing in LED2 is 120 times the current flowing through R <sub>SET</sub> , I <sub>SET</sub> . When using fewer than six LEDs this pin can be left unconnected.
6	7	FB3	LED3 Cathode connection and Charge Pump Feedback. The current flowing in LED3 is 120 times the current flowing through R <sub>SET</sub> , I <sub>SET</sub> . When using fewer than six LEDs this pin can be left unconnected.
7	8	FB4	LED4 Cathode connection and Charge Pump Feedback. The current flowing in LED4 is 120 times the current flowing through R <sub>SET</sub> , I <sub>SET</sub> . When using fewer than six LEDs this pin can be left unconnected.
8	9	FB5	LED5 Cathode connection and Charge Pump Feedback. The current flowing in LED5 is 120 times the current flowing through R <sub>SET</sub> , I <sub>SET</sub> . When using fewer than six LEDs this pin can be left unconnected.
9	11	FB6/NC	LED6 Cathode connection and Charge Pump Feedback. The current flowing in LED6 is 120 times the current flowing through R <sub>SET</sub> , I <sub>SET</sub> . When using fewer than six LEDs this pin can be left unconnected. This Pin is No Connect in the ADM8846.
10	10	GND	Device Ground Pin.
11	1	C2-	Flying Capacitor 2 Negative Connection.
12	12	CTRL2	Digital Input. 3 V CMOS Logic. Used with CTRL1 to control the operation of the LEDs.
13	13	CTRL1	Digital Input. 3 V CMOS Logic. Used with CTRL2 to control the operation of the LEDs.
14	14	C1-	Flying Capacitor 1 Negative Connection.
15	15	V <sub>CC</sub>	Positive Supply Voltage Input. Connect this pin to a 2.6 V to 5.5 V supply with a 4.7 $\mu$ F decoupling capacitor.
16	16	C1+	Flying Capacitor 1 Positive Connection.

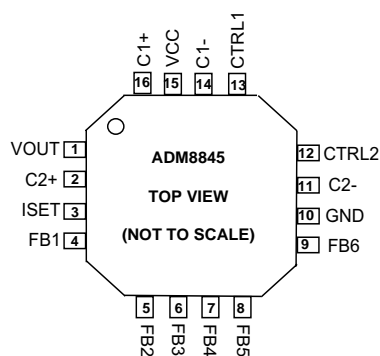


Figure 3. ADM8845 PIN CONFIGURATION

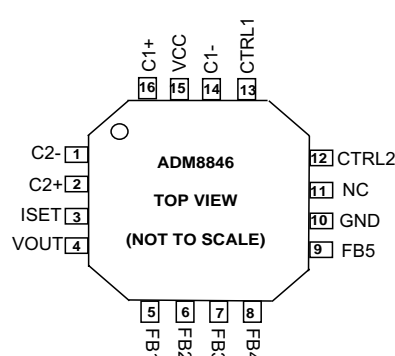


Figure 4. ADM8846 PIN CONFIGURATION

**ADM8845 LED BRIGHTNESS CONTROL WITH A DIGITAL PWM SIGNAL**

PWM brightness control provides the widest brightness control by pulsing the LEDs on and off using the digital input control pins, CTRL1 and CTRL2. The LEDs operate at either zero or full current (set by the R<sub>SET</sub> resistor). The PWM signal turns the current control sinks on and off. The average current through the LEDs changes with the PWM signal duty cycle.

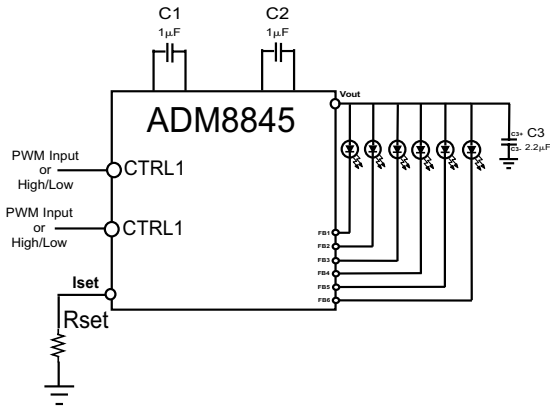


Figure 4. ADM8845 Digital PWM Brightness Control Application Diagram

By applying a PWM signal to the digital input control pins, CTRL1 and/or CTRL2 you can adjust the brightness of the sub and main displays. The ADM8845 six LEDs are organised into 2 groups, Main Display (FB1-FB4) and Sub Display (FB4 - FB6), refer to Figure 2, Page 2.

The ADM8845 main and sub display brightness can be controlled together or separately. By applying a digital PWM signal to both CTRL1 and CTRL2 pins. The Duty Cycle of the applied PWM determines the brightness of the main and sub displays together. By varying the duty cycle of the applied PWM signal you vary the brightness of the main and sub displays from 0% to 100%.

By holding CTRL1 low and applying a digital PWM signal to CTRL2, the sub display is turned off and the main display is on, the brightness of the main display is determined by the duty cycle off the applied digital PWM signal.

Also applying a digital PWM signal to CTRL1 and holding CTRL2 low ,the sub display is turned on and the main display is off, the brightness of the sub display is determined by the duty cycle off the applied digital PWM signal.

Also applying a digital PWM signal to CTRL1 and holding CTRL2 high ,the sub display is turned on and the main display is on, the brightness of the sub display is determined by the duty cycle off the applied digital PWM signal. The brightness of the main display is set to the maximum (maximum is set by the R<sub>SET</sub> resistor).

By holding CTRL1 high and applying a digital PWM signal to CTRL2, the sub display is turned on and the main display is on, the brightness of the main display is determined by the duty cycle off the applied digital PWM signal. The brightness of the sub display is set to the maximum (maximum is set by the R<sub>SET</sub> resistor)

When CTRL1 and CTRL2 go low the LED Current Control Sinks shutdown. Shutdown of the Charge Pump is delayed by 15mS. This timeout period allows the ADM8845 to determine if a PWM signal is present on CTRL1 and CTRL2 or if the user has selected a full chip shutdown.

The minimum frequency of the PWM signal is 100Hz, if a PWM signal of frequency of less than 100Hz is used the part shuts down. The PWM signal is applied to digital input pins, CTRL1 and/or CTRL2. If digital PWM brightness control of the LEDs is not required then a constant logic level 1 or 0 must be applied, refer to Page 6, Figure 7. ADM8845 Digital Inputs Truth Table and also Page 5 Figure 4. ADM8845 PWM Brightness Control Application Diagram.

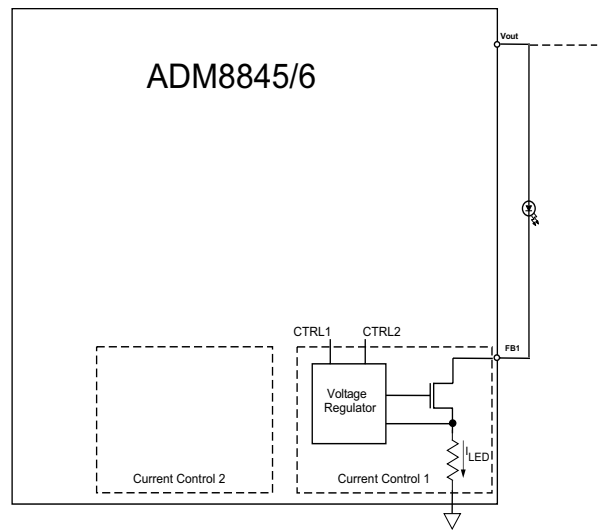


Figure 5. ADM8845/6 Current Control Sinks

ADM8845/6

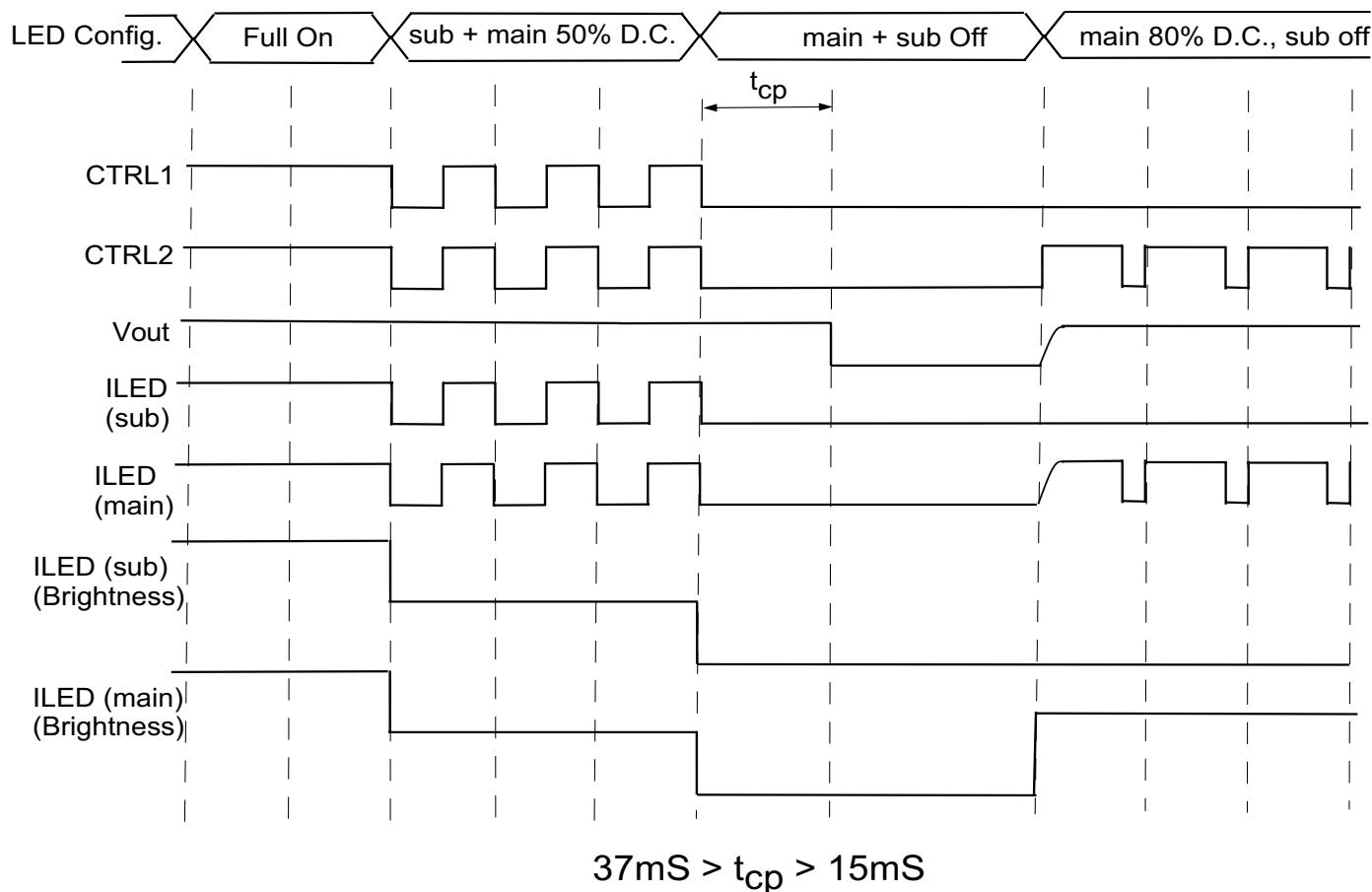


Figure 6. ADM8845 Application Timing

CTRL1	CTRL2	LED Operation	Notes
0	0	Sub Display Off / Main Display Off (Full SHDN)	1,4
0	1	Sub Display Off / Main Display On	1,3
1	0	Sub Display On / Main Display Off	1,4
1	1	Sub Display On / Main Display On (Full On)	1,3
0	PWM	Sub Display Off / Digital PWM Brightness Control On Main Display	2,5
PWM	0	Digital PWM Control On Sub Display / Main Display Off	5,4
1	PWM	Sub Display On / Digital PWM Brightness Control On Main Display	1,5
PWM	1	Digital PWM Brightness Control On Sub Display / Main Display On	5,3
PWM	PWM	Digital PWM Brightness Control On Sub Display and Main Display	5,5

Figure 7. ADM8845 Digital Inputs Truth Table

Because the ADM8845 has its 6 LEDs arranged into 2 groups, sub and main. It is possible to configure the 6 LEDs as in Figure 7. ADM8845 Digital Inputs Truth Table, refer also to Figure 6. ADM8845 Application Timing.

Note 1: Sub Display on means the display is on with the maximum brightness set by the  $R_{SET}$  resistor. CTRL1 = 1 means a constant logic level (Vcc) is applied to CTRL1.

Note 2: Sub Display off means the sub display only is off. CTRL1 = 0 means a constant logic level (Gnd) is applied to CTRL1.

Note 3: Main Display on means the display is on with the maximum brightness set by the  $R_{SET}$  resistor. CTRL2 = 1 means a constant logic level (Vcc) is applied to CTRL2.

Note 4: Main Display off means the main display only is off. CTRL2 = 0 means a constant logic level (Gnd) is applied to CTRL2.

Note 5: PWM means a Digital PWM signal is applied to the CTRL pin with a frequency from 100Hz to 200kHz.

**ADM8846 THREE LEVELS OF BRIGHTNESS CONTROL WITH CTRL1 AND CTRL2 PINS**

The ADM8846 only allows all 5 LEDs brightness to be controlled together. The ADM8846 has 3 levels of brightness. By applying a constant logic CTRL1 = 0 and CTRL2 = 0 to the digital control pins the 5 LEDs are turned off (Full SHDN).

Applying a constant logic CTRL1 = 0 and CTRL2 = 1 to the digital control pins all 5 LEDs are set to maximum brightness (set by the R<sub>SET</sub> resistor).

A constant logic CTRL1 = 1 and CTRL2 = 0 on digital control pins sets all 5 LEDs to one-third (1/3) the maximum brightness.

A constant logic CTRL1 = 1 and CTRL2 = 1 on digital control pins sets all 5 LEDs to two-thirds (2/3) the maximum brightness.

Refer to Page 6, Figure 8. ADM8846 Digital Inputs Truth Table.

ADM8846 Digital Input Control Pins

CTRL1	CTRL2	LED Operation
0	0	Full SHDN (All 6 LEDs)
0	1	Max Brightness (1/1)
1	0	One-Third Brightness (1/3)
1	1	Two-Thirds Brightness (2/3)

Figure 8. ADM8846 Digital Inputs Truth Table

**ADM8845/6 LED BRIGHTNESS CONTROL USING A PWM SIGNAL APPLIED TO V<sub>PWM</sub>**

By adding 2 external resistors and a capacitor as shown on figure 9, this configuration can also be used to achieve PWM brightness control. This PWM brightness control can be used instead of CTRL1 and/or CTRL2 PWM brightness control. With this configuration CTRL1 and CTRL2 digital logic pins can be used to control the LEDs operation while V<sub>PWM</sub> can be used to control the brightness of the LEDs. By applying a high-frequency PWM signal (0V to 2.5V) to drive an R-C-R filter on the I<sub>SET</sub> pin of the ADM8845/6 (See Figure 4). A 0% PWM duty cycle corresponds to 20mA/LED, while a 100% PWM duty cycle corresponds to a 0mA/LED. At PWM frequencies above 5kHz, C5 may be reduced. Refer to Figure 9. ADM8845/6 PWM Brightness Control Using Filtered-PWM Signal. The amplitude of the PWM signal must be 0 V and 2.5 V only, in order to have 20mA flowing in each LED.

$$I_{LED} = \frac{I_{SET\_Voltage}}{\frac{R_{SET} * 2R}{R_{SET} + 2R}} * 120 * \frac{(1 - Duty Cycle)}{100}$$

**AUTOMATIC GAIN CONTROL**

The Automatic Gain Control block controls the operation of the Charge Pump, by selecting the appropriate Gain for the Charge Pump to maintain the correct outputs at a high power efficiency. The Charge Pump Switching thresholds are:

- From 1.5x to 2x : 3.33V
- From 2x to 1.5x : 3.36V
- From 1x to 1.5x : 4.77V
- From 1.5x to 1x : 4.81V

Refer to ADM8845/6 Specification Page 3 for more details.

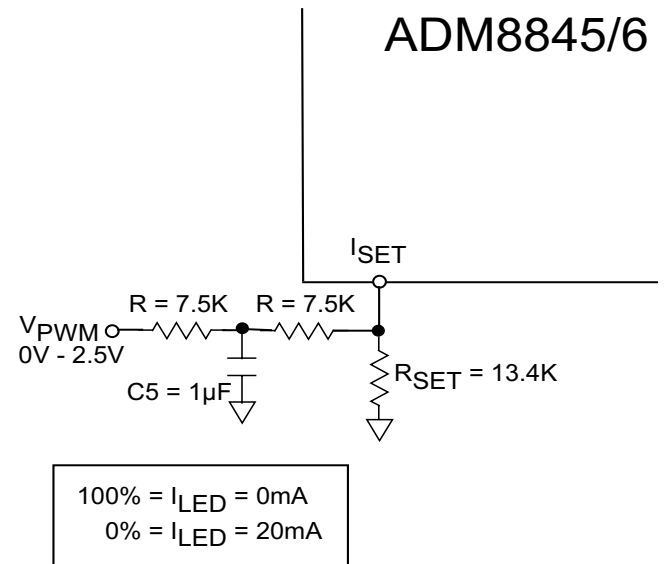


Figure 9. ADM8845/6 PWM Brightness Control Using Filtered-PWM Signal

## ADM8845/6

### ADM8845/6 LED BRIGHTNESS CONTROL USING A DC VOLTAGE APPLIED TO $V_{\text{BRIGHT}}$

By adding 1 resistor as shown in figure 10 , this configuration can also be used to achieve brightness control of the LEDs. Figure 11 shows an application example of LED Brightness control using a DC Voltage applied to  $V_{\text{BRIGHT}}$ .

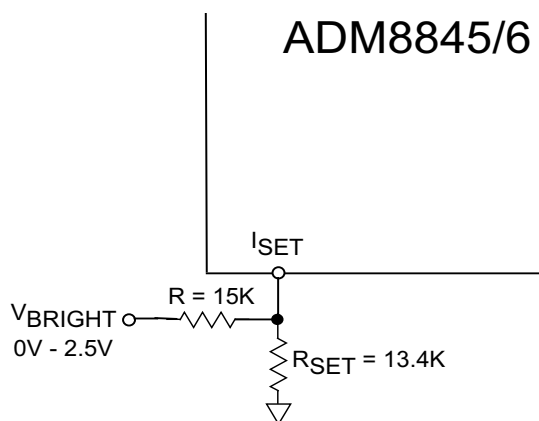


Figure 10. ADM8845/6 PWM Brightness Control Using a DC Voltage applied to  $V_{\text{BRIGHT}}$

The equation for  $I_{\text{LED}}$  is:

$$I_{\text{SET}} = (1/R_{\text{SET}} + 1/R)(V_{\text{SET}}) - (1/R)(V_{\text{BRIGHT}})$$

$$I_{\text{LED}} = 120 * I_{\text{set}}$$

Where  $R = 15\text{k Ohm}$ ,  $V_{\text{SET}} =$  voltage at Iset pin (1.18V)

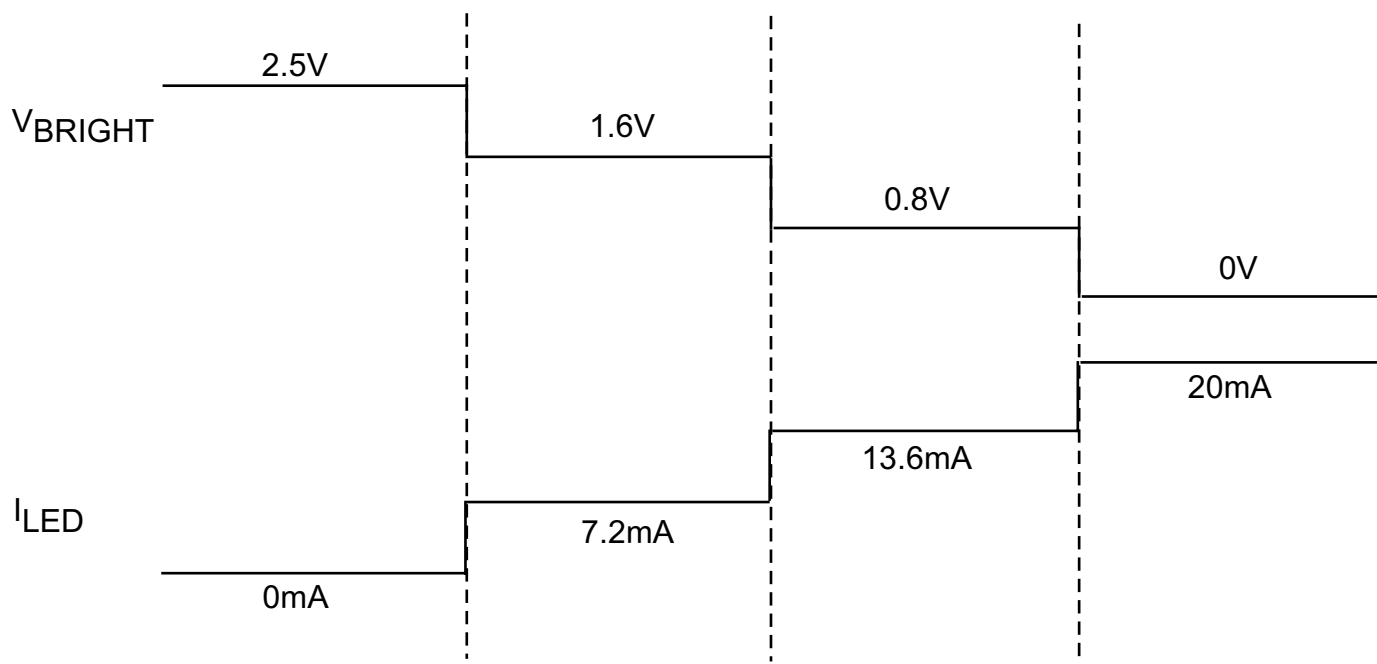


Figure 11. ADM8845/6 PWM Brightness Control Application Diagram Using a DC Voltage applied to  $V_{\text{BRIGHT}}$



# PRELIMINARY TECHNICAL DATA

ADM8845/6

## OUTLINE DIMENSIONS

Dimensions Shown in mm.

### 16-Lead 3mm x 3mm Chip Scale Package (CP-16)

