



### FEATURES

- ADM8845 drives 6 white LEDs from a 2.6V to 5.5V (li-ion) input supply**
- 1x/1.5x/2x Fractional Charge Pump to maximize power efficiency**
- 1% LED Current Matching**
- Power Sub and main Display LEDs**
- 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 with Main and Sub Displays**
- DSC**
- PDA's**

### INTRODUCTION

The ADM8845 Evaluation Board allows the ADM8845 Charge Pump Driver for LCD white LED backlights to be quickly and easily evaluated.

The evaluation board allows all of the input and output functions to be exercised without the need for external components.

### ADM8845 GENERAL DESCRIPTION

The following gives a brief description of the ADM8845 and the evaluation board hardware overview. Further information can be found in the data sheet for the device.

The ADM8845 provides the power required to drive up to 6 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 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  $I_{LED}$  to  $I_{LED}$  matching accuracy of 1% and  $I_{LED}$  to  $I_{SET}$  maximum matching of 1%.

#### Rev. PrB

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The ADM8845 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 sub and main display, the main display refers to 4 of the 6 LEDs (FB1 - FB4) and the sub display refers to the remaining 2 LEDs (FB5 - FB6).

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. Brightness control of the LEDs can also be controlled by a DC voltage. The ADM8845 has soft-start circuitry to limit inrush current flow at power up.

The ADM8845 is fabricated using CMOS technology for minimal power consumption. The part is packaged in a 16-lead LFCSP (Lead Frame Chip Scale Package).

### EVALUATION SYSTEM PACKAGE CONTENTS

The evaluation system contains the following items:

- ADM8845 Evaluation Board
- PC Parallel to Serial Cable
- CD containing evaluation board software

### EVALUATION BOARD HARDWARE

The ADM8845 evaluation board contains the following main components, which can be identified from the block diagram, the schematic diagram and the printed circuit board silkscreen of figures 1,3 and 4 overleaf.

- 13 jumper points to facilitate the connection of external inputs and internal circuitry.
- 21 test points for signal connection and measurement
- A patchwork area to facilitate the connection up the ADM8845 Eval Board to external components.

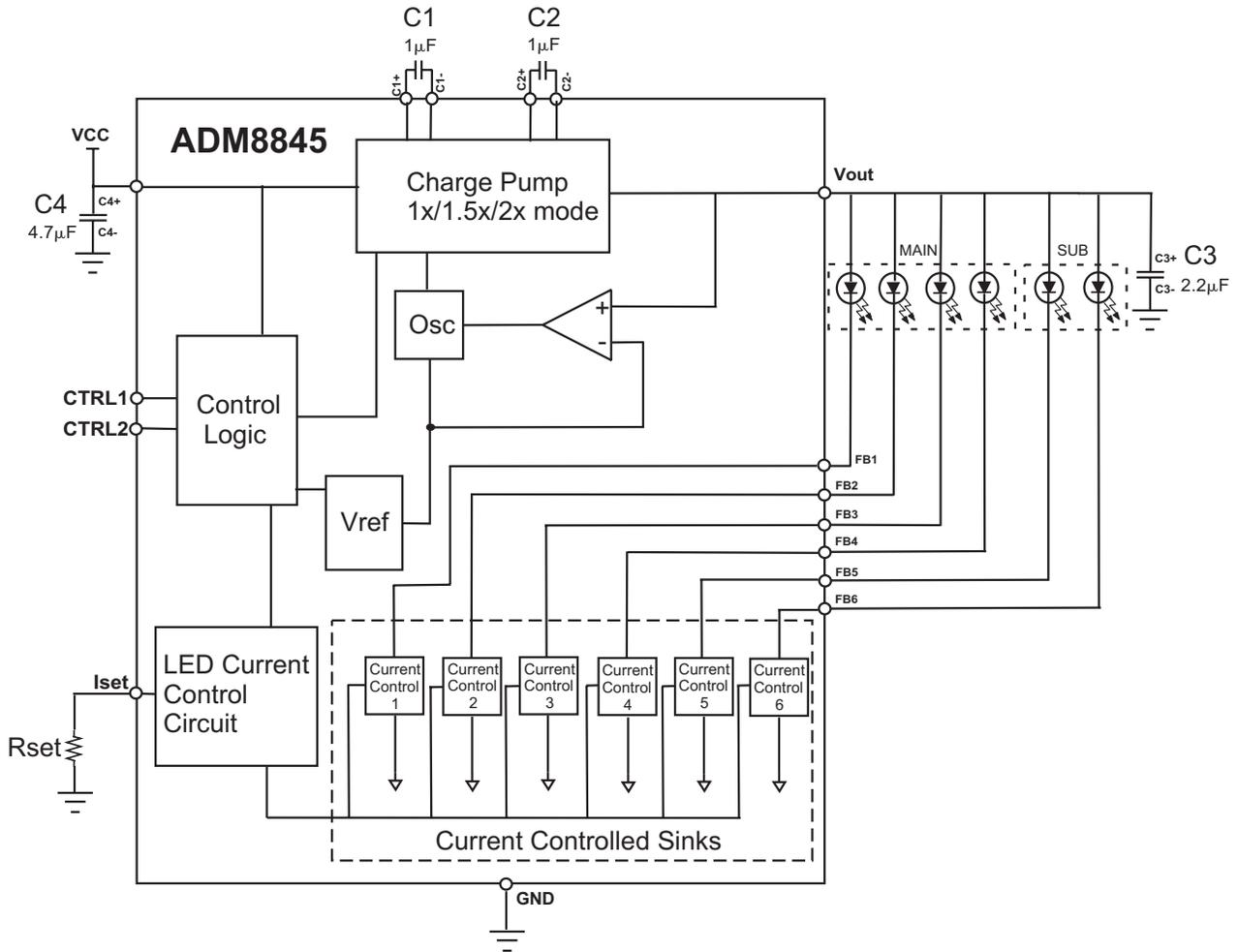


Figure 1. ADM8845 Functional Block Diagram

CTRL1	CTRL2	LED Operation
0	0	Sub Display Off / Main Display Off
0	1	Sub Display Off / Main Display On
1	0	Sub Display On / Main Display Off
1	1	Sub Display On / Main Display On

Figure 2. ADM8845 Digital Inputs Truth Table

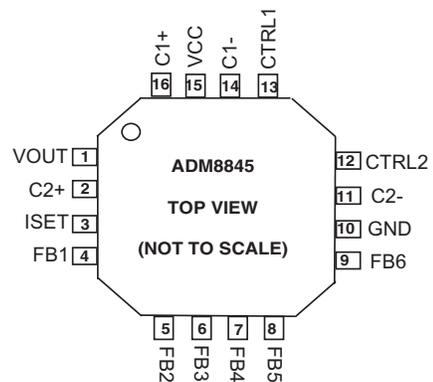


Figure 3. ADM8845 Pin Configuration



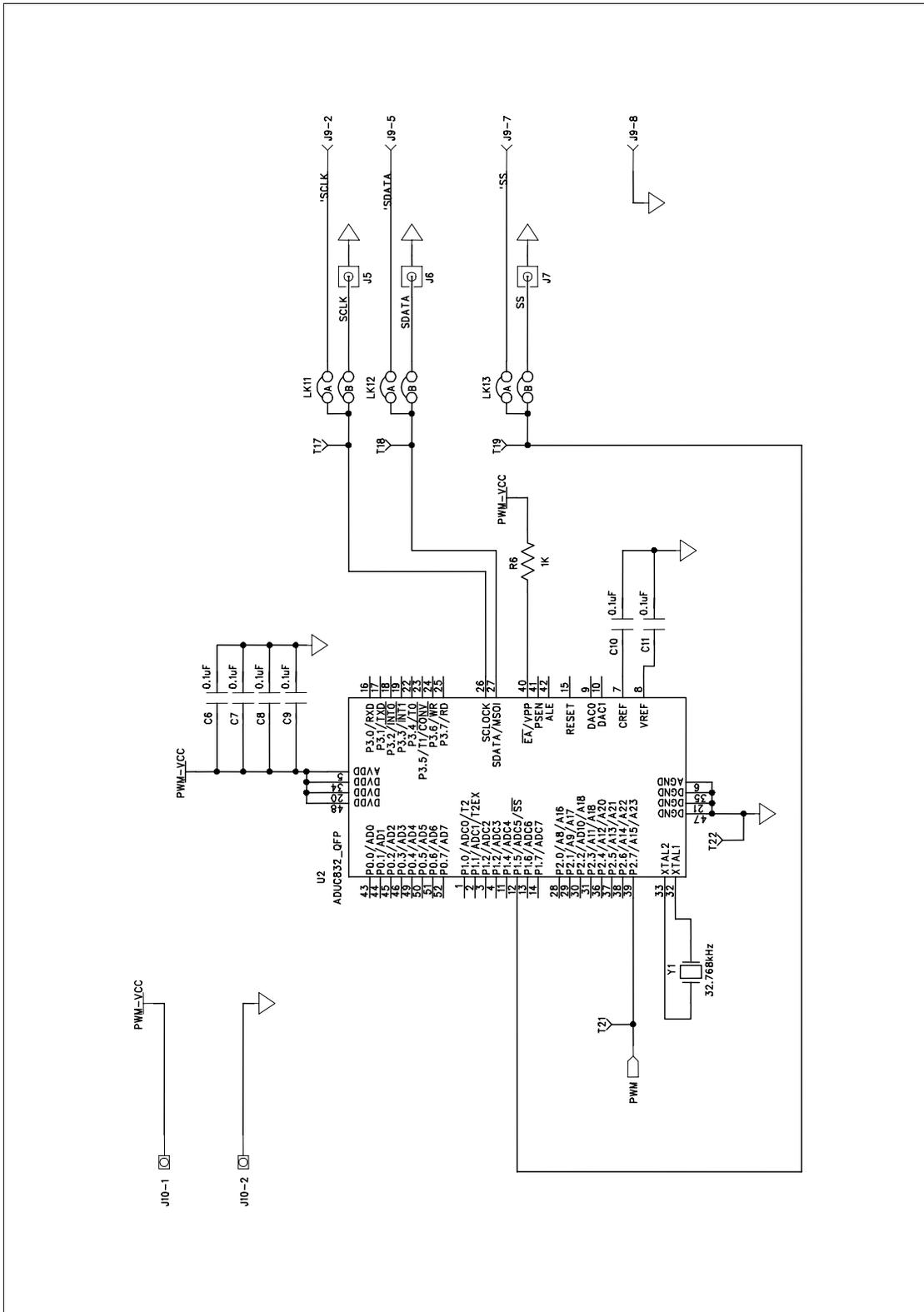
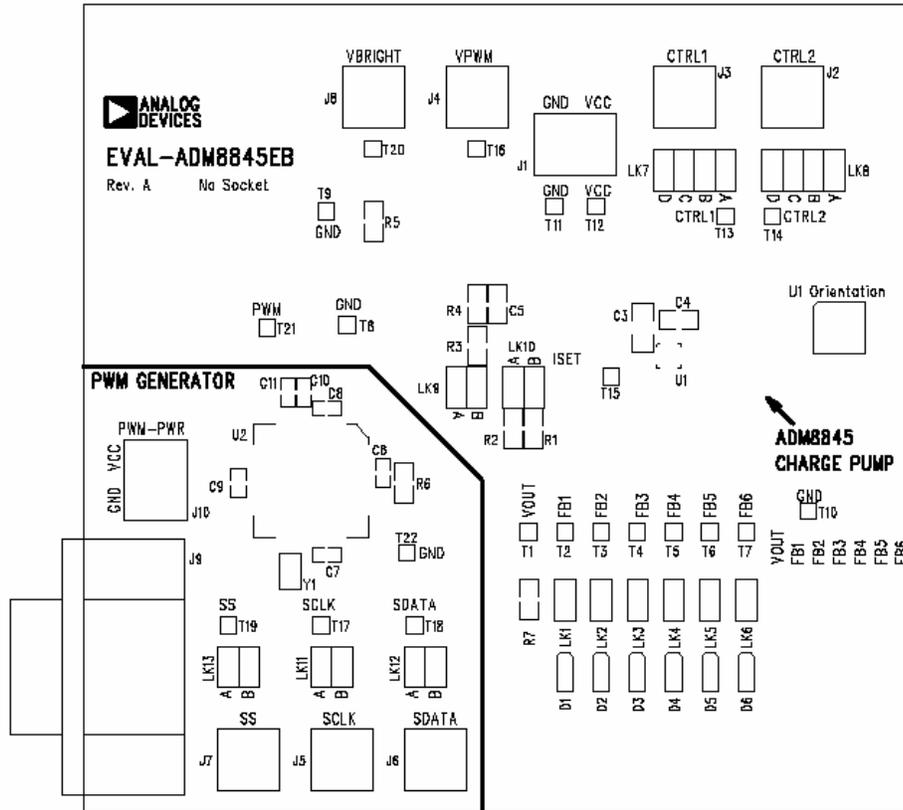


Figure 5. ADM8845 Evaluation Board Schematic Page 2



EVAL-ADM8845EB Rev. A - COMPONENT SIDE VIEW

SILKSCREEN

Figure 6. ADM8845 Evaluation Board Silkscreen

**EVALUATION BOARD CONNECTORS AND JUMPERS**

The function of the various connectors and jumpers on the evaluation board is explained below.

**TABLE 1. EVALUATION BOARD POWER CONNECTORS**

Connector Number	Function
J1	Supply to ADM8845 (3V Nominal)
J2	External CTRL2 input signal
J3	External CTRL1 input signal
J4	External $V_{PWM}$ node input signal
J5	External SCLK input
J6	External SDATA input
J7	External $\overline{SS}$ input
J8	External $V_{BRIGHT}$ node input signal
J9	DB-9 Connector (Serial Interface Connector)
J10	Supply to PWM Micro Converter (3V Nominal)

**TABLE 2. EVALUATION BOARD JUMPERS (LINKS)**

Jumper Name	Description	Default Status
LK1	LED 1 Connected	<b>Inserted</b>
LK2	LED 2 Connected	<b>Inserted</b>
LK3	LED 3 Connected	<b>Inserted</b>
LK4	LED 4 Connected	<b>Inserted</b>
LK5	LED 5 Connected	<b>Inserted</b>
LK6	LED 6 Connected	<b>Inserted</b>
LK7	A Connects CTRL1 (Pin 15) Digital Input to Vcc	<b>Inserted</b>
	B Connects CTRL1 (Pin 15) Digital Input to GND	Removed
	C Connects CTRL1 (Pin 15) Digital Input to SMB connector J3	Removed
	D Connects CTRL1 (Pin 15) Digital Input to Micro Converter PWM	Removed
LK8	A Connects CTRL2 (Pin 14) Digital Input to Vcc	<b>Inserted</b>
	B Connects CTRL2 (Pin 14) Digital Input to GND	Removed
	C Connects CTRL2 (Pin 14) Digital Input to SMB connector J2	Removed
	D Connects CTRL2 (Pin 14) Digital Input to Micro Converter PWM	Removed
LK9	A Connects $I_{SET}$ (Pin 5) to $V_{BRIGHT}$ node	<b>Inserted</b>
	B Connects $I_{SET}$ (Pin 5) to $V_{PWM}$ node	Removed
LK10	A Connects $I_{SET}$ (Pin 5) to $V_{BRIGHT}$ node or $V_{PWM}$ node	Removed
	B Connects $I_{SET}$ (Pin 5) to $I_{SET}$ resistor (7.2k Ohm)	<b>Inserted</b>
LK11	A Connects SCLOCK to DBP Connector (SCLOCK controlled by Software GUI)	<b>Inserted</b>
	B Connects SCLOCK to SMB connector J5	Removed
LK12	A Connects SDATA to DBP Connector (SDATA controlled by Software GUI)	<b>Inserted</b>
	B Connects SDATA to SMB connector J6	Removed
LK13	A Connects SS to DBP Connector PWM (SS controlled by Software GUI)	<b>Inserted</b>
	B Connects SS to SMB connector J7	Removed

**TABLE 3. EVALUATION BOARD COMPONENTS**

Item	Qty	Ref Des	Description
1	1	U1	ADM8845
2	1	U2	ADuC832 Micro Converter
3	2	J1, J10	Power Connector
4	7	J2- J8	SMB Connectors
5	1	J9	DB9 Connector
6	21	T1 - T21	Test points
7	3	C1, C2, C5	CAP, 1 $\mu$ F
8	1	C3	CAP, 2.2 $\mu$ F
9	1	C4	CAP, 4.7 $\mu$ F
10	6	C6 - C11	CAP, 0.1 $\mu$ F
11	1	R1	7.32K Ohm
12	1	R2	13.4K Ohm
13	2	R3, R4	7.5K Ohm
14	1	R5	15K Ohm
15	1	R6	1K Ohm
16	1	R7	0 Ohm
17	6	D1 - D6	White LEDs (FEC 335-7996)
18	1	Y1	32.768kHz Osc

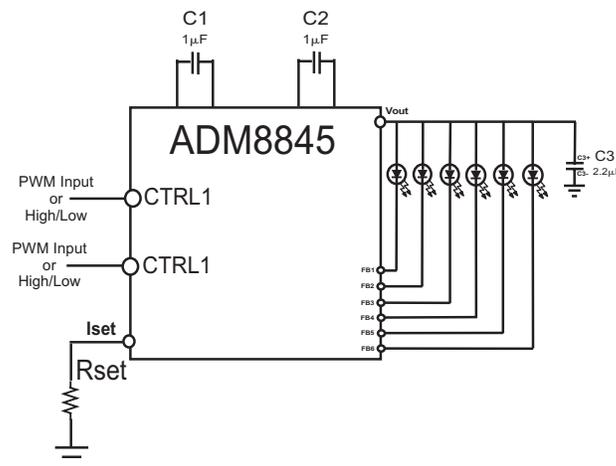
## SETTING UP THE ADM8845 EVAL BOARD

Insert the following links to evaluate the ADM8845 with both the main and sub display on with approx. 20mA per LED:

1. Insert LK1 – LK6, this attaches all 6 LEDs to the Vout pin (Pin 3) of the ADM8845 chip. We are now going to operate the ADM8845 Eval Board with 6 LEDs in parallel.
2. Insert LK7 A and LK8 A. This turns on both the main and sub display.
3. Insert LK10 B. This connect a 7.32K Ohm resistor to the I<sub>SET</sub> pin. This will give approx. 20mA per LED.  
 $1.18V/7.32k\Omega = 161.20\mu A$ . This is then scaled up by 120 to give  $161.20\mu A * 120 = 19.344mA$  per LED
4. Remove all other Links
5. Apply power to Power Connector J1 (3V Nominal)

Insert the following links to evaluate the ADM8845 part with both the main and sub display on with approx. 20mA per LED, brightness controlled by a digital PWM signal applied to both CTRL1 and CTRL2:

1. Insert LK1 – LK6, this attaches all 6 LEDs to the Vout pin (Pin 3) of the ADM8845 chip. We are now going to operate the ADM8845 Eval Board with 6 LEDs in parallel.
2. Insert LK7 D and LK8 D. This turns on both the main and sub display for digital PWM brightness control.
3. Insert LK10 B. This connect a 7.32K Ohm resistor to the I<sub>SET</sub> pin. This will give approx. 20mA per LED.  
 $1.18V/7.32k\Omega = 161.20\mu A$ . This is then scaled up by 120 to give  $161.20\mu A * 120 = 19.344mA$  per LED
4. Insert LK11 A, LK12 A and LK13 A, this connect the ADuC832 to the software GUI to program the digital PWM frequency and duty cycle.
5. Remove all other Links
6. Apply power to Power Connector J1 (3V Nominal). This power up the ADM8845
7. Apply power to Power Connector J10 (3V Nominal). This powers up the ADuC832 which provides the digital PWM signal to CTRL1 and CTRL2.
8. Attach the PC cable provided to the parallel port of a PC and the Eval Board.
9. Open up the ADM8845/6 Software GUI and program the digital PWM frequency and duty cycle as required.



Insert the following links to evaluate the ADM8845 part with both the main and sub display on, brightness controlled by a DC voltage applied to the V<sub>BRIGHT</sub> node, SMB J8.

1. Insert LK1 – LK6, this attaches all 6 LEDs to the Vout pin (Pin 3) of the ADM8845 chip. We are now going to operate the ADM8845 Eval Board with 6 LEDs in parallel.
2. Insert LK7 A and LK8 A. This turns on both the main and sub display.
3. Insert LK10 A and LK 9 A. This connects in the 13.4K Ohm resistor to ground and also the 15K Ohm resistor.
4. Apply a DC voltage from 0V to 2.5V to adjust the current flowing through the 6 LEDs, thereby adjusting their brightness.
5. The Following formula describes the relationship between I<sub>SET</sub> and I<sub>LED</sub>

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

$$I_{LED} = 120 * I_{SET}$$

Where R = 15K Ohm, V<sub>SET</sub> = 1.18V (Voltage at I<sub>SET</sub> pin)

6. Remove all other Links
7. Apply power to Power Connector J1 (3V Nominal). This power up the ADM8845

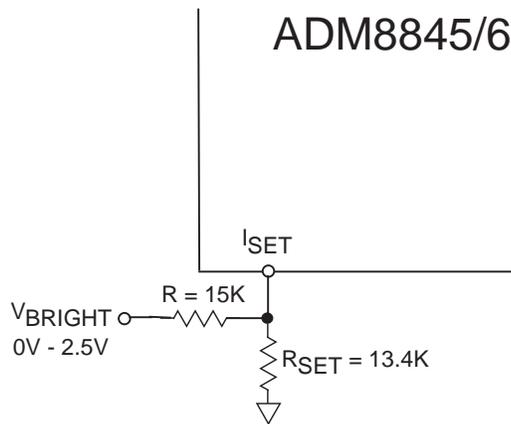


Figure 8. V<sub>BRIGHT</sub> Node

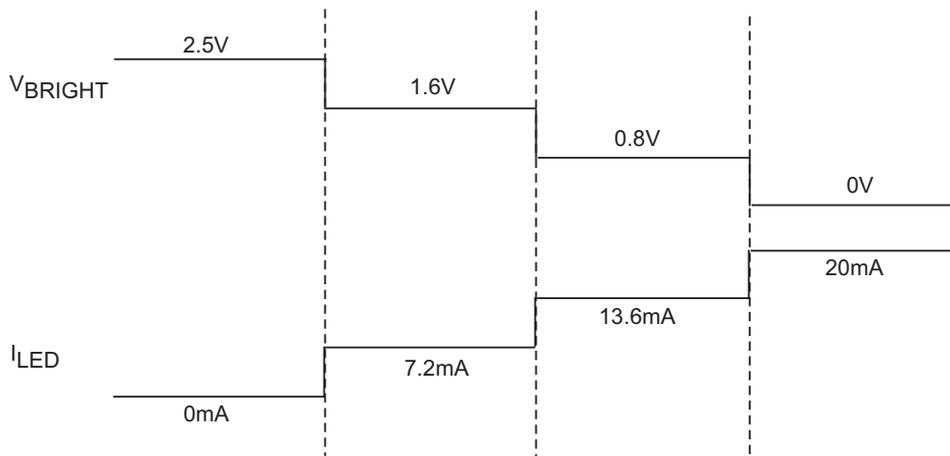


Figure 9. V<sub>BRIGHT</sub> Node Operation

Insert the following links to evaluate the ADM8845 part with both the main and sub display on, brightness controlled by a PWM signal applied to the  $V_{PWM}$  node, SMB J4.

1. Insert LK1 – LK6, this attaches all 6 LEDs to the Vout pin (Pin 3) of the ADM8845 chip. We are now going to operate the ADM8845 Eval Board with 6 LEDs in parallel.
2. Insert LK7 A and LK8 A. This turns on both the main and sub display.
3. Insert LK10 A and LK 9 B. This connects in the 13.4K Ohm resistor to ground and also the two 7.5K Ohm resistors and the 1 $\mu$ F capacitor to ground between them.
4. Apply a PWM signal (Amplitude from 0V - 2.5V only) to adjust the current flowing through the 6 LEDs, thereby adjusting their brightness.
5. The Following formula describes the relationship between  $V_{PWM}$  and  $I_{LED}$

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

Where R = 7.5K Ohm,  $V_{SET}$  = 1.18V (Voltage at  $I_{SET}$  pin)

6. Remove all other Links
7. Apply power to Power Connector J1 (3V Nominal). This power up the ADM8845.

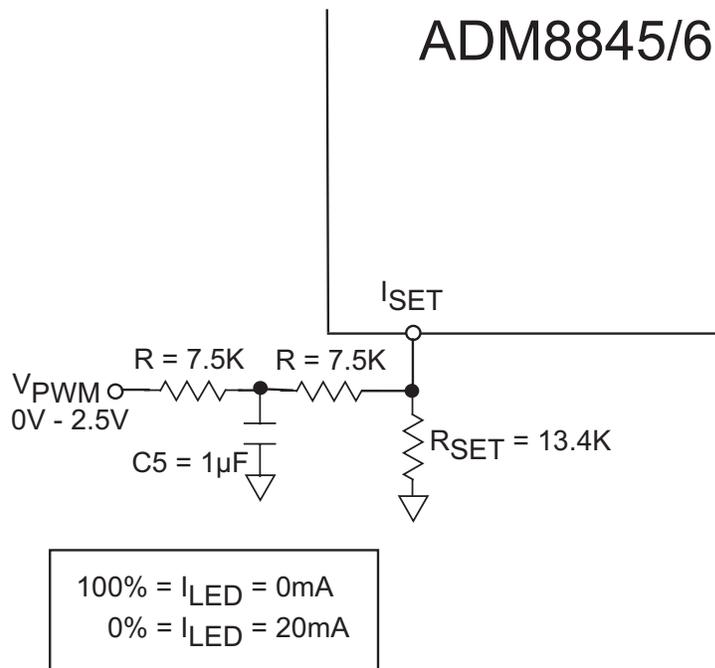


Figure 10.  $V_{PWM}$  Node Operation

USING THE ADM8845 SOFTWARE GUI TO PROGRAM THE ADUC832 PWM

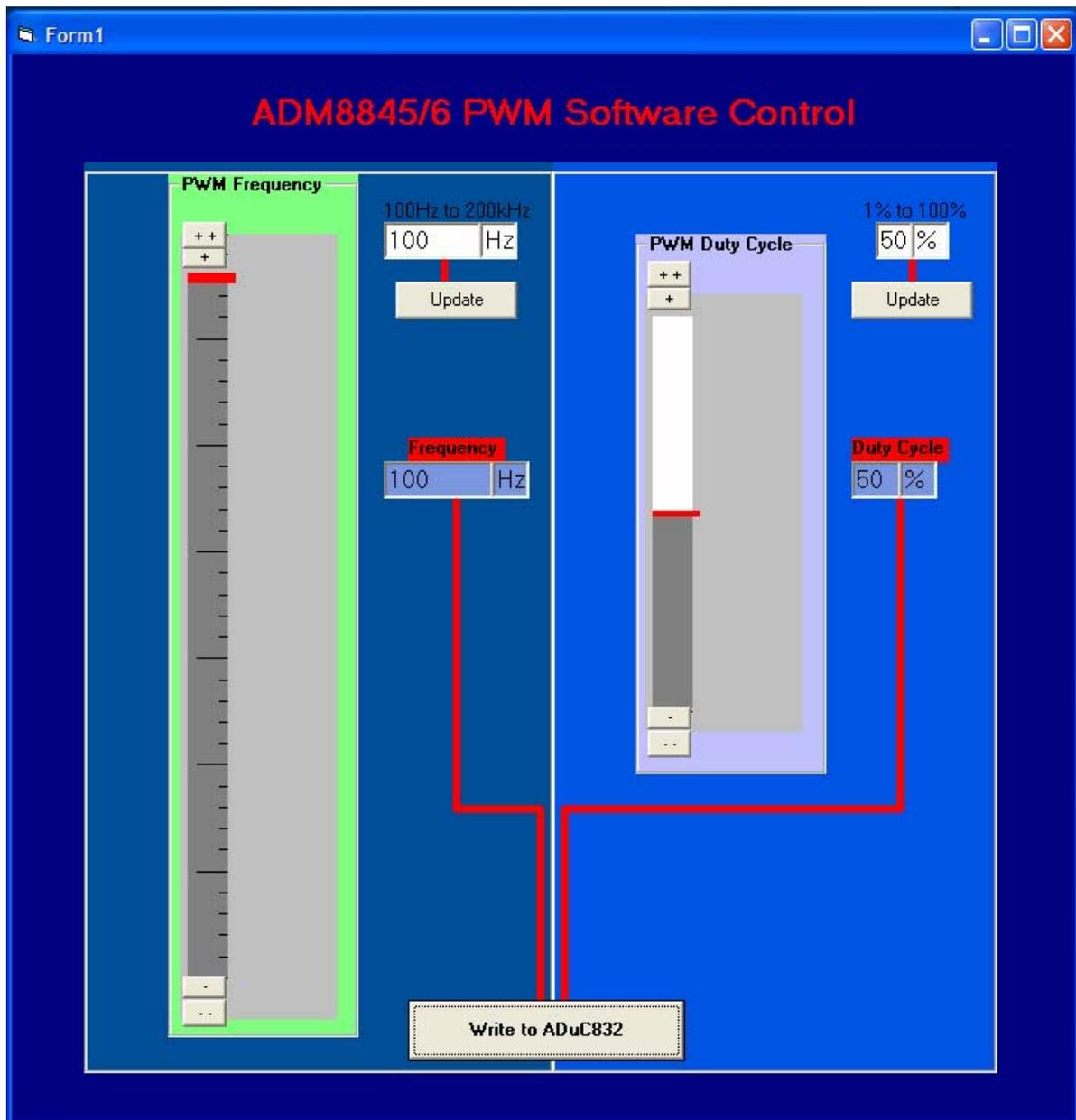


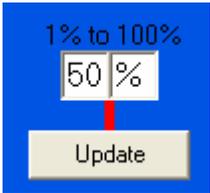
Figure 11. ADM8845 Digital PWM Software GUI

The ADM8845 software GUI allows the user to program the on-board ADuC832 to generate a PWM signal from 100Hz to 200 kHz with a duty cycle from 1% to 100%.

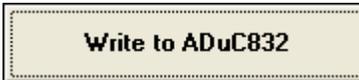
1. The user can enter the required frequency in Hz into the frequency text box and press the update button.



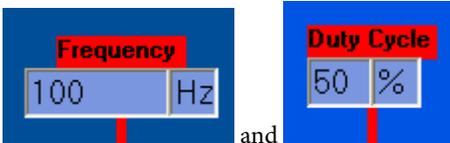
2. Also the user can enter the duty cycle required and press the update button.



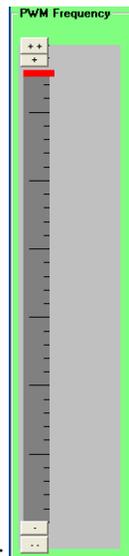
3. Then the corresponding values can be written to the ADuC832 over the parallel port to the eval board by pressing the Write to ADuC832 button.



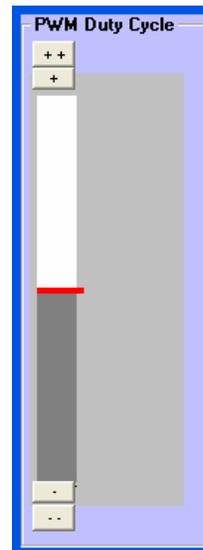
4. The values of frequency and duty cycle which are written to the ADuC832 are shown on the software GUI.



5. The user may also use the vertical sliding bars to select the frequency and duty cycle required.



6. Frequency vertical sliding bar :



- Duty Cycle vertical sliding bar :

**ADuC832 PWM**

The ADuC832 is operated in single variable resolution PWM (Mode 1), in this mode the pulse length and the cycle time (period) are programmable in user code, allowing the resolution of the PWM to be variable.

PWM1H/L sets the period of the output waveform. Reducing PWM1H/L reduces the resolution of the PWM output but increases the maximum output rate of the PWM. (e.g., setting PWM1H/L to 65536 gives a 16-bit PWM with a maximum output rate of 266Hz (16.777MHz/65536), because the maximum output rate is 266Hz and the ADM8845 PWM brightness control requires the output to go as low as 100Hz we have to use a lower frequency clock (32kHz) to generate the lower frequencies below 256Hz.

Setting PWM1H/L to 4096 gives a 12-bit PWM with a maximum output rate of 4096Hz (16.777MHz/4096).

PWH0H/L sets the duty cycle of the PWM output waveform, as shown on Figure 2.

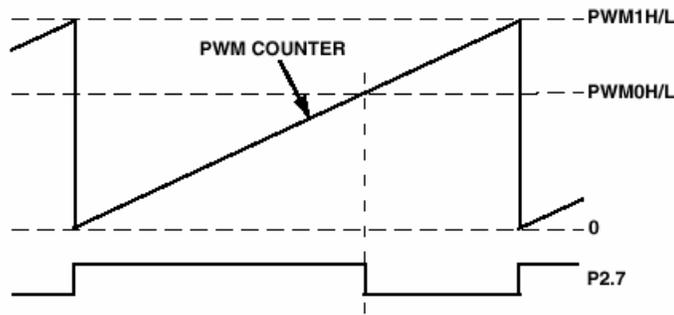


Figure 12. ADuC832 PWM in Mode 1

**WRITING TO THE ADuC832**

To program the ADuC832 PWM generator, five 8 bit words are written to the ADuC832 using the SPI interface.

- 1: PWM Frequency Low Bit
- 2: PWM Frequency High Bit
- 3: PWM Duty Low Bit
- 4: PWM Duty High Bit
- 5: PWM Mode

The ADuC832 takes a 16.777612MHz clock and divides this down by a 16 bit divisor

(PWM Frequency High Bit & PWM Frequency Low Bit)

This gives the PWM Frequency

The Duty Cycle 16 bit value is = (PWM Frequency High Bit & PWM Frequency Low Bit) \* duty cycle

The PWM mode sets the PWMCON SFR

**For example: 100 kHz and 80 % Duty Cycle**

Frequency Divisor:  $16.777612 \text{ MHz} / 100\text{kHz} = 167.77612 \Rightarrow 168$

Duty Cycle:  $168 * 0.80 = 134.4 \Rightarrow 134$

- 1: PWM Frequency Low Bit = 10101000
- 2: PWM Frequency High Bit = 00000000
- 3: PWM Duty Low Bit = 10000110
- 4: PWM Duty High Bit = 00000000
- 5: PWM Mode = 10011

**For example: 100Hz and 60 % Duty Cycle**

Frequency Divisor:  $32 \text{ kHz} / 100\text{Hz} = 320$

Duty Cycle:  $320 * 0.60 = 192$

- 1: PWM Frequency Low Bit = 01000000
- 2: PWM Frequency High Bit = 00000001
- 3: PWM Duty Low Bit = 11000000
- 4: PWM Duty High Bit = 00000000
- 5: PWM Mode = 10001

The details of the ADuC832 can be found at: <http://products.analog.com/products/info.asp?product=ADuC832>

## ADM8845 LAYOUT GUIDE

### Layout considerations and noise

Because of the ADM8845 switching behavior, PCB trace layout is an important consideration. To ensure optimum performance a ground plane should be used, all capacitors (C1,C2,C3,C4) and the R<sub>SET</sub> resistor particularly should be located with minimal track lengths to the I<sub>SET</sub> pin of the ADM8845.