

### General Description

The AAT2830/31 is a total solution IC for portable display applications. Based on a tri-mode charge pump power engine, it is capable of delivering 800mA of output current with individual driving circuitries for light emitting diode (LED) backlights, photo flash, and RGB. The high conversion efficiency and high level of integration make the AAT2830/31 the optimum solution for battery life and size-critical applications.

AnalogicTech's AS<sup>2</sup>Cwire™ (Advanced Simple Serial Control™) serial digital input is used to enable, disable, and set current for all of the outputs. Each backlight LED output can be programmed to 30mA over 16 discrete steps. The AAT2830/31 can also deliver up to 600mA to drive flash LEDs over four individual channels, with excellent current matching between channels. A built-in safety timer function allows easy, one-trigger system control for photo flash applications.

The RGB output can be adjusted to handle up to 60mA, and the AS<sup>2</sup>Cwire signal can drive the RGB module in up to 4096 (AAT2830) or 64 (AAT2831) color intensity combinations.

The AAT2830/31 is available in a Pb-free, thermal-enhanced 24-pin 4x4x0.75mm TQFN package.

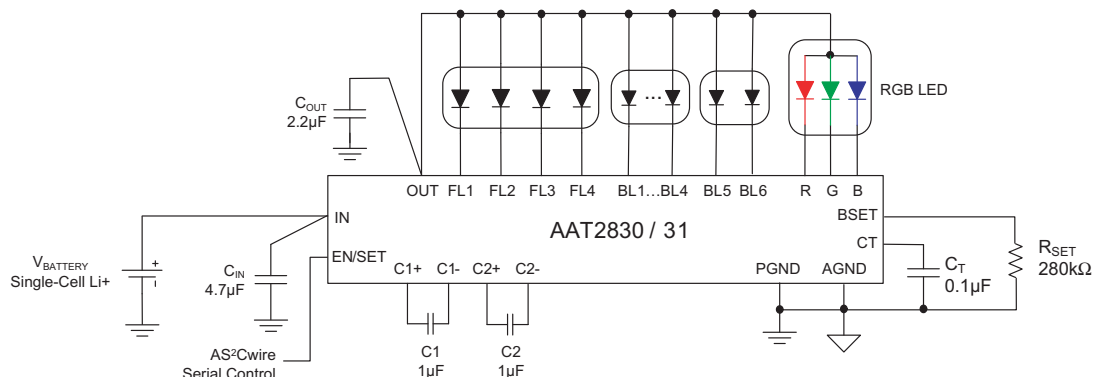
### Applications

- Digital Still Cameras
- LCD Display Modules
- MP3 Players
- White LED Drivers
- Wireless Handsets

### Features

- Input Supply Voltage Range: 2.7V to 5.5V
- Tri-Mode (1X/1.5X/2X) Charge Pump:
  - Delivers up to 800mA of Output Current
  - Switching Frequency: Up to 2MHz
- Total Display Solution for RGB and Backlight Applications
  - 6-Channel Backlight WLED Backlight
    - User-Programmable Full-Scale Current, up to 30mA
  - 4-Channel Flash WLED Drive
    - User-Programmable Full-Scale Current, up to 150mA
    - Torch/Flashlight/Movie Mode Operation
    - Auto-/Safety Flash Timer
  - 3-Channel RGB
    - User-Programmable Full-Scale Output Current/Duty Cycle
    - AAT2830: 4096 Color/Intensity Combinations
    - AAT2831: 64 Color/Intensity Combinations
- Single-Wire AS<sup>2</sup>Cwire Serial Interface for Configuration/Control
  - Fourteen Addressable Registers
  - Fast, 1MHz Serial Interface
- True Load Disconnect in Shutdown,  $I_{IN} < 1\mu A$
- Built-in Thermal Protection
- Built-in Auto-Disable for Open LED Condition
- Automatic Soft-Start Minimizes Inrush Current
- Available in 4x4x0.75mm TQFN44-24 Package

### Typical Application

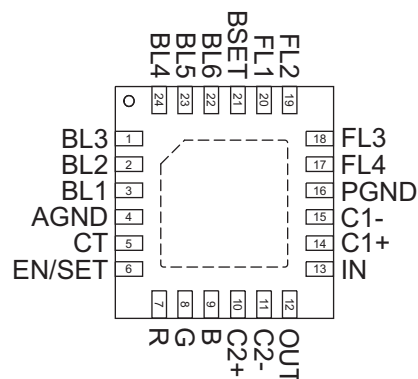


### Pin Description

Pin #	Symbol	Function
1	BL3	Power return (cathode) for backlight channel 3. If not used, connect to the OUT pin.
2	BL2	Power return (cathode) for backlight channel 2. If not used, connect to the OUT pin.
3	BL1	Power return (cathode) for backlight channel 1. If not used, connect to the OUT pin.
4	AGND	Signal ground.
5	CT	Safety flash timer control capacitor input.
6	EN/SET	Enable and AS <sup>2</sup> Cwire serial interface control input.
7	R	Power return (cathode) for Red LED of the RGB module.
8	G	Power return (cathode) for Green LED of the RGB module.
9	B	Power return (cathode) for Blue LED of the RGB module.
10	C2+	Positive node of flying capacitor 2.
11	C2-	Negative node of flying capacitor 2.
12	OUT	Output voltage pin. Connect to anode of all LEDs.
13	IN	Input voltage pin.
14	C1+	Positive node of flying capacitor 1.
15	C1-	Negative node of flying capacitor 1.
16	PGND	Power ground.
17	FL4	Power return (cathode) for flash channel 4. If not used, connect to the OUT pin.
18	FL3	Power return (cathode) for flash channel 3. If not used, connect to the OUT pin.
19	FL2	Power return (cathode) for flash channel 2. If not used, connect to the OUT pin.
20	FL1	Power return (cathode) for flash channel 1. If not used, connect to the OUT pin.
21	BSET	Maximum backlight current programming resistor input. Ground this pin to use default values.
22	BL6	Power return (cathode) for backlight channel 6. If not used, connect to the OUT pin.
23	BL5	Power return (cathode) for backlight channel 5. If not used, connect to the OUT pin.
24	BL4	Power return (cathode) for backlight channel 4. If not used, connect to the OUT pin.
EP		Exposed pad (bottom); connect to GND directly beneath the package

### Pin Configuration

TQFN44-24  
(Top View)



## Absolute Maximum Ratings<sup>1</sup>

$T_A = 25^\circ\text{C}$ , unless otherwise noted.

Symbol	Description	Value	Units
$V_N$	[OUT, IN, BL1-BL6, FL1-FL4, R, G, B] to GND	-0.3 to 6.0	V
$V_N$	[C1+, C2+] to GND	-0.3 to $V_{OUT} + 0.3$	V
$V_N$	[EN/SET, CT, BSET, C1-, C2-] to GND	-0.3 to $V_{IN} + 0.3$	V
$T_J$	Operating Junction Temperature Range	-40 to +150	$^\circ\text{C}$
$T_{LEAD}$	Maximum Soldering Temperature (at leads, 10 sec)	300	$^\circ\text{C}$

## Thermal Characteristics<sup>2</sup>

Symbol	Description	Value	Units
$\theta_{JA}$	Maximum Thermal Resistance	50	$^\circ\text{C}/\text{W}$
$P_D$	Maximum Power Dissipation	2.0	W

## Recommended Operating Conditions

Symbol	Description	Value	Units
T	Ambient Temperature Range	-40 to +85	$^\circ\text{C}$

1. Stresses above those listed in Absolute Maximum Ratings may cause damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum Rating should be applied at any one time.
2. Mounted on a demo board (FR4, in still air).

### Electrical Characteristics<sup>1</sup>

$V_{IN} = 3.6V$ ;  $C_{IN} = 4.7\mu F$ ;  $C1 = C2 = 1\mu F$ ;  $C_{OUT} = 2.2\mu F$ ;  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are  $T_A = 25^\circ C$ .

Symbol	Description	Conditions	Min	Typ	Max	Units
<b>Charge Pump Section</b>						
$V_{IN}$	IN Operating Supply Voltage Range		2.7		5.5	V
$I_{IN}$	IN Operating Supply Current	1X Mode, Address = 0, Data = 1, $V_{EN/SET} = V_{IN}$			0.6	mA
		1.5X Mode, Address = 0, Data = 1, $V_{EN/SET} = V_{IN}$			4	
		2X Mode, Address = 0, Data = 1, $V_{EN/SET} = V_{IN}$			5	
		1X LL Mode, Address = 3, Data = 1, $V_{EN/SET} = V_{IN}$			0.3	
$I_{SHDN}$	IN Shutdown Current	$V_{EN/SET} = 0V$ , $T_A = 25^\circ C$			1	$\mu A$
$I_{OUT}$	OUT Maximum Output Current			240		mA
$V_{TH(HYS)}$	BL1-BL6, RGB Charge Pump Mode Transition Hysteresis			500		mV
$V_{BSET}$	BSET Pin Voltage			0.7		V
$f_{OSC}$	Charge Pump Oscillator Frequency			2		MHz
$t_{SS}$	Charge Pump Soft-Start Delay			200		$\mu s$
$T_{SD}$	Over-Temperature Shutdown Threshold			140		$^\circ C$
$T_{SD(HYS)}$	Over-Temperature Shutdown Hysteresis			15		$^\circ C$
<b>BL1-BL6 Backlight LED Outputs</b>						
$I_{BL(MAX)}$	BL1-BL6 Maximum Current	Address = 0, Data = 1, $V_{IN} - V_F = 1.5V$	27	30	33	mA
$\Delta I_{BL}$	BL1-BL6 Current Matching <sup>2</sup>	Address = 0, Data = 1, $V_{IN} - V_F = 1.5V$			1	%
$V_{BL(TH)}$	BL1-BL6 Charge Pump Mode Transition Threshold			100		mV
<b>FL1-FL4 Flash LED Outputs</b>						
$I_{FL(MAX)}$	FL1-FL4 Maximum Current	Address = 4, Data = 1, $V_{IN} - V_F = 1.5V$	135	150	165	mA
$\Delta I_{FL}$	FL1-FL4 Current Matching <sup>2</sup>	Address = 4, Data = 1, $V_{IN} - V_F = 1.5V$			4	%
$V_{FL(TH)}$	FL1-FL4 Charge Pump Mode Transition Threshold			300		mV
$I_{CT}$	Flash Timer Current			3.4		$\mu A$
<b>RGB LED Outputs</b>						
$I_{RGB(MAX)}$	R-G-B Maximum Current	Address = 12, Data = 7, $V_{IN} - V_F = 1.5V$	51	60	69	mA
$V_{RGB(TH)}$	RGB Charge Pump Mode Transition Threshold			100		mV

1. The AAT2830/31 is guaranteed to meet performance specifications over the  $-40^\circ C$  to  $+85^\circ C$  operating temperature range and is assured by design, characterization, and correlation with statistical process controls.
2. Current matching is defined as the deviation of any sink current from the average of all active channels.

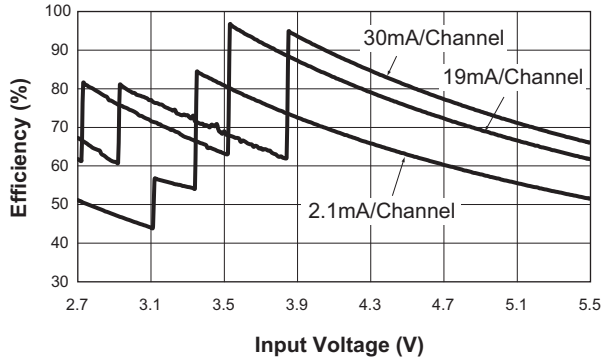
### Electrical Characteristics<sup>1</sup>

$V_{IN} = 3.6V$ ;  $C_{IN} = 4.7\mu F$ ;  $C1 = C2 = 1\mu F$ ;  $C_{OUT} = 2.2\mu F$ ;  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are  $T_A = 25^{\circ}C$ .

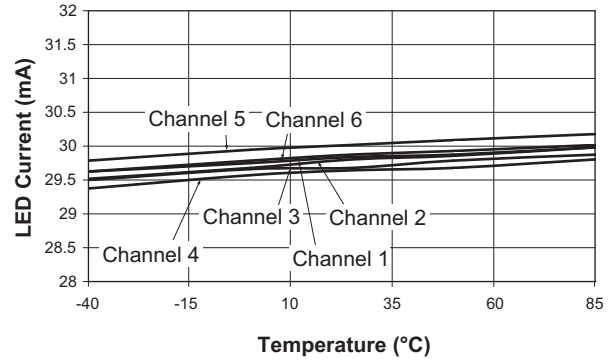
Symbol	Description	Conditions	Min	Typ	Max	Units
<b>EN/SET Logic Control</b>						
$V_{ENS(L)}$	EN/SET Input Low Threshold Voltage				0.4	V
$V_{ENS(H)}$	EN/SET Input High Threshold Voltage		1.4			V
$I_{EN/SET}$	EN/SET Input Leakage Current		-1		1	$\mu A$
$T_{EN/SET\_LO}$	EN/SET Low Time		0.3		75	$\mu s$
$T_{EN/SET\_HL\_MIN}$	Minimum EN/SET High Time			50		ns
$T_{EN/SET\_HL\_MAX}$	Maximum EN/SET High Time				75	$\mu s$
$T_{OFF}$	EN/SET Off Timeout				500	$\mu s$
$T_{LAT}$	EN/SET Latch Timeout				500	$\mu s$

### Typical Characteristics

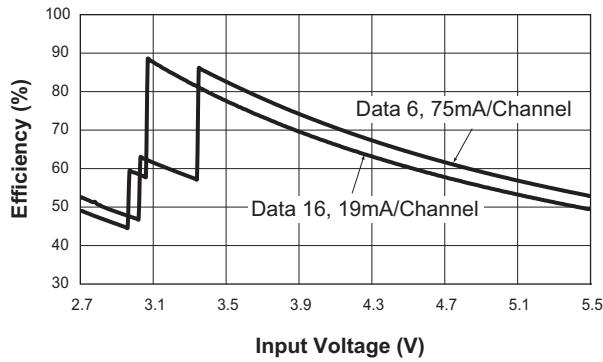
**AAT2830 Backlight Section Efficiency**



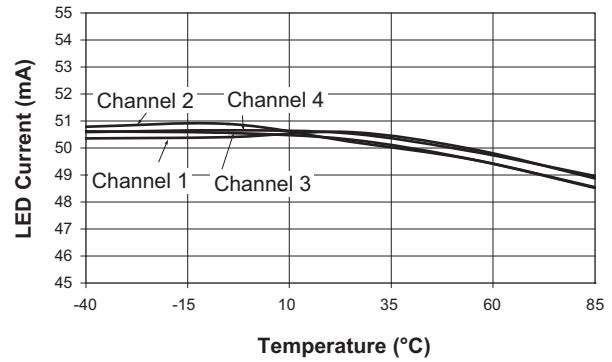
**Backlight Current Matching vs. Temperature**



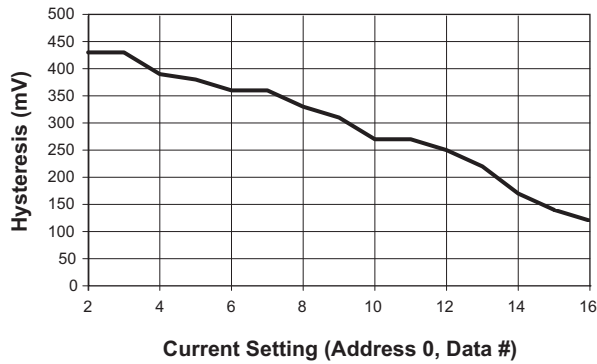
**AAT2830 Flash Section Efficiency**



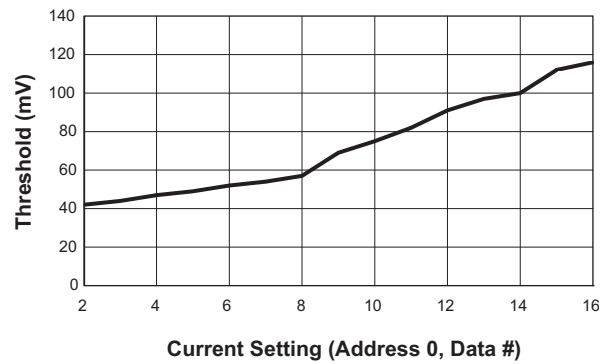
**Flash Current Matching vs. Temperature**



**1X Mode Hysteresis vs. Current Settings**

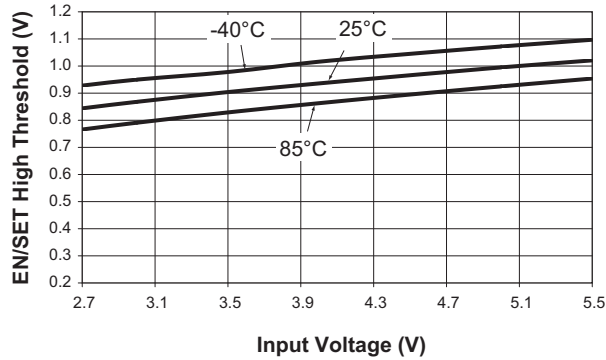


**BL1-BL6 Mode Transition Threshold vs. Current Setting**

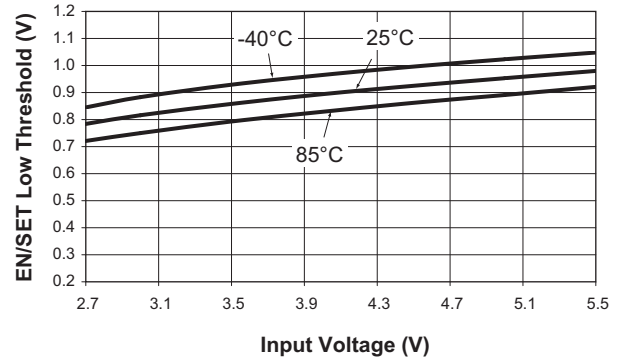


### Typical Characteristics

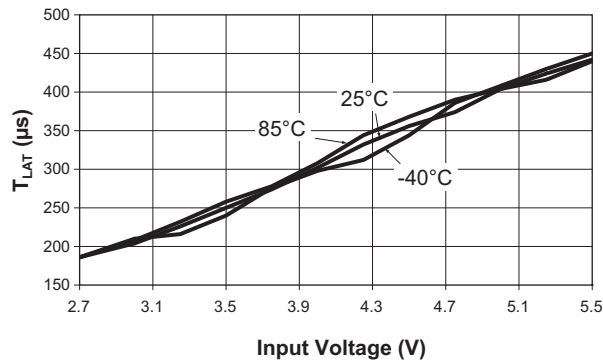
**EN/SET High Threshold Voltage vs. Input Voltage**



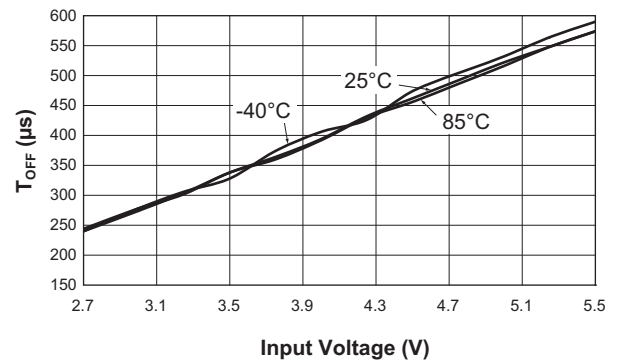
**EN/SET Low Threshold Voltage vs. Input Voltage**



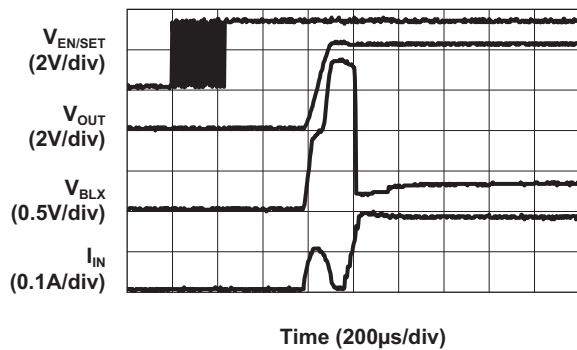
**EN/SET Latch Timeout vs. Input Voltage**



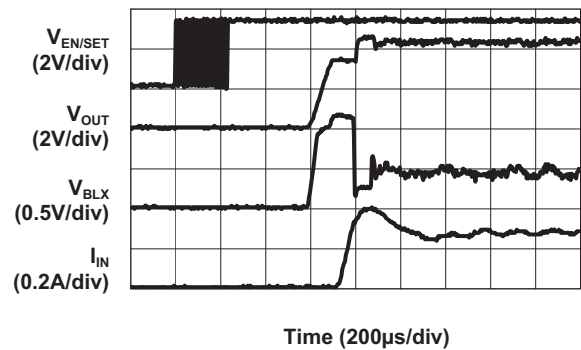
**EN/SET Off Timeout vs. Input Voltage**



**Turn On to 1X Mode Backlight**  
(30mA/channel; Address 0, Data 16;  $V_{IN} = 4.4V$ )

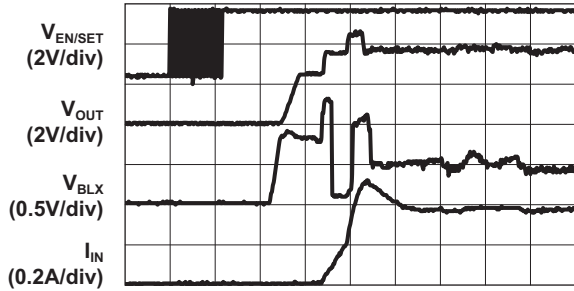


**Turn On to 1.5X Mode Backlight**  
(30mA/channel; Address 0, Data 16;  $V_{IN} = 3.5V$ )



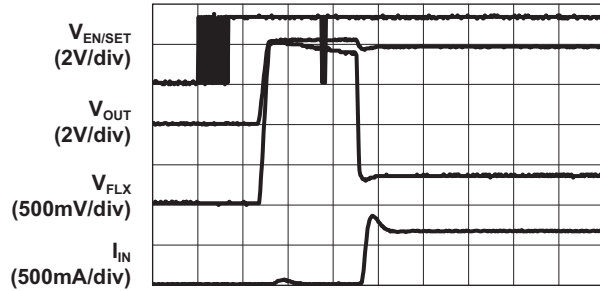
### Typical Characteristics

**Turn On to 2X Mode Backlight**  
(30mA/channel; Address 0, Data 16;  $V_{IN} = 2.7V$ )



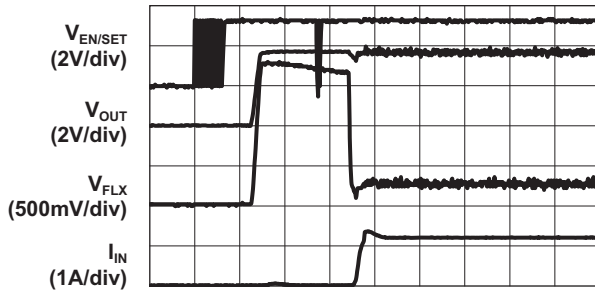
Time (200 $\mu$ s/div)

**Turn On to 1X Mode Flash**  
(150mA/channel; Address 4, Data 1;  $V_{IN} = 4.2V$ )



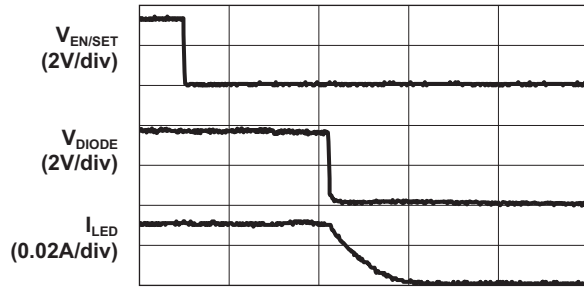
Time (100 $\mu$ s/div)

**Turn On to 2X Mode Flash**  
(150mA/channel; Address 4, Data 1;  $V_{IN} = 3.7V$ )



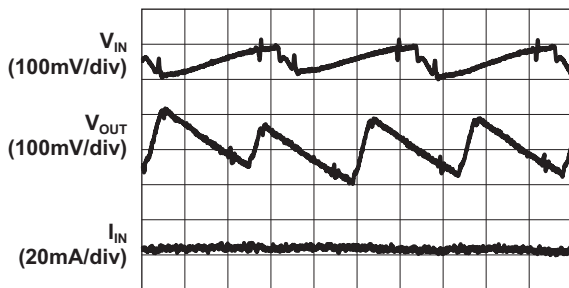
Time (500 $\mu$ s/div)

**Turn Off from 1.5X Mode Backlight**  
(30mA/channel; Address 0, Data 16)



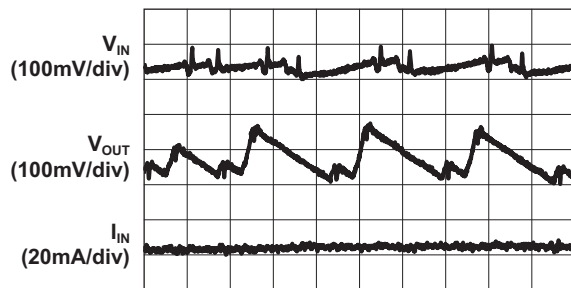
Time (100 $\mu$ s/div)

**Operating Characteristics**  
( $V_{IN} = 3.4V$ ; 1.5X Mode;  
30mA/channel; AC Coupled)



Time (500ns/div)

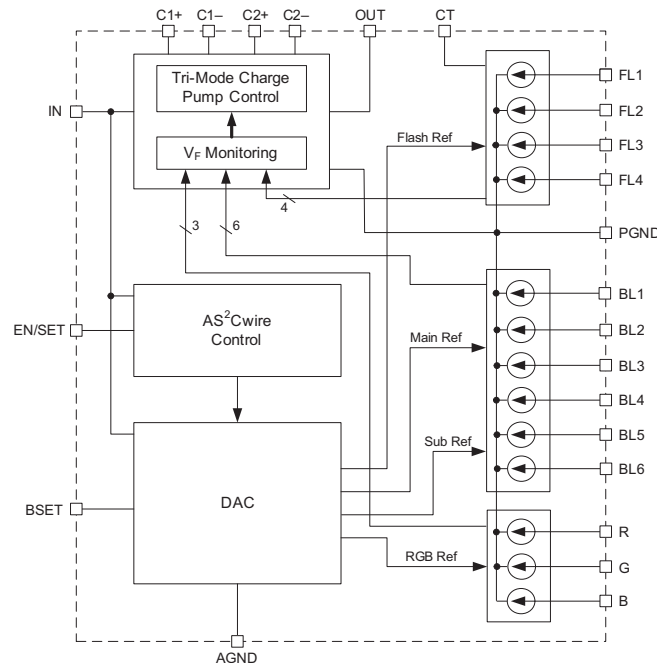
**Operating Characteristics**  
( $V_{IN} = 2.7V$ ; 2X Mode;  
30mA/channel; AC Coupled)



Time (500 $\mu$ s/div)



### Functional Block Diagram



### Functional Description

The AAT2830/31 is a multi-function power solution for display systems in portable devices. It includes six individual driving channels for backlight LEDs, four for flash LEDs, and three for RGB fashion or auxiliary, or status LEDs. All of these functions are powered by a high efficiency tri-mode charge pump engine that is capable of 800mA load current, ideal for driving high brightness white LEDs.

The six backlight outputs can be turned on or off together (BL1-BL6), in two groups or individually. The two-group operation allows LEDs to be turned on and off in two banks: the main group (BL1-BL4) and sub-group (B5-B6) displays. An individual on/off feature supports applications other than main/sub-display backlights, such as keypad, navigate key, side key backlight, and RGB LEDs. The maximum backlight current is programmable with an external resistor.

The maximum flash current is set by the AS<sup>2</sup>Cwire interface, and the four flash LED outputs can be turned on or off together (FL1-FL4) or as a group of one (FL1) and three (FL2-FL4). The flash time can either be controlled via the EN/SET pin or by an

internal programmable timer. Maximum flash time is set by an external capacitor, C<sub>T</sub>. The RGB outputs can be programmed with up to 4096 (AAT2830) or 64 (AAT2831) different combinations of colors and intensities. R, G, and B outputs are individually controlled and can be used for alternative functions, such as keyboard lighting, "fun" lights, etc.

The RGB channels can be programmed with up to 4096 or 64 different combinations of colors and lighting intensities (brightness). R, G, and B channels are individually controlled and can be used for alternative functions, such as keyboard lighting, "fun" lighting, etc.

### AS<sup>2</sup>Cwire Serial Interface

Each current channel input on the AAT2830/31 is controlled by AnalogicTech's AS<sup>2</sup>Cwire serial digital interface. The AS<sup>2</sup>Cwire interface uses the number of rising edges on the EN/SET pin to address and load the LED configuration registers. AS<sup>2</sup>Cwire latches data or addresses after the EN/SET pin has been held logic high for longer than T<sub>LAT</sub> (500µs). Addresses and data are differentiated by the number of EN/SET rising edges. Since the data registers are 4 bits each, the differentiating number of pulses is 2<sup>4</sup>

or 16, so that Address 0 is signified by 17 rising edges, Address 1 by 18 rising edges, Address 2 by 19 rising edges, and so on. Data is set to any number of rising edges between 1 and including 16.

A typical write protocol consist of the following: first a burst of EN/SET rising edges that identify/target a particular address followed by EN/SET being held logic high for the  $T_{LAT}$  timeout period to latch the address value in the registers, then another burst of rising edges that signify data with the accompanying  $T_{LAT}$  timeout period to latch the data value in the registers. Once an address is set, then multiple writes to the corresponding data register are allowed without having to write to the address for every change in data values. When EN/SET is held low longer than  $T_{OFF}$  (500 $\mu$ s), the AAT2830/31 enters shutdown mode operation and draws less than 1 $\mu$ A from the input supply voltage. Data and address registers are cleared (reset to 0) in shutdown mode operation.

Table 1a contains the AS<sup>2</sup>Cwire serial interface address functionality when independent channel control is disabled (independent channel control is disabled by default) and conversely Table 1b contains the AS<sup>2</sup>Cwire serial interface address functionality when independent channel control is enabled.

Address	EN/SET Rising Edges	Function
0	17	Backlight Current BL1-BL6
1	18	Main Backlight Current BL1-BL4
2	19	Sub Backlight Current BL5-BL6
3	20	Low Backlight Current
4	21	Flash Current
5	22	Flash Channel Control
6	23	Flash Timer
7	24	Red Color
8	25	Green Color
9	26	Blue Color
10	27	RGB Intensity
11	28	RGB Mode
12	29	RGB Current
15	32	Backlight Independent Channel Control

**Table 1a: AS<sup>2</sup>Cwire Serial Interface Addressing with Independent Channel Control Disabled.**

Address	EN/SET Rising Edges	Function
0	17	Not Applicable
1	18	Backlight Current BL1-BL6
2	19	BL1-BL4 On/Off Control
3	20	BL5-BL6 On/Off Control
4	21	Flash Current
5	22	Flash Channel Control
6	23	Flash Timer
7	24	Red Color
8	25	Green Color
9	26	Blue Color
10	27	RGB Intensity
11	28	RGB Mode
12	29	RGB Current
15	32	Not Applicable

**Table 1b: AS<sup>2</sup>Cwire Serial Interface Addressing with Independent Channel Control Enabled.**

### Backlight Current Control (Addresses 0-2)

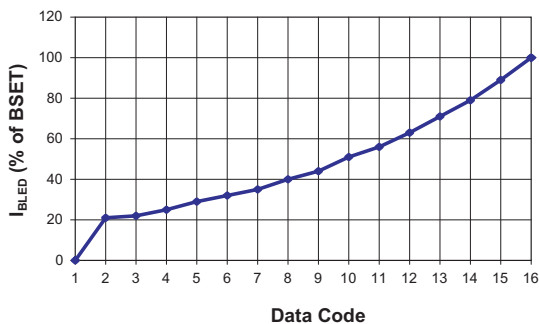
The six channel backlight inputs, BL1-BL6, can drive six individual LEDs to a maximum current of 30mA per channel. The EN/SET AS<sup>2</sup>Cwire serial interface enables all channels and sets the current magnitude as a percentage of the maximum current, programmed by an external resistor at BSET (see Figure 5). To set the backlight current (minimum to maximum current) of the main display LEDs (BL1-BL4), the user would write data to Address 1. To set the backlight current for the sub display LEDs (BL5-BL6), the user would write data to Address 2. To write to both main display and sub display LEDs (BL1-BL6) at the same time, the user would write to Address 0.

Data	BL % of BSET	Data	BL % of BSET
1	0	9	44
2	21	10	51
3	22	11	56
4	25	12	63
5	29	13	71
6	32	14	79
7	35	15	89
8	40	16	100

**Table 2a: Addresses 0-2 with Independent Channel Control Disabled, Backlight Current Level.**

Data	BL % of BSET	Data	BL % of BSET
1	0	9	44
2	21	10	51
3	22	11	56
4	25	12	63
5	29	13	71
6	32	14	79
7	35	15	89
8	40	16	100

**Table 2b: Address 1 with Independent Channel Control Enabled, Backlight Current Level.**



**Figure 1: Addresses 0-2 Backlight Current Level.**

### Low Backlight Current (Address 3)

In addition to the current levels set by Addresses 0, 1, and 2 (shown in Table 2a and Figure 1), there is also a low backlight current level that can be set. To set the low backlight current level, the user would write data to Address 3, as shown in Table 3.

For example, to toggle between 1.7% and 25% of the maximum backlight current on all LEDs, write Data = 14 to Address 3 and Data 4 to Address 0. To set BL1-BL4 to 25% and BL5-BL6 to 0.2%, write Data = 5 to Address 3, and Data = 4 to Address 2.

Data	BL1-BL4 Current On	BL5-BL6 Current On	BL % of BSET
1	No	No	0
2	No	No	0
3	No	No	0
4	No	No	0
5	No	Yes	0.2
6	No	Yes	1.7
7	No	Yes	3.5
8	No	Yes	7.0
9	Yes	No	0.2
10	Yes	No	1.7
11	Yes	No	3.5
12	Yes	No	7.0
13	Yes	Yes	0.2
14	Yes	Yes	1.7
15	Yes	Yes	3.5
16	Yes	Yes	7.0

**Table 3: Address 3 with Independent Channel Control Disabled, Low-Backlight Current Levels ( $R_{BSET} = 280k\Omega$ ).**

### Backlight Independent Channel Control (Address 15)

The AAT2830/31 can also individually control each backlight channel. This mode allows the user to turn on some or all of the channels in any desired combination. This control is achieved by changing the functionality of the AS<sup>2</sup>Cwire registers. To enable individual LED control mode, a user would write Data 8 to Address 15. All channels that are enabled must carry the same current, which is set using the new functionality of Address 1 (see Table 2b).

Data	Individual BL Control
8	On

**Table 4: Address 15, Backlight Independent Channel Control**

Data	BL6	BL5	BL4	BL3
1	Off	Off	Off	Off
2	Off	Off	Off	On
3	Off	Off	On	Off
4	Off	Off	On	On
5	Off	On	Off	Off
6	Off	On	Off	On
7	Off	On	On	Off
8	Off	On	On	On
9	On	Off	Off	Off
10	On	Off	Off	On
11	On	Off	On	Off
12	On	Off	On	On
13	On	On	Off	Off
14	On	On	Off	On
15	On	On	On	Off
16	On	On	On	On

**Table 5: Address 2 with Independent Channel Control Enabled, BL3-BL6 On/Off Control.**

Data	BL2	BL1
1	Off	Off
2	Off	Off
3	Off	Off
4	Off	Off
5	Off	On
6	Off	On
7	Off	On
8	Off	On
9	On	Off
10	On	Off
11	On	Off
12	On	Off
13	On	On
14	On	On
15	On	On
16	On	On

**Table 6: Address 3 with Independent Channel Control Enabled, BL1-BL2 On/Off Control.**

With independent channel control enabled, the functionality of Addresses 1, 2, and 3 will conform to what is described in Tables 2b, 5, and 6. Also, Addresses 0 and 15 are no longer applicable after independent channel control has been enabled. As indicated by the possible settings listed in the tables, any combination of backlight channels can be enabled and disabled. The original functionalities (Sub Backlight Current BL5-BL6 and Low Backlight Current) of Addresses 2 and 3 are no longer available unless the internal state machine has been reset to default mode operation (when EN/SET is logic low for >500µs). The functionality of Addresses 7-12 are unmodified by the enabling of independent channel control.

### Flash/Movie Mode Operation

The flash current level is set via the serial interface according to a logarithmic scale where each code is 1.5dB lower than the previous code. By writing in Address 4, a total flash current of 19mA to 150mA can be programmed to each of the four flash output channels (see Table 7 and Figure 3). For lower current applications, such as torch, flashlight, or movie light, write to Address 5 to enable FL1 only, or FL2-FL4 only (see Table 8). Higher flash currents can be produced by combining one or more of the FL1-FL4 flash current outputs.

Data	Flash Current (mA)
1	150
2	130
3	114
4	99
5	86
6	75
7	65
8	57
9	50
10	43
11	38
12	33
13	28
14	25
15	22
16	19

**Table 7: Address 4, Flash Current Level.**

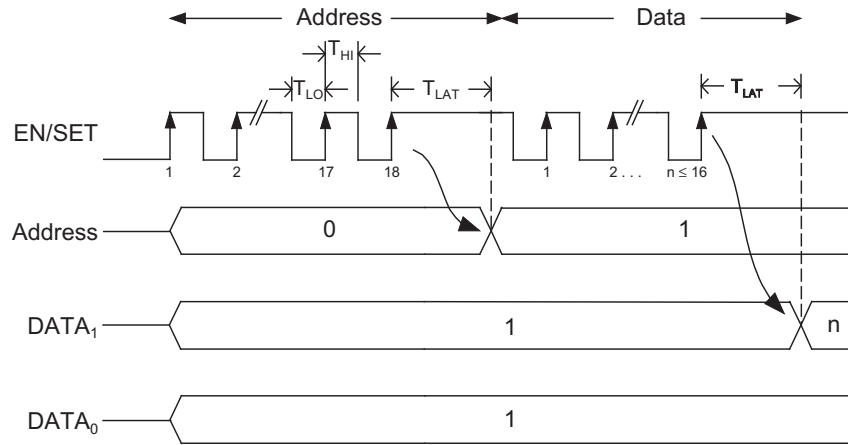


Figure 2: AS<sup>2</sup>Cwire Serial Interface Timing Details.

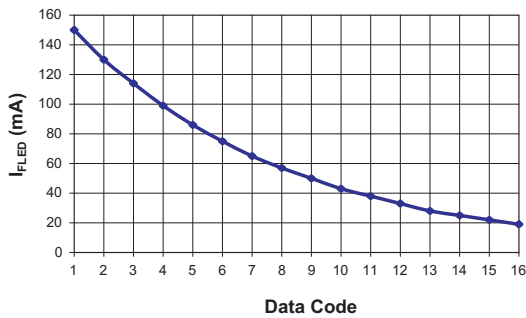


Figure 3: Address 4, FL1-FL4 Flash Current Level.

Data	FL1	FL2-FL4
1	Off	Off
2	Off	On
3	On	Off
4	On	On

Table 8: Address 5, Torch/Flashlight/Movie Mode Control; All Channels ON when C<sub>T</sub> Enabled.

A timer function that enables the flash current sinks for a programmed amount of time is incorporated in the AAT2830/31. The on-time is programmed by loading the timing register at Address 6 with a value from 1 to 16 and by choosing a value for the external timing capacitor, C<sub>T</sub> (see Table 9). When data is latched into the Flash Timing Register, the flash current sinks are automatically enabled for the duration of the programmed time and then disabled. The timing feature eliminates the need for an external controller to keep track of flash duration. This function also serves as a protection feature to avoid thermal damage to the flash LEDs because of software-related errors in or disconnection from an external processor. The flash section's safety timer will only be initiated if writing data to Address 6.

The flash time base T can be calculated by the following equation:

$$T = 10 \cdot C_T$$

Where, T is in seconds and C<sub>T</sub> is in μF.

For example, for a 0.1μF capacitor:

$$\begin{aligned} T &= 10 \cdot 0.1 \\ &= 1s \end{aligned}$$

Data	FL1-FL4 Flash On Time
1	16/16 x T
2	15/16 x T
3	14/16 x T
4	13/16 x T
5	12/16 x T
6	11/16 x T
7	10/16 x T
8	9/16 x T
9	8/16 x T
10	7/16 x T
11	6/16 x T
12	5/16 x T
13	4/16 x T
14	3/16 x T
15	2/16 x T
16	1/16 x T

**Table 9: Address 6, Programmable Flash Timer Duration; Time T is Determined by External Capacitor, C<sub>T</sub>.**

Activating the timer will automatically reset the Flash ON/OFF control (Register 5).

### RGB Control

The Red, Green, and Blue LED PWM timing, along with the overall period, is controlled by five registers. The current level for the RGB LEDs is controlled by another register (Address 12) which makes it possible to change the peak currents from 33% up to 200% of the backlight maximum current set by R<sub>BSET</sub>. A mode register (Address 11) sets the method of update for the color and intensity registers. All registers are updated simultaneously or individually, depending on how the mode register is set. If updated simultaneously, the color registers are updated when the period register is updated. Up to 4096 different color/brightness combinations are programmable in the AAT2830 and 64 color/brightness combinations are programmable in the AAT2831.

#### Address 7, 8, 9: RGB Color Registers

The AAT2830's RGB color registers store up to 16 levels of lighting intensity for a given color channel. The first level (DATA = 1) is reserved for the off-state. Every setting thereafter increases the on-time of the

respective LED by 128μs. The settings can be calculated as follows:

$$R = (\text{DATA}_7 - 1) \cdot 128\mu\text{s}$$

$$G = (\text{DATA}_8 - 1) \cdot 128\mu\text{s}$$

$$B = (\text{DATA}_9 - 1) \cdot 128\mu\text{s}$$

Where R, G, and B are the on-times of the respective LEDs and DATA<sub>7</sub>, DATA<sub>8</sub>, and DATA<sub>9</sub> are the data inputs into Registers 7, 8, and 9, respectively. DATA<sub>N</sub> can be set to a value from 1 to 16 with the default DATA<sub>N</sub> value equal to 1. Since the AAT2831 supports 64 color/brightness combinations, DATA<sub>N</sub> can be set from 1 to 4.

#### Address 10: RGB Timebase Register - T

The overall period is set by the AAT2830/31's T register. Adjusting this register allows a user to adjust how often the RGB LED sequence is repeated. The longer the period, the smaller the effective duty cycle, and thus RGB light intensity (brightness) is reduced. The RGB period can be calculated using the following equation:

$$T = [(\text{DATA}_{10} - 1) \cdot 3 + 15] \cdot 128\mu\text{s}$$

Where T is the period of repetition and DATA<sub>10</sub> is the data input into Register 10. In the AAT2830, DATA<sub>10</sub> can be set to a value from 1 to 16, with the default DATA<sub>10</sub> value equal to 1. In the AAT2831, DATA<sub>10</sub> can be set from 1 to 4, with the default DATA<sub>10</sub> value equal to 1.

**Please note that if the user sets the period to be smaller than the combined on-times (R+G+B), then the RGB sequence will automatically begin again once time T has been reached, whether or not all on-times have been completed.**

#### Address 11: RGB Mode Register

The AAT2830/31's RGB mode register can have one of two DATA<sub>11</sub> values. If DATA<sub>11</sub> is set to 1 (the default), then each RGB LED on-time will be updated immediately after their respective register is set. If DATA<sub>11</sub> is set to 2, then as the user sets the Red, Green, and Blue on-time registers, none of the LEDs will be updated until the timebase register is set. For example, if the user wants to set a certain Red-Green-Blue combinations, the Red on-time

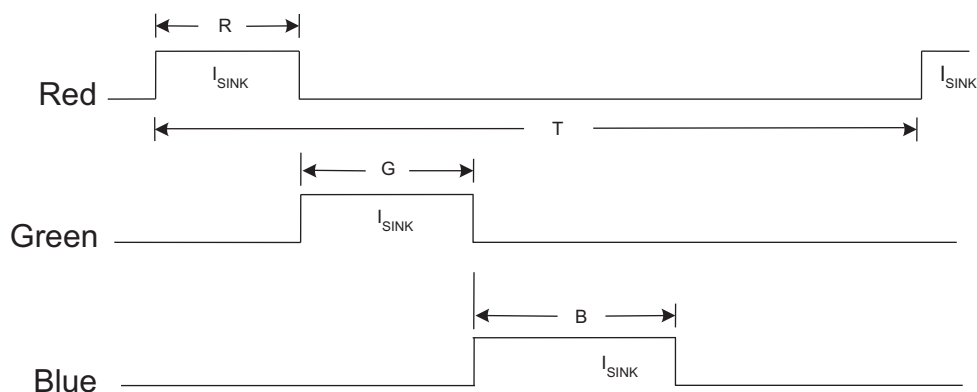
can be programmed first, followed by the Green on-time, followed by the Blue on-time, and then the RGB period T last. If DATA<sub>11</sub> is set to 1, then after the Red on-time is programmed the user will see the Red LED turn on immediately. After the Green on-time is programmed, the Red-Green color combinations will appear, etc. If DATA<sub>11</sub> is set to 2, then none of those intermediate colors will appear until the RGB period register T has been set and loaded.

### Address 12: RGB Current Level Register, I<sub>SINK</sub>

The I<sub>SINK</sub> current level in the RGB LED can be adjusted by writing data to Register 12. The maximum current is two times (200%) the maximum backlight current set by R<sub>BSET</sub> (see Table 10). By increasing or decreasing the current, the brightness level can easily be changed for any particular color combination.

Data	RGB Current as % of BSET
1	0
2	33
3	66
4	100
5	133
6	167
7	200

**Table 10: Address 12, RGB Current Level Register (I<sub>SINK</sub>).**



**Figure 4: RGB Diode Current Timing.**

### RGB LED Current Calculation

The average current in a particular color channel is a function of the values in the R, G, B, T, and I<sub>SINK</sub> registers, as follows:

$$I_R = I_{SINK} \cdot \frac{R}{T}$$

$$I_G = I_{SINK} \cdot \frac{G}{T}$$

$$I_B = I_{SINK} \cdot \frac{B}{T}$$

### Shutdown

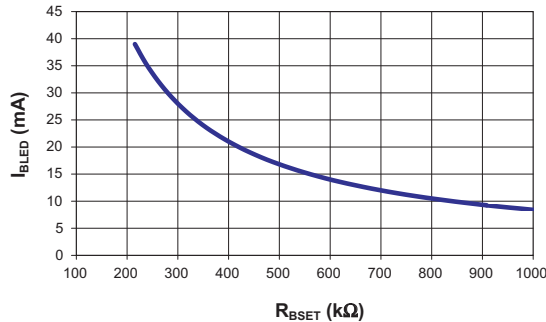
Since the channel backlight power returns are the only power returns for all the LEDs, there is no leakage current if all channels are disabled. Applying a HIGH-to-LOW transition on the EN/SET pin and holding LOW for at least T<sub>OFF</sub> (500µs) will activate the AAT2830/31's shutdown mode. Data and Address registers are cleared (reset to 0) during shutdown.

### Applications Information

#### Adjusting the Maximum Backlight LED Current Level

The value of  $R_{BSET}$  determines the maximum LED current level for the backlight section. In the typical application, selecting  $R_{BSET} = 280k\Omega$  results in a maximum 30mA/channel LED current level.

The relationship between  $R_{BSET}$  and the maximum backlight current is illustrated graphically in Figure 5. The AAT2830/31's LED current control circuits have been optimized for full-scale current settings higher than 15mA,  $R_{BSET} > 550k\Omega$ .



**Figure 5: Maximum Backlight LED Current vs  $R_{BSET}$ .**

#### Device Power Efficiency

The AAT2830/31's power conversion efficiency depends on the charge pump mode of operation. By definition, device efficiency is expressed as the output power delivered to the LEDs divided by the total input power consumed.

$$\eta = \frac{P_{LEDs}}{P_{IN}} = \frac{V_{LED1} \cdot I_{LED1} + \dots + V_{LED4} \cdot I_{LED4}}{V_{IN} \cdot I_{IN}}$$

When the input voltage is sufficiently greater than the LED forward voltages, the device optimizes efficiency by operating in 1X mode. In 1X mode, the device is working as a bypass switch and passing the input supply directly to the output. By simplifying the conditions such that the LEDs have uniform  $V_F$ , the power conversion efficiency can be approximated by:

$$\eta = \frac{P_{LEDs}}{P_{IN}} = \frac{V_{LED1} \cdot I_{LED1} + \dots + V_{LED4} \cdot I_{LED4}}{V_{IN} \cdot I_{IN}}$$

$$\eta = \frac{4 \cdot V_{LEDX} \cdot I_{LEDX}}{V_{IN} \cdot I_{IN}} ; x = 1, 2, 3 \text{ or } 4 \text{ and } I_{IN} = 4 \cdot I_{LEDX}$$

$$\eta = \frac{V_{LEDX}}{V_{IN}}$$

Due to the very low 1X mode quiescent current, the input current nearly equals the total output current delivered to the LEDs. Further, the low resistance bypass switch introduces a negligible voltage drop from input to output.

The AAT2830/31 further maintains optimized performance and efficiency by detecting when the input voltage is not sufficient to sustain the LED bias current. The device automatically switches to 1.5X mode when the input voltage drops too low in relation to the LED forward voltages.

In 1.5X mode, the output voltage can be boosted to 1.5X the input voltage. The 1.5X conversion ratio introduces a corresponding 0.5X increase in input current. For ideal conversion, the 1.5X mode efficiency is given by:

$$\eta = \frac{P_{LEDs}}{P_{IN}} = \frac{V_{LED1} \cdot I_{LED1} + \dots + V_{LED4} \cdot I_{LED4}}{V_{IN} \cdot I_{IN}}$$

$$\eta = \frac{4 \cdot V_{LEDX} \cdot I_{LEDX}}{V_{IN} \cdot I_{IN}} ; x = 1, 2, 3 \text{ or } 4 \text{ and } I_{IN} = 1.5(4 \cdot I_{LEDX})$$

$$\eta = \frac{V_{LEDX}}{1.5V_{IN}}$$

Similarly, when the input falls further, such that 1.5X mode can no longer sustain the LED bias currents, the AAT2830/31 will automatically switch to 2X mode. In 2X mode, the output voltage can be boosted to 2X the input voltage. The 2X conversion ratio introduces a corresponding 1X increase in input current. For ideal conversion, the 2X mode efficiency is given by:

$$\eta = \frac{P_{LEDs}}{P_{IN}} = \frac{V_{LED1} \cdot I_{LED1} + \dots + V_{LED4} \cdot I_{LED4}}{V_{IN} \cdot I_{IN}}$$

$$\eta = \frac{4 \cdot V_{LEDX} \cdot I_{LEDX}}{V_{IN} \cdot I_{IN}} ; x = 1, 2, 3 \text{ or } 4 \text{ and } I_{IN} = 2(4 \cdot I_{LEDX})$$

$$\eta = \frac{V_{LEDX}}{2V_{IN}}$$



### LED Selection

The AAT2830/31 is designed to drive high-intensity white LEDs. It is particularly suitable for LEDs with an operating forward voltage in the range of 4.2V to 1.5V.

The AAT2830/31 can also drive other loads that have similar characteristics to white LEDs. For various load types, the AAT2830/31 provides a high current, programmable, ideal constant current channel/sink.

### Capacitor Selection

Careful selection of the four external capacitors  $C_{IN}$ , C1, C2, and  $C_{OUT}$  are important because they will affect turn-on time, output ripple, and transient performance. Optimum performance will be obtained when low equivalent series resistance (ESR) ceramic capacitors are used. In general, low ESR is defined as a resistance that is less than 100m $\Omega$ .

X7R and X5R ceramic capacitors are highly recommended over all other types of capacitors for use with the AAT2830/31. For the input ( $C_{IN}$ ) and output ( $C_{OUT}$ ) capacitors, a 2.2 $\mu$ F or greater value is recommended, and a 1 $\mu$ F or greater value is recommended for the flying (C1/C2) capacitors. Ceramic capacitors offer many advantages over their tantalum and aluminum electrolytic counterparts. A ceramic capacitor typically has very low ESR, is lowest cost, has a smaller PCB footprint, and is non-polarized. Low ESR ceramic capacitors help maximize charge pump transient response.

### PCB Layout

To achieve adequate electrical and thermal performance, careful attention must be given to the printed circuit board (PCB) layout. In the worst-case operating condition, the chip must dissipate considerable power at full load. Adequate heat-sinking must be achieved to ensure intended operation.

Figures 7 and 8 illustrate an example PCB layout. The bottom of the package features an exposed metal pad. The exposed pad acts, thermally, to transfer heat from the chip and, electrically, as a ground connection.

The junction-to-ambient thermal resistance ( $\theta_{JA}$ ) for the AAT2830/31 package can be significantly reduced by following a couple of important PCB design guidelines. The PCB area directly underneath the package should be plated so that the exposed pad can be mated to the top layer PCB copper during the reflow process. Multiple copper plated thru-holes should be used to electrically and thermally connect the AAT2830/31's exposed pad area to additional ground plane(s).

The chip ground is internally connected to both the paddle and to the AGND and PGND pins. It is good practice to connect the GND pins to the exposed pad area with traces as shown in Figure 6.

The flying capacitors (C1 and C2), input capacitor (C4), and output capacitor (C3) should be connected as close as possible to the IC. In addition to the external passive components being placed as close as possible to the IC, all traces connecting the AAT2830/31 should be as short and wide as possible to minimize path resistance and potential coupling.

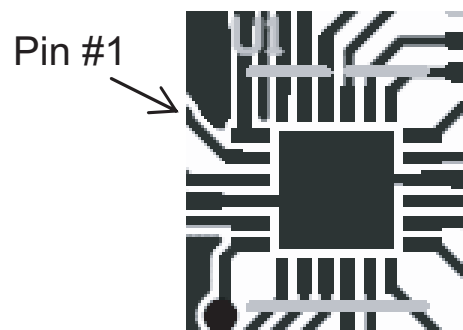


Figure 6: AAT2830/31 Package PCB Layout.

### Evaluation Board Layout

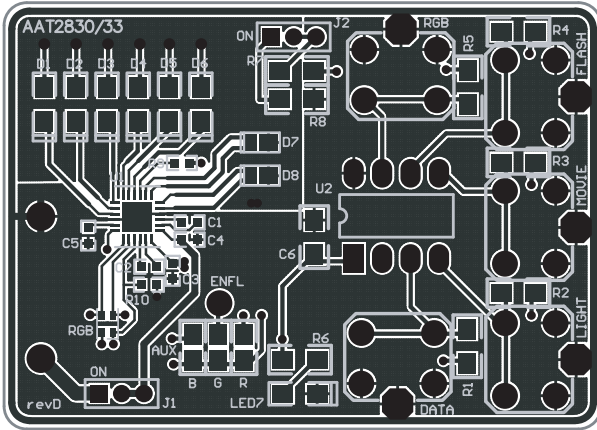


Figure 7: AAT2830/31 Evaluation Board Component Side Layout.

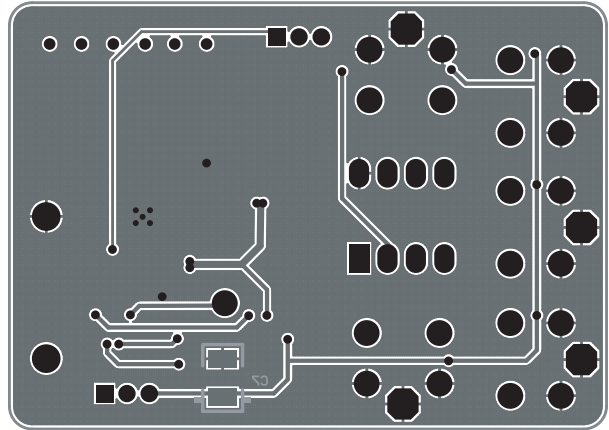


Figure 8: AAT2830/31 Evaluation Board Solder Side Layout.

### Evaluation Board Schematic

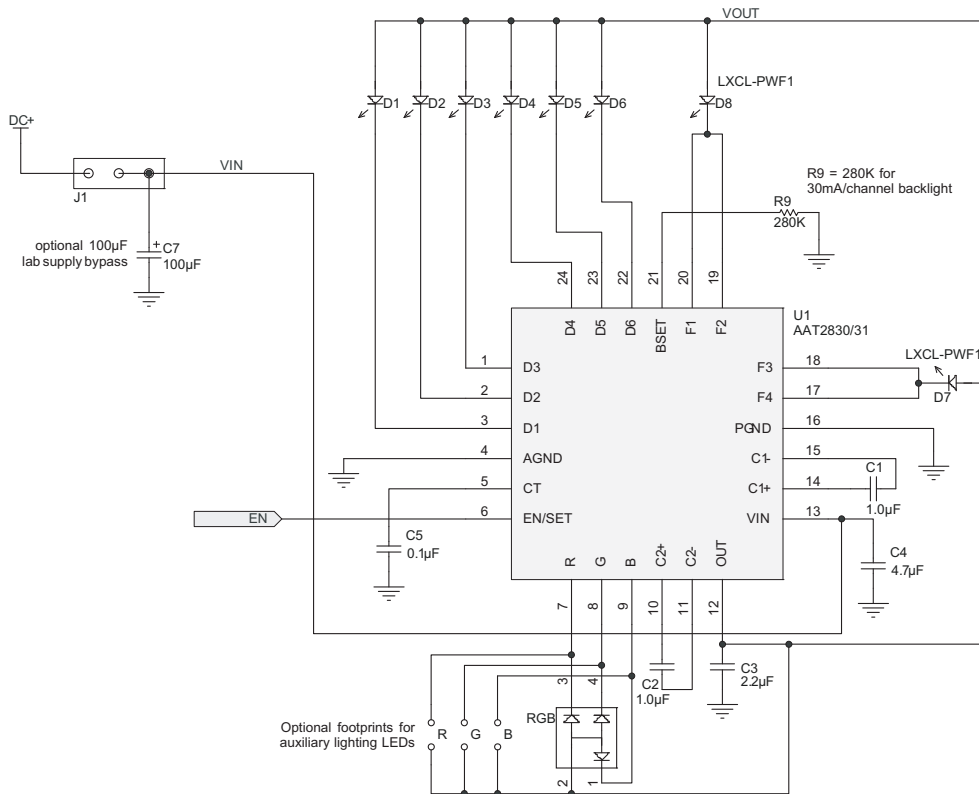
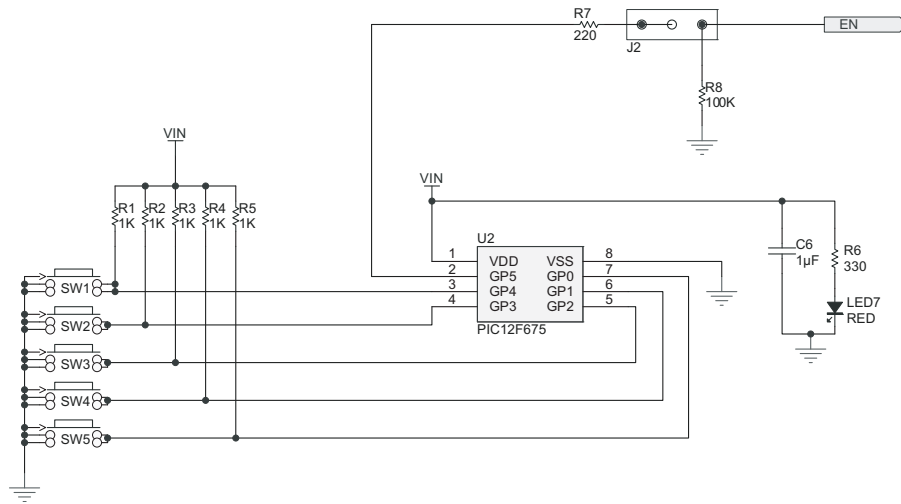


Figure 9: AAT2830/31 Evaluation Board Schematic.



**Figure 9: AAT2830/31 Microcontroller Section Schematic.**

### Options

Option	Flash	Backlight	RGB	Package	Function
AAT2830	Y	Y	Y	TQFN44-24	Total Solution, 4096-Combination RGB
AAT2831	Y	Y	Y	TQFN44-24	Total Solution, 64-Combination RGB

### Ordering Information

Package	Marking <sup>1</sup>	Part Number (Tape and Reel) <sup>2</sup>
TQFN44-24	SUXYY	<b>AAT2830IBK-T1</b>
TQFN44-24		<b>AAT2831IBK-T1</b>

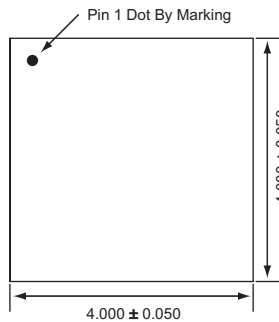


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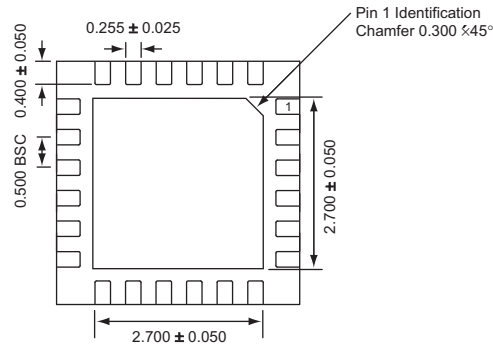
1. XYY = assembly and date code.  
 2. Sample stock is generally held on part numbers listed in **BOLD**.  
 3. Contact factory for AAT2831 availability.

### Package Information

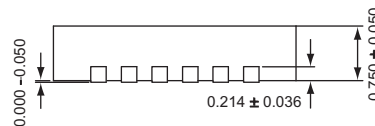
#### TQFN44-24



Top View



Bottom View



Side View

All dimensions in millimeters.

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