General Description

The AAT3132 is a low noise, constant frequency charge pump DC/DC converter that uses fractional (1.5X) conversion to maximize efficiency for White LED applications. The device can be used to produce current levels up to 20mA in three of its outputs, and up to 25 or 30mA in one of its outputs to drive LEDs from a 2.7V to 5.5V input. Outputs may be operated individually or paralleled for driving higher-current LEDs. Low external parts count (two 1µF flying capacitors and two small 1µF capacitors at V_{IN}, and OUT) make the AAT3132 ideally suited for small battery-powered applications.

AnalogicTech™'s Simple Serial Control™ (S^2Cwire™) interface is used to enable, disable and set the LED drive current in two groups: the three 20mA outputs and the single 30mA output with multiple level logarithmic scales. The AAT3132 has a thermal management system to protect the device in the event of a short circuit condition at the output pin. Built-in soft-start circuitry prevents excessive inrush current during start-up. A high charge pump switching frequency enables the use of very small external capacitors. A low current shutdown feature disconnects the load from V_{IN} and reduces quiescent current to less than 1µA. The AAT3132 is available in very small 12 pin TSOPJW12 package.

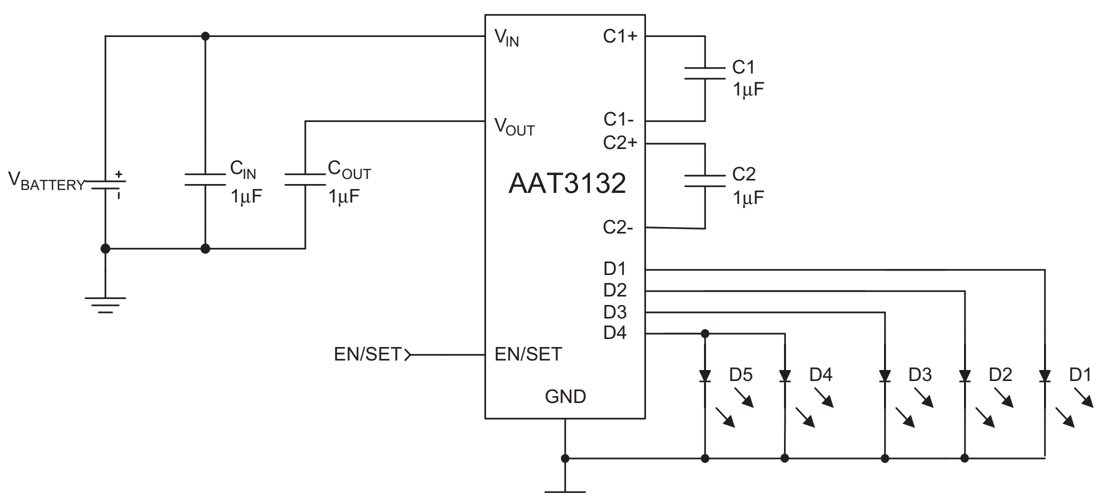
Features

- V_{IN} Range: 2.7 - 5.5 Volts
- < 1.0µA of Shutdown current
- 1.0 MHz Switching Frequency
- White LED Backlighting
- Fully Independent Display Lighting
- Drives Low-V_F & High-V_F Type LEDs
- Up to three 20mA Outputs
- Single 25 or 30mA Output
- Multi Position Logarithmic Scale with Digital Control
- Low Noise Constant Frequency Operation
- Regulated Output Current
- Automatic Soft-Start
- No Inductors
- -40 to +85°C Temperature Range
- 12 pin TSOPJW-12 package

Applications

- White LED Backlighting
- White Photo-Flash for DSC's
- Color (RGB) Lighting
- Programmable Current Source

Typical Application

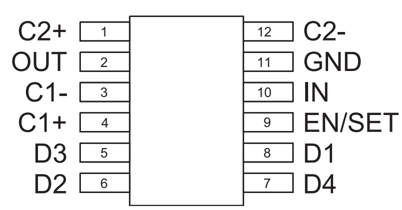


Pin Descriptions

Pin #	Symbol	Function
1	C2+	Flying Capacitor 2 + terminal. Connect a 1µF capacitor between C2+ and C2-.
2	OUT	Charge pump output. Requires 1µF capacitor connected between this pin and ground.
3	C1-	Flying Capacitor 1 - terminal
4	C1+	Flying Capacitor 1 + terminal. Connect a 1µF capacitor between C1+ and C1-.
5	D3	Current source output #3
6	D2	Current source output #2
7	D4	Current source output #4
8	D1	Current source output #1
9	EN/SET	Control Pin
10	IN	Input power supply. Requires 1µF capacitor connected between this pin and ground.
11	GND	Ground
12	C2-	Flying Capacitor 2 - terminal

Pin Configuration

TSOPJW-12
(Top view)



Absolute Maximum Ratings[1]

Symbol	Description	Value	Units
V_{IN}	Input Voltage	-0.3 to 6	V
V_{OUT}	Charge Pump Output	-0.3 to 6	V
F_B, $V_{EN/SET}$	FB or EN/SET to GND Voltage	-0.3 to 6	V
$V_{EN/SET(MAX)}$	Maximum EN/SET to Input Voltage	V_{IN} - 0.3	V
I_{OUT} [(2)]	Maximum DC Output Current	150	mA
T_J	Operating Junction Temperature Range	-40 to 150	°C

Notes:
1. Stresses above those listed in Absolute Maximum Ratings may cause permanent 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. Based on long-term current density limitation.

Thermal Information

Symbol	Description	Value	Units
θ_{JA}	Thermal Resistance [3]	160	°C/W
P_D	Maximum Power Dissipation (T_A = 25°C) [3, 4]	625	mW

Note 3: Mounted on a FR4 board.
Note 4: Derate 6.25mW/°C above 25°C.

Electrical Characteristics[1]

V_{IN} = 3.5V, C_{IN} = C_{OUT} = C1 = C2 = 1.0µF; T_A = -40 to 85°C unless otherwise noted. Typical values are T_A = 25°C.

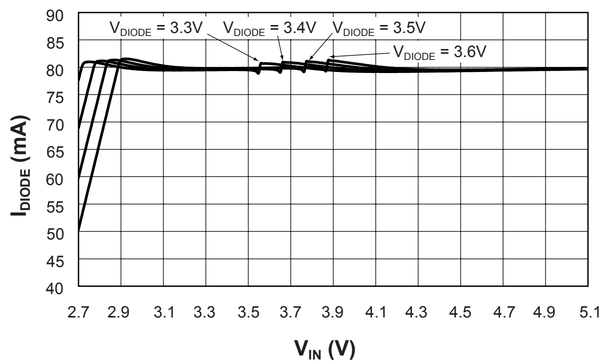
Symbol	Description	Conditions	Min	Typ	Max	Units
Input Power Supply						
V_{IN}	Operation Range		2.7		5.5	V
I_{CC}	Operating Current	$3.0 \le V_{IN} \le 5.5$, Active, No Load Current		1.8	3.5	mA
I_{SHDN}	Shutdown Current	EN = 0			1.0	µA
I_{DX}	Max. Output Current D1 to D3	$3.0 \le V_{IN} \le 5.5$	18	20	22	mA
I_{DX}	Max. Output Current D4	T_A = 25°C AAT3132-1	22.5	25	27.5	mA
		T_A = 25°C AAT3132	27	30	33	
$I_{(D\text{-}Match)}$	Current Matching between any two outputs	VD1:D3 = 3.6, V_{IN} = 3.3V		0.5		%
η_{CP}	Charge Pump Section Efficiency	V_{IN} = 3.5V, $I_{OUT(TOTAL)}$ = 90mA, Measured from IN to OUT		93		%
Charge Pump Section						
T_{SS}	Soft start time			200		µs
F_{CLK}	Clock Frequency			1000		kHz
EN/SET						
$V_{EN(L)}$	Enable Threshold Low				0.5	V
$V_{EN(H)}$	Enable Threshold High		1.4			V
$T_{EN/SET\ LO}$	EN/SET low time	$V_{EN/SET}$ < 0.5	0.3		75	µs
$T_{EN/SET\ HI}$	Minimum EN/SET high time	$V_{EN/SET}$ > 1.4		50		ns
T_{OFF}	EN/SET Off Timeout	$V_{EN/SET}$ < 0.5			500	µs
Input Current	EN/SET input leakage		-1		1	µA

Notes:
1. The AAT3132 is guaranteed to meet performance specification over the -40 to 85°C operating temperature range and are assured by design, characterization and correlation with statistical process controls.

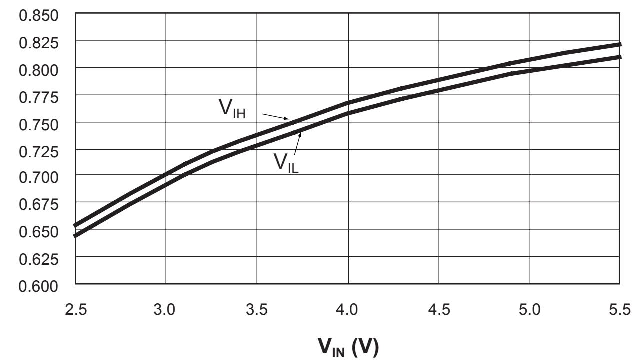
Typical Characteristics

(Unless otherwise noted, V_{IN} = 3.5V, C_{IN} = C_{OUT} = C1 = C2 = 1µF, T_A = 25°C)

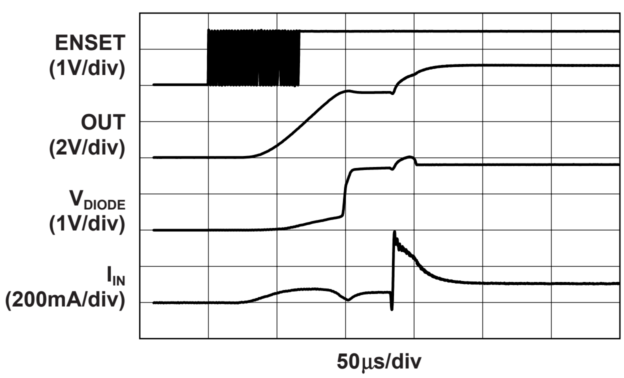
I_{DIODE} vs. V_{IN} (4x20mA)



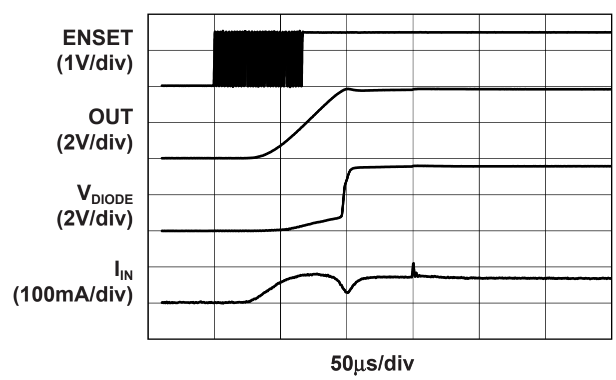
V_{IH} and V_{IL} vs. V_{IN}



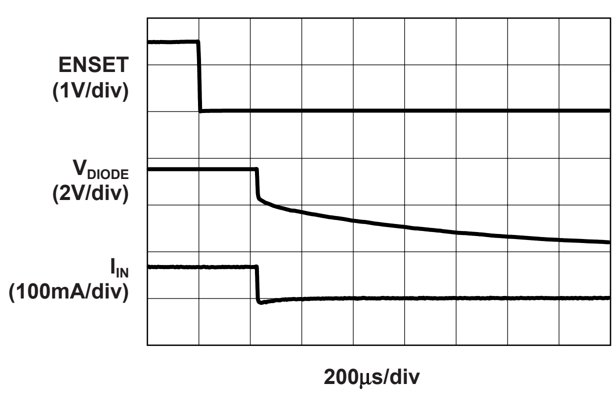
Turn-On to Full Scale Charge-Pump



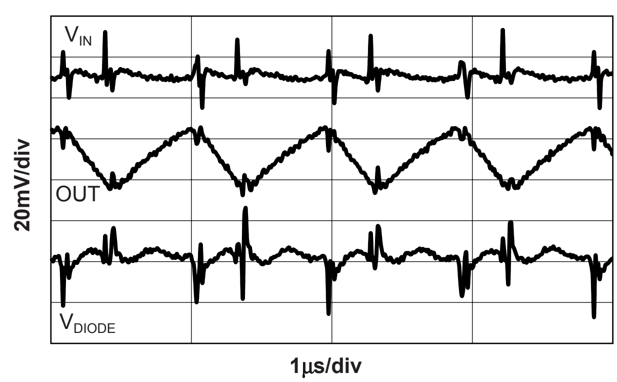
Turn-On to Full Scale Load-Switch



Turn-Off



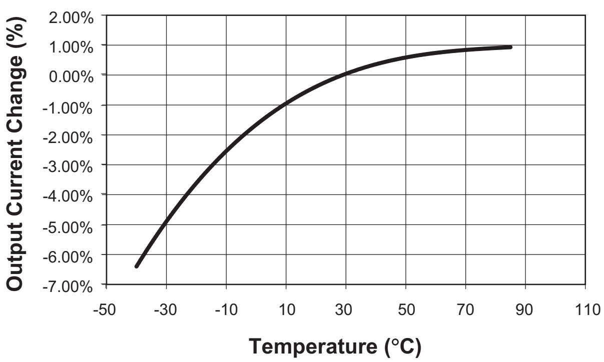
80mA Load Characteristics



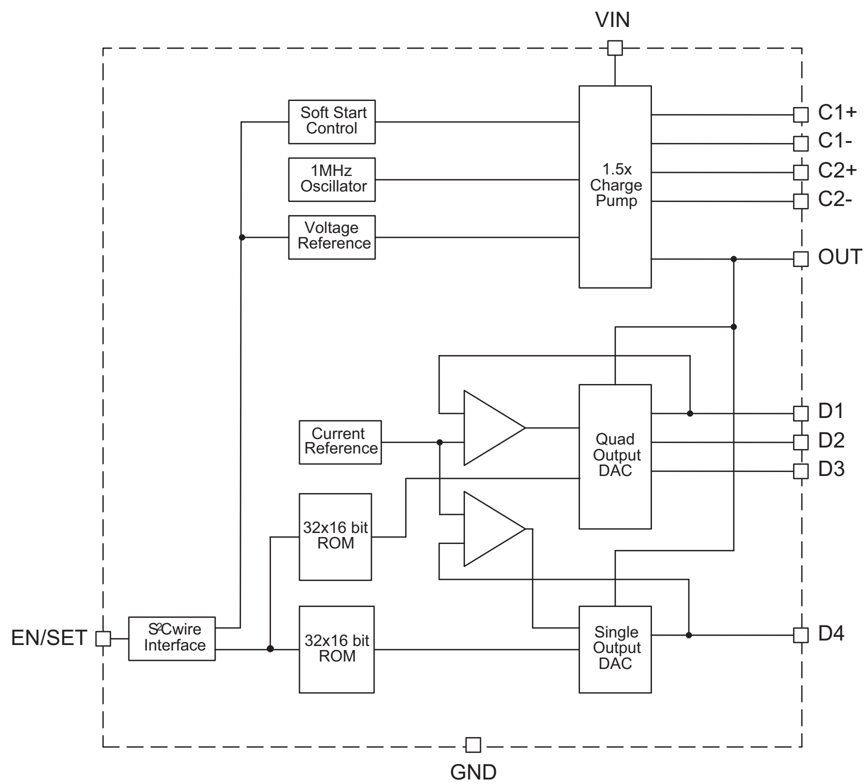
Typical Characteristics

(Unless otherwise noted, V_{IN} = 3.5V, C_{IN} = C_{OUT} = C1 = C2 = 1µF, T_A = 25°C)

I_{DIODE} vs. Temperature



Functional Block Diagram



Functional Description

The AAT3132 is a high efficiency (1.5X) fractional charge pump device intended for white LED back light applications. It consists of a 1.5X charge pump with multiple current-source outputs. To maximize power conversion efficiency an internal feedback control sensing circuit monitors the voltage required on the constant current source outputs.

The AAT3132 requires only four external components: two 1µF ceramic capacitors for the charge pump flying capacitors (C1 and C2), one 1µF ceramic input capacitor (C_{IN}) and one 0.33µF to 1µF ceramic output capacitor (C_{OUT}). The 1.5X charge pump output is converted into three (D1 to D3) constant current outputs to drive three individual LEDs with a maximum current of 20mA each, and one (D4) constant current output with a maximum current of 25 or 30mA. The current source output magnitude is controlled by the EN/SET serial data interface. The interface records rising edges of the EN/SET pin, and decodes them into 32 addresses corresponding to individual current level settings.

The 32 addresses are divided up such that outputs D1-D3 can be controlled independently of output D4. For addresses 1 to 8, 9 to 16, 17 to 24, and 25 to 32, outputs D1-D3 start at 0mA and increase from 0.5mA to 20mA in three 8dB steps and three 2.5dB steps. Output D4 remains constant over these address ranges which provides orthogonal control of the two channels. For addresses 1 to 8, D4 is set to 0mA. For addresses 9 to 16, D4 is set to the next brightness setting, and likewise for addresses 17 to 24 and for addresses 25 to 32. This is summarized in Table and Figure 1.

The modulo 32 interface wraps states back to state 1 after the 32nd clock. With each EN/SET pulse, the output current changes to the next setting in the address decoding. To change settings to the previous address decoding, 31 EN/SET clock pulses are required. The counter can be clocked at speeds up to 1MHz, so intermediate states are not visible. The first rising edge of EN/SET enables the IC and initially sets the output LED currents 0mA. Additional clocks are required to set the desired current level. Once the final clock cycle is input for the desired brightness level, the EN/SET pin is held high to maintain the device output current at the programmed level. The device is disabled 500µs after the EN/SET pin transitions to a logic low state.

Applications Information

Constant Current Output Level Settings

The constant current source output amplitude for output D1 to D3 and D4 are set via the serial interface according to a logarithmic scale depicted in Figure 1. Using a logarithmic scale, LED brightness appears linear with each increasing code count. Because the outputs D1 to D4 are true independent constant current sources, the voltage observed on any single given output will be determined by the actual forward voltage (V_F) for the LED being driven.

Since the output current of the AAT3132 is programmable through its simple serial control (S²Cwire™), no PWM (pulse width modulation) or additional control circuitry is needed to control LED brightness. This feature greatly reduces the burden on a microcontroller or system IC to manage LED or display brightness, allowing the user to "set it, and forget it." Furthermore, with its high speed serial interface (1MHz data rate), the output current of the AAT3132 can changed successively to brighten or dim LEDs, in smooth transitions (e.g. to fade-out) or in abrupt steps, giving the user complete programmability and real time control of LED brightness.

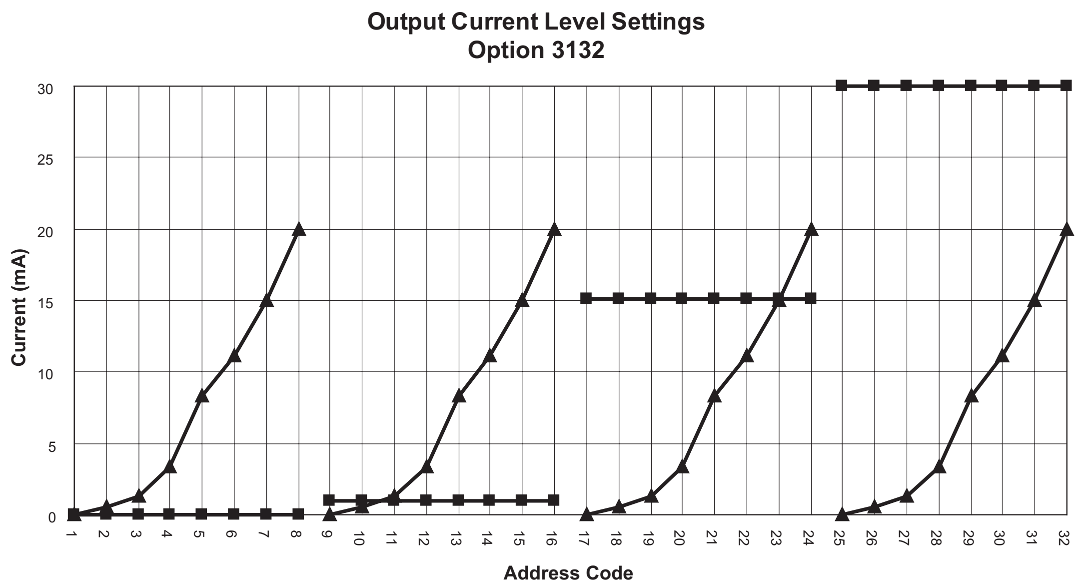


Figure 1.

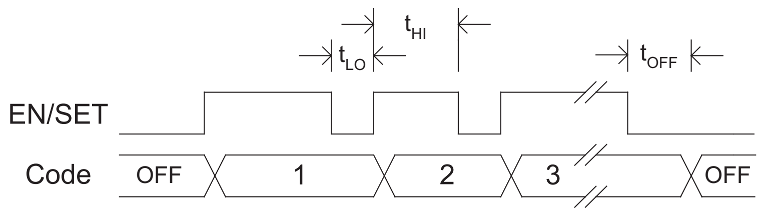
Table 1: Constant Current Source Output Programming Levels (mA)

Address	Current Level Settings		
	D1-3	D4 (AAT3132)	D4(AAT3132-1)
1	0.0	0	0
2	0.5	0	0
3	1.3	0	0
4	3.3	0	0
5	8.3	0	0
6	11.1	0	0
7	15.0	0	0
8	20.0	0	0
9	0.0	1	15
10	0.5	1	15
11	1.3	1	15
12	3.3	1	15
13	8.3	1	15
14	11.1	1	15
15	15.0	1	15
16	20.0	1	15
17	0.0	15	20
18	0.5	15	20
19	1.3	15	20
20	3.3	15	20
21	8.3	15	20
22	11.1	15	20
23	15.0	15	20
24	20.0	15	20
25	0.0	30	25
26	0.5	30	25
27	1.3	30	25
28	3.3	30	25
29	8.3	30	25
30	11.1	30	25
31	15.0	30	25
32	20.0	30	25

EN/SET Serial Interface (S^2Cwire™)

The current source output magnitude is controlled by the EN/SET serial data interface. The interface records rising edges of the EN/SET pin, and decodes them into 32 individual current level settings summarized in Table 1. The modulo 32 interface wraps states back to state 1 after the 32nd clock, so the previous state is achieved by clocking the EN/SET pin 31 times. The counter can be clocked at speeds up to 1MHz, so intermediate states are not visible. The first rising edge of EN/SET enables the IC and initially sets the output LED current to 0. Once the final clock cycle is input for the desired brightness level, the EN/SET pin is held high to maintain the device output current at the programmed level. The device is disabled 500µs after the EN/SET pin transitions to a logic low state. The EN/SET timing is designed to accommodate a wide range of data rates. After the first rising edge of EN/SET, the charge pump is enabled and reaches full capacity after the soft start time (t_{SS}). During the soft start time, multiple clock pulses may be entered on the EN/SET pin to set the final output current level with a single burst of clocks. Alternatively, the EN/SET clock pulses may be entered one at a time to gradually increase the LED brightness over any desired time period. A constant current is sourced as long as EN/SET remains in a logic high state. The current source outputs are switched off after EN/SET has remained in a low state for at least the t_{OFF} timeout period.

EN/SET Timing Diagram



LED Selection

The AAT3132 is specifically intended for driving white LEDs. However, the device design will allow the AAT3132 to drive most types of LEDs with forward voltage specifications ranging from 2.0V to 4.3V. LED applications may include main and sub-LCD display backlighting, camera photo-flash applications, color (RGB) LEDs, infrared (IR) diodes for remotes, and other loads benefiting from a controlled output-current generated from a varying input-voltage. Since the D1 to D4 output current sources are matched with negligible voltage dependence, the LED brightness will be matched regardless of the specific LED forward voltage (V_F) levels.

In some instances (e.g. in high-luminous-output applications such as photo-flash) it may be necessary to drive high-V_F type LEDs. The low-dropout current-sources in the AAT3132 makes it capable of driving LEDs with forward voltages as high as 4.3V at full current from an input supply as low as 3.0V. Outputs can be paralleled to drive high current LEDs without complication.

Device Switching Noise Performance

The AAT3132 operates at a fixed frequency of approximately 1MHz to control noise and limit harmonics that can interfere with the RF operation of cellular telephone handsets or other communication devices. Back-injected noise appearing on the input pin of the Charge Pump is 20mV peak-to-peak, typically ten times less than inductor-based DC/DC boost converter white LED backlight solutions. The AAT3132 soft-start feature prevents noise transient effects associated with in-rush currents during the start up of the charge pump circuit.

Power Efficiency and Device Evaluation

The charge pump efficiency discussion in the following sections only account for the efficiency of the charge pump section itself. Due to the unique circuit architecture and design of the AAT3132, it is very difficult to measure efficiency in terms of a percent value comparing input power over output power.

Since the AAT3132 outputs are pure constant current sources and typically drive individual loads, it is difficult to measure the output voltage for a given output (D1 to D4) to derive an overall output power measurement. For any given application, white LED forward voltage levels can differ, yet the output drive current will be maintained as a constant.

This makes quantifying output power a difficult task when taken in the context of comparing to other white LED driver circuit topologies. A better way to quantify total device efficiency is to observe the total input power to the device for a given LED current drive level. The best white LED driver for a given application should be based on trade-offs of size, external component count, reliability, operating range and total energy usage...Not just "% efficiency".

The AAT3132 efficiency may be quantified under very specific conditions and is dependant upon the input voltage versus the output voltage seen across the loads applied to outputs D1 through D4 for a given constant current setting. The efficiency (η) can be simply defined as a linear voltage regulator with an effective output voltage that is equal to one and a half times the input voltage. Efficiency (η) for an ideal 1.5x charge pump can typically be expressed as the output power divided by the input power.

$$\eta = \frac{P_{OUT}}{P_{IN}}$$

In addition, with an ideal 1.5x charge pump, the output current may be expressed as 2/3 of the input current. The expression to define the ideal efficiency (η) can be rewritten as:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times 1.5I_{OUT}} = \frac{V_{OUT}}{1.5V_{IN}}$$

$$\eta(\%) = 100\left(\frac{V_{OUT}}{1.5V_{IN}}\right)$$

For a charge pump with an output of 5 volts and a nominal input of 3.5 volts, the theoretical efficiency is 95%. Due to internal switching losses and IC quiescent current consumption, the actual efficiency can be measured at 93%. These figures are in close agreement for output load conditions from 1mA to 100mA. Efficiency will decrease as load current drops below 0.05mA or when level of V_{IN} approaches V_{OUT}. Refer to the Typical Characteristics section for measured plots of efficiency versus input voltage and output load current for the given charge pump output voltage options.

Capacitor Selection

Careful selection of the four external capacitors C_{IN}, C1, C2, C_{OUT} is important because they will affect turn on time, output ripple and transient performance. Optimum performance will be obtained when low ESR (<100mΩ) ceramic capacitors are used. In general, low ESR may be defined as less than 100mΩ. A capacitor value of 1µF for all four capacitors is a good starting point when choosing capacitors. If the LED current sources are only programmed for light current levels, then the capacitor size may be decreased.

Capacitor Characteristics

Ceramic composition capacitors are highly recommended over all other types of capacitors for use with the AAT3132. 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. Since ceramic capacitors are non-polarized, they are not prone to incorrect connection damage.

Equivalent Series Resistance (ESR)

ESR is an important characteristic to consider when selecting a capacitor. ESR is a resistance internal to a capacitor, which is caused by the leads, internal connections, size or area, material composition and ambient temperature. Capacitor ESR is typically measured in milliohms for ceramic capacitors and can range to more than several ohms for tantalum or aluminum electrolytic capacitors.

Ceramic Capacitor Materials

Ceramic capacitors less than 0.1µF are typically made from NPO or COG materials. NPO and COG materials typically have tight tolerance and are stable over temperature. Large capacitor values are typically composed of X7R, X5R, Z5U or Y5V dielectric materials. Large ceramic capacitors, typically greater than 2.2 F are often available in low cost Y5V and Z5U dielectrics, but capacitors greater than 1µF are typically not required for AAT3132 applications.

Capacitor area is another contributor to ESR. Capacitors that are physically large will have a lower ESR when compared to an equivalent material smaller capacitor. These larger devices can improve circuit transient response when compared to an equal value capacitor in a smaller package size.

Thermal Protection

The AAT3132 has a thermal protection circuit that will shut down the charge pump if the die temperature rises above the thermal limit as is the case during a short circuit of the OUT pin.

Driving Multiple LEDs, White LED display module back lights and individual LEDs connected in parallel

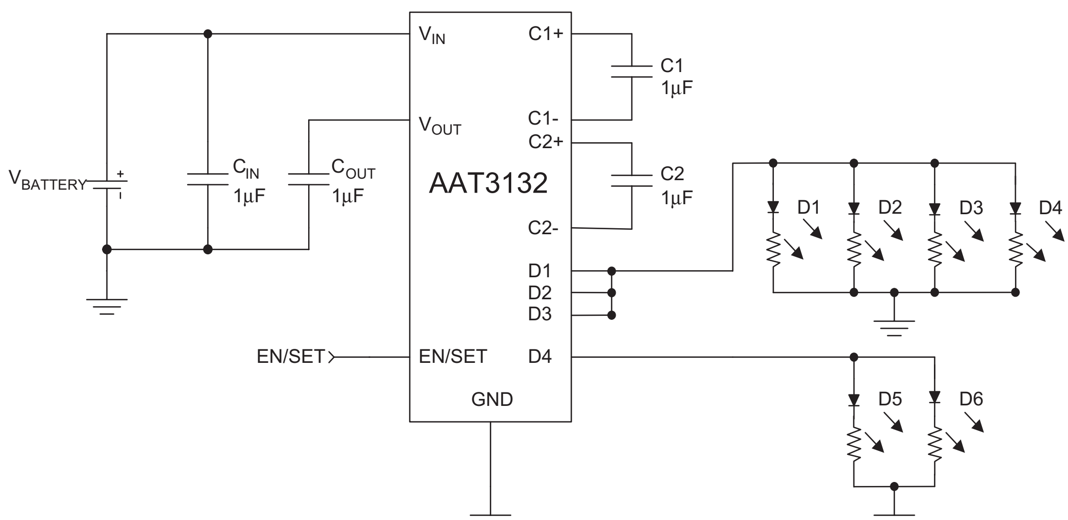
The AAT3132 D1 to D4 outputs are true constant current sources capable of driving up to 20mA (D1 - D3) or 25/30mA (D4) each over the operation input voltage range. Since these outputs are true constant current sources, they may be connected in parallel to drive a single power output. Any combination of outputs (D1 to D4) may be connected in parallel. The maximum total output current is a sum of how many current sources are parallel connected. This feature is particularly useful to power pre-manufactured display modules which are pre-wired with white LED backlights connected in a parallel circuit configuration. Any combination of outputs may be connected in parallel to drive groups of LEDs. The AAT3132 internal current source reference circuit bases feedback from current sensed on the D1 and D4 outputs. For best operation, the only requirement for this type of application is the outputs D1 and D4 should always be connected to the load circuit.

The AAT3132 may be used to drive multiple LEDs having differing forward voltages. Using feedback techniques, the current in D1 to D3 are referenced to the current in the LED connected to D1. Current source output D4 is its own reference. If all LEDs are of similar type, the diodes will be matched in current, maintaining uniform LED brightness despite variations in manufacturer, production, etc.

If however, the diodes are dramatically different in type comprising a mix of high-VF type and low-VF-type LEDs, the AAT3132 has the capability to optimally drive up to four LEDs of one-type and up to two LEDs of another type simultaneously. Such a feature can be useful for driving different color LEDs; driving both display backlight and photo-flash LEDs; or for driving main-LCD and sub-LCD display LED backlights from a single Charge Pump IC. For example, when driving independent RGB LEDs, the green and blue type LEDs typically require a high VF to operate (e.g. 3.7V) while the red LED needs a low forward voltage (e.g. 2V). By connecting the green and blue diodes to outputs D1 to D3 and the red diodes to D4, good control and uniformity in brightness is maintained despite the 2V difference in the diode forward voltages.

Similarly, if a 4V photo-flash LED-array is connected to outputs D1 through D3 (with the outputs shorted together) and two 3.3V sub-LCD-display backlight LEDs are connected to output D4, then the AAT3132 can optimally drive each set of LEDs at the programmed current level (see application schematics).

Additional Application Circuit



AAT3132 Driving Two Groups of Paralleled White LEDs (e.g. main-LCD & sub-LCD backlights)

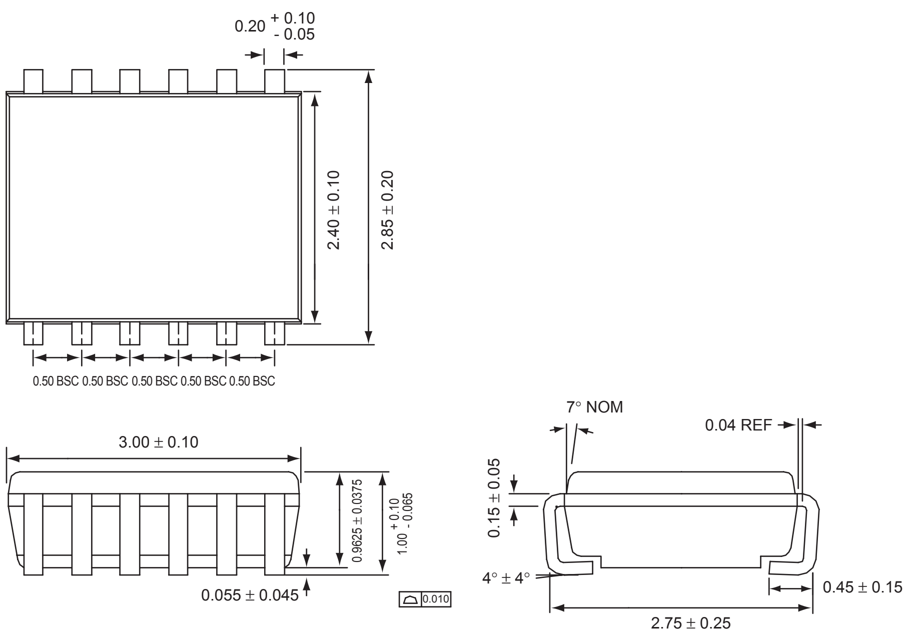
Ordering Information

Package	Marking[1]	Part Number (Tape and Reel)
TSOPJW-12	**JAXYY**	**AAT3132ITP-T1**
TSOPJW-12		AAT3132ITP-1-T1

Note: Sample stock is generally held on all part numbers listed in **BOLD**.
Note 1: XYY = assembly and date code.

Package Information

TSOPJW-12



All dimensions in millimeters.

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