

General Description

The AAT3134 is a low noise, constant frequency charge pump DC/DC converter that uses a dual mode Load Switch (1X) and fractional (1.5X) conversion to maximize efficiency for White LED applications. The device can be used to produce current levels up to 20mA in each of its six outputs to drive LED's from a 2.7V to 5.5V input. Outputs may be operated individually or paralleled for driving higher-current LED's. Low external parts counts (two 1 μ F flying capacitors and two small 1 μ F capacitors at V_{IN} , and OUT) make the AAT3134 ideally suited for small battery-powered applications.

AnalogicTech's Simple Serial Control (S²Cwire™) interface is used to enable, disable and set the LED drive current in two groups of four outputs and two outputs with multiple level independently controlled brightness scales. The AAT3134 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 1 μ A. The AAT3134 is available in a 16-pin quad QFN package.

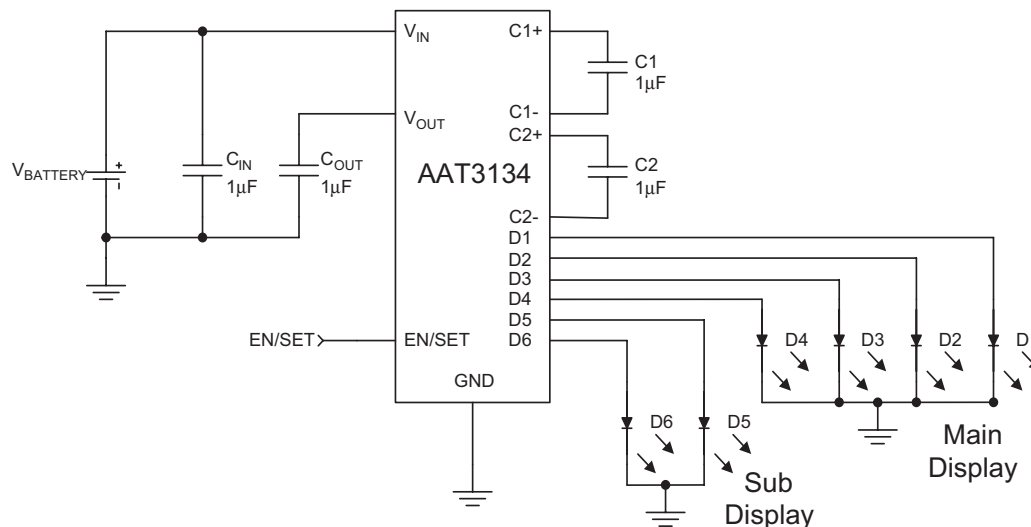
Features

- V_{IN} Range: 2.7 - 5.5 Volts
- < 1.0 μ A of Shutdown
- 1 MHz Switching Frequency
- Fully Independent Display Lighting
- Dual Mode 1x and 1.5x Charge Pump for Maximum Efficiency
- Drives Low- V_F & High- V_F Type LED's
- Up to Six 20mA Outputs
- Multi Position Brightness Scale with Digital Control
- Low Noise Constant Frequency Operation
- Small Application Circuit
- Regulated Output Current
- Automatic Soft-Start
- No Inductors
- 16-pin QFN package
- -40 to +85°C Temperature range

Applications

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

Typical Application

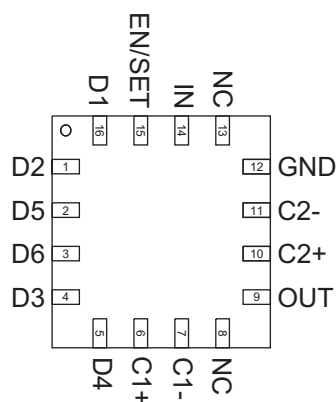


Pin Descriptions

Pin #	Symbol	Function
1	D2	Current source output #2
2	D5	Current source output #5
3	D6	Current source output #6
4	D3	Current source output #3
5	D4	Current source output #4
6	C1+	Flying Capacitor 1 + terminal. Connect a 1 μ F capacitor between C1+ and C1-.
7	C1-	Flying Capacitor 1 - terminal
8,13	NC	No Connection
9	OUT	Charge pump output. Requires 1 μ F capacitor connected between this pin and ground.
10	C2+	Flying Capacitor 2 + terminal. Connect a 1 μ F capacitor between C2+ and C2-.
11	C2-	Flying Capacitor 2 - terminal
12	GND	Ground
14	IN	Input power supply. Requires 1 μ F capacitor connected between this pin and ground.
15	EN/SET	Control Pin
16	D1	Current source output #1

Pin Configuration

QFN44-16
(top view)



Absolute Maximum Ratings¹

Symbol	Description	Value	Units
V_{IN}	Input Voltage	-0.3 to 6.0	V
V_{OUT}	Charge Pump Output	-0.3 to 6.0	V
FB, $V_{EN/SET}$	FB or EN/SET to GND Voltage	-0.3 to 6.0	V
$V_{EN/SET(MAX)}$	Maximum EN/SET to Input Voltage	0.3	V
I_{OUT}^2	Maximum DC Output Current	150	mA
T_J	Operating Junction Temperature Range	-40 to 150	°C

Notes:

- 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.
- Based on long-term current density limitation

Thermal Information

Symbol	Description	Value	Units
θ_{JA}	Thermal Resistance ¹	50	°C/W
θ_{JC}	Thermal Resistance ¹	15	
P_D	Maximum Power Dissipation ¹	2	W

Note 1: Mounted on a FR4 board.

Electrical Characteristics¹

$V_{IN} = 3.5V$, $C_{IN} = C_{OUT} = C1 = C2 = 1.0\mu F$; $T_A = -40$ to $85^\circ C$. Unless otherwise noted, typical values are $T_A = 25^\circ C$.

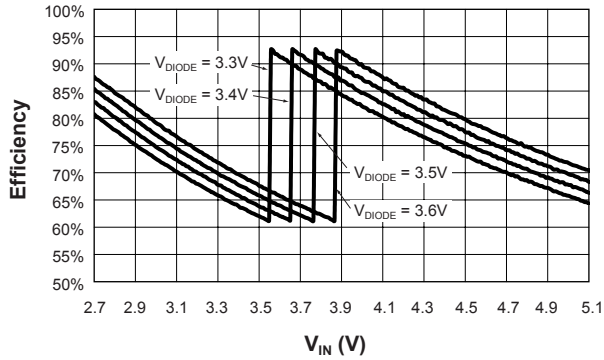
Symbol	Description	Conditions	Min	Typ	Max	Units
Input Power Supply						
V_{IN}	Operation Range		2.7		5.5	V
I_{CC}	Operating Current	$3.0 \leq V_{IN} \leq 5.5$, Active, No Load Current		1.8	3.5	mA
I_{SHDN}	Shutdown Current	EN/SET=0			1.0	μA
$I_{DX(MAX)}$	Maximum Output Current	$V_{IN} = 3.6$, Code = 32	18	20	22	mA
$I_{(D-Match)}$	Current Matching between any two outputs	VD1:D4 = 3.6, $V_{IN} = 3.5V$ VD5:VD6 = 3.6, $V_{IN} = 3.5V$		0.5		%
Charge Pump Section						
T_{SS}	Soft start time			200		μs
F_{CLK}	Clock Frequency			1000		kHz
η_{CP}	Charge Pump Section Efficiency	$V_{IN} = 3.5V$, $I_{OUT(TOTAL)} = 120mA$, Measured from IN to OUT		93		%
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		-1.0		1.0	μA

Note 1: The AAT3134 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.

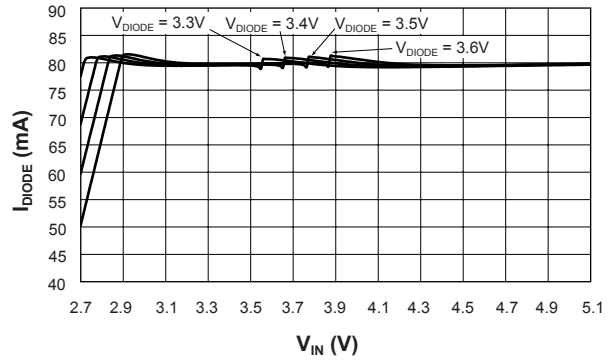
Typical Characteristics

(Unless otherwise noted, $V_{IN} = 3.5V$, $C_{IN} = C_{OUT} = C_1 = C_2 = 1\mu F$, $T_A = 25^\circ C$)

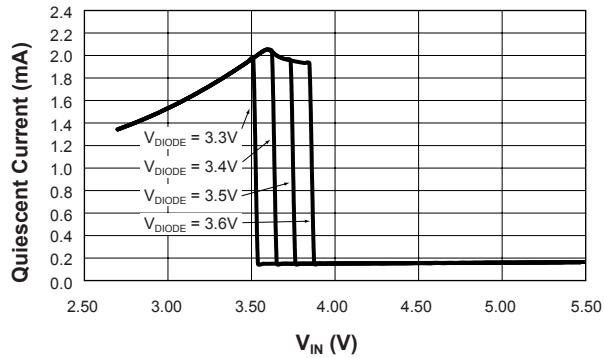
Efficiency vs. V_{IN} (4x20mA)



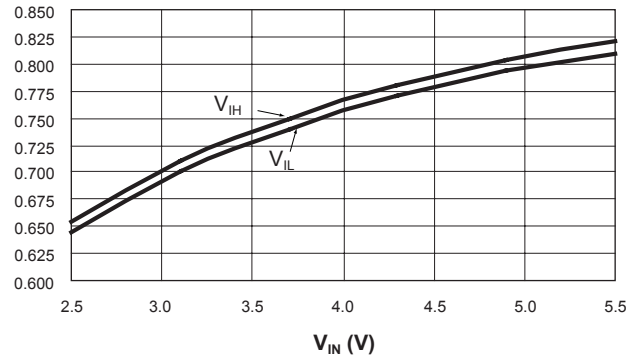
I_{DIODE} vs. V_{IN} (4x20mA)



Quiescent Current vs. V_{IN}



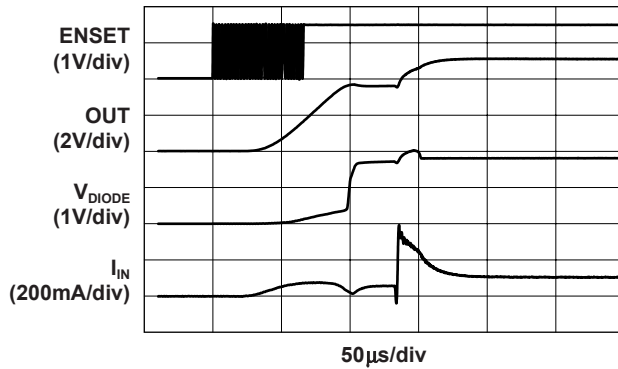
V_{IH} and V_{IL} vs. V_{IN}



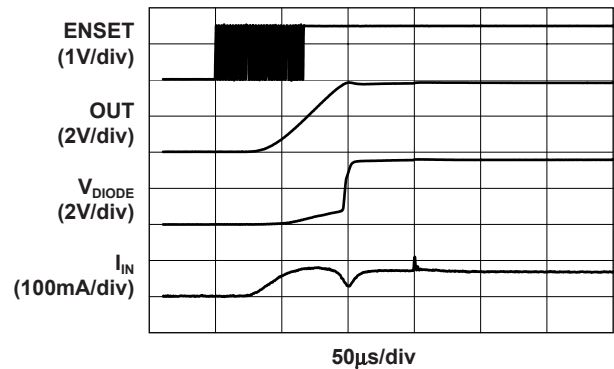
Typical Characteristics

(Unless otherwise noted, $V_{IN} = 3.5V$, $C_{IN} = C_{OUT} = C1 = C2 = 1\mu F$, $T_A = 25^\circ C$)

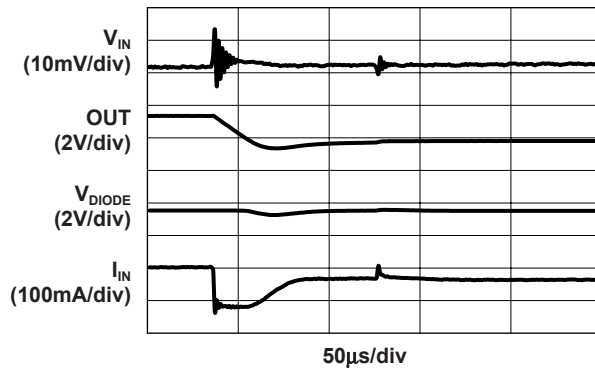
Turn-On to Full Scale Charge-Pump



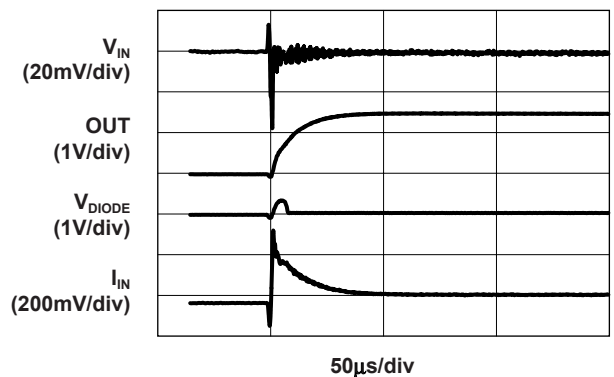
Turn-On to Full Scale Load-Switch



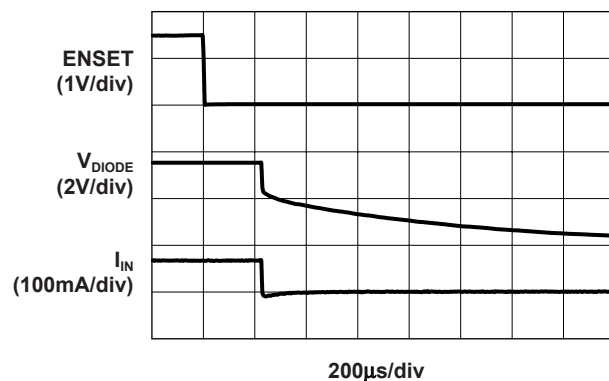
Charge Pump to Load Switch (80mA)



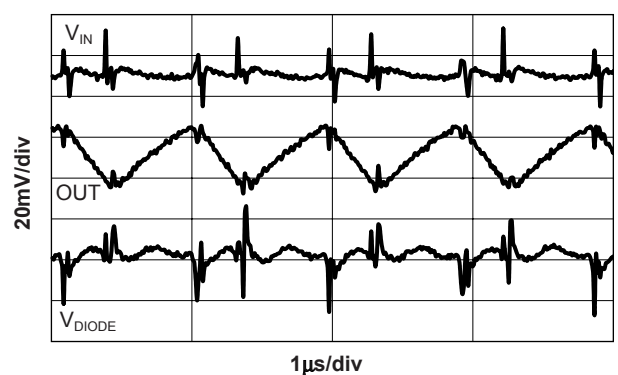
Load Switch to Charge Pump (80mA)



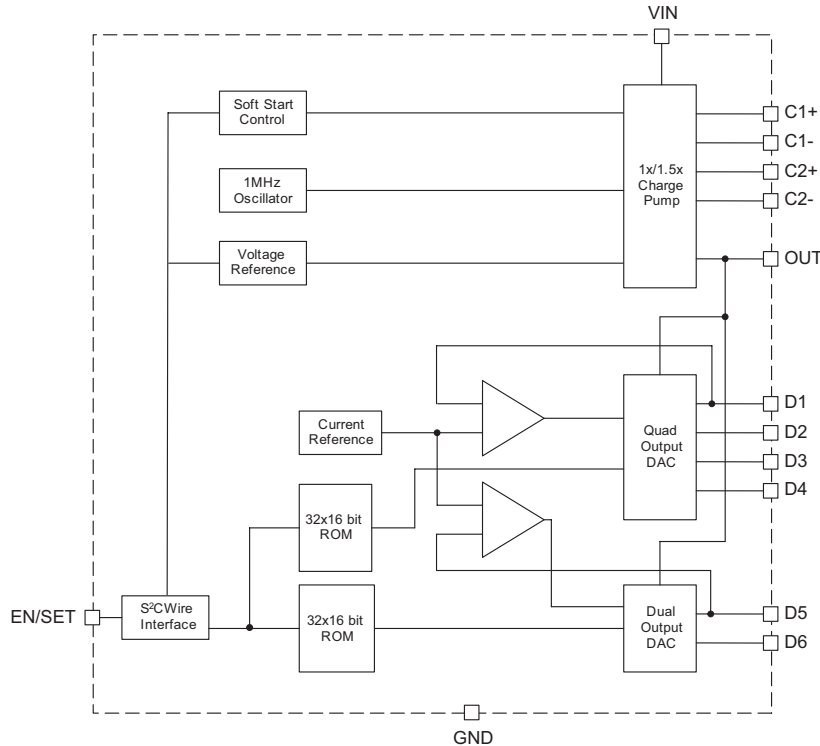
Turn-Off



80mA Load Characteristics



Functional Block Diagram



Functional Description

The AAT3134 is a dual mode Load Switch (1X) and high efficiency (1.5X) fractional charge pump device intended for white LED back light applications. The fractional charge pump consists of a low dropout linear voltage regulator followed by 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. This control circuit then sets the load switch and charge pump functions based upon the input voltage level versus the output voltage level needed. This function significantly enhances over all device efficiency when the input voltage level is greater than the voltage required at the constant current source outputs. The 1X Load Switch/1.5X charge pump mode decision is based on the voltage levels sensed on either the D1 output or the D5 output, whichever is greater. Switchover between the 1.5X (charge-pump) operating mode and the 1X (load switch)

mode occurs automatically (as a function of input and output voltages) and does not require user intervention to maintain maximum efficiency.

The AAT3134 requires only four external components: two $1\mu\text{F}$ ceramic capacitors for the charge pump flying capacitors (C1 and C2), one $1\mu\text{F}$ ceramic input capacitor (C_{IN}) and one $0.33\mu\text{F}$ to $1\mu\text{F}$ ceramic output capacitor (C_{OUT}). The LDO/1.5X charge pump output is converted into four (D1 to D4) constant current outputs to drive four individual LED's with a maximum current of 20mA each, and two (D5 and D6) constant current outputs with a maximum current of 20mA. 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-D4 can be controlled independently of outputs D5-D6. For addresses 1 to 6, 7 to 12, 13 to 18, 19 to 24, and 25 to 30, outputs D1-D4 start at 0mA and increase from 1mA to 20mA in four steps. Outputs D5 and D6 remain

constant over these address ranges which provides orthogonal control of the two channels. For addresses 1 to 6, D5 and D6 are set to 0mA, addresses 7 to 12 are 1mA, addresses 13 to 18 are 10mA, addresses 19 to 24 are 12mA, and addresses 25 to 30 are 15mA. For maximum brightness control, addresses 31 and 32 set D5 and D6 to the maximum 20mA level. For design flexibility, D1-D4 are set to 0mA at address 31, and 20mA at address 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 D4 and D5 to D6 are set via the serial interface according to the scale described in figure 1 and the previous section. Because the outputs D1 to D6 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 AAT3134 is programmable through the S²CWire serial interface, 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 AAT3134 can be changed successively to brighten or dim LED's, in smooth transitions (e.g. to fade-out) or in abrupt steps, giving the user complete programmability and real time control of LED brightness.

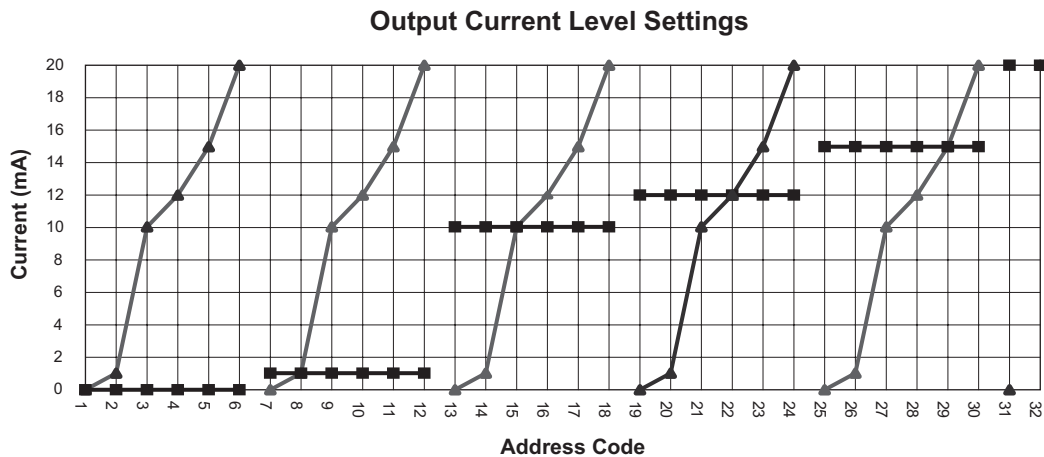


Figure 1.

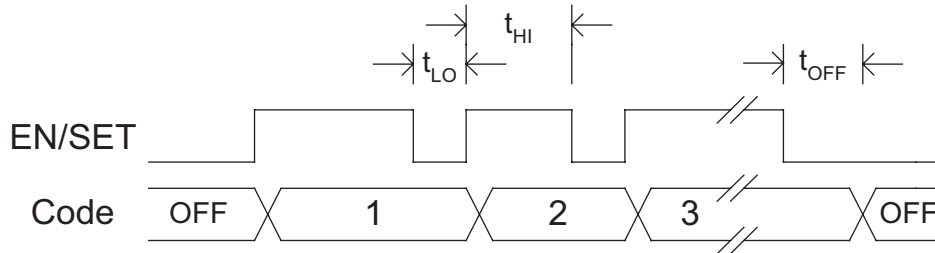
Table 1: Constant Current Source Output Programming Levels (mA)

Address	Current Level Settings	
	D1-D4	D5-D6
1	0	0
2	1	0
3	10	0
4	12	0
5	15	0
6	20	0
7	0	1
8	1	1
9	10	1
10	12	1
11	15	1
12	20	1
13	0	10
14	1	10
15	10	10
16	12	10
17	15	10
18	20	10
19	0	12
20	1	12
21	10	12
22	12	12
23	15	12
24	20	12
25	0	15
26	1	15
27	10	15
28	12	15
29	15	15
30	20	15
31	0	20
32	20	20

EN/SET Serial Interface (S²Cwire™)

The current source output magnitude is controlled by the EN/SET serial 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 AAT3134 is specifically intended for driving white LED's. However, the device design will allow the AAT3134 to drive most types of LED's 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) LED's, infrared (IR) diodes for remotes, and other loads benefiting from a controlled output-current generated from a varying input-voltage. Since the D1 to D6 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 LED's. The *low-dropout* current-sources in the AAT3134 makes it capable of driving LED's 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 LED's without complication

Device Switching Noise Performance

The AAT3134 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, typ-

ically ten times less than inductor-based DC/DC boost converter white LED backlight solutions. The AAT3134 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 AAT3134, it is very difficult to measure efficiency in terms of a percent value comparing input power over output power.

Since the AAT3134 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 AAT3134 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. Depending upon the case of V_{IN} being greater than the specific voltage seen across the load on D1 (or D4) the device will operate in "Load Switch" mode. If V_{IN} is less than the voltage required on the constant current source, the device will operate in 1.5X charge pump mode. Each of these two modes will yield different efficiency values. One should refer to the following two sections for explanations for each operational mode

Load Switch Mode Efficiency

The AAT3134 load switch mode is operational at all times and functions alone to enhance device power conversion efficiency when the condition exists where V_{IN} is greater then voltage across the load connected to the constant current source outputs. When in "Load Switch" mode, the voltage conversion efficiency is defined as output power divided by input power:

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

The expression to define the ideal efficiency (η) can be rewritten as:

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

-or-

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

Charge Pump Section Efficiency

The AAT3134 contains a fractional charge pump which will boost the input supply voltage in the event where V_{IN} is less than the voltage required on the constant current source outputs. The efficiency (η) can be simply defined as a linear voltage regu-

lator 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 (<100m Ω) ceramic capacitors are used. In general, low ESR may be defined as less than 100m. A capacitor value of 1 μ F 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 AAT3134. 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

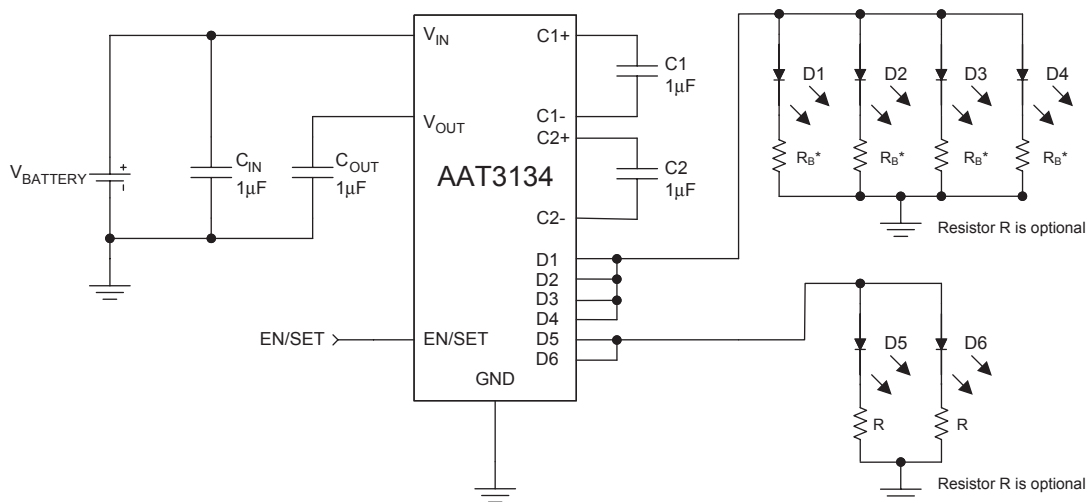
Ceramic capacitors less than 0.1μF are typically made from NPO or COG materials. NPO and COG materials typically have tight tolerance and are stable over temperature. Large capacitor values are typically composed of X7R, X5R, Z5U or Y5V dielectric materials. Large ceramic capacitors, typically greater than 2.2μF are often available in low cost Y5V and Z5U dielectrics, but capacitors greater than 1μF are typically not required for AAT3134 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 AAT3134 has a thermal protection circuit that will shut down the internal LDO and charge pump if the die temperature rises above the thermal limit as is the case during a short circuit of the OUT pin.

Additional Application Circuits



*In some applications, white LED forward voltages (V_F) can vary significantly. Ballast resistors between the LED cathodes and ground are recommended for balancing the forward voltage differences. The ballast resistor value may be approximated by the following equation:

$$R_B = \frac{V_{SOURCE} - V_F}{I_F}$$

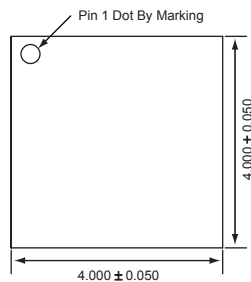
Ordering Information

Package	Marking ¹	Part Number (Tape and Reel)
QFN44-16	JBXYY	AAT3134ISN-T1

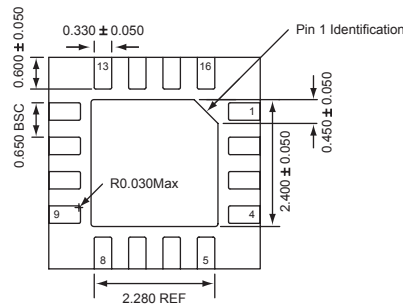
Note 1: XYY = Assembly and date code.

Package Information

QFN44-16



Top View



Bottom View



Side View

All dimensions in millimeters.

AnalogicTech cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in an AnalogicTech product. No circuit patent licenses, copyrights, mask work rights, or other intellectual property rights are implied.

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