

### General Description

The AAT3113/4 are low noise, constant frequency charge pump DC/DC converters that use fractional (1.5X) conversion to increase efficiency in White LED applications. The devices can be used to produce current levels up to 10mA or 20mA for each output from a 2.75V to 5.5V input. Low external parts counts (two 1µF flying capacitors and two small bypass capacitors at V<sub>IN</sub>, and OUT) make the AAT3113/4 ideally suited for small battery-power applications.

A serial digital input is provided to enable, disable and set the LED drive current for a 32 level logarithmic scale LED brightness control. The AAT3113/4 have a thermal management system to protect the device in the event of a short circuit condition on any of the output pins. Built-in soft-start circuitry prevents excessive inrush current during start-up. High switching frequency enables the use of small external capacitors. A low current shutdown feature disconnects the load from V<sub>IN</sub> and reduces quiescent current to less than 1µA. The AAT3113 provides 4 LED current source outputs, and the AAT3114 provides 6. The AAT3113/4 are available in 16-pin quad QFN packages.

### Features

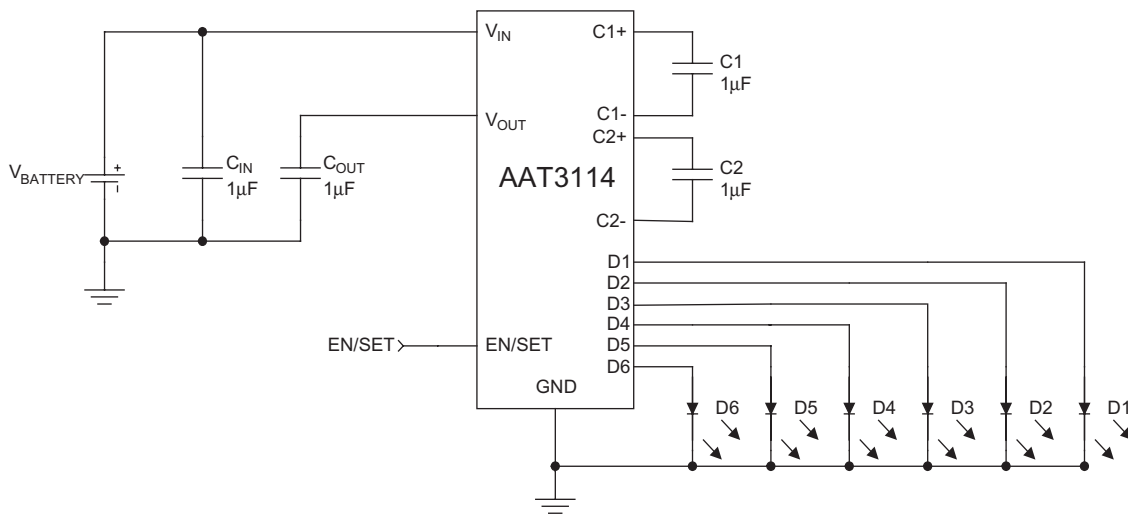
- White LED Backlighting
- AAT3113 - 4 Outputs
- AAT3114 - 6 Outputs
- 10mA or 20mA Option
- 32 Position Logarithmic Scale with Digital Control
- Low Noise Constant Frequency Operation
- 33% Less Input Current Than Doubler Charge Pump
- High Accuracy Brightness Matching
- Small Application Circuit
- Regulated Output Current
- Automatic Soft-Start
- VIN Range: 2.7V to 5.5V
- No Inductors
- 600kHz Switching Frequency
- I<sub>q</sub> < 1µA in Shutdown
- 16-Pin QFN Package

### Applications

- White LED Backlighting
- Programmable Current Source

Preliminary Information

### Typical Application



### Pin Descriptions

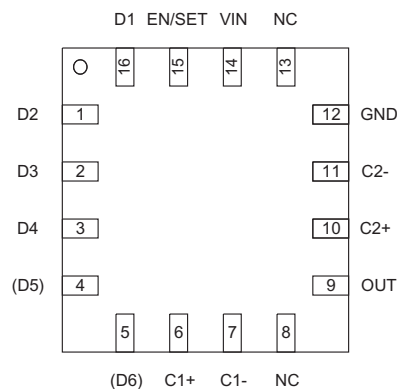
Pin #	Symbol	Function
1	D2	Current source output
2	D3	Current source output
3	D4	Current source output
4	D5	Current source output (3114 option only)
5	D6	Current source output (3114 option only)
6	C1+	Flying Capacitor 1 + terminal
7	C1-	Flying Capacitor 1 - terminal
8	NC	No Connect
9	OUT	Charge pump output. Requires 1uF bypass capacitor to ground.
10	C2+	Flying Capacitor 2 + terminal
11	C2-	Flying Capacitor 2 - terminal
12	GND	Ground
13	NC	No Connect
14	VIN	Input power supply. Requires 1uF bypass capacitor to ground.
15	EN/SET	Control Pin
16	D1	Current source output 1. Required reference current source.

### Part Number Descriptions

Part Number	Function
AAT3113-10	4 Diode outputs, 10mA full scale
AAT3113-20	4 Diode outputs, 20mA full scale
AAT3114-10	6 Diode outputs, 10mA full scale
AAT3114-20	6 Diode outputs, 20mA full scale

### Pin Configuration

**16 LD 4x4mm QFN  
(Top View)**



### Absolute Maximum Ratings ( $T_A=25^\circ\text{C}$ unless otherwise noted)

Symbol	Description	Value	Units
$V_{IN}$	Input Voltage	-0.3 to 6	V
$V_{OUT}$	Charge Pump Output	-0.3 to 6	V
$V_{EN/SET}$	EN/SET to GND Voltage	-0.3 to 6	V
$V_{EN/SET(MAX)}$	Maximum EN/SET to Input Voltage	0.3	V
$I_{OUT}$ (note2)	Maximum DC Output Current (Sum of Iout and D currents)	150	mA
$\theta_{JA}$	Thermal Resistance	37	$^\circ\text{C}/\text{W}$
$T_J$	Operating Junction Temperature Range	-40 to 150	$^\circ\text{C}$
$T_{LEAD}$	Maximum Soldering Temperature (at leads, 10 sec)	300	$^\circ\text{C}$

### Electrical Characteristics

The specs are applied over the full operation temp. range, otherwise specification are at room temp. ( $25^\circ\text{C}$ )  
 $V_{IN} = 3.3\text{V}$ , unless otherwise noted.

Symbol	Description	Conditions	Min	Typ	Max	Units	
<b>Input Power Supply</b>							
$V_{IN}$ operation range			2.4		5.5	V	
$I_{CC}$	Operating Current	$3.0 \leq V_{IN} \leq 5.5$ , Active, No Load Current		1	3	mA	
$I_{SHDN}$	Shutdown Current	EN=0			1	mA	
$I_{DX}$	Output Current	$3.0 \leq V_{IN} \leq 5.5$	10 mA	9	10	11	mA
			20 mA	18	20	22	
$I_{DX}$	Output Current Line Regulation	$3.0 \leq V_{IN} \leq 5.5$	-1		1	%	
I(D-Match)	Current Matching between any two outputs	VD1:Dn=3.6, $V_{IN}=3.3\text{V}$		0.3		%	
$\eta$	Efficiency	$V_{IN}=3.5$ , $I_{OUT(total)}=40\text{mA}$		93		%	
<b>Charge Pump</b>							
$t_{SS}$	Soft start time			200		ms	
$F_{CLK}$	Clock Frequency		300	600	900	KHz	
<b>EN/SET</b>							
$V_{EN(L)}$	Enable Threshold Low		0.4			V	
$V_{EN(H)}$	Enable Threshold High				1.4	V	
$t_{LO}$	EN/SET low time	$V_{EN/SET} < 0.6$	0.3		75	$\mu\text{s}$	
$t_{HI}$	Minimum EN/SET high time	$V_{EN/SET} < 0.6$		50		ns	
$t_{OFF}$	EN/SET Off Timeout	$V_{EN/SET} < 0.6$			500	ms	
Input Current	EN/SET input leakage		-1		1	mA	

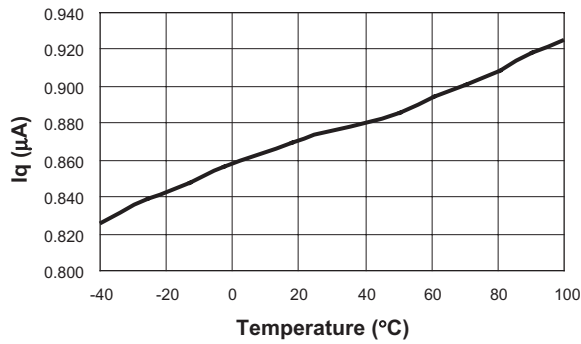
Note 1: The AAT3113 is guaranteed to meet performance specification from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ . Specification over the  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  operating temperature range are assured by design, characterization and correlation with statistical process controls.

Note 2: based on long-term current density limitation.

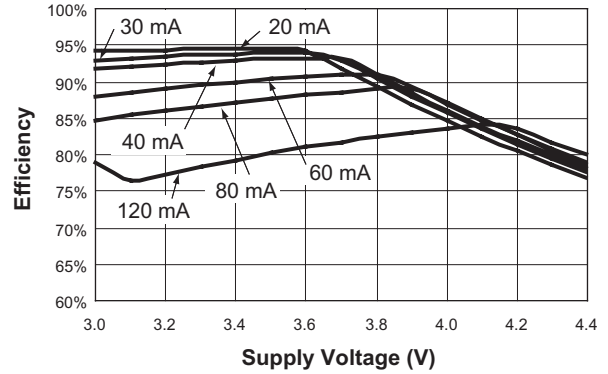
### Typical Characteristics

(unless otherwise noted:  $V_{IN}=3.6V$ ,  $C_{IN}=C_{OUT}=C1=C2=1\mu F$ ,  $T_A=25^\circ C$ )

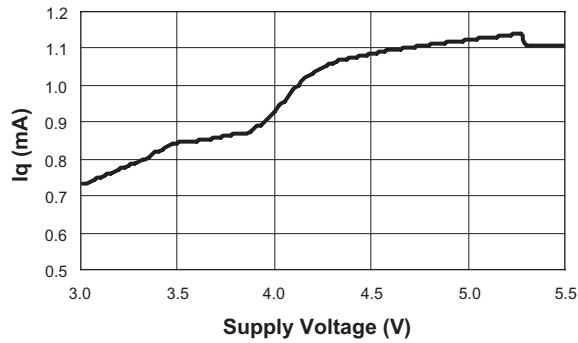
**Quiescent Current vs. Temperature**



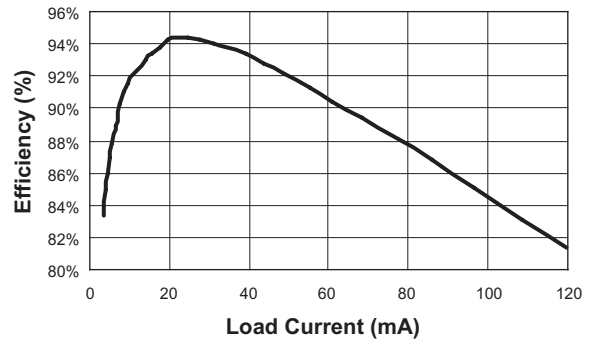
**Efficiency vs. Supply Voltage**



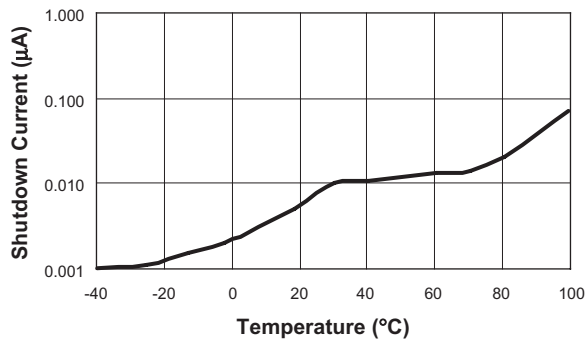
**Quiescent Current vs. Supply Voltage**



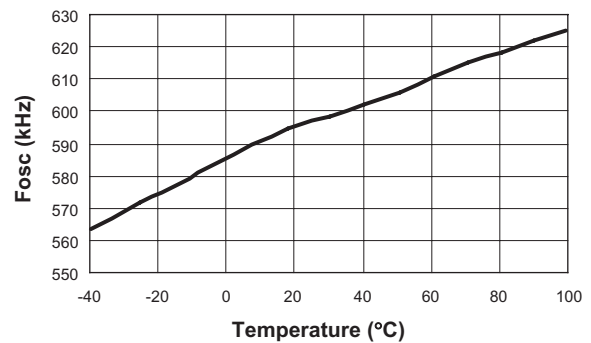
**Efficiency vs. Load Current**



**Shutdown Current vs. Temperature**



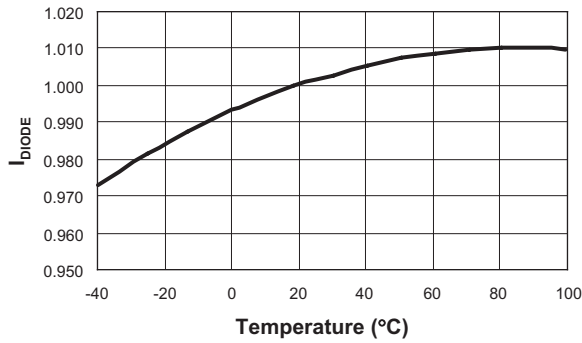
**Oscillator Frequency vs. Temperature**



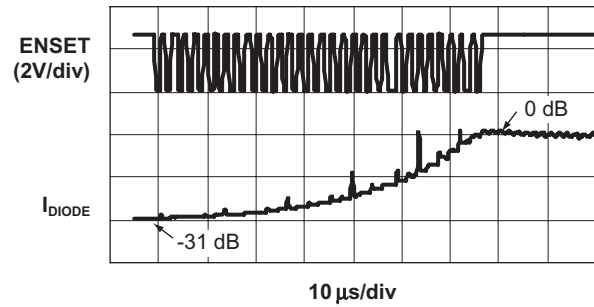
### Typical Characteristics

(unless otherwise noted:  $V_{IN}=3.6V$ ,  $C_{IN}=C_{OUT}=C1=C2=1\mu F$ ,  $T_A=25^\circ C$ )

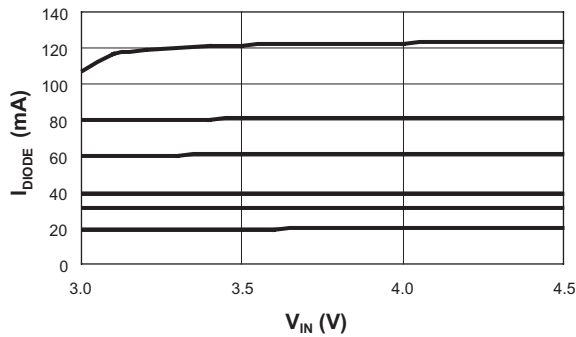
**Normalized  $I_{DIODE}$  vs. Temperature**



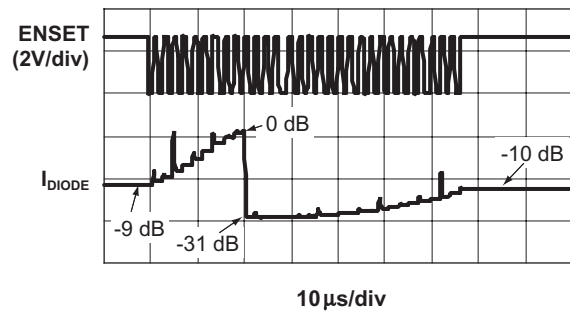
**$I_{DIODE}$  Response  
-31dB to 0dB**



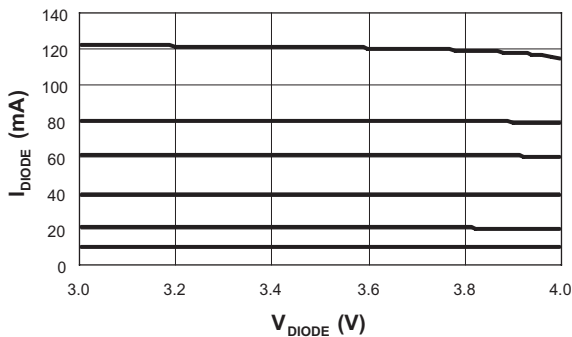
**$I_{DIODE}$  vs.  $V_{IN}$**



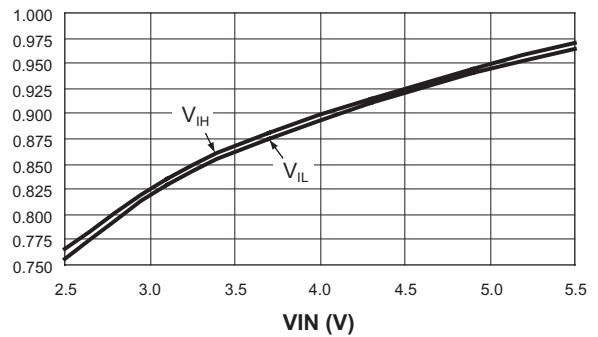
**$I_{DIODE}$  Response  
-9dB to -10dB**



**$I_{DIODE}$  vs.  $V_{DIODE}$**



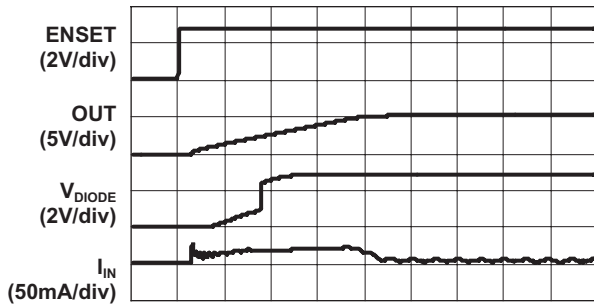
**$V_{IH}$  and  $V_{IL}$  vs.  $V_{IN}$**



### Typical Characteristics

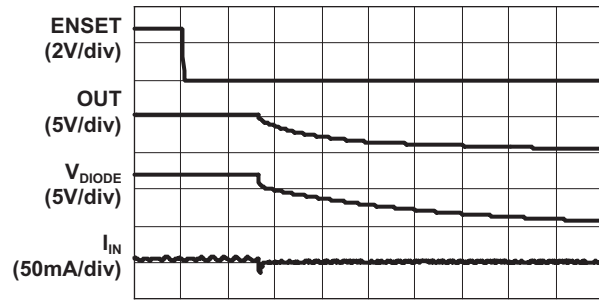
(unless otherwise noted:  $V_{IN}=3.6V$ ,  $C_{IN}=C_{OUT}=C1=C2=1\mu F$ ,  $T_A=25^\circ C$ )

Turn-On



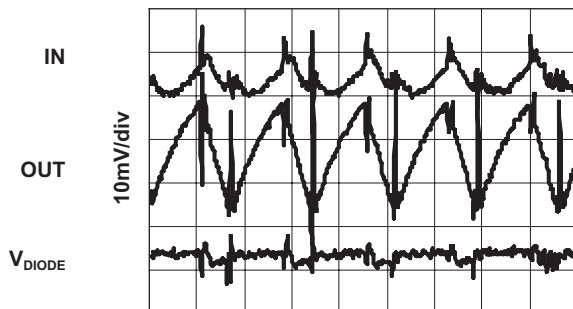
100 $\mu s$ /div

Turn-Off



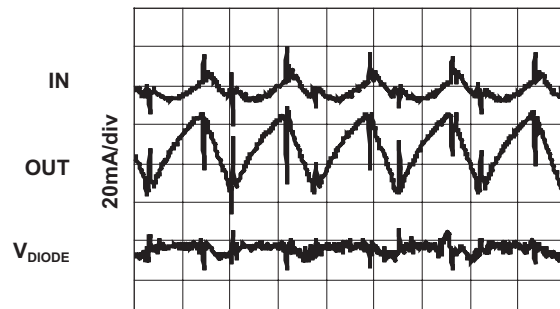
200 $\mu s$ /div

40mA Load Characteristics



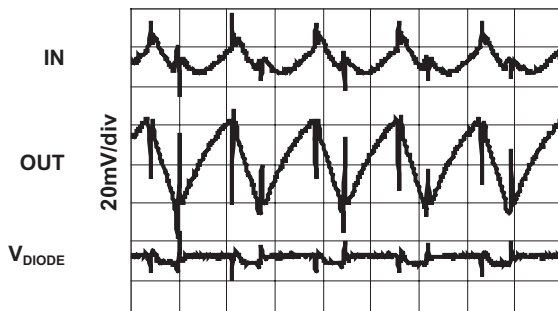
1 $\mu s$ /div

60mA Load Characteristics



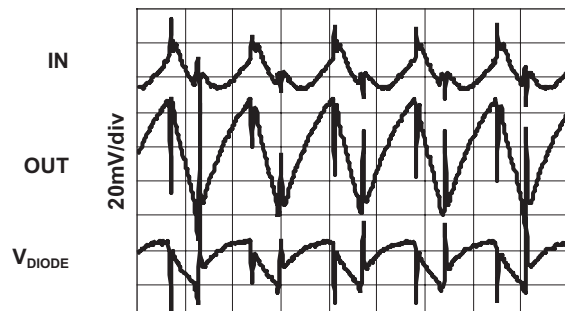
1 $\mu s$ /div

80mA Load Characteristics



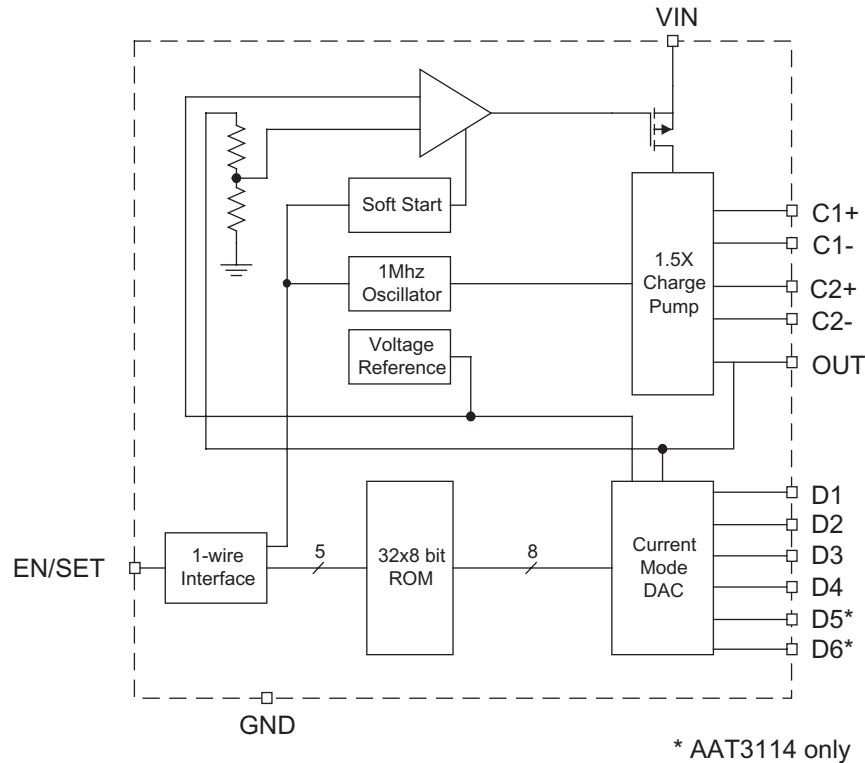
1 $\mu s$ /div

120mA Load Characteristics



1 $\mu s$ /div

### Functional Block Diagram



### Functional Description

The AAT3113/4 is a high efficiency 1.5X fractional charge pump device intended for white led back light applications. The fractional charge pump consists of a linear regulator followed by a 1.5X charge pump. The AAT3113/4 requires only four external components: two 1 $\mu$ F ceramic capacitors for the charge pump flying capacitors (C1 and C2), one 1 $\mu$ F ceramic capacitor for C<sub>IN</sub>, and one 0.33 $\mu$ F to 1 $\mu$ F ceramic capacitor for C<sub>OUT</sub>. The charge pump output is converted into four or six constant current outputs (D1 to D4 or D6) to drive four or six individual LEDs with a maximum of 10mA or 20mA each. The current source output magnitude is controlled by the EN/SET serial data 1-wire interface. The interface records rising edges of the EN/SET pin, and decodes them into 32 individual current

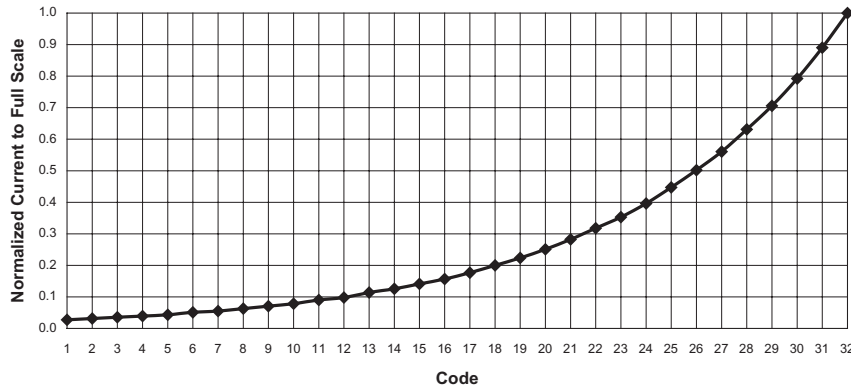
level settings each 1dB apart (see Current Level Settings below). Code 32 is full scale, and Code 1 is full scale attenuated by 31dB. The modulo 32 interface wraps states back to state 1 after the 32nd clock. With each EN/SET pulse, the output current increases by 1dB. To decrease the output current by 1dB, 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 current to -31dB, the lowest setting: 275 $\mu$ A (for 10mA full scale) or 525 $\mu$ A (for 20mA full scale). 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 500 $\mu$ s after the EN/SET pin transitions to a logic low state.

### Applications Information

#### Current Level Settings

LED current level is set via the serial interface according to a logarithmic scale where each code is 1dB greater than the previous code. In this manner, the LED brightness appears linear with each increasing code.

Normalized Current Level Settings



#### Current Levels (mA)

Code	20 mA max	10 mA max
1	0.549	0.275
2	0.627	0.314
3	0.706	0.353
4	0.784	0.392
5	0.863	0.431
6	1.020	0.510
7	1.098	0.549
8	1.255	0.627
9	1.412	0.706
10	1.569	0.784
11	1.804	0.902
12	1.961	0.980
13	2.275	1.137
14	2.510	1.255
15	2.824	1.412
16	3.137	1.569

Code	20 mA max	10 mA max
17	3.529	1.765
18	4.000	2.000
19	4.471	2.235
20	5.020	2.510
21	5.647	2.824
22	6.353	3.176
23	7.059	3.529
24	7.922	3.961
25	8.941	4.471
26	10.039	5.020
27	11.216	5.608
28	12.627	6.314
29	14.118	7.059
30	15.843	7.922
31	17.804	8.902
32	20.000	10.000



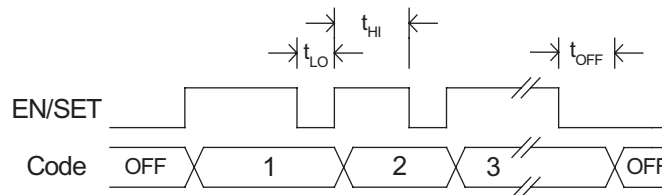
### EN/SET Serial Interface

The current source output magnitude is controlled by the EN/SET serial data 1-wire interface. The interface records rising edges of the EN/SET pin, and decodes them into 32 individual current level settings each 1dB apart. Code 32 is full scale, and Code 1 is full scale attenuated by 31dB. The modulo 32 interface wraps states back to state 1 after the 32nd clock, so 1dB of attenuation 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 -31dB, the lowest setting: 275µA (for 10mA full scale) or 525µA (for 20mA full scale). 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



### LED Selection

The AAT3113/4 devices are designed to drive white LEDs with forward voltages of less than 4.2V. Since the D1:D6 output current sources are matched with negligible voltage dependence, the LED brightness will be matched regardless of their forward voltage matching.

### Charge Pump Efficiency

The AAT3113/4 is a fractional charge pump. The efficiency ( $\eta$ ) 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 ( $\eta$ ) for an ideal 1.5x charge pump can typically be expressed as the output power divided by the input power.

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

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 ( $\eta$ ) can be rewritten as:

$$\eta = P_{OUT} / P_{IN} = (V_{OUT} \times I_{OUT}) / (V_{IN} \times 1.5 I_{OUT}) = V_{OUT} / 1.5 V_{IN}$$

$$\eta(\%) = 100(V_{OUT} / 1.5 V_{IN})$$

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 ( $<100\text{m}\Omega$ ) ceramic capacitors are used. In general, low ESR may be defined as less than  $100\text{m}\Omega$ . A capacitor value of  $1\text{mF}$  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 AAT3113/4 products. 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.

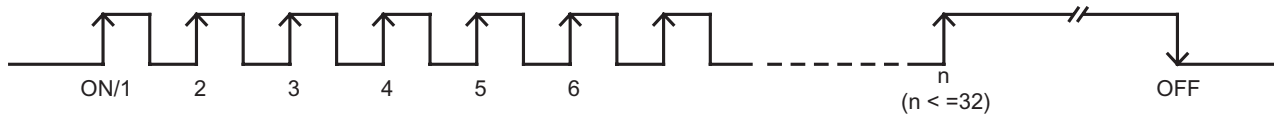
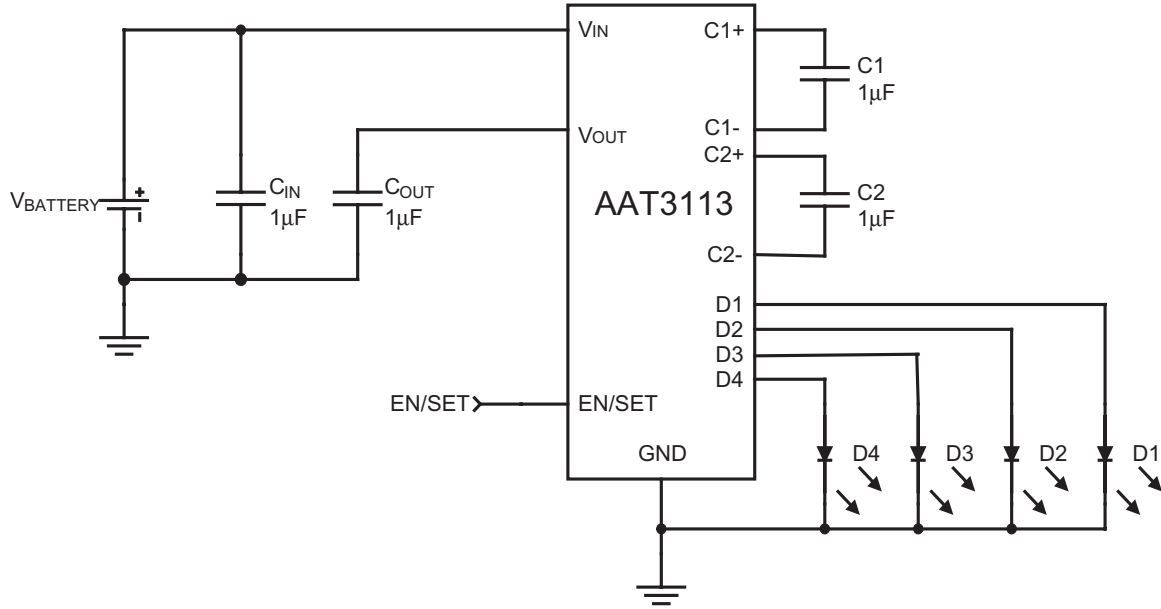
**Ceramic Capacitor Materials:** Ceramic capacitors less than  $0.1\mu\text{F}$  are typically made from NPO or COG materials. NPO and COG materials typically have tight tolerance and are stable over temperature. Large capacitor values are typically composed of X7R, X5R, Z5U or Y5V dielectric materials. Large ceramic capacitors, typically greater than  $2.2\mu\text{F}$  are often available in low cost Y5V and Z5U dielectrics, but large capacitors are not required in the AAT3113/4 application.

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

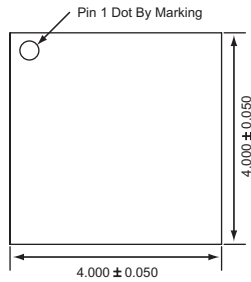
The AAT3113/4 have a thermal protection circuit that will shut down the charge pump and current outputs if the die temperature rises above the thermal limit. However, thermal resistance of the QFN package is so low, that if, in the case of the AAT3114, all six outputs are shorted to ground at maximum  $20\text{mA}$  output level, the die temperature will not rise sufficiently to trip the thermal protection. The thermal protection will only trip if  $C_{OUT}$  is shorted to ground and the ambient temperature is high.

### Application Circuit

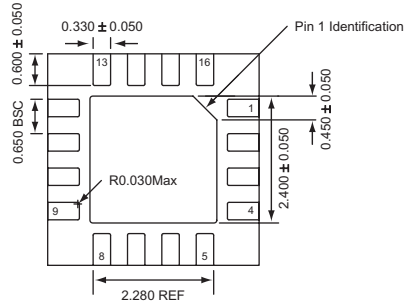


Enable / Disable / LED Brightness Level Set Data Input

### Package Information



Top View



Bottom View



Side View