AAT3113/4
High Efficiency 1.5X Fractional Charge Pumps For White LED Applications

ChargePump™

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 20mA for each output from a 2.7V to 5.5V input. Low external parts counts (two 1µF flying capacitors and two small bypass capacitors at V_{IN}, and OUT) make the AAT3113/4 ideally suited for small battery-power applications.

AnalogicTech™'s Simple Serial Control™ (S²Cwire™) interface is used 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_{IN} 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, and the AAT3113 is also available in the 12-pin TSOPJW package.

Features

- White LED Backlighting
- AAT3113 - 4 Outputs
- AAT3114 - 6 Outputs
- 20mA Full Scale Current
- 32 Position Logarithmic Scale with Digital Control
- Simple Serial Control™ (S²Cwire™) interface
- 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
- Iq < 1µA in Shutdown
- Temperature Range -40 to 85°C.
- 16-Pin QFN, 12-Pin TSOPJW Package

Applications

- White LED Backlighting
- Programmable Current Source

Typical Application
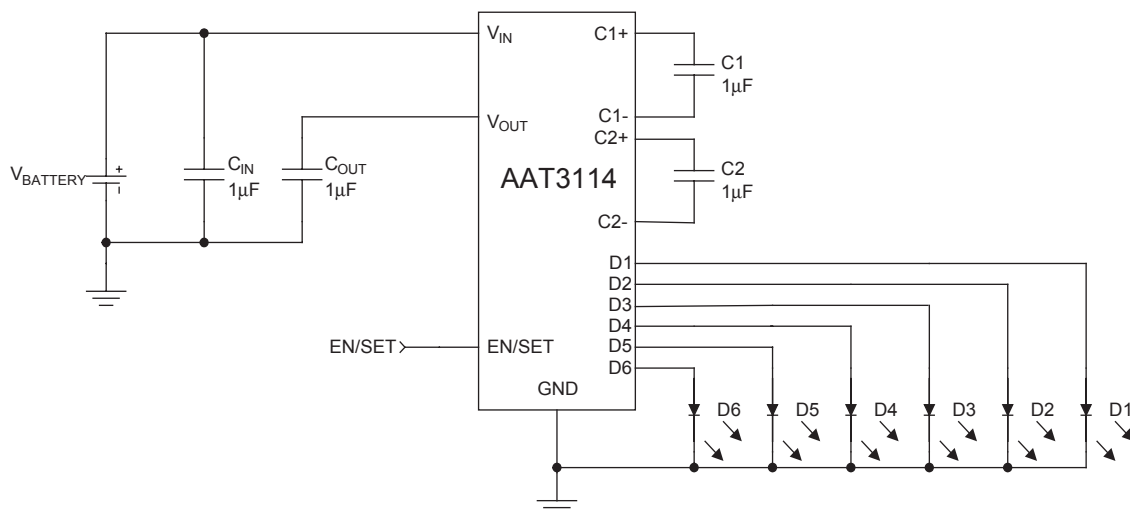
Pin Descriptions

Pin #		Symbol	Function
QFN44-16	TSOPJW-12		
1	7	D2	Current source output
2	6	D3	Current source output
3	5	D4	Current source output
4	N/A	D5	Current source output (3114 option only)
5	N/A	D6	Current source output (3114 option only)
6	4	C1+	Flying Capacitor 1 + terminal
7	3	C1-	Flying Capacitor 1 - terminal
8	N/A	NC	No Connect
9	2	OUT	Charge pump output. Requires 1uF bypass capacitor to ground.
10	1	C2+	Flying Capacitor 2 + terminal
11	12	C2-	Flying Capacitor 2 - terminal
12	11	GND	Ground
13	N/A	NC	No Connect
14	10	VIN	Input power supply. Requires 1uF bypass capacitor to ground.
15	9	EN/SET	Control Pin using S^{2}Cwire serial interface.
16	8	D1	Current source output 1. Required reference current source.

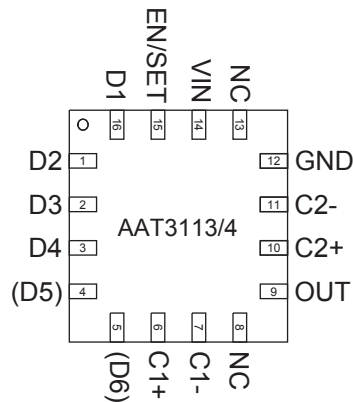## Part Number Descriptions

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

Pin Configuration

12-Lead TSOPJW
(Top View)
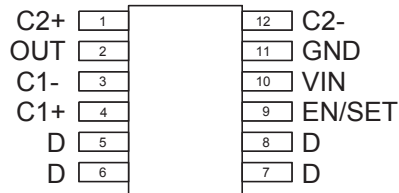
16 LD 4x4mm QFN
(Top View)

Absolute Maximum Ratings (T_A=25°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}	Maximum DC Output Current (Sum of Iout and D currents)	150	mA
θ_{JA}	Thermal Resistance	37	°C/W
T_J	Operating Junction Temperature Range	-40 to 150	°C

Electrical Characteristics

V_{IN}=3.5V, T_A = -40 to 85°C unless otherwise noted. Typical values are at 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	Active, No Load Current			1	2	mA
I_{SHDN}	Shutdown Current	EN=0				1	µA
IDX	Output Current	3113: 3.0 ≤ V_{IN} ≤ 5.5	T_A = 25°C, All Outputs Max Current	18	20	22	mA
		3114: 3.2 ≤ V_{IN} ≤ 5.5					
$\Delta I_D/\Delta V_{IN}$	Output Current Line Regulation	3.0 ≤ V_{IN} ≤ 5.5		-2		2	%/V
I(D-Match)	Current Matching between any two outputs	VD1:Dn=3.6, V_{IN}=3.3V			0.3		%
η	Efficiency	V_{IN}=3.5, $I_{OUT(total)}$=40mA			93		%
Charge Pump							
t_{SS}	Soft start time				400		µs
F_{CLK}	Clock Frequency			300	600	900	KHz
EN/SET							
$V_{EN(L)}$	Enable Threshold Low	V_{IN} = 2.7 to 5.5V				0.5	V
$V_{EN(H)}$	Enable Threshold High	V_{IN} = 2.7 to 5.5V		1.4			V
t_{LO}	EN/SET low time			0.3		75	µs
t_{HI}	Minimum EN/SET high time				50		ns
t_{OFF}	EN/SET Off Timeout				300	500	µs
Input Current	EN/SET input leakage	V_{IN} = 5.5V		-1		1	µA

Typical Characteristics

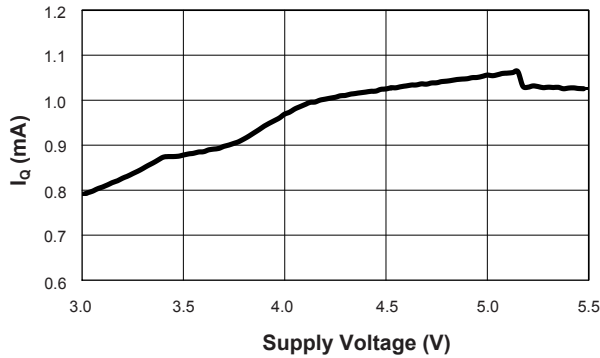(unless otherwise noted: V_{IN}=3.5V, C_{IN}=C_{OUT}=C1=C2=1µF, T_A=25°C)
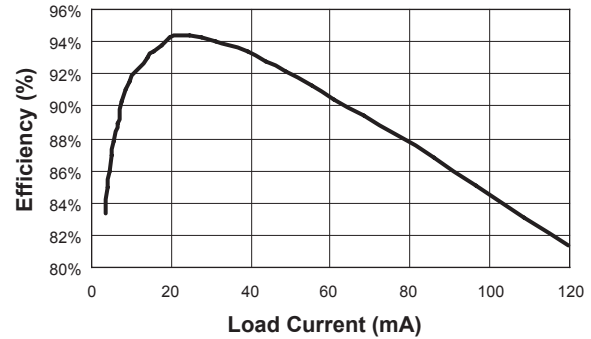
Quiescent Current vs. Temperature
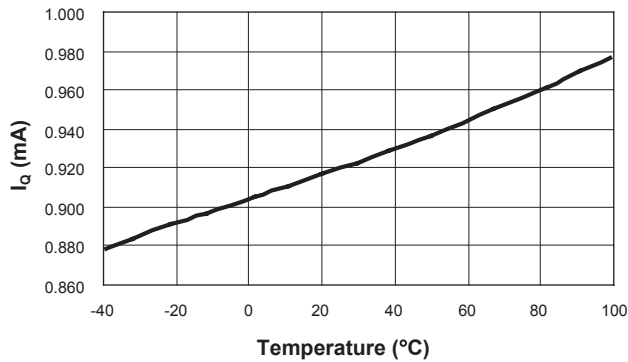
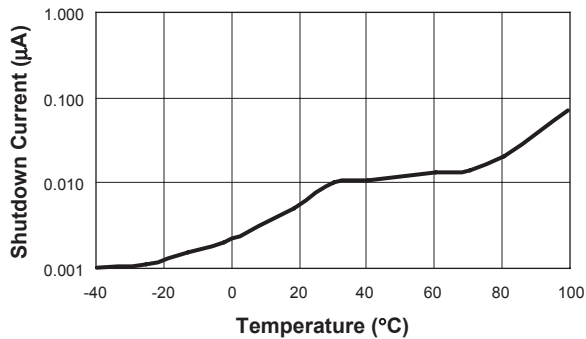**Efficiency vs. Supply Voltage**
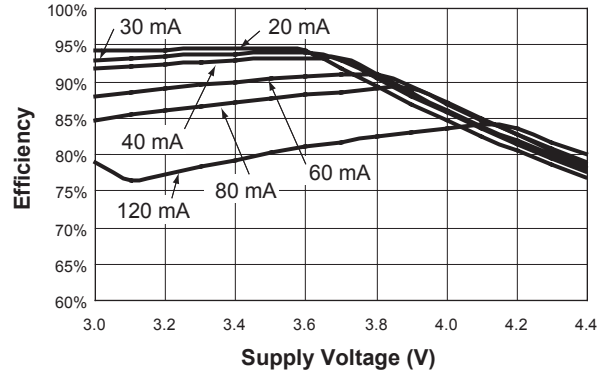
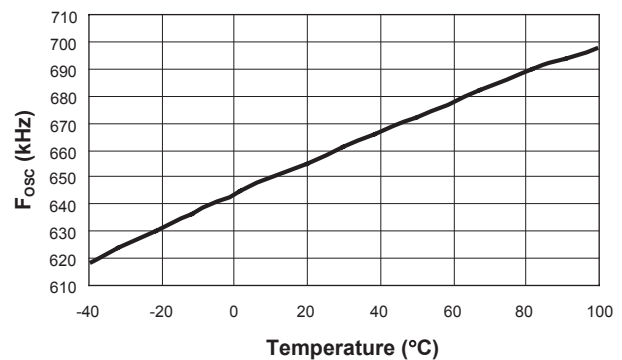
Quiescent Current vs. Supply Voltage

Efficiency vs. Load Current
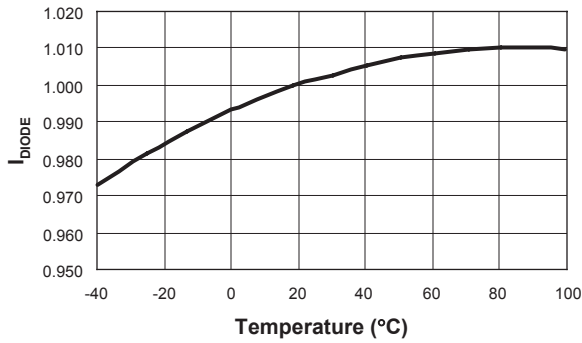

Shutdown Current vs. Temperature
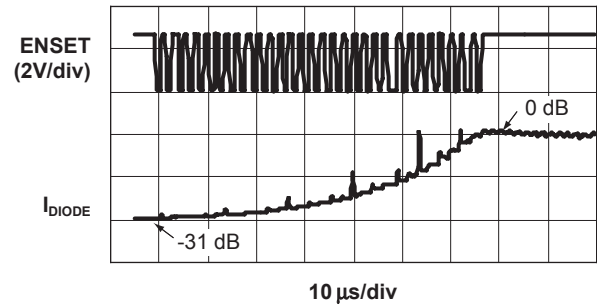

Oscillator Frequency vs. Temperature

Typical Characteristics

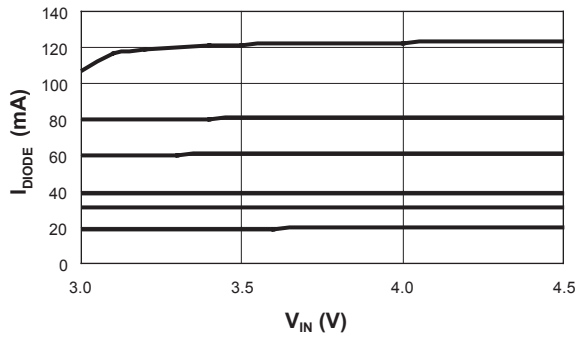(unless otherwise noted: V_{IN}=3.5V, C_{IN}=C_{OUT}=C1=C2=1µF, T_A=25°C)
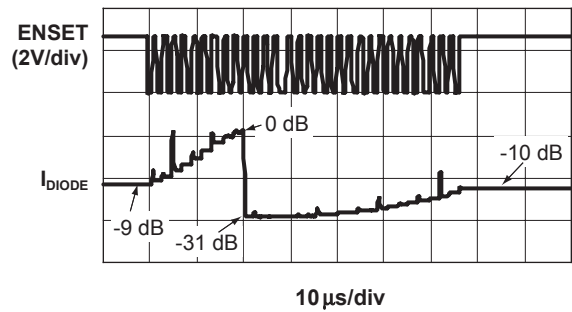
Normalized I_{DIODE} vs. Temperature
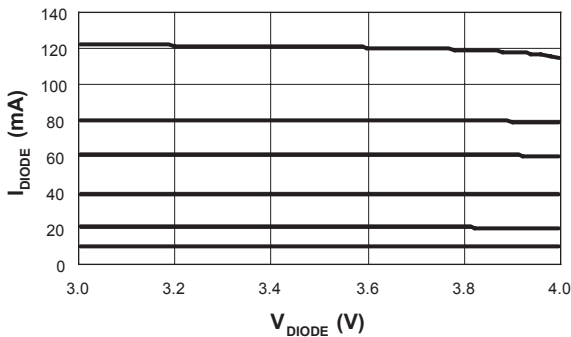
**I_{DIODE} Response
-31dB to 0dB**

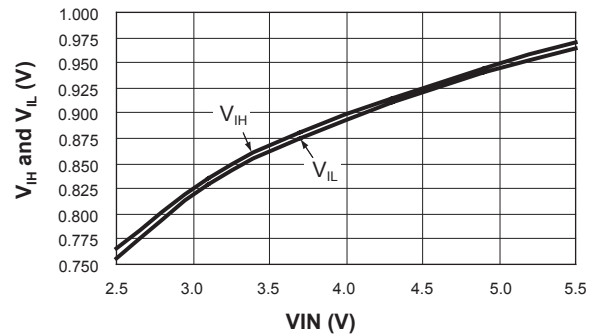**I_{DIODE} vs. VIN**

**I_{DIODE} Response
-9dB to -10dB**
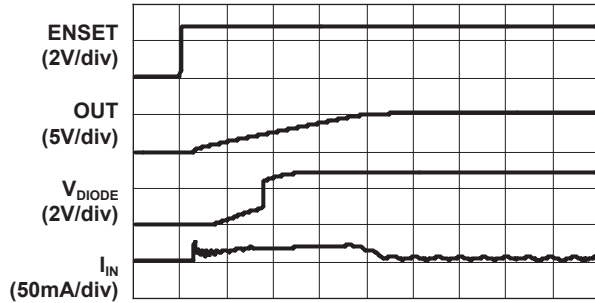
I_{DIODE} vs. V_{DIODE}

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

Typical Characteristics

(unless otherwise noted: V_{IN}=3.5V, C_{IN}=C_{OUT}=C1=C2=1µF, T_A=25°C)
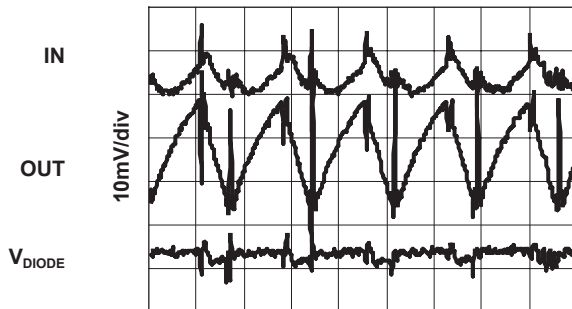
Turn-On

ENSET
(2V/div)

OUT
(5V/div)

V_{DIODE}
(2V/div)

I_{IN}
(50mA/div)

100µs/div

Turn-Off

ENSET
(2V/div)

OUT
(5V/div)

V_{DIODE}
(5V/div)

I_{IN}
(50mA/div)
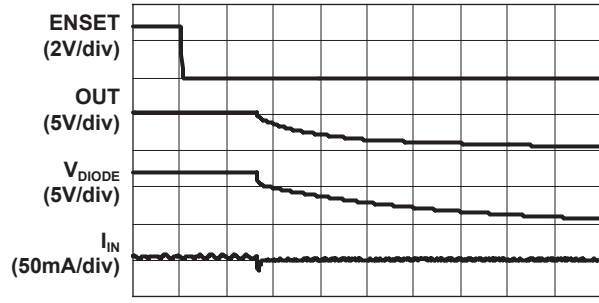
200µs/div

40mA Load Characteristics

IN

OUT

V_{DIODE}

10mV/div

1µs/div

60mA Load Characteristics

IN

OUT

V_{DIODE}

20mV/div
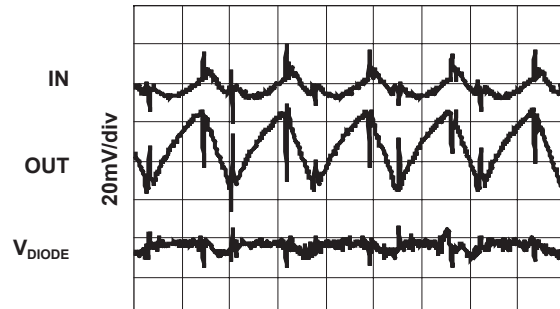
1µs/div

80mA Load Characteristics

IN

OUT

V_{DIODE}

20mV/div
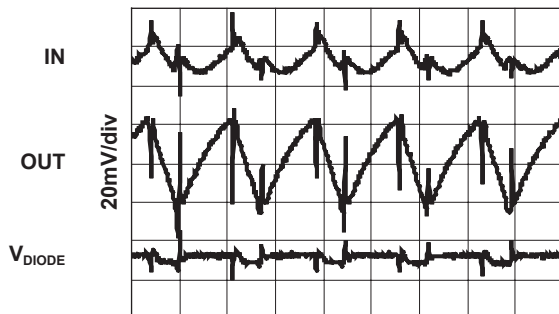
1µs/div

120mA Load Characteristics

IN

OUT

V_{DIODE}

20mV/div
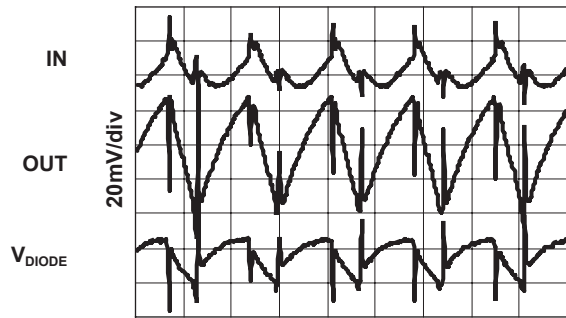
1µs/div

Functional Block Diagram

* AAT3114 only
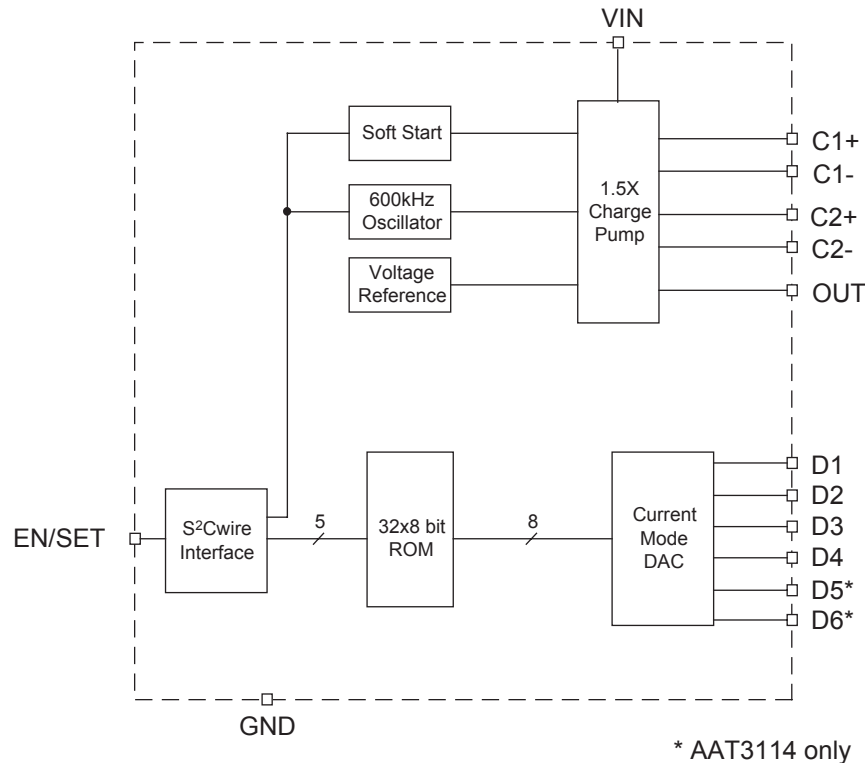
Functional Description

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 1µF ceramic capacitors for the charge pump flying capacitors (C1 and C2), one 1µF ceramic capacitor for C_{IN}, and one 0.33µF to 1µF ceramic capacitor for C_{OUT}. 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 20mA each. The current source output magnitude is controlled by the EN/SET serial data S^2C interface. The interface records rising edges of the EN/SET pin, and
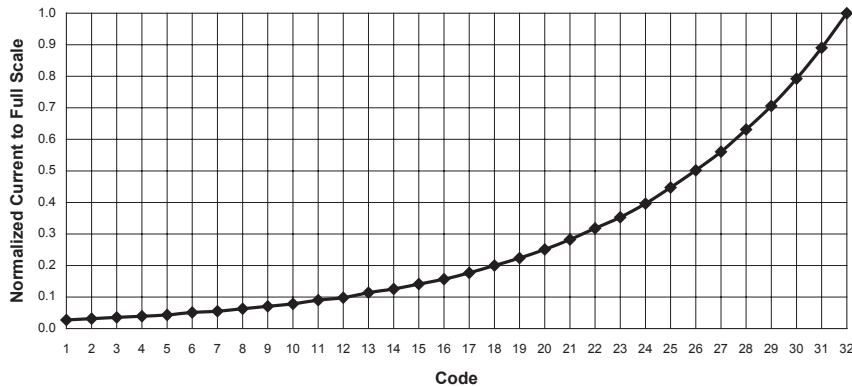
decodes them into 32 individual current level settings each 1dB apart (see Current Level Settings below). Code 32 is full scale, and Code 1 is full scale attenuated by 31dB. The modulo 32 interface wraps states back to state 1 after the 32nd clock. With each EN/SET pulse, the output current increases 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 equal to 525µA. 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

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		Code	20 mA max
1	0.549		17	3.529
2	0.627		18	4.000
3	0.706		19	4.471
4	0.784		20	5.020
5	0.863		21	5.647
6	1.020		22	6.353
7	1.098		23	7.059
8	1.255		24	7.922
9	1.412		25	8.941
10	1.569		26	10.039
11	1.804		27	11.216
12	1.961		28	12.627
13	2.275		29	14.118
14	2.510		30	15.843
15	2.824		31	17.804
16	3.137		32	20.000

EN/SET Serial Interface

The current source output magnitude is controlled by the EN/SET pin using AnalogicTech's Simple Serial Control (S²Cwire) 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 (see graph titled "IDIODE Response -9dB to -10dB" on page 5). 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 equal to 525µA. 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
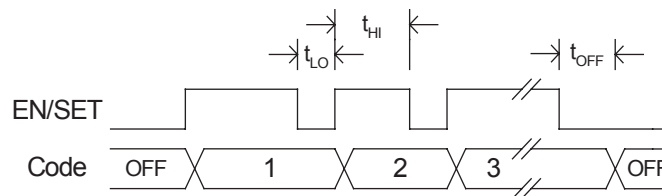
LED Selection

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 (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.

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

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:

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

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

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.

Power Efficiency and Device Evaluation:

The charge pump efficiency discussion of the previous section only accounts for the efficiency of the charge pump section itself. Due to the unique circuit architecture and design of the AAT3113/14, it is very difficult to measure efficiency in terms of a percent value comparing input power over output power. Since the AAT3113/14 outputs are pure constant current sources, it is difficult to measure the output voltage for a given output (D1 to D6) to derive an 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".*

AAT3114 Input Power vs. LED Current
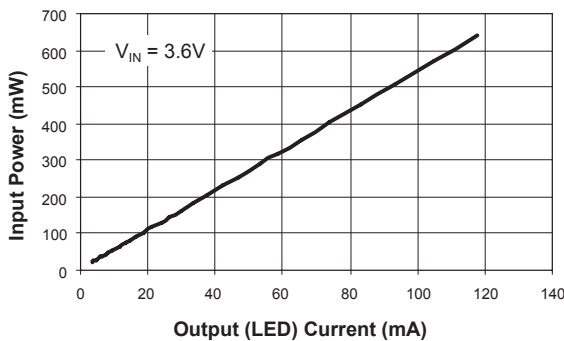
Capacitor Selection

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 minimal 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 0.1µF 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 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 20mA 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 Circuits

**Typical AAT3113 Application Circuit:**
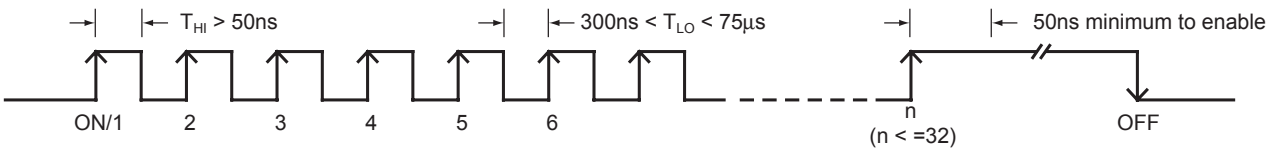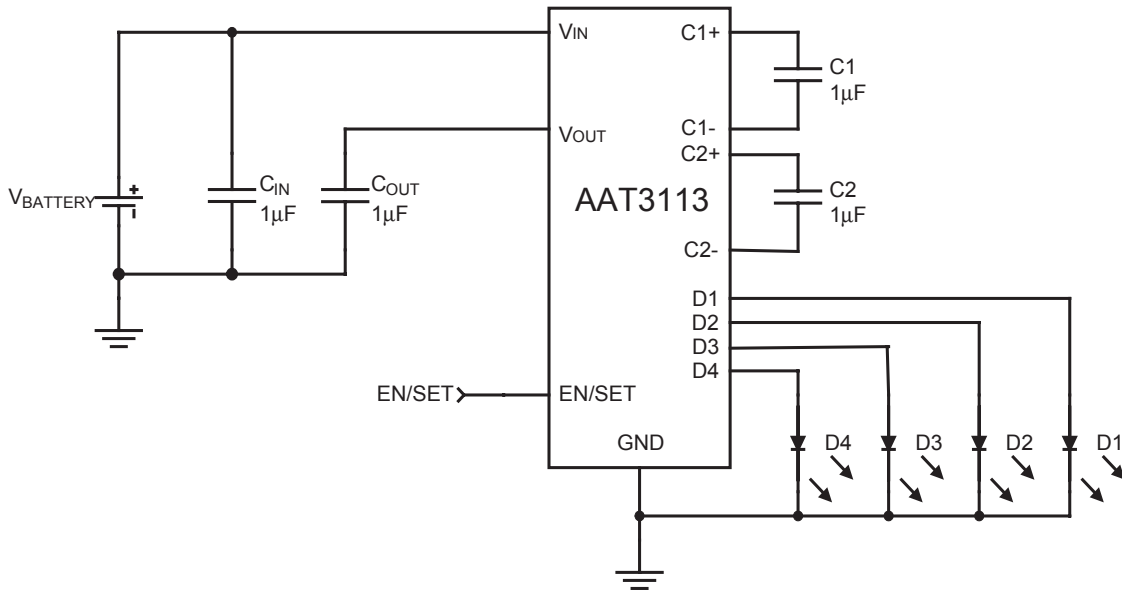
Enable / Disable / LED Brightness Level Set Data Input

**Driving White LED display module back lights and individual white LED's connected in parallel:**

The AAT3113/14 D1 to D6 outputs are true constant current sources capable of driving up to 20mA 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 D6) 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. All output may be connected in parallel to drive groups of LED's as well. The internal current source reference circuit bases feedback from current sensed on the D1 output. For best operation, the only requirement for this application is the output D1 should always be connected to the load circuit.

AAT3114 application driving a display module with six parallel connected white LEDs:
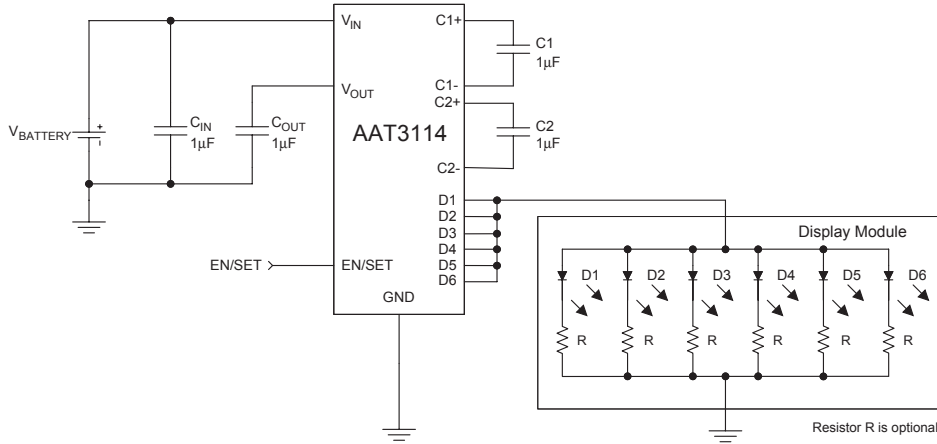
AAT3114 Dual Backlight Control Circuit:
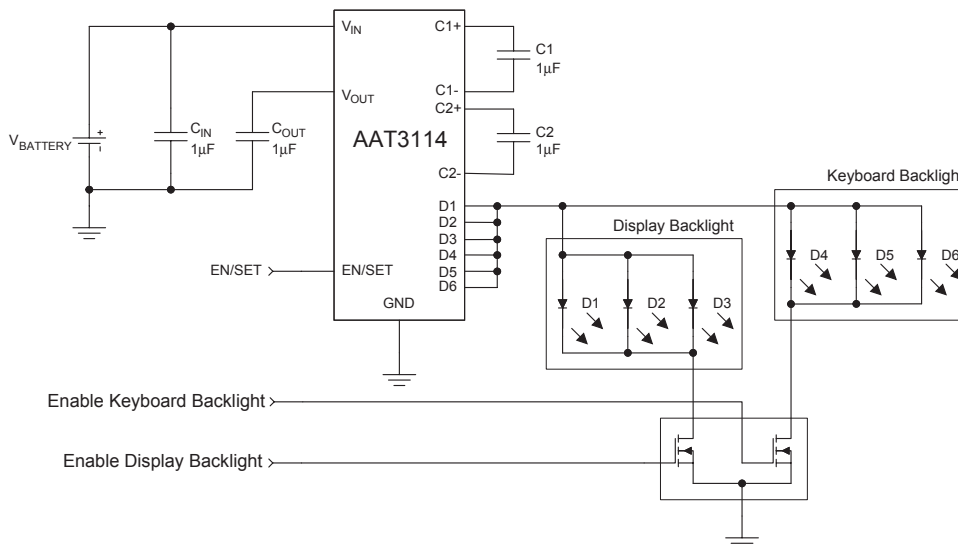
Ordering Information

Package	Marking[1]	Part Number (Tape and Reel)
QFN44-16	EUXYY	**AAT3113ISN-20-T1**
QFN44-16	FGXYY	**AAT3114ISN-20-T1**
TSOPJW-12	HTXYY	**AAT3113ITP-20-T1**

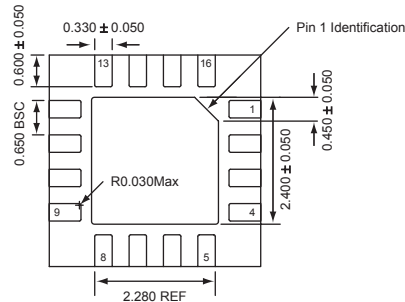Note: Sample stock is generally held on all part numbers listed in **BOLD**.
Note 1: XYY = assembly and date code.
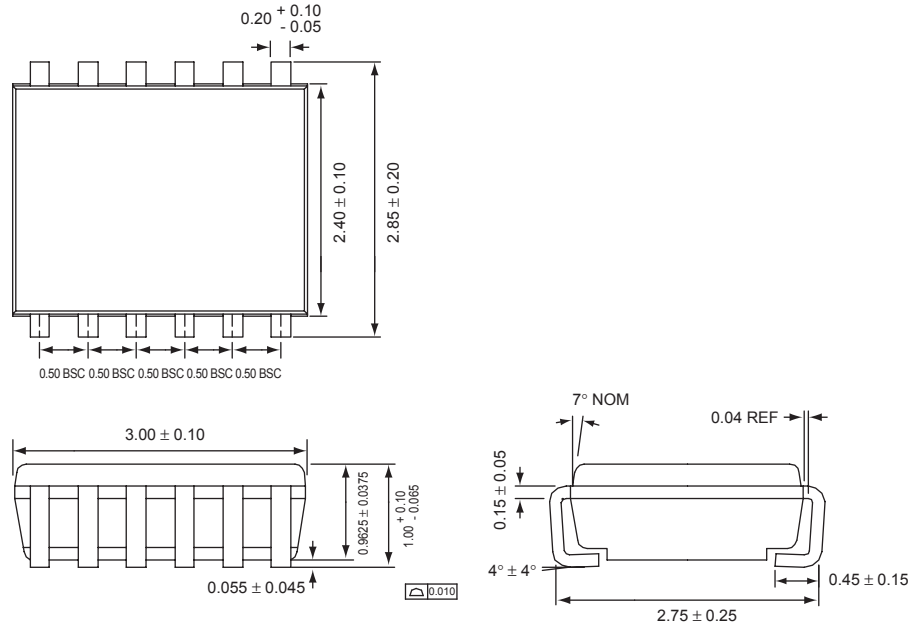
Package Information

QFN44-16
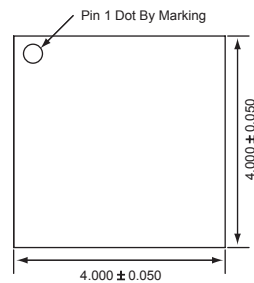
Top View

Bottom View

Side View

All dimensions in millimeters.

TSOPJW-12

All dimensions in millimeters.