# AAT3351

*High Efficiency 1x/1.5x Charge Pump*

## General Description

The AAT3351 is a low-noise, constant-frequency charge pump DC/DC converter that uses a dual-mode load switch (1x) and fractional (1.5x) charge pump to maximize efficiency for white LED applications. The AAT3351 is capable of driving 4 white LEDs at a total of 120mA from single 2.7V to 5.5V input. The current sinks may be operated individually or in parallel while driving higher-current LEDs. A low external parts count (two 1µF flying capacitors and two small 1µF capacitors at $V_{IN}$ and $V_{OUT}$) makes the AAT3351 ideal for small battery-powered applications.

Skyworks' S2Cwire™ serial digital input is used to enable, disable, and set current to one of 32 levels for the LEDs.

The AAT3351 is equipped with built-in short-circuit protection. The soft-start circuitry prevents excessive inrush current at start-up and mode transitions. The AAT3351 family is available in Pb-free, space-saving TSOPJW and TDFN33 packages, and operates over the -40°C to +85°C ambient temperature range.
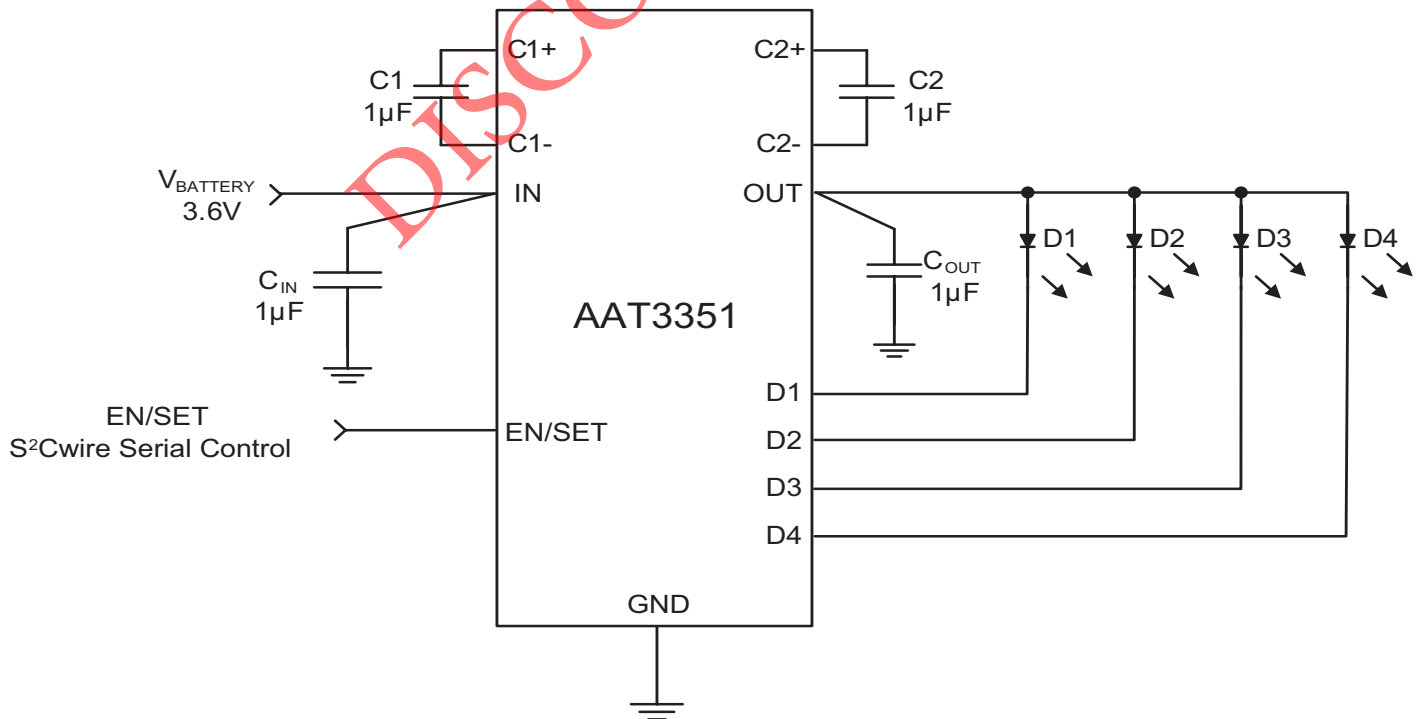
## Features

- Drives up to 4 LEDs at up to 30mA, each
- Automatic Switching Between 1x and 1.5x Modes
- 1MHz Switching Frequency
- Linear LED Output Current Control
  - Single-wire, S2Cwire Interface
  - 32-step
- ±10% LED Output Current Accuracy
- 3% LED Output Current Matching
- Low-Current Shutdown Mode
- Automatic Soft-Start
- TSOPJW-14 and TDFN33-12 Packages

## Applications

- Cellular and Smart Phones
- Digital Still and Video Cameras
- PDAs
- Portable Devices
- Portable Media Players
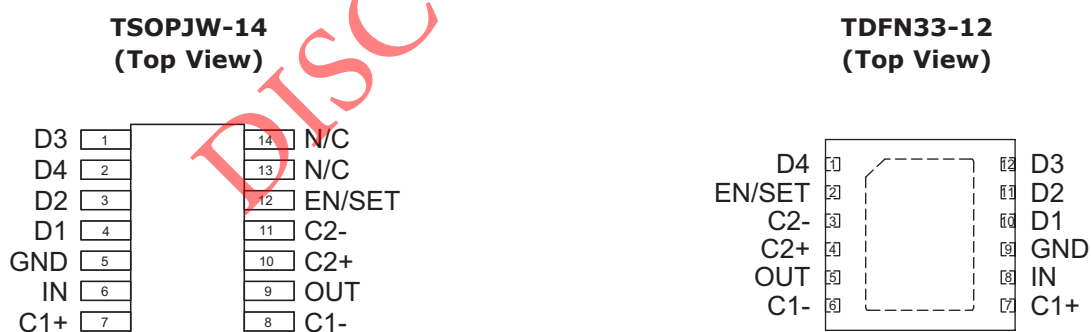- Other White LED Backlighting

## Typical Application

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## Pin Descriptions

| Pin Number | | Name | Function |
|---|---|---|---|
| TDFN33-12 | TSOPJW-14 | | |
| 1 | 2 | D4 | Backlight LED 4 current sink. D4 controls the current through backlight LED 4. Connect the cathode of backlight LED 4 to D4. If not used, connect D4 to OUT. |
| 2 | 12 | EN/SET | S²Cwire serial interface control pin. |
| 3 | 11 | C2- | Negative terminal of charge pump capacitor 2. |
| 4 | 10 | C2+ | Positive terminal of charge pump capacitor 2. Connect the 1µF charge pump capacitor 2 from C2+ to C2-. |
| 5 | 9 | OUT | Charge pump output. OUT is the output of the charge pump and supplies current to the backlight LEDs. Connect the backlight LED anodes to OUT. Bypass OUT to PGND with a 1µF or larger ceramic capacitor as close to the AAT3351 as possible. |
| 6 | 8 | C1- | Negative terminal of charge pump capacitor 1. |
| 7 | 7 | C1+ | Positive terminal of charge pump capacitor 1. Connect the 1µF charge pump capacitor 1 from C1+ to C1-. |
| 8 | 6 | IN | Power input. Connect IN to the input source voltage. Bypass IN to GND with a 1µF or larger ceramic capacitor as close to the AAT3351 as possible. |
| 9 | 5 | GND | Ground pin. |
| 10 | 4 | D1 | Backlight LED 1 current sink. D1 controls the current through backlight LED 1. Connect the cathode of backlight LED 1 to D1. If not used, connect D1 to OUT. |
| 11 | 3 | D2 | Backlight LED 2 current sink. D2 controls the current through backlight LED 2. Connect the cathode of backlight LED 2 to D2. If not used, connect D2 to OUT. |
| 12 | 1 | D3 | Backlight LED 3 current sink. D3 controls the current through backlight LED 3. Connect the cathode of backlight LED 3 to D3. If not used, connect D3 to OUT. |
| N/A | 13, 14 | N/C | Not connected. |
| EP | N/A | EP | Exposed paddle (bottom). Connect to GND directly beneath package. |

## Pin Configuration

**TSOPJW-14**
**(Top View)**

| | | |
|---|---|---|
| D3 | 1 | 14 N/C |
| D4 | 2 | 13 N/C |
| D2 | 3 | 12 EN/SET |
| D1 | 4 | 11 C2- |
| GND | 5 | 10 C2+ |
| IN | 6 | 9 OUT |
| C1+ | 7 | 8 C1- |

**TDFN33-12**
**(Top View)**

| | | |
|---|---|---|
| D4 | 1 | 12 D3 |
| EN/SET | 2 | 11 D2 |
| C2- | 3 | 10 D1 |
| C2+ | 4 | 9 GND |
| OUT | 5 | 8 IN |
| C1- | 6 | 7 C1+ |

DISCONTINUED

## 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 $V_{EN/SET}$ to $V_{IN}$ Voltage ($V_{EN/SET}$ - $V_{IN}$) | +0.3 | V |
| $I_{OUT}$ | Maximum DC Output Current | 150 | mA |
| $T_J$ | Operating Junction Temperature Range | -40 to 150 | °C |

## Thermal Information[1]

| Symbol | Description | | Value | Units |
|---|---|---|---|---|
| $P_D$ | Maximum Power Dissipation[1] | TDFN33-12[2] | 2000 | mW |
| | | TSOPJW-14[3] | 625 | |
| $\theta_{JA}$ | Maximum Thermal Resistance | TDFN33-12 | 50 | °C/W |
| | | TSOPJW-14 | 160 | |

1. Mounted on 1.6mm thick FR4 circuit board.
2. Derate 25mW/°C above 25°C ambient temperature.
3. Derate 6.25mW/°C above 25°C ambient temperature.

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## Electrical Characteristics

$V_{IN}$ = 3.6V; $C_{IN}$ = $C_{OUT}$ = 1µF; $C_1$ = $C_2$ = 1µF; $T_A$ = -40°C to 85°C unless otherwise noted. Typical values are $T_A$ = 25°C.

| Symbol | Description | Conditions | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| **Input Power Supply** | | | | | | | |
| $V_{IN}$ | Input Voltage Range | -40°C ≤ $T_A$ ≤ 85°C | | 2.7 | | 5.5 | V |
| $I_{IN}$ | Input Operating Current | EN/SET = IN | 1x Mode, $I_{D1}$ = $I_{D2}$ = $I_{D3}$ = $I_{D4}$ = OFF | | 2 | 4 | mA |
| | | | 1.5x Mode, $I_{D1}$ = $I_{D2}$ = $I_{D3}$ = $I_{D4}$ = OFF | | 6 | 7.2 | |
| $I_{IN(SHDN)}$ | Shutdown Current | EN/SET = GND | | | | 1 | µA |
| $V_{IN\_(TH)}$ | Charge Pump Mode Hysteresis | 1x to 1.5x Transition at Any $I_{DX}$ | | | 0.15 | | V |
| **LED Current Sink Outputs** | | | | | | | |
| $I_{D\_(MAX)}$ | D1-D4 Current Accuracy | EN/SET = S²C DATA 1 | | 27 | 30 | 33 | mA |
| $I_{D\_(DATA31)}$ | D1-D4 Current Accuracy | EN/SET = S²C DATA 31 | | | 0.5 | | mA |
| $\Delta I_{(D\_X)}/I_{D\_AVG}$ | D1-D4 Current Matching[1] | EN/SET = S²C DATA 1, $I_{D1}$ = $I_{D2}$ = $I_{D3}$ = $I_{D4}$ = 30mA | | | ±3 | | % |
| $V_{D\_(TH)}$ | Hysteresis for Mode Change | $I_{D1}$ = $I_{D2}$ = $I_{D3}$ = $I_{D4}$ = 30mA, 1.5x to 1x Mode | | | 0.15 | 0.25 | V |
| $I_{OUT(MAX)}$ | Charge Pump Maximum Output Current | $V_{IN}$ = 3.0V, $V_F$ = 4.0V | | | 150 | | mA |
| $f_{OSC}$ | Clock Frequency | | | | 1 | | MHz |
| $V_{D\_(TH)}$ | Charge Pump Mode Transition Threshold | EN/SET = IN; $V_{IN}$ - $V_F$ = 1V | | | 0.15 | | V |
| $t_{SS}$ | Charge Pump Startup Time | | | | 150 | | µs |
| **EN/SET S²Cwire Control** | | | | | | | |
| $V_{ENH}$ | EN/SET Input High Threshold Voltage | | | 1.4 | | | V |
| $V_{ENL}$ | EN/SET Input Low Threshold Voltage | | | | | 0.4 | V |
| $I_{EN(LKG)}$ | EN Input Leakage Current | EN/SET = IN = 5V | | -1 | | 1 | µA |
| $t_{EN/SET(HI\_MIN)}$ | EN/SET Minimum High Time | | | | 50 | | ns |
| $t_{EN/SET(HI\_MAX)}$ | EN/SET Maximum High Time | | | | | 75 | µs |
| $t_{EN/SET(LOW)}$ | EN/SET Input Low Time | | | 0.3 | | 75 | µs |
| $t_{EN/SET(OFF)}$ | EN/SET Input OFF Timeout | | | | | 500 | µs |
| $t_{EN/SET(LAT)}$ | EN/SET Input Latch Timeout[3] | | | | | 500 | µs |

1. LED current match is defined as 100 $(I_{DX} - I_{AVG})/I_{AVG}$.
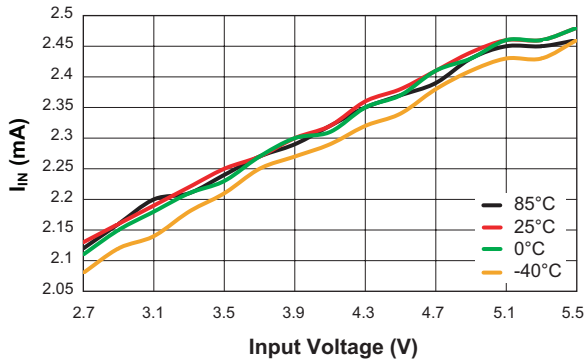2. 1x mode output impedance is defined as $(V_{IN} - V_{OUT})/I_{OUT}$.
3. If the part has been shut down, the latch time will be 500µs longer for soft start of charge pump.

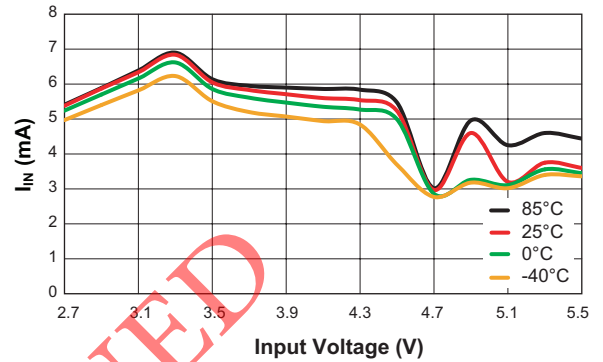## Typical Characteristics

$V_{IN}$ = 3.6V, $C_{IN}$ = $C_{OUT}$ = $C_1$ = $C_2$ = 1µF; $T_A$ = 25°C, unless otherwise noted.
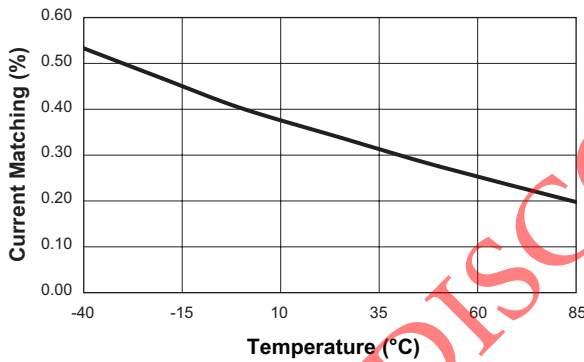
**No Load Operating Current vs. Input Voltage**
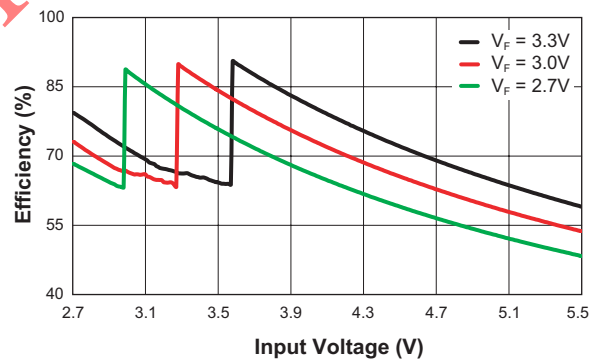**(1x Mode)**

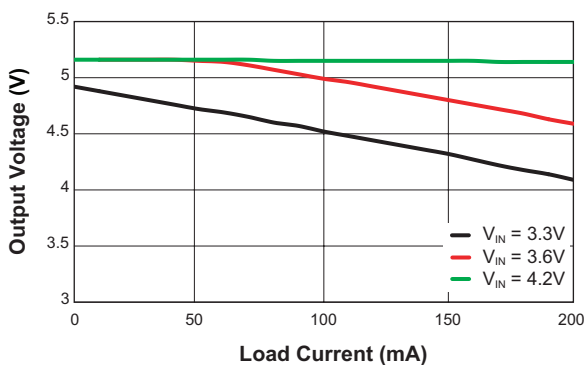**No Load Operating Current vs. Input Voltage**
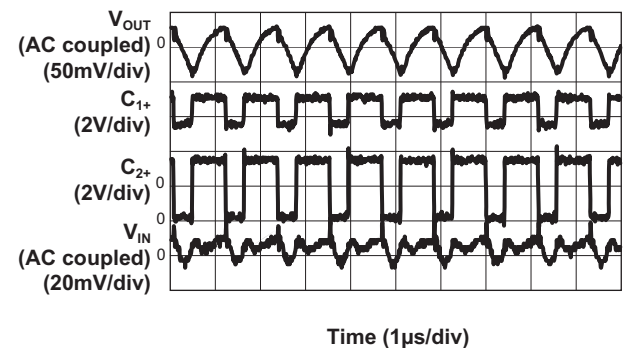**(1.5x Mode)**

**Backlight Current Matching vs. Temperature**
**(30mA/ch)**

**Efficiency vs. Input Voltage**
**(DATA = 1, 30mA/ch)**

**1.5x Output Voltage vs. Load Current**

**1.5x Mode Operating Characteristics**
**($V_{IN}$ = 3.3V; 30mA/ch Backlight, 1.5x Mode, $C_{OUT}$ = 1µF)**

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## Typical Characteristics

$V_{IN}$ = 3.6V, $C_{IN}$ = $C_{OUT}$ = $C_1$ = $C_2$ = 1µF; $T_A$ = 25°C, unless otherwise noted.

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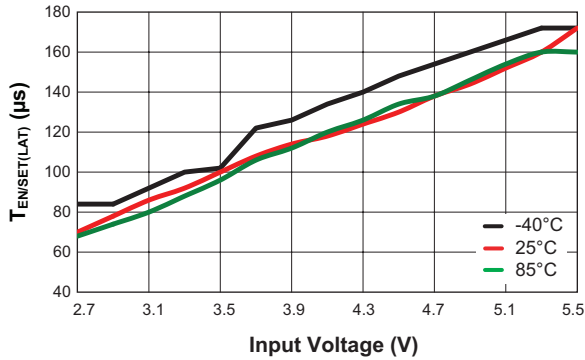


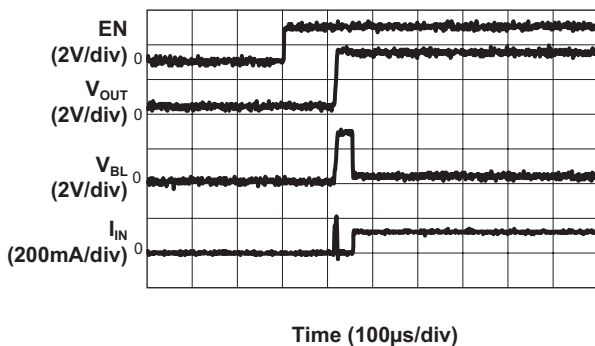**EN/SET Input Off Timeout vs. Input Voltage**
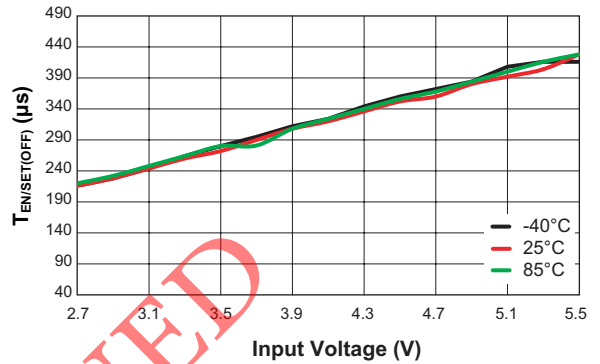


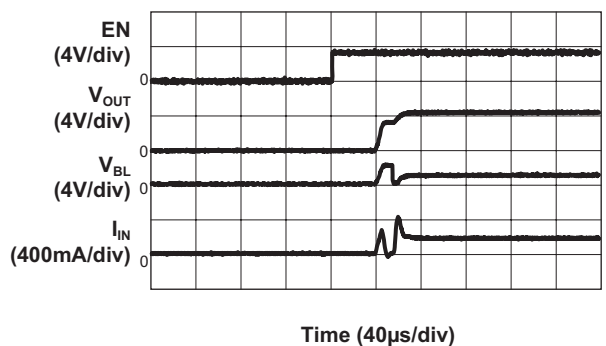**EN Input High Threshold Voltage vs. Input Voltage**
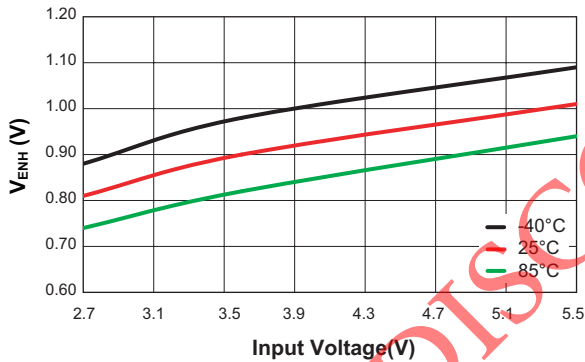


**EN Input Low Threshold Voltage vs. Input Voltage**
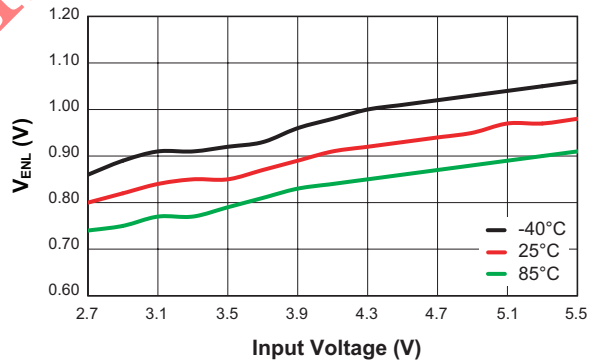


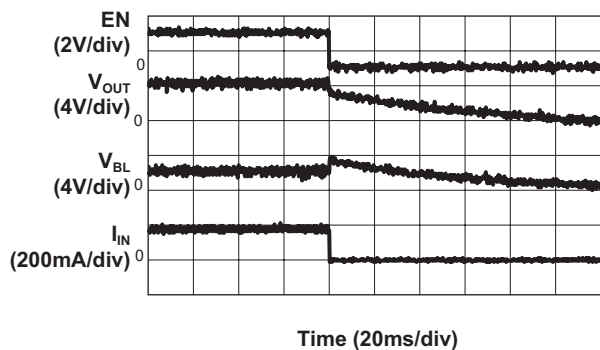**Turn-On to 1x Mode Backlight**
($V_{IN}$ = 3.6V; 30mA/ch)



**Turn-On to 1.5x Mode Backlight**
($V_{IN}$ = 3.3V; 30mA/ch)

## Typical Characteristics

$V_{IN}$ = 3.6V, $C_{IN}$ = $C_{OUT}$ = $C_1$ = $C_2$ = 1µF; $T_A$ = 25°C, unless otherwise noted.

**Turn-Off from 1.5x Mode Backlight**
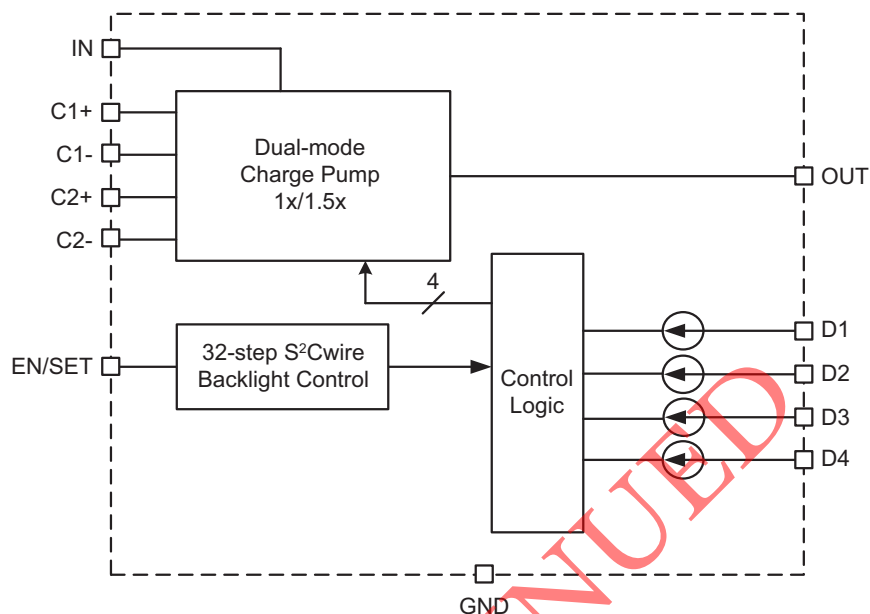($V_{IN}$ = 3.3V; 30mA/ch)



Time (20ms/div)

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## Functional Block Diagram



## Functional Description

The AAT3351 is a high efficiency charge pump white LEDs driver for portable applications which can drive 4 channels at up to 30mA each.

The current sink magnitude is controlled by the EN/SET serial data S$^2$Cwire interface. The interface records rising edges of the EN/SET pin and decodes them into 32 individual current level settings.

### LED Drivers

The AAT3351 is a fractional charge pump and can multiply the input voltage by 1 or 1.5 times. The charge pump switches at a fixed frequency of 1MHz. The internal-mode-selection-circuit automatically switches the mode between 1x and 1.5x mode based on the input voltage, LED forward voltage, and load current. This mode switching maximizes the efficiency throughout the entire load range. When the input voltage is high enough, the AAT3351 operates in 1x mode to provide maximum efficiency. If the input voltage drops too low to supply programmed LED current when the battery discharges and the voltage decays, 1.5x mode is automatically enabled. When the battery is connected to a charger and the input voltage increases sufficiently, the device will switch back to 1x mode.

## Application Information

### Current Level Settings

LED current level is set via Skyworks' Simple Serial Control (S$^2$Cwire) interface in a linear scale. The LED current decreases linearly with each increasing code in steps of approximately 1mA as shown in Table 1 and Figure 1.

| S$^2$Cwire Data | LED Current (mA) | S$^2$Cwire Data | LED Current (mA) |
|---|---|---|---|
| 1 | 30 | 17 | 14.5 |
| 2 | 29 | 18 | 13.5 |
| 3 | 28 | 19 | 12.6 |
| 4 | 27.1 | 20 | 11.6 |
| 5 | 26.1 | 21 | 10.6 |
| 6 | 25.2 | 22 | 9.7 |
| 7 | 24.2 | 23 | 8.7 |
| 8 | 23.2 | 24 | 7.7 |
| 9 | 22.3 | 25 | 6.8 |
| 10 | 21.3 | 26 | 5.8 |
| 11 | 20.3 | 27 | 4.8 |
| 12 | 19.4 | 28 | 3.9 |
| 13 | 18.4 | 29 | 2.9 |
| 14 | 17.4 | 30 | 1.9 |
| 15 | 16.5 | 31 | 1 |
| 16 | 15.5 | 32 | 0.5 |

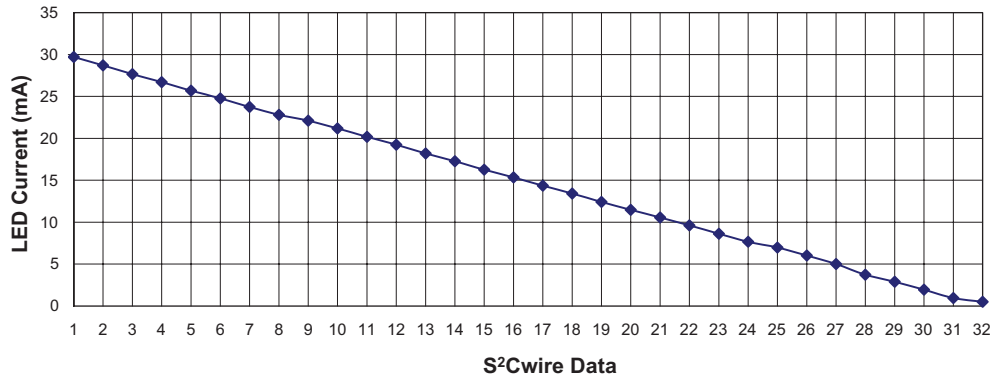**Table 1: S$^2$Cwire Data vs. LED Current.**

**Figure 1: S²Cwire Data vs. LED Current.**

## EN/SET Serial Interface

The LED current magnitude is controlled by the EN/SET pin using the S²Cwire interface. The interface records rising edges of the EN/SET pin and decodes them into 32 individual current level settings. Code 1 is full scale, and Code 32 is the lowest setting equal to 500µA. The interface resets back to state 1 after the 32nd clock. The EN/SET counter can be clocked at speeds up to 1MHz, so intermediate states are not visible, but is designed to accommodate a wide range of data rates. The first rising edge of EN/SET enables the charge pump, which reaches full capacity after the soft-start time $t_{SS}$. and initially sets the output LED current to full scale. Once EN/SET has been held in the logic high state for time $t_{LAT}$, the programmed current is seen at the current sink outputs.

When EN/SET is held low for an amount of time greater than $t_{OFF}$, the AAT3351 enters into shutdown mode and draws less than 1µA from IN. The internal data register is reset to 0 during shutdown. The EN/SET timing diagram is shown on Figure 2.
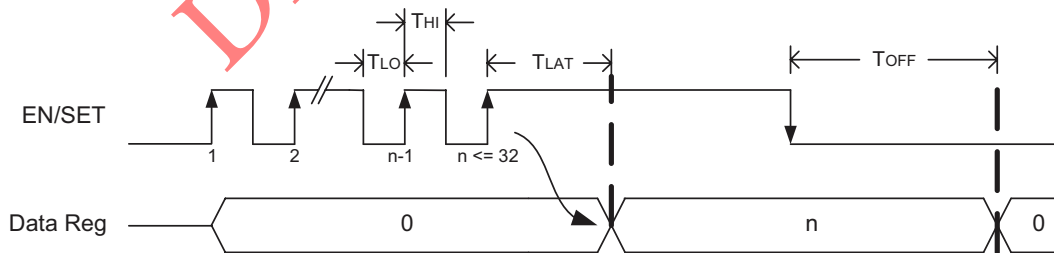


**Figure 2: EN/SET Timing Diagram.**

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## LED Selection

The AAT3351 is designed to drive white LEDs with forward voltages from 2V to 4.8V. Since D1 through D4 output current sinks are matched with negligible voltage dependence; the LED constant current and brightness will be matched regardless of their forward voltage ($V_F$) levels.

## Test Current/Channel Disable

Each current sink channel is equipped with a test current function. While it is enabled, the AAT3351 automatically detects the presence of LEDs all the time. Unused channels that are tied to OUT or LED loads that are failed will be automatically disabled.

## Device Switching Noise Performance

The AAT3351 operates at a fixed frequency of 1MHz to control noise and limit harmonics that can interfere with the RF operation of cellular telephone handsets or other communication devices. Noise injected back to 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 AAT3351 soft-start feature prevents noise transient effects associated with inrush currents during startup of the charge pump circuit.

## Power Efficiency and Device Evaluation

The charge pump efficiency discussion in the following sections accounts only for efficiency of the charge pump section itself. Due to the unique circuit architecture and design of the AAT3351, it is very difficult to measure efficiency in terms of a percent value comparing input power over output power. Since the AAT3351 outputs are pure constant current sinks and typically drive individual loads, it is difficult to measure the output voltage for a given output 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 components count, reliability, operating range, and total energy usage...*not just % efficiency*.

The AAT3351 efficiency may be quantified under specific conditions and is dependent upon the input voltage and voltage on D1 through D4 for a given constant current setting.

Depending on the combination of $V_{IN}$ and voltages sensed at the current sinks D1-D4, the device will operate in 1X mode. When any one of the voltages sensed at the current sinks D1-D4 drops below the charge pump mode transient threshold, the device will operate in 1.5X charge pump mode. Each of these modes will yield different efficiency values. Refer to the following two sections for efficiency calculation of each mode.

### 1x Mode Efficiency

The AAT3351's 1x mode is operational at all times and functions alone to enhance device power conversion efficiency when $V_{IN}$ is higher than the voltage across the load. When in 1x mode, voltage conversion efficiency is defined as output power divided by input power.

An expression for the ideal efficiency (η) in 1x charge pump mode can be expressed as:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_F \cdot I_{OUT}}{V_{IN} \cdot I_{OUT}} \approx \frac{V_F}{V_{IN}}$$

-or-

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

### 1.5x Charge Pump Mode Efficiency

The AAT3351 contains a fractional charge pump which will boost the input supply voltage when $V_{IN}$ is less than the voltage required to supply the output. The efficiency (η) can be simply defined as a linear voltage regulator with an effective output voltage that is equal to one and one half times the input voltage. Efficiency (η) for an ideal 1.5x charge pump can be calculated by the following equation:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_F \cdot I_{OUT}}{V_{IN} \cdot I_{OUT}} = \frac{V_F \cdot I_{OUT}}{V_{IN} \cdot 1.5 \cdot I_{OUT}} \approx \frac{V_F}{1.5 \cdot V_{IN}}$$

-or-

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

## Capacitor Selection

Careful selection of the four external capacitors $C_{IN}$, $C_1$, $C_2$, and $C_{OUT}$ is important because they will affect turn-on time, output ripple, and transient load performance. Optimum performance will be obtained when low equivalent series resistance (ESR) ceramic capacitors are used. In general, low ESR may be defined as less than 100mΩ. A value of 1µF for all four capacitors is a good starting point when choosing capacitors. If the LED current sinks are only programmed for low 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 AAT3351. Ceramic capacitors offer many advantages over their tantalum and aluminum electrolytic counterparts. A ceramic capacitor has very low ESR, is lowest cost, has a smaller PCB footprint, and is non-polarized. Low ESR ceramic capacitors help to maximize charge pump transient response. Since ceramic capacitors are non-polarized, they are not prone to incorrect connection damage.

## Equivalent Series Resistance

ESR is an important characteristic to consider when selecting a capacitor. ESR is a resistance internal to a capacitor that 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 C0G materials. NPO and C0G materials have tight tolerance and are stable over temperature. Capacitors with large values are typically composed of X7R, X5R, Z5U, or Y5V dielectric materials.

Large ceramic capacitors, greater than 2.2µF, are often available in low-cost Y5V and Z5U dielectrics, but capacitors greater than 1µF are usually not required for AAT3351 applications.

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

## Evaluation Board Layout

When designing a PCB for the AAT3351, the key requirements are:

1. Place two flying capacitors $C_1$ and $C_2$ as close to the chip as possible; otherwise 1.5x mode performance will be compromised.
2. Place input and output decoupling caps as close to the chip as possible to reduce switching noise and output ripple.

| Manufacturer | Part Number | Value (µF) | Voltage (V) | Temperature Coefficient | Case |
|---|---|---|---|---|---|
| Murata | GRM219R71C104KA01 | 0.1 | 10 | X7R | 0805 |
| | GRM188R61A105KA61 | 1 | 10 | X5R | 0603 |
| | GRM219R61A475KE19 | 4.7 | 10 | X5R | 0805 |
| AVX | 0603ZD105K | 1 | 10 | X5R | 0603 |
| TDK | C1608X5R1E105K | 1 | 25 | X5R | 0603 |
| | C1608X5R1A475K | 4.7 | 10 | X5R | 0603 |
| Taiyo Yuden | LMK107BJ475KA | 4.7 | 10 | X5R | 0603 |

**Table 2: Surface Mount Capacitors.**

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# Evaluation Board Schematic
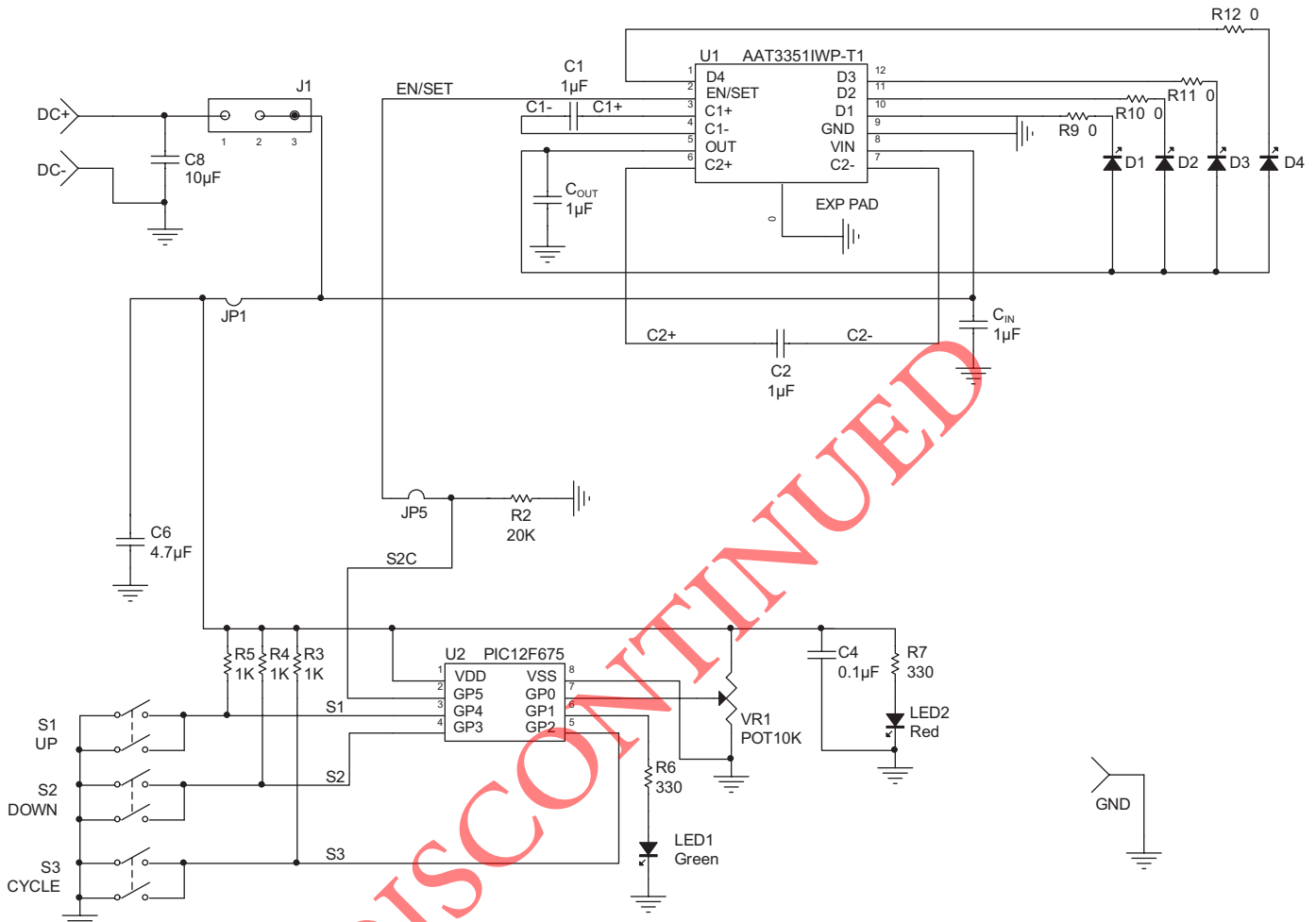


**Figure 3: AAT3351IWP Evaluation Board Schematic.**
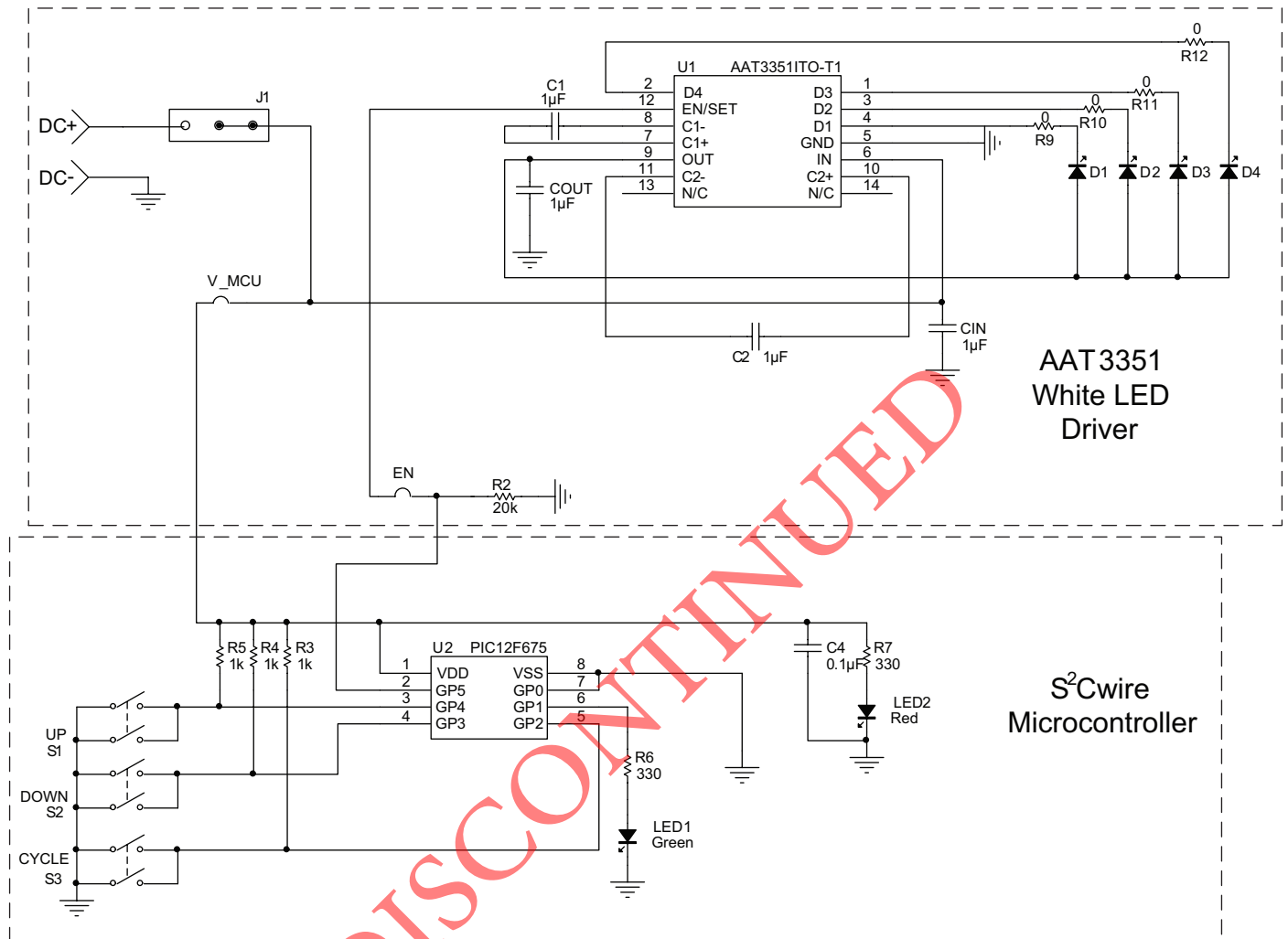
**Figure 4: AAT3351ITO Evaluation Board Schematic.**

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## Evaluation Board Layout
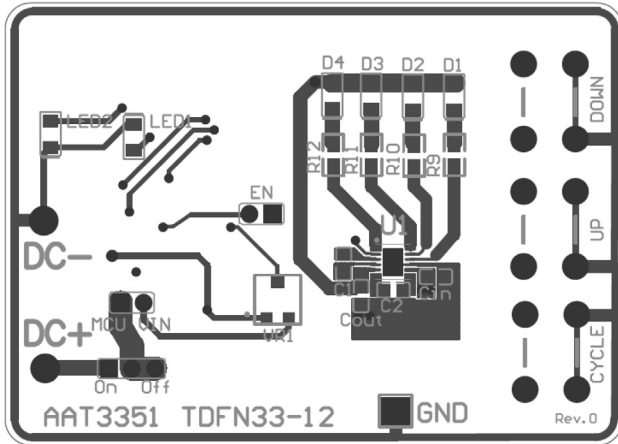


**Figure 5: AAT3351IWP Evaluation Board
Top Side Layout.**
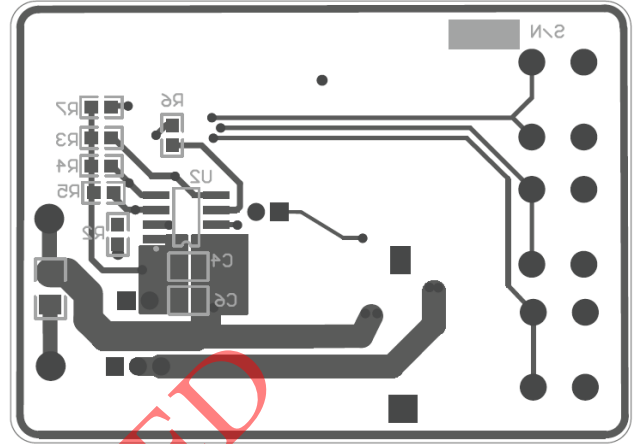


**Figure 6: AAT3351IWP Evaluation Board
Bottom Side Layout.**
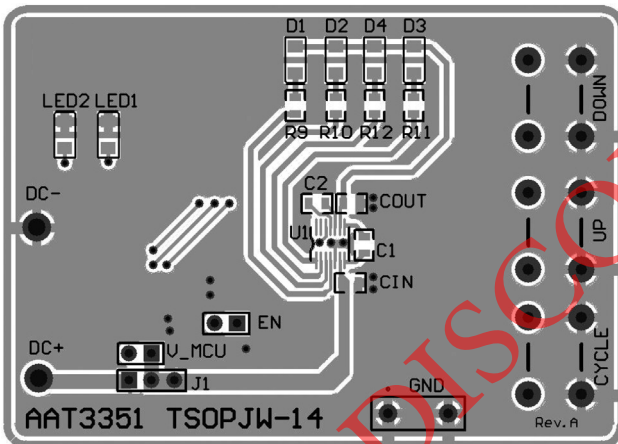


**Figure 7: AAT3351ITO Evaluation Board
Top Side Layout.**
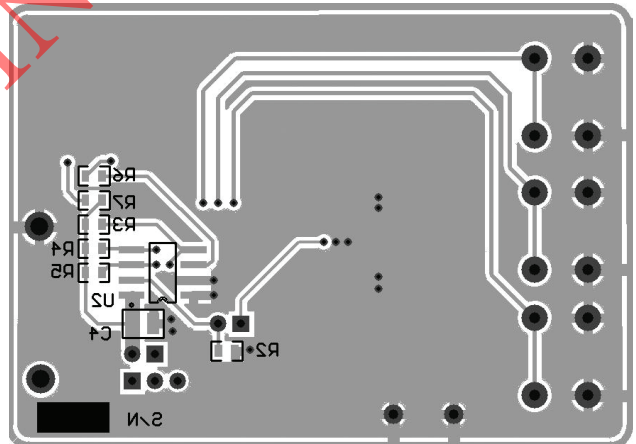


**Figure 8: AAT3351ITO Evaluation Board
Bottom Side Layout.**

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## AAT3351 Evaluation Board Bill of Materials

| Component | Part Number | Description | Manufacturer |
|---|---|---|---|
| U1 | AAT3351IWP-T1/AAT3351ITO-T1 | High Efficiency 1X/1.5X Charge Pump for White LED; TDFN33-12/TSOPJW-14 Package | Skyworks |
| U2 | PIC12F675 | 8-Bit CMOS, FLASH-Based µC; 8-Pin MCU | Microchip |
| $C_{IN}$, $C_{OUT}$, C1, C2 | GRM188R61A105KA61 | 1µF, 10V, X5R, 10%, 0603 | Murata |
| C4 | GRM219R71C104KA01 | 0.1µF, 10V, X7R, 10%, 0805 | Murata |
| C6 | GRM219R61A475KE19 | 4.7µF, 10V, X5R, 10%, 0805 | Murata |
| C8 | DNP | Do Not Place | |
| D1-D4 | LW M673 | Mini TOPLED White LED | Osram |
| LED1 | 21UGC/TR8 Green LED; 0805 | LED0 CMD15 | Chicago Miniature Lamp |
| LED2 | 21SRC/TR8 Red LED; 0805 | LED7 CMD15 | Chicago Miniature Lamp |
| R2 | Chip Resistor | 20K, 1/16W, 1%, 0603 | Vishay |
| R3-R5 | Chip Resistor | 1K, 1/16W, 1%, 0603 | Vishay |
| R6-R7 | Chip Resistor | 330, 1/16W, 1%, 0603 | Vishay |
| R8 | Chip Resistor | 1M, 1/16W, 1%, 0603 | Vishay |
| R9-R12 | Chip Resistor | 0, 1/16W, 1%, 0603 | Vishay |
| S1, S2, S3 | PTS645TL50 | Switch Tact, SPST, 5mm | ITT Industries |
| VR1 | EVN-5ESX50B14 | 10K POT; 3mm Squared SMD | Panasonic-ECG |

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## Ordering Information

| Package | Marking[1] | Part Number(Tape & Reel)[2] |
|---|---|---|
| TSOPJW-14 | 8UXYY | **AAT3351ITO-T1** |
| TDFN33-12 | 5YXYY | **AAT3351IWP-T1** |

Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

## Package Information[3]

**TSOPJW-14**



Top View

Side View

End View
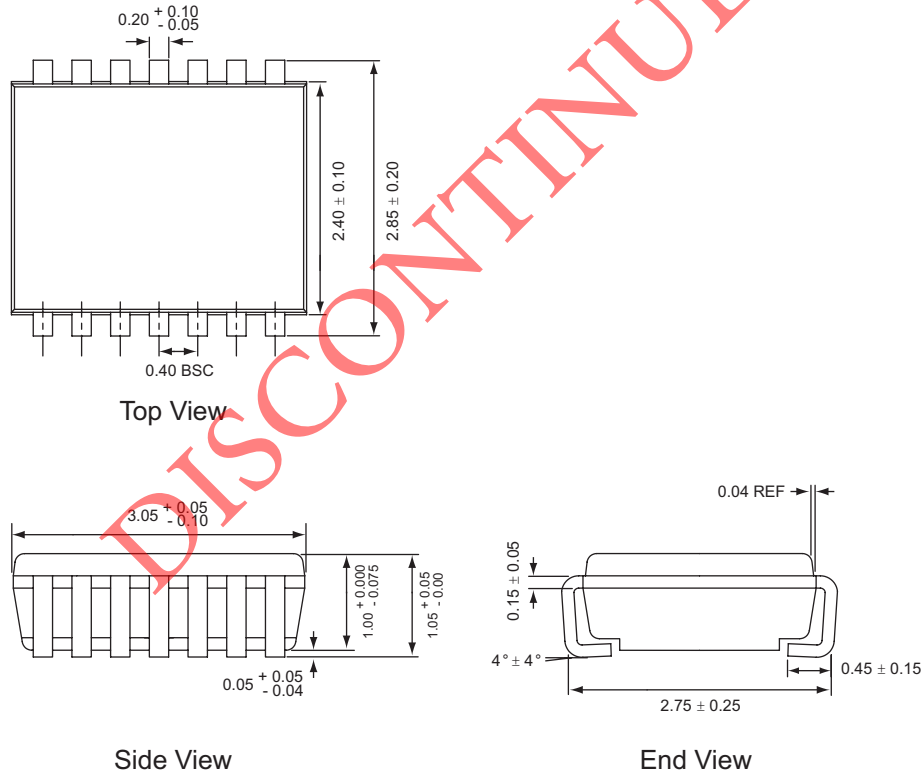
All dimensions in millimeters.

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1. XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.
3. The leadless package family, which includes QFN, TQFN, DFN, TDFN and STDFN, has exposed copper (unplated) at the end of the lead terminals due to the manufacturing process. A solder fillet at the exposed copper edge cannot be guaranteed and is not required to ensure a proper bottom solder connection.

**TDFN33-12**

Index Area

3.00 ± 0.05

3.00 ± 0.05

Top View

Detail "A"

2.40 ± 0.05

1.70 ± 0.05

Bottom View

0.43 ± 0.05

0.1 REF

C0.3

Pin 1 Indicator
(optional)

0.45 ± 0.05

0.23 ± 0.05

Detail "A"

0.75 ± 0.05

0.23 ± 0.05

0.05 ± 0.05

Side View
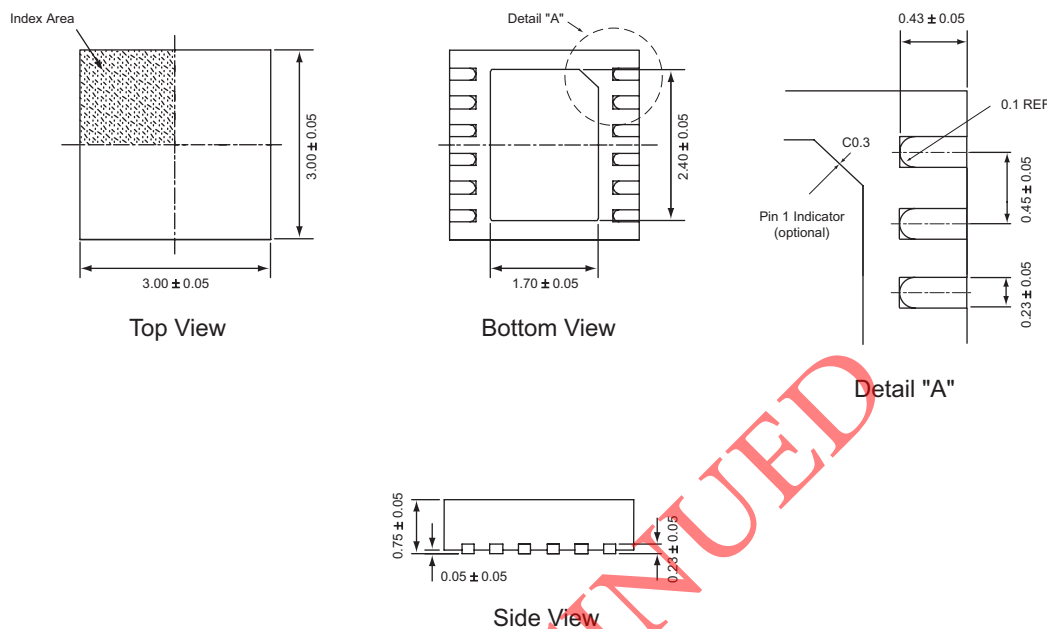
All dimensions in millimeters.

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