# AHK3294

*Four-Channel LED Driver*

## General Description

The AHK3294 is a linear current-sink LED driver, capable of driving one, two, three or four LEDs up to 30.2mA each. Featuring individual low resistance, low drop-out voltage current sinks, the AHK3294 allows the LEDs to be regulated directly from a Lithium Ion/Polymer battery without the need for an additional step-up power supply, thereby reducing the external component count, eliminating switching noise and maximizing efficiency.

Skyworks' Simple Serial Control™ (S²Cwire™) interface is used to enable, disable, and set the LED drive current for 32-level linear scale LED brightness control. For flexible control the maximum LED current of up to 30.2mA per channel is set via an external resistor.

The AHK3294 is packaged in a Pb-free, 8 pin SC70JW package and is available over a -40 to +85°C temperature range.
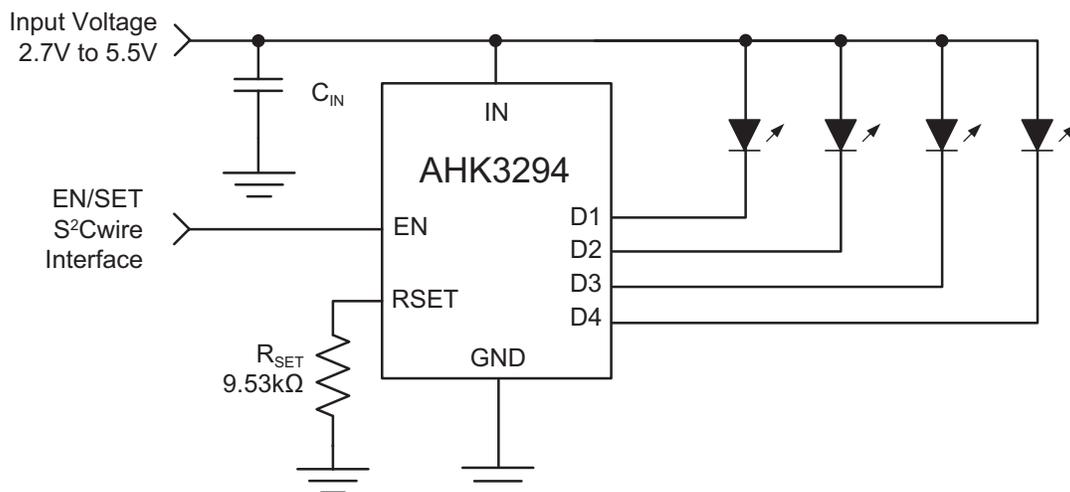
## Features

- 2.7V to 5.5V Input Supply Range
- Drives up to 4 LEDs at up to 30.2mA each
- Low-Dropout, Low Resistance Current Sinks
  - Typically 40.5mV at Full Scale
- Linear LED Output Current Control
  - S²Cwire Interface
    - Single-wire
    - 32 Steps
- External $R_{SET}$ Resistor
- ±10% LED Output Current Accuracy
- ±3% LED Output Current Matching
- Low Current Shutdown Mode
- Small 8-Pin SC70JW Package

## Applications

- Entry Level Mobile Phones
- Keyboard Backlight
- MP3 Players
- Indicator LEDs

## Typical Application

Skyworks Solutions, Inc. • Phone [781] 376-3000 • Fax [781] 376-3100 • sales@skyworksinc.com • www.skyworksinc.com

202172A • Skyworks Proprietary Information • Products and Product Information are Subject to Change Without Notice. • July 13, 2012

1

## Pin Descriptions

*Pinout is preliminary and subject to change during development*

| Pin # | Symbol | Function | Description |
|-------|--------|----------|-------------|
| 1 | D1 | O | Backlight LED 1 current sink output. Connect the cathode of LED 1 to D1. If not used, connect D1 to IN. |
| 2 | D2 | O | Backlight LED 2 current sink output. Connect the cathode of LED 2 to D2. If not used, connect D2 to IN. |
| 3 | D3 | O | Backlight LED 3 current sink output. Connect the cathode of LED 3 to D3. If not used, connect D3 to IN. |
| 4 | D4 | O | Backlight LED 4 current sink output. Connect the cathode of LED 4 to D4. If not used, connect D4 to IN. |
| 5 | RSET | I | Connect resistor from this pin to GND to set the maximum LED current level. For optimal LED output current accuracy and matching in the AHK3294, use a 9.53kΩ 1% resistor to set each full-scale output current to 30.2mA maximum. |
| 6 | EN | I | $S^2C$wire serial input. EN is used for ON/OFF control. EN is also the data input for the $S^2C$wire interface used to control the 32 levels of LED brightness according to the maximum current set by RSET. |
| 7 | GND | I/O | Ground. Connect this pin to the system ground. |
| 8 | IN | I | Input power pin. Connect IN to the power source, typically the battery. Bypass IN to GND with a 1µF or larger ceramic capacitor. |

## Pin Configuration

**SC70JW-8**
**(Top View)**

| | |
|---|---|
| D1 — 1 | 8 — IN |
| D2 — 2 | 7 — GND |
| D3 — 3 | 6 — EN |
| D4 — 4 | 5 — RSET |
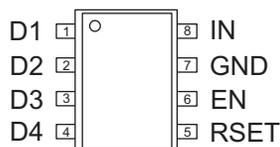
## Absolute Maximum Ratings[1]

$T_A$ = 25°C unless otherwise noted.

| Symbol | Description | Value | Units |
|--------|-------------|-------|-------|
| $V_N$ | IN, D1, D2, D3, D4 & RSET to GND | -0.3 to 6.0 | V |
| $V_{EN}$ | VEN to GND | -0.3 to $V_{IN}$ + 0.3 | |

## Thermal Information[2]

| Symbol | Description | Value | Units |
|--------|-------------|-------|-------|
| $\Theta_{JA}$ | Thermal Resistance[3] | 160 | °C/W |
| $P_D$ | Maximum Power Dissipation | 625 | mW |
| $T_A$ | Operating Temperature Range | -40 to 85 | °C |
| $T_J$ | Junction Temperature Range | -40 to 150 | |
| $T_{LEAD}$ | Maximum Soldering Temperature (at Leads) | 300 | |

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum Rating should be applied at any one time.
2. Mounted on an FR4 board.
3. Derate 6.25mW/°C above 25°C ambient temperature.

Skyworks Solutions, Inc.  •  Phone [781] 376-3000  •  Fax [781] 376-3100  •  sales@skyworksinc.com  •  www.skyworksinc.com

202172A  •  Skyworks Proprietary Information  •  Products and Product Information are Subject to Change Without Notice.  •  July 13, 2012

3

## Electrical Characteristics[1]

IN = EN = 3.6V, $C_{IN}$ = 1µF; $T_A$ = -40°C to 85°C unless otherwise noted. Typical values are at $T_A$ = 25°C.

| Symbol | Description | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Power Supply** | | | | | | |
| $V_{IN}$ | Input Voltage Range | | 2.7 | | 5.5 | V |
| $I_{IN}$ | Input Operating Current | $I_{D1} = I_{D2} = I_{D3} = I_{D4}$ = 30.2mA (DATA 1) excluding $I_{D1}, I_{D2,} I_{D3}$ and $I_{D4}$ | | 2.5 | 4.0 | mA |
| $I_{IN(SHDN)}$ | Input Shutdown Current | IN = 5.5V; EN = GND | | | 1 | µA |
| $V_{DO}$ | Current Sink Drop-out Voltage[2] | $I_{D1} = I_{D2} = I_{D3} = I_{D4}$ = 30.2mA (DATA 1) | | 40.5 | 125 | mV |
| | | $I_{D1} = I_{D2} = I_{D3} = I_{D4}$ = 15.2mA (DATA 16) | | 36 | 85 | |
| **LED Current Sink Outputs** | | | | | | |
| $I_{D(MAX)}$ | D1, D2, D3, D4  Current Accuracy | $I_{D1} = I_{D2} = I_{D3} = I_{D4}$ = 30.2mA (DATA 1) | 27.18 | 30.2 | 33.22 | mA |
| $\Delta I_{D(MAX)}$ | D1, D2, D3, D4 Current Matching | $I_{D1} = I_{D2} = I_{D3} = I_{D4}$ = 30.2mA (DATA 1) | | ±3 | | % |
| $t_S$ | Start-up Period | EN = IN | | 150 | | µs |
| $I_{SET}$ | Current Set Ratio | $I_{SINK}/I_{RSET}$ | | 240 | | A/A |
| $V_{SET}$ | RSET Pin Voltage | | | 1.2 | | V |
| **EN and S²Cwire Control** | | | | | | |
| $V_{EN(L)}$ | EN Input Low Threshold | | | | 0.4 | V |
| $V_{EN(H)}$ | EN Input High Threshold | | 1.4 | | | V |
| $I_{EN}$ | EN Input Leakage Current | EN = IN = 5V | -1 | | 1 | µA |
| $T_{EN(LOW)}$ | EN Serial Interface Low Time | | 0.3 | | 75 | µs |
| $T_{EN(HI\_MIN)}$ | Minimum EN high Time | | | 50 | | ns |
| $T_{EN(HI\_MAX)}$ | Maximum EN High Time | | | | 75 | µs |
| $T_{EN(OFF)}$ | EN Off Timeout | | | | 500 | µs |
| $T_{EN(LAT)}$ | EN Latch Timeout | | | | 500 | µs |

The AHK3294 is guaranteed to meet the performance specifications over the -40OC to +85OC operating temperature range and is assured by design, characterization and correlation with statistical process controls.
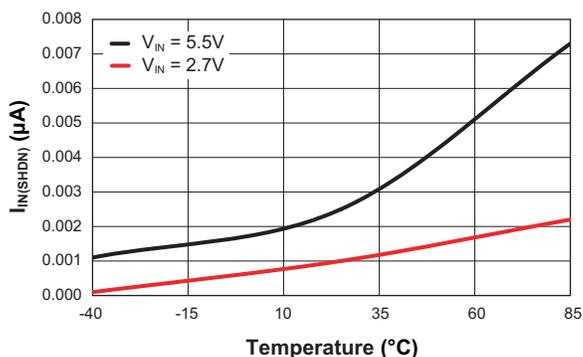The current sink drop-out voltage is defined as when the current at D1 or D2 or D3 or D4 drops to 90% of its nominal value.
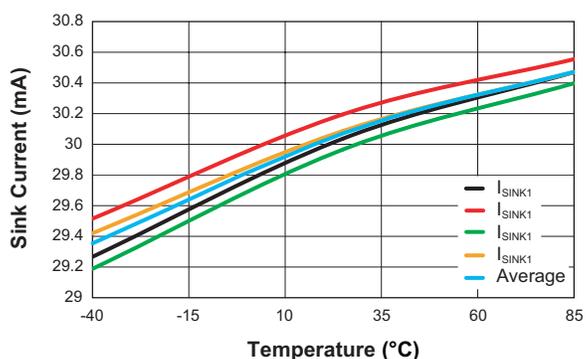
## Typical Characteristics

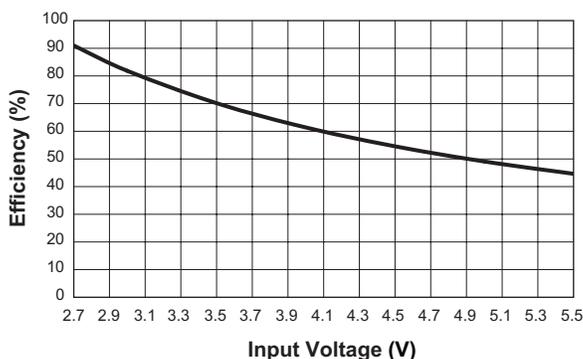### Input Operating Current vs. Input Voltage
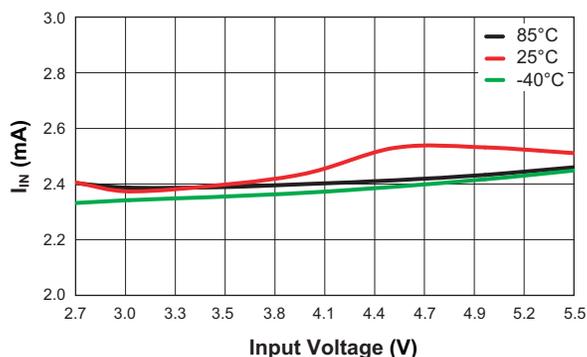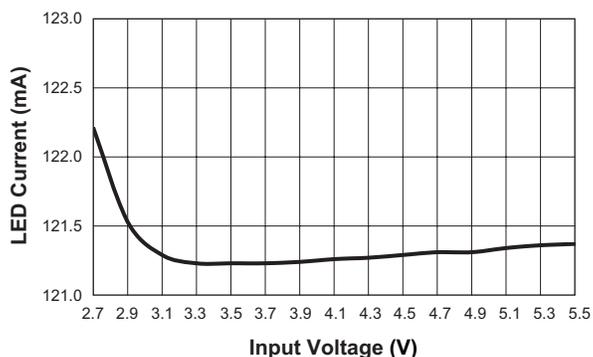


### Input Shutdown Current vs. Temperature



### D1-D4 Current Matching



### Efficiency vs. Input Voltage
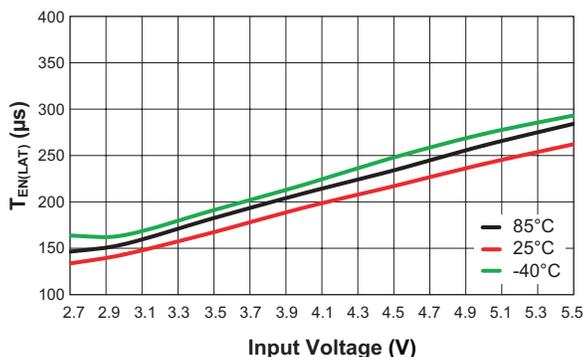($V_F$ = 2.5V)



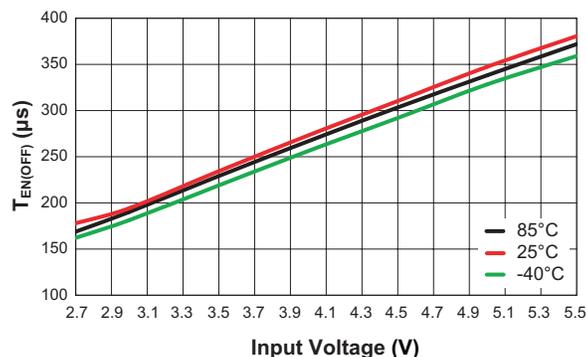### Line Regulation
(30.2mA/ch)



### Line Regulation
(30.2mA/ch)

Skyworks Solutions, Inc. • Phone [781] 376-3000 • Fax [781] 376-3100 • sales@skyworksinc.com • www.skyworksinc.com

202172A • Skyworks Proprietary Information • Products and Product Information are Subject to Change Without Notice. • July 13, 2012

5
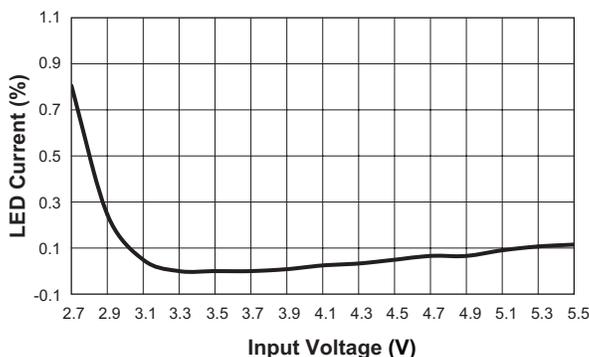
## Typical Characteristics

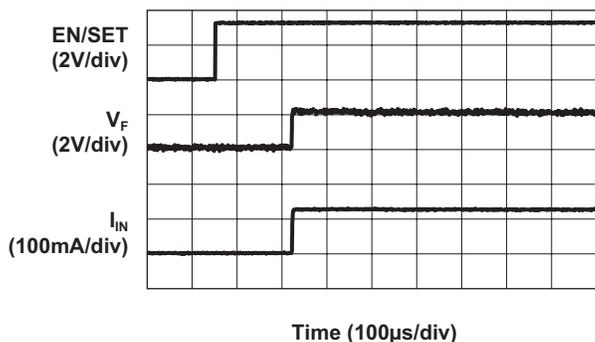### EN Latch Timeout vs. Input Voltage



### EN Off Timeout vs. Input Voltage



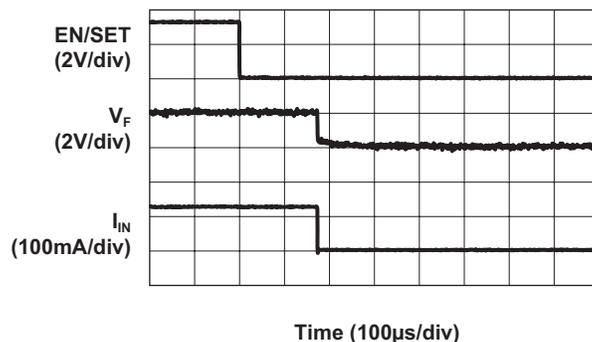### EN Input High Threshold vs. Input Voltage
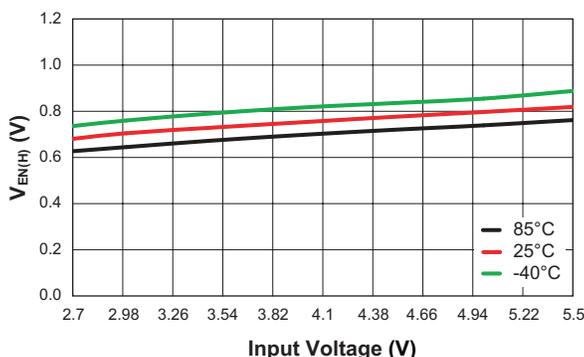


### EN Input Low Threshold vs. Input Voltage
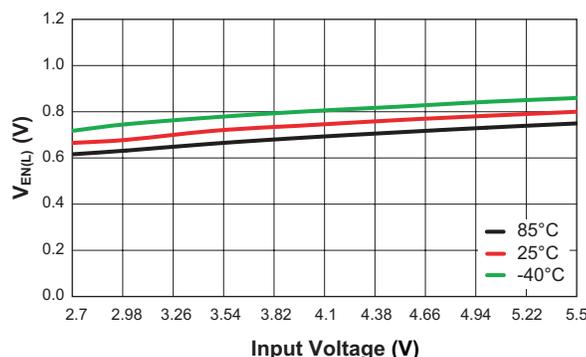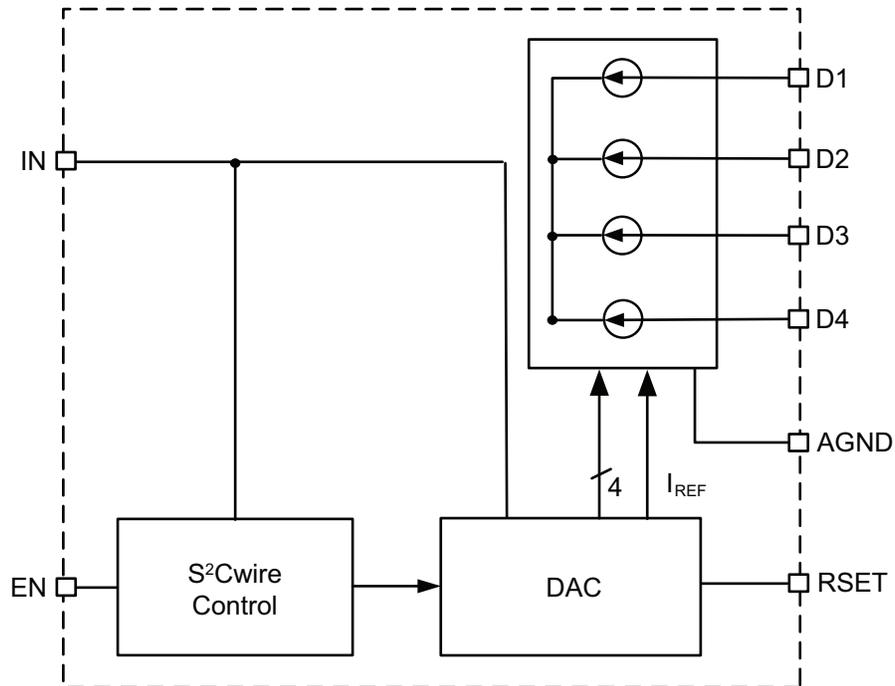


### Turn On to Bypass
($V_{IN}$ = 3.6V; 30.2mA/ch)



### Turn Off to Bypass
($V_{IN}$ = 3.6V; 30.2mA/ch)

## Functional Block Diagram



## Functional Description

The AHK3294 is an entry level driver IC, designed to drive up to four white LEDs. The AHK3294 operates directly from a 2.7V to 5.5V power source and enables and controls the current to the LEDs. LED current is individually controlled through integrated current sinks powered from an external power supply. Low resistance and low-drop out voltage current sinks allow the LEDs to operate very close to the input supply voltage, eliminating the need for an additional noisy boost power supplies.

The AHK3294 requires only two external components: one 1µF ceramic input capacitor ($C_{IN}$) and a resistor ($R_{SET}$) to set the maximum LED current. The AHK3294 can drive up to four constant output sinks (D1, D2, D3 and D4) each with a maximum current of up to 30.2mA which is set by an external resistor. Skyworks' S²Cwire serial interface enables the AHK3294 and changes the current sink magnitude through the EN pin, thereby changing the LED current.

### S²Cwire Serial Interface

The LED output current of the AHK3294 is controlled by Skyworks' S²Cwire serial interface. Since the LED current is programmable, no PWM 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." With its high-speed serial interface (1MHz data rate), the LED current can be changed quickly and easily. Also the non-pulsating LED current reduces system noise and improves LED reliability.

The S²Cwire interface relies on the number of rising edges to the EN/SET pin to set the register. A typical write protocol is a burst of EN rising edges, followed by a pause with EN held high for at least $t_{LAT}$ (500µs). The programmed current is then seen at the current sink outputs. When EN is held low for an amount of time longer than $t_{OFF}$ (500µs), the AHK3294 enters into shutdown mode and draws less than 1µA from the input and the internal data register is reset to zero.

The AHK3294 serial interface reduces the LED current on each rising pulse of the enable input. If the AHK3294 is in shutdown, the first rising edge of the EN input turns on the LED driver with maximum current per channel. Successive rising edges decrease the LED current as shown in Table 1 and Figure 1 for the AHK3294.

Skyworks Solutions, Inc.  •  Phone [781] 376-3000  •  Fax [781] 376-3100  •  sales@skyworksinc.com  •  www.skyworksinc.com
202172A  •  Skyworks Proprietary Information  •  Products and Product Information are Subject to Change Without Notice.  •  July 13, 2012
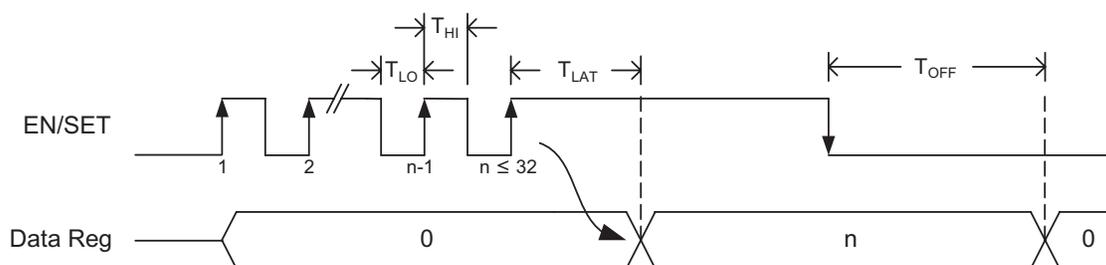
7

**Figure 1: S²Cwire Serial Interface Timing.**

| Data | EN Rising Edges | D1- D4 Output Current (mA) | Data | EN Rising Edges | D1- D4 Output Current (mA) |
|------|-----------------|----------------------------|------|-----------------|----------------------------|
| 1 | 1 | 30.2 | 17 | 17 | 14.6 |
| 2 | 2 | 29.2 | 18 | 18 | 13.6 |
| 3 | 3 | 28.3 | 19 | 19 | 12.7 |
| 4 | 4 | 27.3 | 20 | 20 | 11.7 |
| 5 | 5 | 26.3 | 21 | 21 | 10.7 |
| 6 | 6 | 25.3 | 22 | 22 | 9.7 |
| 7 | 7 | 24.4 | 23 | 23 | 8.8 |
| 8 | 8 | 23.4 | 24 | 24 | 7.8 |
| 9 | 9 | 22.4 | 25 | 25 | 6.8 |
| 10 | 10 | 21.4 | 26 | 26 | 5.8 |
| 11 | 11 | 20.5 | 27 | 27 | 4.9 |
| 12 | 12 | 19.5 | 28 | 28 | 3.9 |
| 13 | 13 | 18.5 | 29 | 29 | 2.9 |
| 14 | 14 | 17.5 | 30 | 30 | 1.9 |
| 15 | 15 | 16.6 | 31 | 31 | 1.0 |
| 16 | 16 | 15.6 | 32 | 32 | 0.5 |

**Table 1: AHK3294 LED Current Settings.**



**Figure 2: AHK3294 Current Profile.**

| $I_{LED}$ (mA) | $R_{SET}$(kΩ) |
|----------------|----------------|
| 30.2 | 9.53 |
| 25 | 11.5 |
| 20.1 | 14.3 |
| 18.2 | 15.8 |
| 15.1 | 19.1 |
| 10 | 28.7 |

**Table 2: Maximum LED Current vs. $R_{SET}$ Resistor Values (1% Resistor Tolerance).**

## Constant Current Control Using External $R_{SET}$

The AHK3294's maximum current is programmed by an external resistor connected to the RSET pin. The full-scale LED current can be set between 30.2mA and 0.5mA as shown in Figure 2. Table 2 shows $R_{SET}$ resistor values for various full-scale current levels. For maximum accuracy, a 1% tolerance resistor is recommended.

## Applications Information

### LED Selection

The AHK3294 is specifically intended for driving white LEDs. However, the device design will allow the AHK3294 to drive most types of LEDs with forward voltage speci-fications typically ranging from 2.2V to 4.7V depending upon supply voltage. LED applications may include mixed arrangements for display backlighting, keypad display, and any other application that needs a constant current sink generated from a varying input voltage. Since the D1 to D4 constant current sinks are matched within 3% with negligible supply voltage dependence, the constant current channels will be matched regardless of the specific LED forward voltage ($V_F$) levels. The low dropout current sinks in the AHK3294 maximize perfor-mance and make it capable of driving LEDs with high forward voltages. The two channels can be combined to obtain a higher LED drive current without complication.

### Shutdown

Since the current switches are the only power supplies for all loads, there is no leakage current when all sink switches are disabled. To activate the shutdown opera-tion, the EN input for the AHK3294 should be strobed low for longer than $t_{OFF}$ (500µs). In this state, the AHK3294 typically draws less than 1µA from the input. Registers are reset to 0 in shutdown.

### Additional Applications

The current sinks of the AHK3294 can be combined to drive higher current levels through two LEDs. As an example, two LEDs can typically be driven at 60.4mA each by combining the D1-D2 and D3-D4 outputs as shown in Figure 3.

### Capacitor Selection

Careful selection of the external capacitor $C_{IN}$ is impor-tant because it will affect turn-on time and transient performance. Optimum performance will be obtained when low equivalent series resistance (ESR) ceramic capacitor is used; in general, low ESR may be defined as less than 100mΩ. A value of 1µF for the input capacitor is a good starting point when choosing it. If the constant current sinks are only programmed for light current lev-els, then the input capacitor size may be decreased.

### Capacitor Characteristics

Ceramic composition capacitor is highly recommended over all other types of capacitors for use with the AHK3294. Ceramic capacitors offer many advantages over their tantalum and aluminum electrolytic counter-parts. A ceramic capacitor typically has very low ESR, is lower cost, has a smaller PCB footprint, and is non-polar-ized. Since ceramic capacitors are non-polarized, they are not prone to incorrect connection damage.
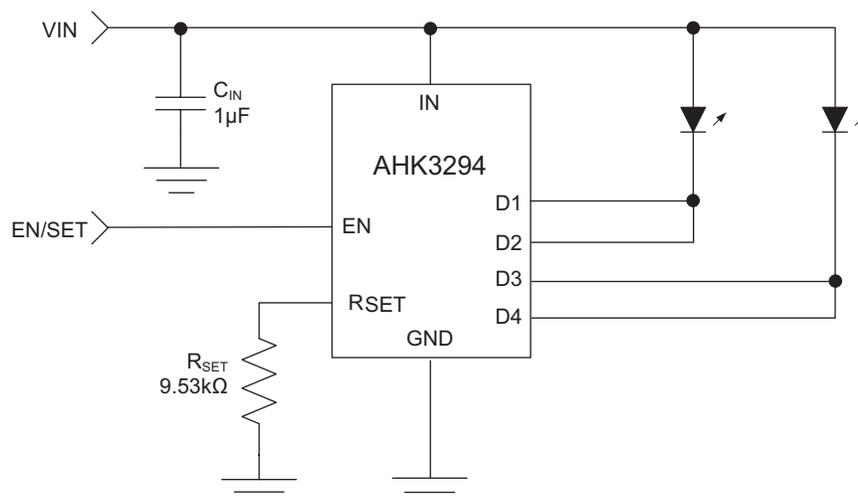


**Figure 3: Higher Current Dual LED Application.**

Skyworks Solutions, Inc.  •  Phone [781] 376-3000  •  Fax [781] 376-3100  •  sales@skyworksinc.com  •  www.skyworksinc.com
202172A  •  Skyworks Proprietary Information  •  Products and Product Information are Subject to Change Without Notice.  •  July 13, 2012

9

## 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 generally have tight tolerance and are very stable over temperature. Larger capacitor values are usually composed of X7R, X5R, Z5U, or Y5V dielectric materials. Large ceramic capacitors (i.e., larger than 2.2µF) are often available in low cost Y5V and Z5U dielectrics, but capacitors larger than 1µF are not typically required for AHK3294 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.

## Evaluation Board User Interface

The user interface for the AHK3294 evaluation board is provided by three buttons and two connection terminals. The board is operated by supplying external power and pressing individual buttons or button combinations.

Table 3 indicates the function of each button or button combination. To power-on the evaluation board, connect a power supply or battery to the DC- and DC+ terminals. A red LED indicates that power is applied. The evaluation board is made flexible so that the user can disconnect the enable line from the microcontroller and apply external enable signal. External enable signal must be applied to the EN pin.

When applying external enable signal, consideration must be given to the voltage levels. The externally applied voltage should not exceed the supply voltage that is applied to the IN pins of the device (DC+).

## User Interface Functionality

| Button(s) Pushed | Description |
|---|---|
| UP | [Push/Release once] D1 to D4 are turned on with 0.5mA per channel. With every push/release the current is increased according to Table 1. |
| DOWN | [Push/Release once] D1 to D4 are turned on with 30.2mA per channel. With every push/release the current is decreased according to Table 1. |
| CYCLE | [Push/Release together] Auto cycling up and down. |

**Table 3: AHK3294 Evaluation Board User Interface.**
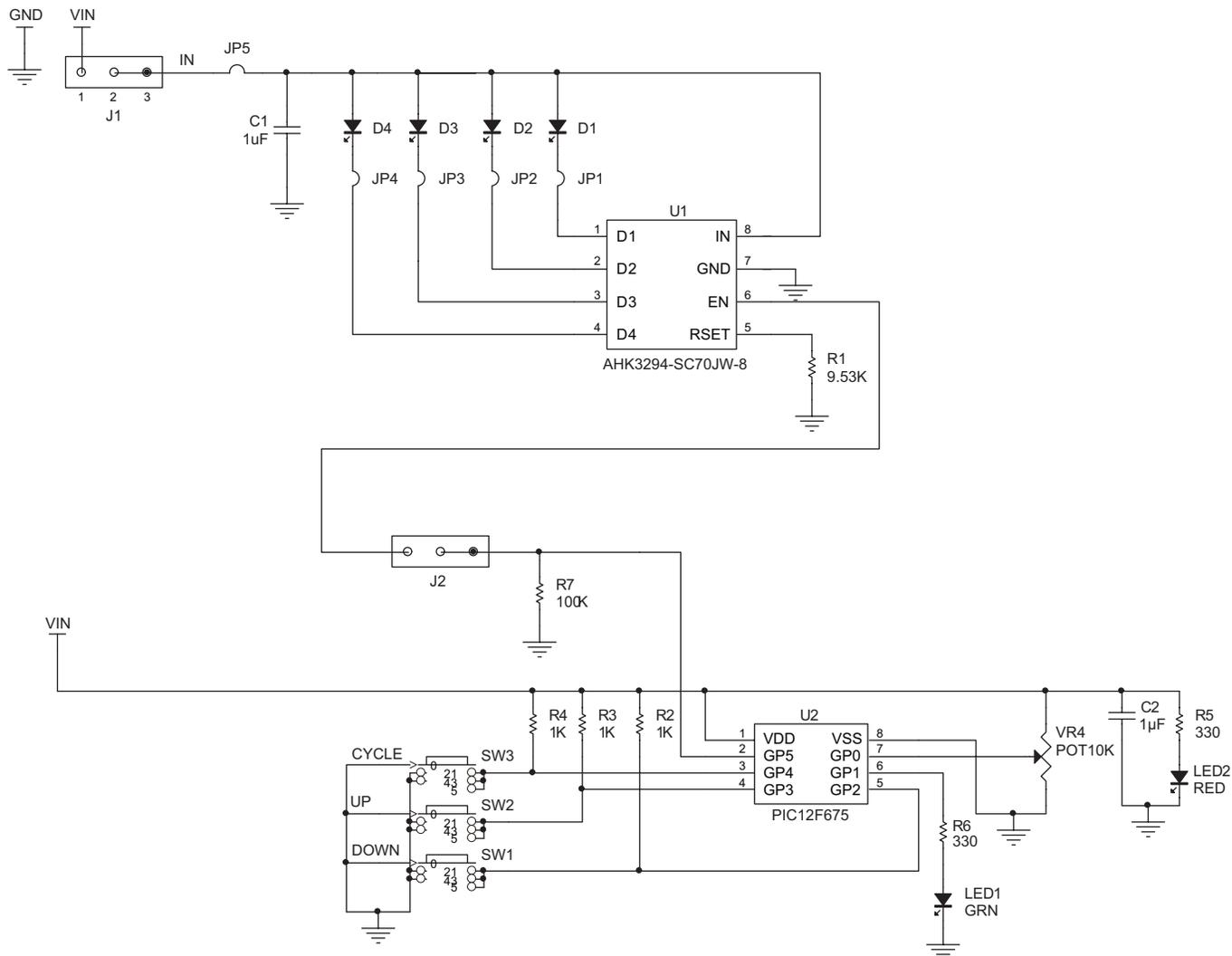
**Figure 4: AHK3294 Evaluation Board Schematic.**

Skyworks Solutions, Inc. • Phone [781] 376-3000 • Fax [781] 376-3100 • sales@skyworksinc.com • www.skyworksinc.com

202172A • Skyworks Proprietary Information • Products and Product Information are Subject to Change Without Notice. • July 13, 2012
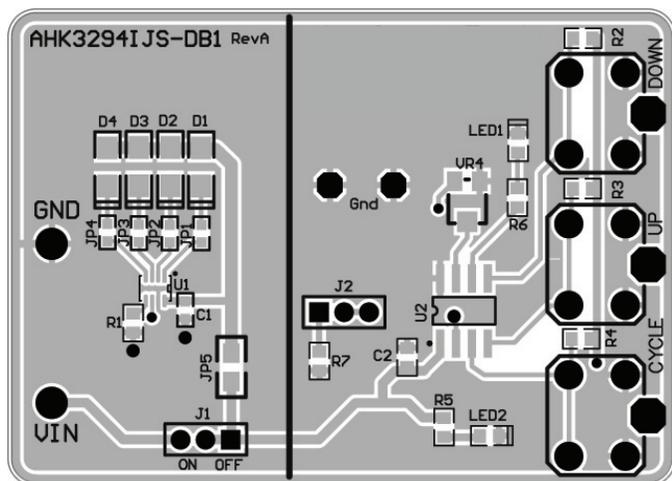
11

**Figure 5: AHK3294 Evaluation Board Top Side Layout.**
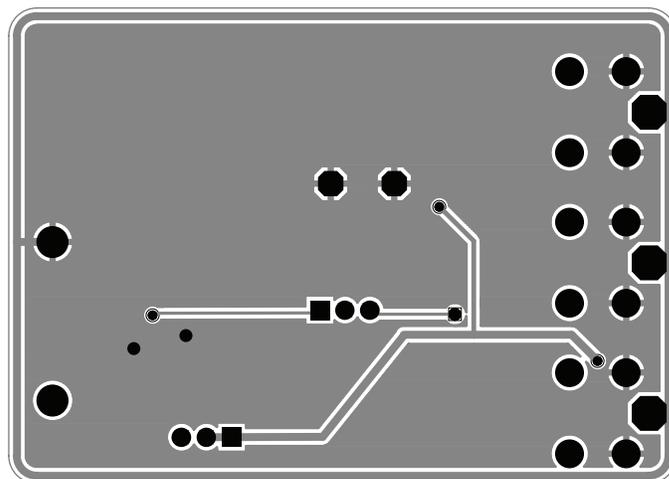


**Figure 6: AHK3294 Evaluation Board Bottom Side Layout.**

## AAT3294 EVAL Component Listing

| Component | Part Number | Description | Manufacturer |
|---|---|---|---|
| U1 | AHK3294IJS | Four Channel LED driver; SC70JW-8 package | Skyworks |
| U2 | PIC12F675 | 8-bit CMOS, FLASH-based µC; 8-pin PDIP package | Microchip |
| CYCLE, UP, DOWN | PTS645TL50 | Switch Tact, SPST, 5mm | ITT Industries |
| R1 | Chip Resistor | 9.53kΩ, 1%, 1/4W; 0603 | Vishay |
| R5, R6 | Chip Resistor | 330Ω, 1%, 1/4W; 0603 | Vishay |
| R7 | Chip Resistor | 100KΩ, 5%, 1/4W; 0603 | Vishay |
| R2, R3, R4 | Chip Resistor | 1KΩ, 5%, 1/4W; 0603 | Vishay |
| C1, C2 | GRM185R60J105KE21 | 1µF, 6.3V, X7R, 10%, 0603 | Murata |
| LED1 | CMD15-21VGC/TR8 | Green LED; 0603 | Chicago Miniature Lamp |
| LED2 | CMD15-21SRC/TR8 | Red LED; 0603 | Chicago Miniature Lamp |
| J1, J2 | PRPN401PAEN | Conn. Header, 2mm zip | Sullins Electronics |
| JP1, JP2, JP3, JP4 | Chip Resistor | 0Ω, 5%, 1/4W; 0603 | Vishay |
| JP5 | Chip Resistor | 0Ω, 5%, 1/2W; 0805 | Vishay |
| D1, D2, D3, D4 | LW M673 | Mini TOPLED White LED; SMD | OSRAM |

**Table 4: AHK3294 Evaluation Board Bill of Materials (BOM).**

## Ordering Information

| Package | Part Marking[1] | Part Number (Tape and Reel)[2] |
|---|---|---|
| SC70JW-8 | 9LXYY | **AHK3294IJS-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

**SC70JW-8**
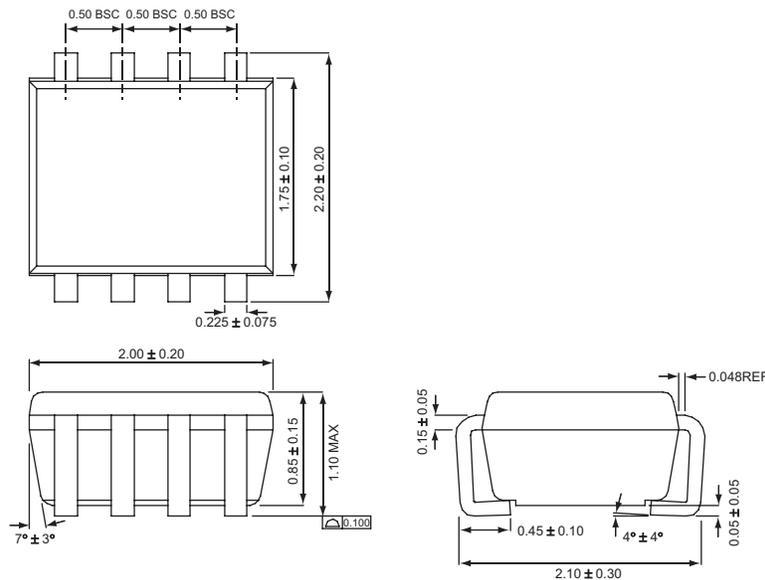


All dimensions in millimeters.

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

Skyworks Solutions, Inc.  •  Phone [781] 376-3000  •  Fax [781] 376-3100  •  sales@skyworksinc.com  •  www.skyworksinc.com

202172A  •  Skyworks Proprietary Information  •  Products and Product Information are Subject to Change Without Notice.  •  July 13, 2012

13