

General Description

The AHK3293 is a linear current-sink LED driver, capable of driving one, two or three LEDs up to 30.2mA each. Featuring individual low resistance, low drop-out voltage current sinks, the AHK3293 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. To minimize the use of external components the LED current is set internally to a maximum of 30.2mA.

The AHK3293 is packaged in a Pb-free 6-pin SOT23 package and operates over the -40 to +85°C temperature range.

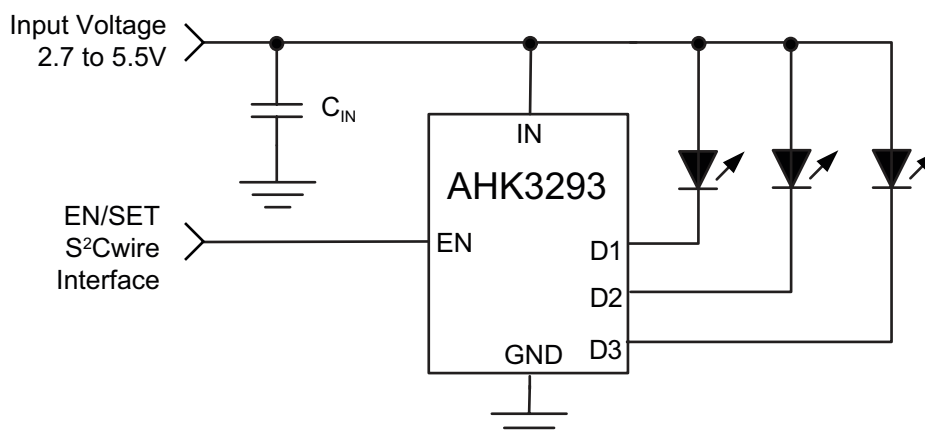
Features

- 2.7V to 5.5V Input Supply Range
- Drives up to 3 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
- ±10% LED Output Current Accuracy
- ±3% LED Output Current Matching
- Low Current Shutdown Mode
- Low-cost 6-pin SOT23 Package

Applications

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

Typical Application

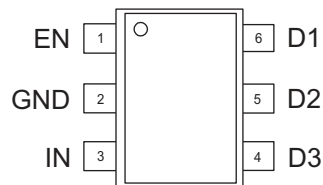


Pin Descriptions

| Pin # | Symbol | Function | Description |
|-------|--------|----------|---|
| 1 | EN | I | S ² Cwire serial input. EN is used for ON/OFF control. EN is also the data input for the S ² Cwire interface used to control the 32 levels of LED brightness according to the maximum current set internally. |
| 2 | GND | I/O | Ground. Connect this pin to the system ground. |
| 3 | IN | I | Input power pin. Connect IN to the power source, typically the battery. Bypass IN to GND with a 1 μ F or larger ceramic capacitor. |
| 4 | D3 | O | Backlight LED 3 current sink output. Connect the cathode of LED 3 to D3. If not used, connect D3 to IN. |
| 5 | D2 | O | Backlight LED 2 current sink output. Connect the cathode of LED 2 to D2. If not used, connect D2 to IN. |
| 6 | D1 | O | Backlight LED 1 current sink output. Connect the cathode of LED 1 to D1. If not used, connect D1 to IN. |

Pin Configuration

SOT23-6
(Top View)



Absolute Maximum Ratings¹

$T_A = 25^\circ\text{C}$ unless otherwise noted.

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

Thermal Information²

| Symbol | Description | Value | Units |
|---------------|--|------------|---------------------------|
| Θ_{JA} | Thermal Resistance ³ | 150 | $^\circ\text{C}/\text{W}$ |
| P_D | Maximum Power Dissipation | 667 | mW |
| T_J | Junction Temperature Range | -40 to 150 | $^\circ\text{C}$ |
| T_A | Operating Temperature Range | -40 to 85 | |
| 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 5.3mW/ $^\circ\text{C}$ above 25 $^\circ\text{C}$.

DATA SHEET

AHK3293

Three-Channel 1x LED Driver

Electrical Characteristics¹

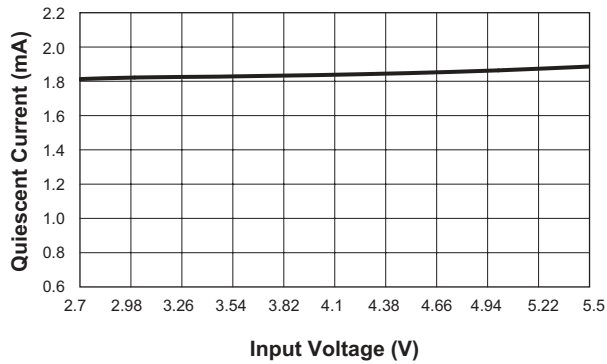
IN = EN = 3.6V, CIN = 1μF; TA = -40°C to 85°C unless otherwise noted. Typical values are at TA = 25°C.

| 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} = 30.2mA (DATA 1) excluding I _{D1} , I _{D2} , and I _{D3} | | 2.5 | 4.0 | mA |
| I _{IN(SHDN)} | Input Shutdown Current | IN = 5.5V; EN = GND | | | 1 | μA |
| V _{DO} | Current Sink Dropout Voltage ² | I _{D1} = I _{D2} = I _{D3} = 30.2mA (DATA 1) | | 40.5 | 125 | mV |
| | | I _{D1} = I _{D2} = I _{D3} = 15.2mA (DATA 16) | | 36 | 85 | |
| LED Current Sink Outputs | | | | | | |
| I _{D(MAX)} | D1, D2, D3 Current Accuracy | I _{D1} = I _{D2} = I _{D3} = 30.2mA (DATA 1), TA = 25°C | 27.18 | 30.20 | 33.22 | mA |
| ΔI _{D(MAX)} | D1, D2, D3 Current Matching | I _{D1} = I _{D2} = I _{D3} = 30.2mA (DATA 1) | | ±3 | | % |
| t _S | Startup Period | EN = IN | | 150 | | μs |
| 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 |

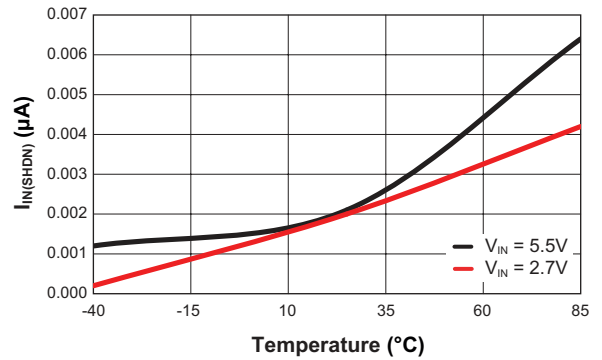
1. The AHK3293 is guaranteed to meet performance specifications over the -40°C to +85°C operating temperature range and is assured by design, characterization and correlation with statistical process controls.
2. The current sink drop-out voltage is defined as when the current at D1 or D2 or D3 drops to 90% of its nominal value.

Typical Characteristics

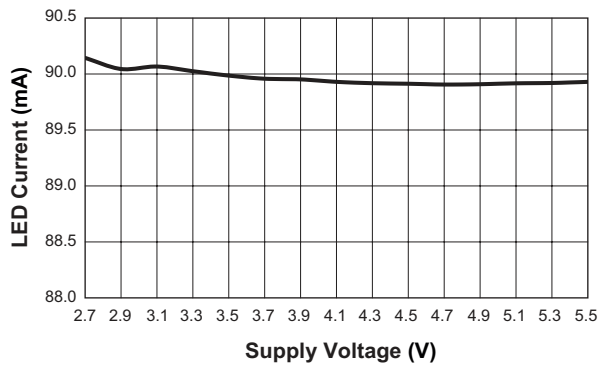
Quiescent Current vs. Input Voltage



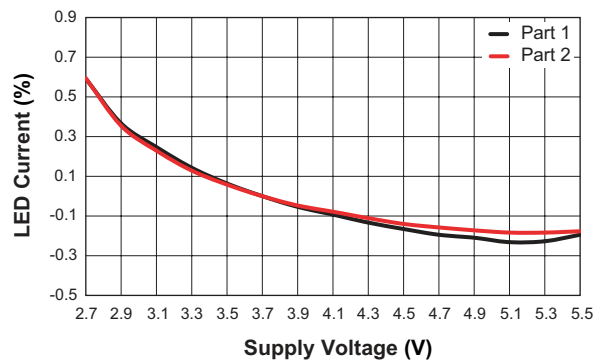
Shutdown Current vs. Temperature



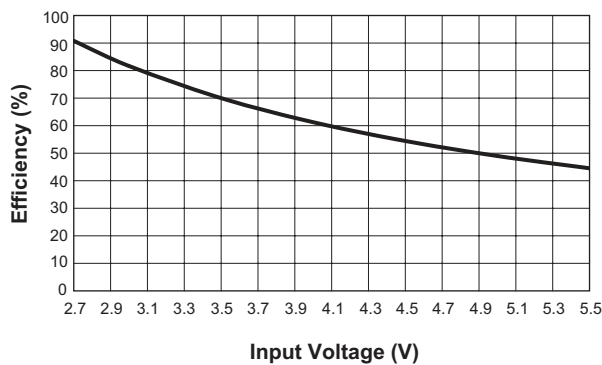
**Line Regulation
(30.2mA/ch)**



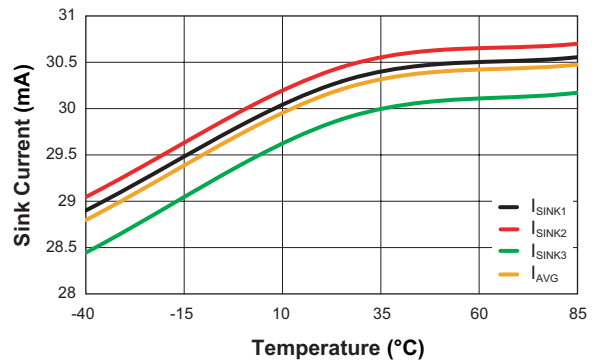
**Line Regulation Accuracy
(30.2mA/ch)**



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

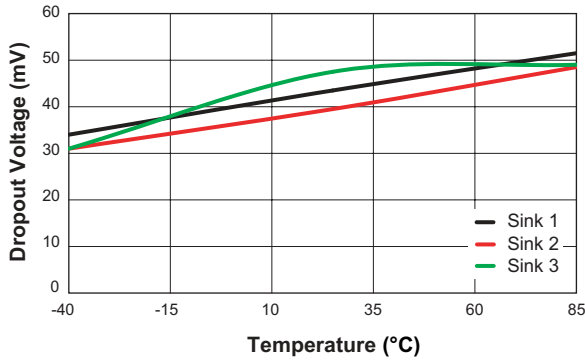


**Sink Current Matching
(30.2mA/ch)**

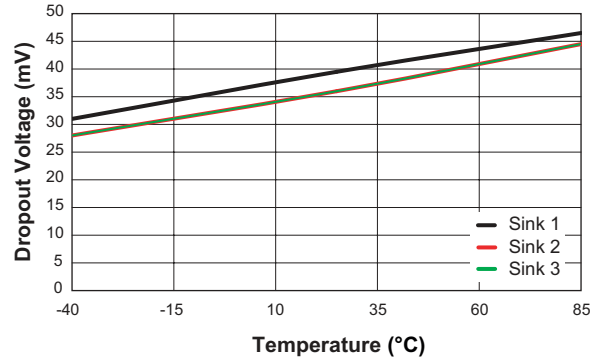


Typical Characteristics

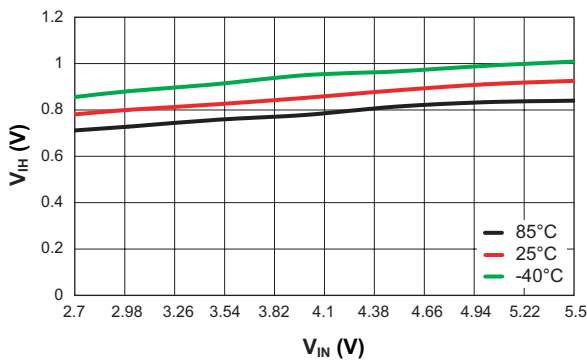
Current Sink Dropout Voltage vs. Temperature
(Data = 1)



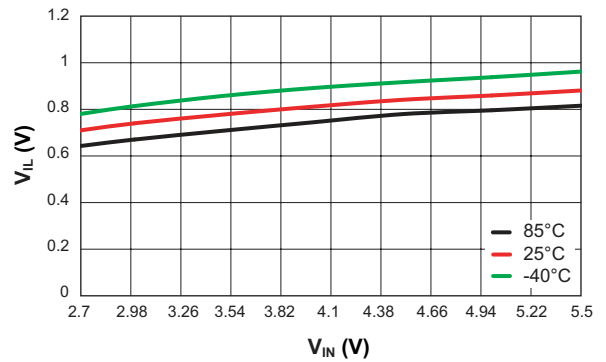
Current Sink Dropout Voltage vs. Temperature
(Data = 16)



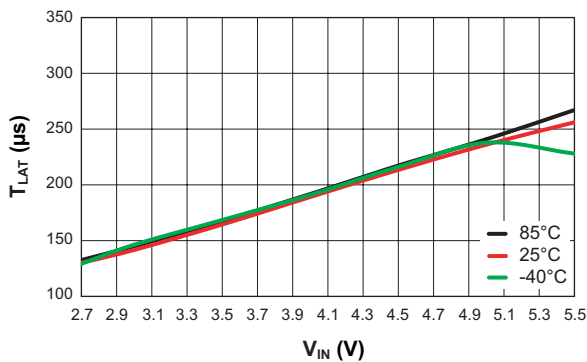
Input High Voltage vs. Input Voltage



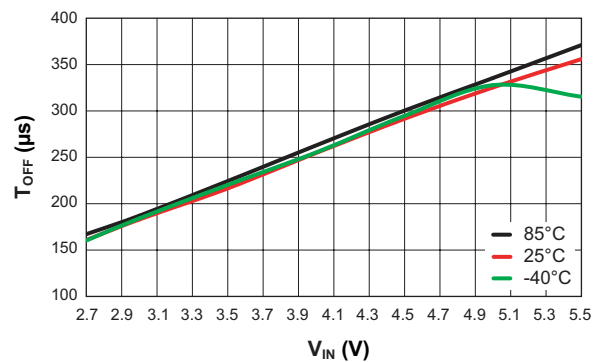
Input Low Voltage vs. Input Voltage



EN Latch Timeout vs. Input Voltage



EN Off Timeout vs. Input Voltage

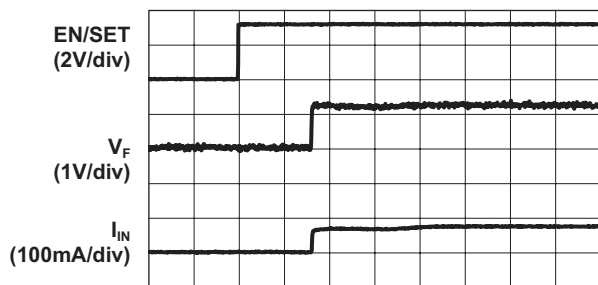


AHK3293

Three-Channel 1x LED Driver

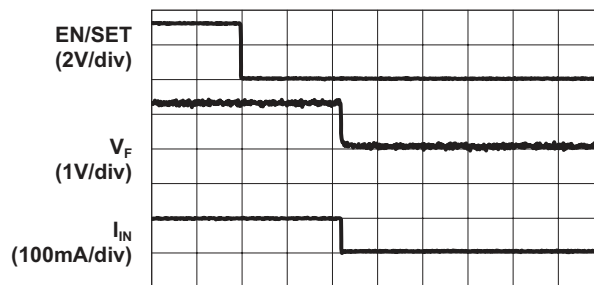
Typical Characteristics

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

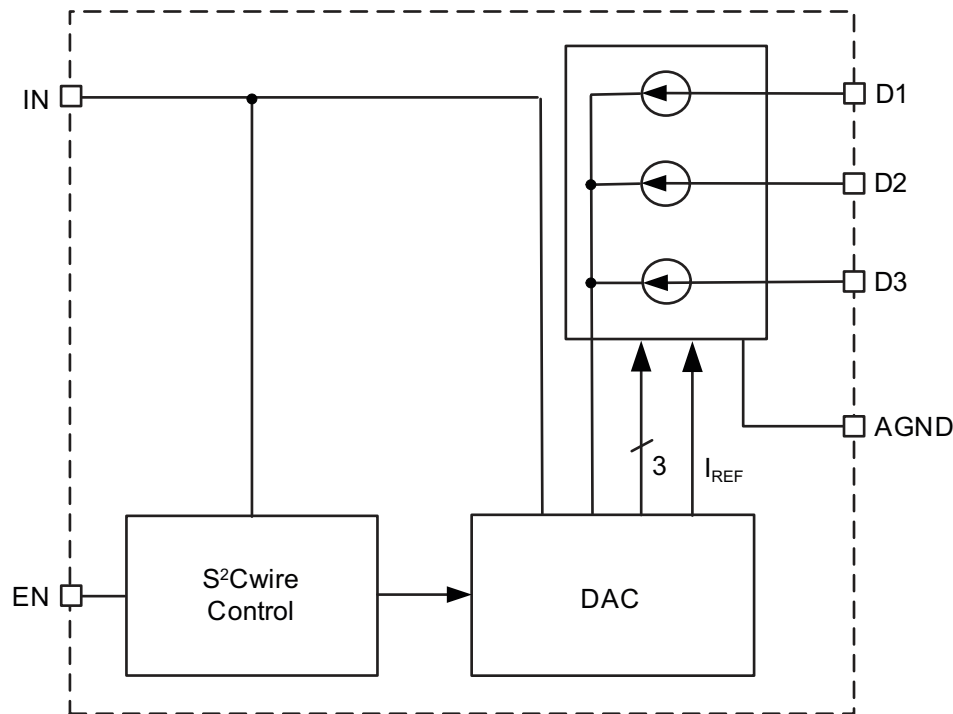


Time (100µs/div)

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



Time (100µs/div)

Functional Block Diagram**Functional Description**

The AHK3293 is an entry level driver IC, designed to drive up to three white LEDs. The AHK3293 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 the input supply voltage, eliminating the need for an additional noisy boost power supplies.

The AHK3293 requires only one external component, a 1 μ F ceramic input capacitor (C_{IN}). The AHK3293 can drive three constant output sinks (D1, D2 and D3) each with a maximum current of up to 30.2mA which is set internally. Skyworks' S²Cwire serial interface enables the AHK3293 and changes the current sink magnitude through the EN pin, thereby changing the LED current.

S²Cwire Serial Interface

The LED output current of the AHK3293 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} (500 μ s). 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} (500 μ s), the AHK3293 enters into shutdown mode and draws less than 1 μ A from the input and the internal data register is reset to zero.

The AHK3293 serial interface reduces the LED current on each rising pulse of the enable input. If the AHK3293 is in shutdown, the first rising edge of the EN input turns on the LED driver to the maximum current. Successive rising edges decrease the LED current as shown in Table 1 and Figure 1 for the AHK3293.

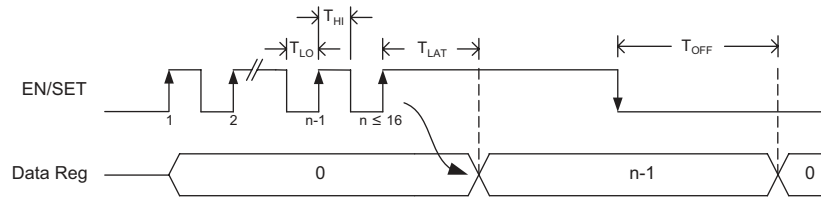


Figure 1: S²Cwire Serial Interface Timing.

| Data | EN Rising Edges | D1- D3 Output Current (mA) | Data | EN Rising Edges | D1-D3 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: AHK3293 LED Current Settings.

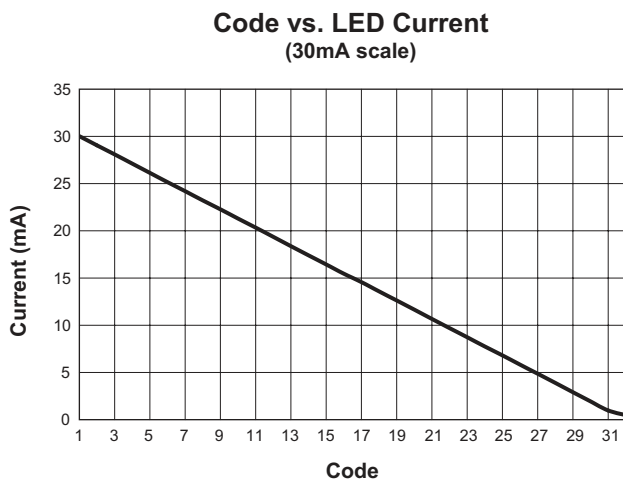


Figure 2: AHK3293 Current Profile.

Applications Information

LED Selection

The AHK3293 is specifically intended for driving white LEDs. However, the device design will allow the AHK3293 to drive most types of LEDs with forward voltage specifications 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 needing a constant current sink generated from a varying input voltage. Since the D1, D2 to D3 constant current sinks are matched 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 AHK3293 maximize performance and make it capable of driving LEDs with high forward voltages. Multiple 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 operation, the EN input for the AHK3293 should be strobed low for longer than t_{OFF} (500 μ s). In this state, the AHK3293 typically draws less than 1 μ A from the input. Registers are reset to 0 in shutdown.

Additional Applications

The current sinks of the AHK3293 can be combined to drive higher current levels through two LEDs. As an example, one LED can typically be driven at 60.4mA by combining the D1-D2 outputs as shown in Figure 3.

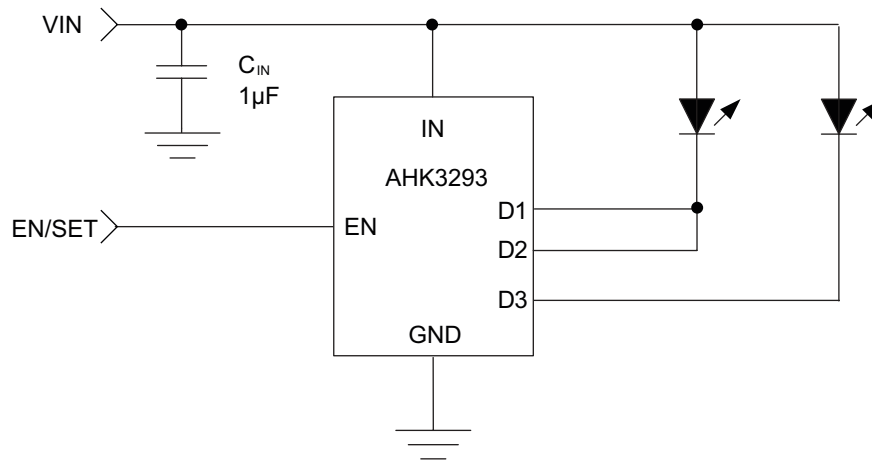


Figure 3: AHK3293 Higher Current Application Circuit.

Capacitor Selection

Careful selection of the external capacitor C_{IN} is important 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 $100m\Omega$. A value of $1\mu F$ for the input capacitor is a good starting point when choosing it. If the constant current sinks are only programmed for light current levels, then the input capacitor size may be decreased.

Capacitor Characteristics

Ceramic composition capacitors are highly recommended over all other types of capacitors for use with the AHK3293. Ceramic capacitors offer many advantages over their tantalum and aluminum electrolytic counterparts. A ceramic capacitor typically has very low ESR, is lower cost, has a smaller PCB footprint, and is non-polarized. 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 connec-

tions, 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 $0.1\mu F$ are typically made from NPO or COG materials. NPO and COG 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 $2.2\mu F$) are often available in low cost Y5V and Z5U dielectrics, but capacitors larger than $1\mu F$ are not typically required for AHK3293 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.

AHK3293

Three-Channel 1x LED Driver

Evaluation Board User Interface

The user interface for the AHK3293 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 2 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 D3 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 D3 are turned on with 30.2mA per channel. With every push/release the current is decreased according to Table 1. |
| CYCLE | [Push/Release once] Auto cycling up and down. |

Table 2: AHK3293 Evaluation Board User Interface.

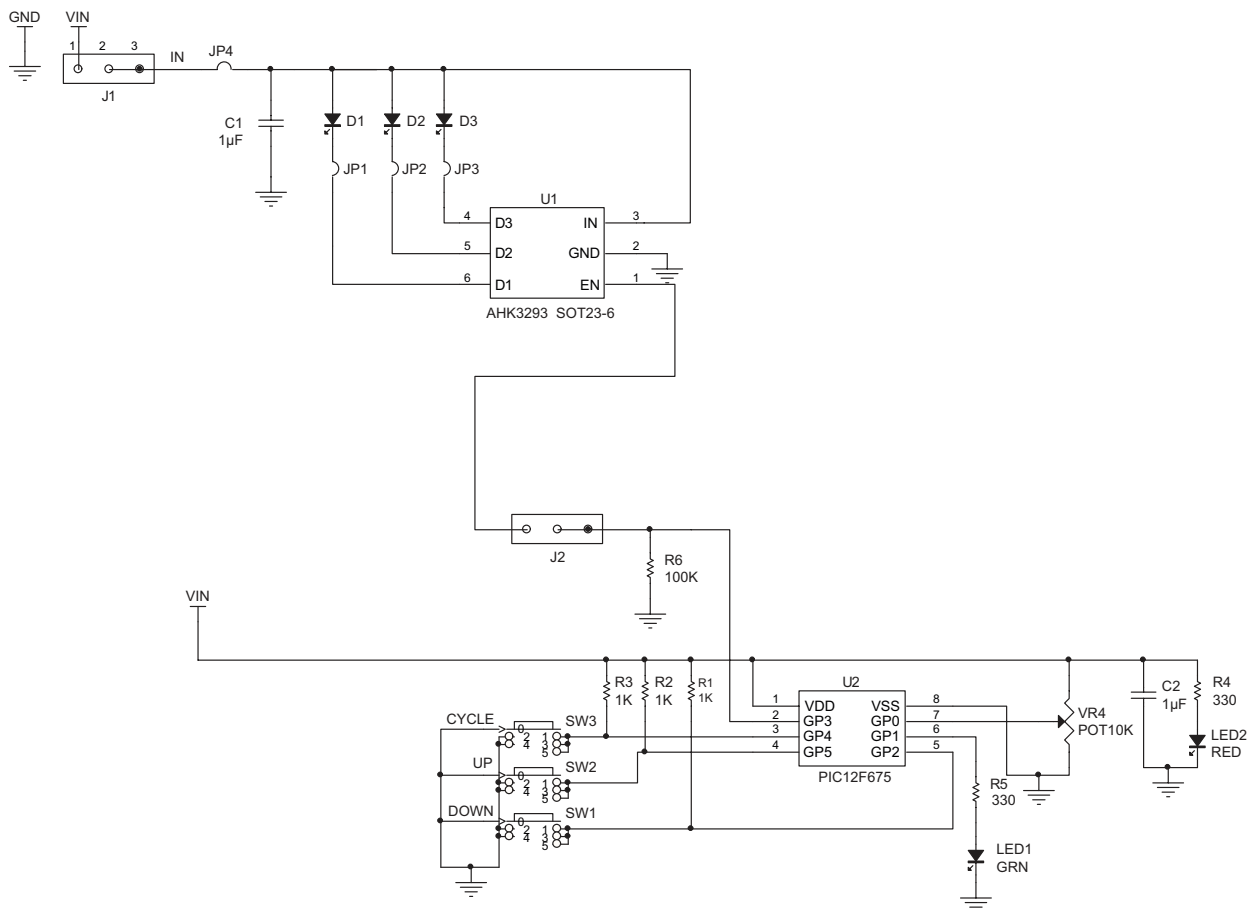


Figure 4: AHK3293 Evaluation Board Schematic.

AHK3293

Three-Channel 1x LED Driver

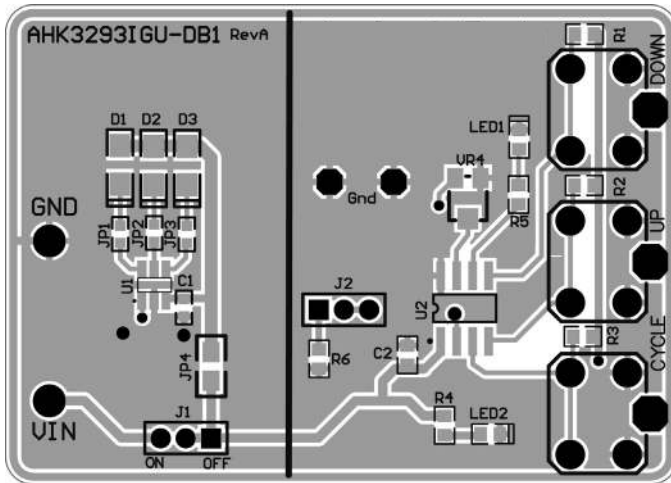


Figure 5: AHK3293 Evaluation Board

Top Side Layout.

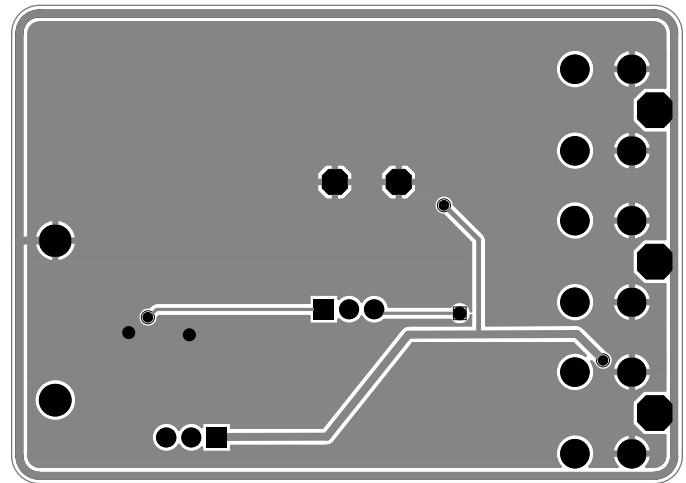


Figure 6: AHK3293 Evaluation Board

Bottom Side Layout.

AAT3293 EVAL Component Listing

| Component | Part Number | Description | Manufacturer |
|-----------------|-------------------|---|------------------------|
| U1 | AHK3293IGU | Three Channel LED driver; SOT23-6 package | Skyworks |
| U2 | PIC12F675 | 8-bit CMOS, FLASH-based μ C; 8-pin PDIP package | Microchip |
| CYCLE, UP, DOWN | PTS645TL50 | Switch Tact, SPST, 5mm | ITT Industries |
| R1, R2, R3 | Chip Resistor | 1K Ω , 5%, 1/4W; 0603 | Vishay |
| R4, R5 | Chip Resistor | 330 Ω , 1%, 1/4W; 0603 | Vishay |
| R6 | Chip Resistor | 100K Ω , 5%, 1/4W; 0603 | Vishay |
| C1, C2 | GRM185R60J105KE21 | 1 μ F, 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 | Chip Resistor | 0 Ω , 5%, 1/4W; 0603 | Vishay |
| JP4 | Chip Resistor | 0 Ω , 5%, 1/2W; 0805 | Vishay |
| D1, D2, D3 | LW M673 | Mini TOPLED White LED; SMD | OSRAM |

Table 4: AHK3293 Evaluation Board Bill of Materials (BOM).

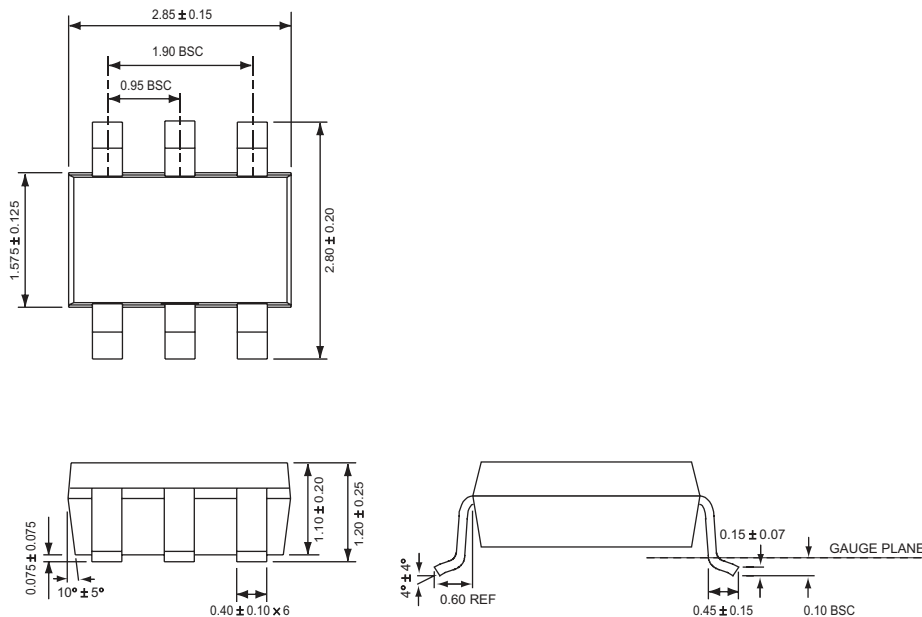
Ordering Information

| Package | Part Marking ¹ | Part Number (Tape and Reel) ² |
|---------|---------------------------|--|
| SOT23-6 | 6LXYY | AHK3293IGU-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**SOT23-6**

All dimensions in millimeters.

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

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