

AAT3192: Two-Channel Charge Pump LED Driver

Applications

- Entry level cordless phone handsets
- Entry level digital cameras
- Entry level mobile phone handsets
- Entry level MP3 and PMP players

Features

- Drives up to two LEDs at up to 30 mA each
- Automatic switching between 1X and 2X modes
- 0.9 MHz switching frequency
- Linear LED output current control:
 - Single-wire, S²Cwire interface
 - AAT3192-1: 16-step
 - AAT3192-2: 8-step
 - AAT3192-3: 4-step
 - ON/OFF or PWM interface
 - AAT3192-4
- ±10% LED output current accuracy
- ±3% LED output current matching
- Low-current shutdown mode
- Built-in thermal protection
- Automatic soft start
- SC70JW-10 (10-lead, 2.0 × 2.2 mm) package (MSL1, 260 °C per JEDEC-J-STD-020)

Description

The AAT3192 is a charge-pump based, current-sink white LED driver capable of driving one or two LEDs up to 30 mA each. It automatically switches between 1X mode and 2X mode to maintain the highest efficiency and optimal LED current accuracy and matching.

The AAT3192 charge pump's 1X mode (bypass mode) has very low resistance allowing LED current regulation to be maintained with input supply voltage approaching the LED forward voltage.

The AAT3192 is available in a 2.0 × 2.2 mm, 10-lead SC70JW-10 package.

A typical application circuit is shown in Figure 1. The pin configuration is shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1. Part number descriptions are given in Table 2.



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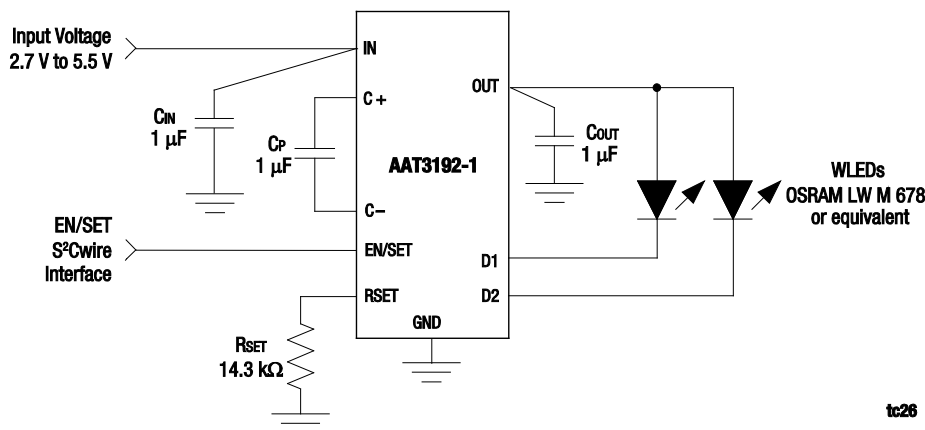


Figure 1. AAT3192-1 Typical Application Circuit

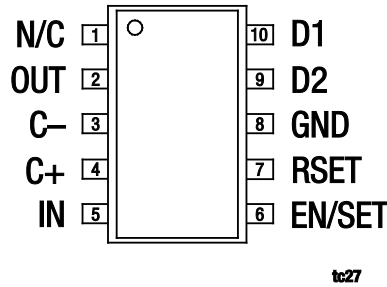


Figure 2. AAT3192 SC70JW-10 (Top View)

Table 1. AAT3192 Signal Descriptions

Pin #	Name	Description
1	N/C	No connection.
2	OUT	Charge pump output. OUT is the output of the charge pump. Bypass OUT to GND with a 1 μ F or larger ceramic capacitor.
3	C-	Charge pump capacitor negative node.
4	C+	Charge pump capacitor positive node. Connect a 1 μ F ceramic capacitor between C+ and C-.
5	IN	Power source input. Connect IN to the power source, typically the battery. Bypass IN to GND with a 1 μ F or larger ceramic capacitor.
6	EN/SET (AAT3192-1/-2/-3)	LED enable and serial control input. EN/SET is the ON/OFF control for the LED and the S ² Cwire digital input for the AAT3192-1/-2/-3 to control serially the LED brightness according to the maximum current set by RSET.
	EN/PWM (AAT3192-4)	LED ON/OFF and Pulse Width Modulation (PWM) control input. This logic input controls the LED outputs for the AAT3192-4. Alternatively, a PWM signal from a GPIO or an equivalent signal from a separate controller can be used to control LED output current linearly. A PWM signal, ranging from 10% to 100% duty cycle, controls the LED current linearly between Zero Scale (ZS) and Full Scale (FS).
7	RSET	A 1% tolerance resistor from this pin to GND sets the maximum LED current level. For optimal LED output current accuracy and matching in the AAT3192-1/-2/-4, a 14.3 k Ω resistor sets each full-scale output current to 20 mA, maximum. For the AAT3192-3, an 11.5 k Ω resistor is recommended.
8	GND	Ground. Connect this pin to the system's ground plane.
9	D2	LED2 current sink input. D2 is the input of LED2 current sink. Connect LED2's anode to OUT and its cathode to D2.
10	D1	LED1 current sink input. D1 is the input of LED1 current sink. Connect LED1's anode to OUT and its cathode to D1.

Table 2. Part Number Descriptions

Part Number	Interface	Current Control, Inverting
AAT3192JQ-1	S ² Cwire	16-step
AAT3192JQ-2	S ² Cwire	8-step
AAT3192JQ-3	S ² Cwire	4-step
AAT3192JQ-4	PWM	Linear

Electrical and Mechanical Specifications

The absolute maximum ratings of the AAT3192 are provided in Table 3, and electrical specifications are provided in Table 4.

Typical performance characteristics of the AAT3192 are illustrated in Figures 3 through 18.

Table 3. AAT3192 Absolute Maximum Ratings (Note 1)

Parameter	Symbol	Minimum	Typical	Maximum	Units
IN, C+, C-, OUT, D1, D2, and RSET pin voltages to GND	V _{IN} , V _{C+} , V _{C-} , V _{OUT} , V _{D1} , V _{D2} , V _{REST}	-0.3		+6.0	V
EN/SET or EN/PWM pin voltage to GND	V _{EN}	-0.3		V _{IN} + 0.3	V
Operating junction temperature range	T _J	-40		+150	°C
Maximum soldering temperature (at leads, 10 seconds)	T _{LEAD}		300		°C
Maximum thermal resistance (Note 2)	θ _{JA}		625		°C/W
Maximum power dissipation (Note 2, 3)	P _D		160		mW

Note 1: Exposure to maximum rating conditions for extended periods may reduce device reliability. There is no damage to device with only one parameter set at the limit and all other parameters set at or below their nominal value. Exceeding any of the limits listed may result in permanent damage to the device.

Note 2: Mounted on an FR4 circuit board.

Note 3: Derate 6.25 mW/°C above 40 °C ambient temperature.

CAUTION: Although this device is designed to be as robust as possible, Electrostatic Discharge (ESD) can damage this device. This device must be protected at all times from ESD. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD precautions should be used at all times.

Table 4. AAT3192 Electrical Specifications (1 of 2) (Note 1)

(V_{IN} = V_{EN} = 3.6 V, C_{IN} = 1 μF, C_{OUT} = 1 μF, C_{CP} = 1 μF, R_{SET} = 14.3 kΩ, T_A = -40 °C to 85 °C, [Typical Values are at T_A = 25 °C], Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
Input voltage	V _{IN}		2.7		5.5	V
Input operating current	I _{IN}	EN/SET or EN/PWM = IN; V _{D1} = V _{D2} = IN			2.5	mA
		EN/SET or EN/PWM = IN; I _{D1} = I _{D2} = FS, V _{IN} - V _F = 1.5 V			2.5	
		Operating, I _{D1} = I _{D2} = FS, D1 and D2 = open			7.0	
Input shutdown current	I _{IN(SHDN)}	I _N = 5.5 V; EN/SET or EN/PWM = GND			1	μA
Charge Pump Section						
Out maximum output current	I _{OUT}			100		mA
Charge pump oscillator frequency	f _{OSC}		0.65	0.9	1.15	MHz
Charge pump mode hysteresis	V _{IN_(TH)}	I _{D1} = I _{D2} = 20 mA; excluding AAT3192-4, PWM option		115	250	mV
Output start-up time	t _{OUT}	EN/SET or EN/PWM = IN		150		μs
AAT3192-1/-2/-4: LED Current Sink Outputs						
D1/D2 current accuracy	I _{D_(MAX)}	DATA = 1; V _{IN} - V _F = 1.5 V	18	20	22	mA
D1/D2 current matching	ΔI _{D_(MAX)}	DATA = 1; V _{IN} - V _F = 1.5 V		±3		%
D1/D2 current accuracy (AAT3192-1 only)	I _{D_(DATA15)}	DATA = 15; V _{IN} - V _F = 1.5 V	1.0	1.3	1.56	mA
D1/D2 current accuracy (AAT3192-2 only)	I _{D_(DATA8)}	DATA = 8; V _{IN} - V _F = 1.5 V	1.0	1.3	1.56	mA
D1/D2 current accuracy (AAT3192-4 only)	I _{D_(10%)}	Duty cycle = 10%; f _{PWM} = 10 kHz; V _{IN} - V _F = 1.5 V		2.4		mA
D1/D2 charge pump mode Transition Threshold	V _{D_(TH)}	I _{D1} = I _{D2} = 20 mA		125		mV

Table 4. AAT3192 Electrical Specifications (2 of 2) (Note 1)

(VIN = VEN = 3.6 V, CIN = 1 μF, COUT = 1 μF, CCP = 1 μF, RSET = 14.3 kΩ, TA = -40 °C to 85 °C, [Typical Values are at TA = 25 °C], Unless Otherwise Noted)

Parameter	Symbol	Test Condition	Min	Typical	Max	Units
AAT3192-3: LED Current Sink Outputs						
D1/D2 current accuracy	ID_(MAX)	RSET = 11.5 kΩ; DATA = 1; VIN - VF = 1.5 V	18	20	22	mA
D1/D2 current matching	ΔID_(MAX)	RSET = 11.5 kΩ; DATA = 1; VIN - VF = 1.5 V		±3		%
D1/D2 current accuracy	ID_(DATA4)	RSET = 11.5 kΩ; DATA = 4; VIN - VF = 1.5 V	0.72	0.9	1.1	mA
D1/D2 charge pump mode transition threshold	VD_(TH)	RSET = 11.5 kΩ; ID1= ID2 = 20 mA		125		mV
AAT3192-1/-2/-3: EN/SET and S²Cwire Control						
EN input high threshold voltage	VENH		1.4			V
EN input low threshold voltage	VENL				0.4	V
EN input leakage current	IEN(LKG)	EN/SET = IN = 5 V	-1		1	μA
EN/SET input OFF timeout	tEN/SET(OFF)				500	μs
EN/SET input latch timeout	tEN/SET(LAT)				500	μs
EN/SET Input low time	tEN/SET(LOW)		0.3		75	μs
EN/SET minimum high time	tENSET(H-MIN)			50		μs
EN/SET maximum high time	tENSET(H-MAX)				75	μs
AAT3192-4: EN/PWM Current Control						
EN/PWM input high threshold voltage	VENH		1.4			V
EN/PWM input low threshold voltage	VENL				0.4	V
EN/PWM input leakage current	IEN(LKG)	EN/PWM = IN = 5 V	-1		1	μA
PWM control turn-on delay	tPWM(ON)			2		μs
EN/PWM input OFF timeout	tEN/PWM		0.15		1	ms
PWM control frequency	fPWM	Duty cycle = 80%			50	kHz

Note 1: Performance is guaranteed only under the conditions listed in this Table.

Typical Performance Characteristics

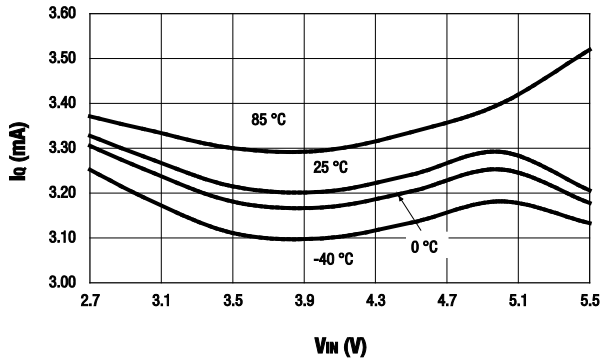


Figure 3. Operating Current (No Load) vs Input Voltage

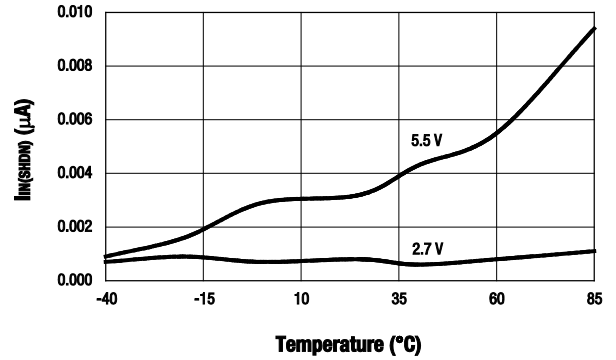


Figure 4. Shutdown Current vs Temperature

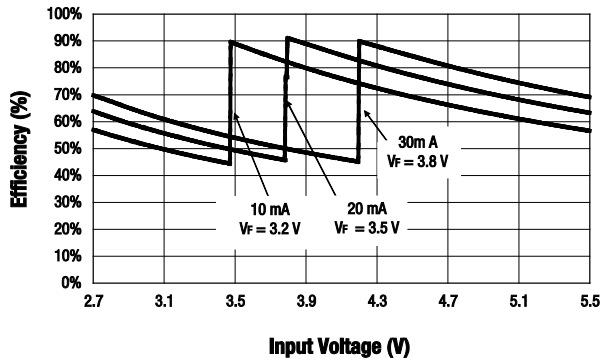


Figure 5. Efficiency vs Input Current

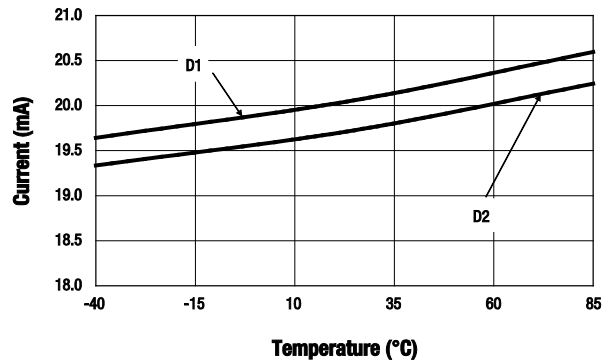


Figure 6. Current Matching vs Temperature

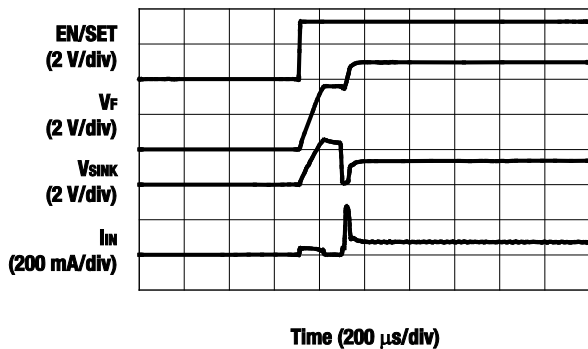


Figure 7. 2X Mode Turn On ($V_{IN} = 3.6\text{ V}$, 19.6 mA/ch)

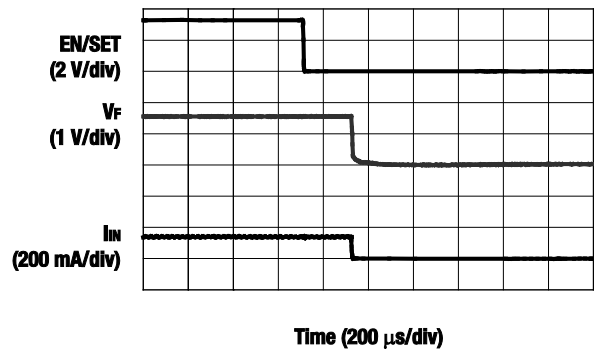


Figure 8. 2X Mode Turn Off ($V_{IN} = 3.6\text{ V}$, 19.6 mA/ch)

Typical Performance Characteristics

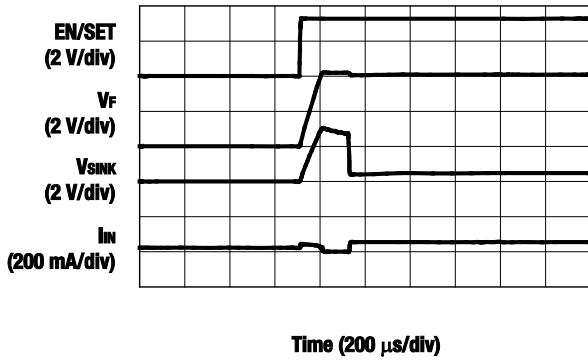


Figure 9. 1X Mode Turn On ($V_{IN} = 4.2\text{ V}$, 19.6 mA/ch)

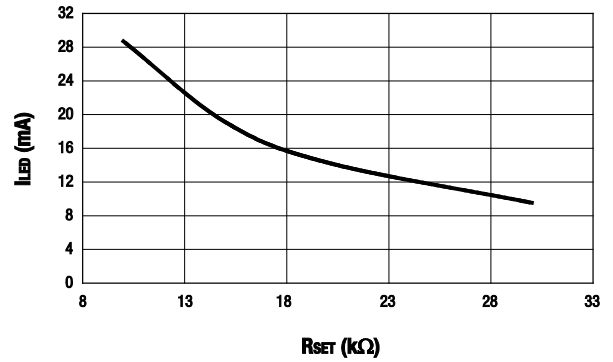


Figure 10. Maximum LED Current vs RSET

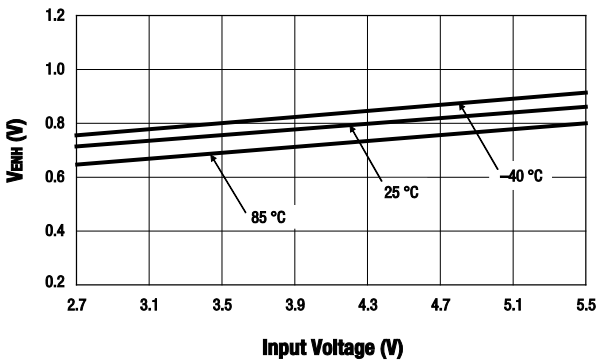


Figure 11. EN Input High Threshold Voltage vs Input Voltage

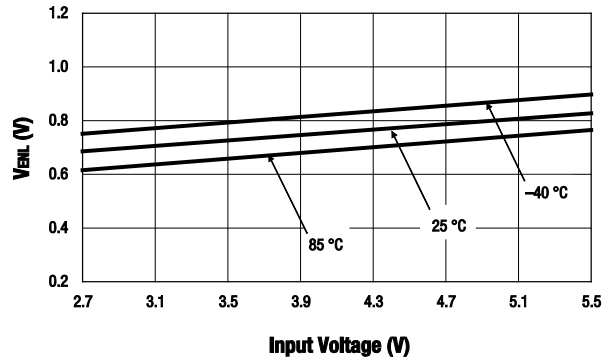


Figure 12. EN Input Low Threshold Voltage vs Input Voltage

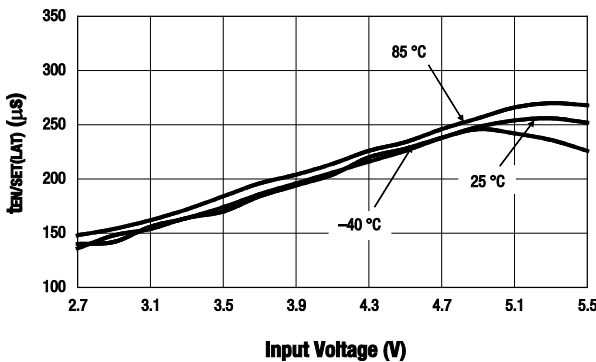


Figure 13. EN/SET Input Latch Timeout vs Input Voltage

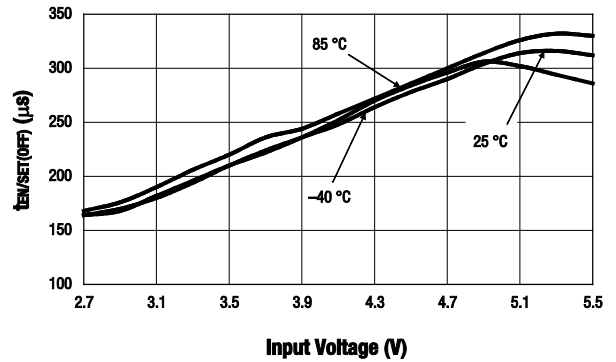


Figure 14. EN/SET Input OFF Timeout vs Input Voltage

Typical Performance Characteristics

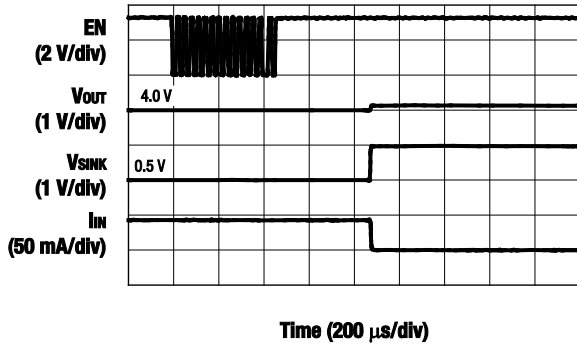


Figure 15. Transition of LED Current (19.6 mA to 1.3 mA)

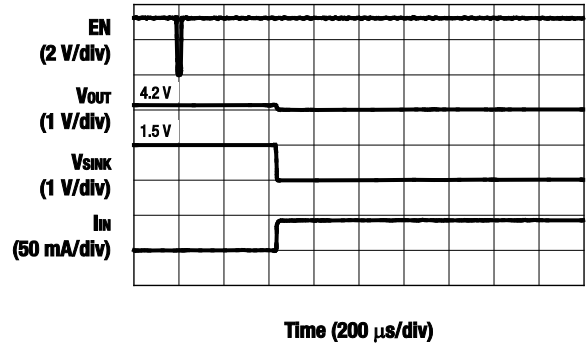


Figure 16. Transition of LED Current (1.3 mA to 19.6 mA)

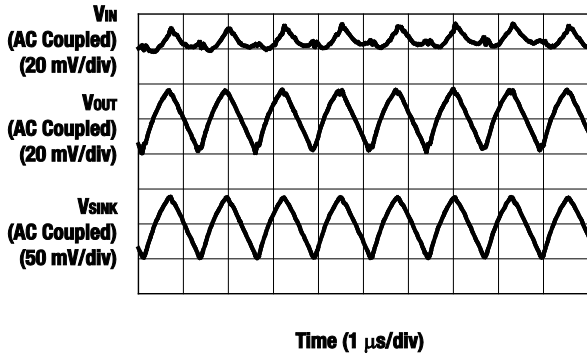


Figure 17. Output Ripple Waveform (2X Mode; 20 mA Load)

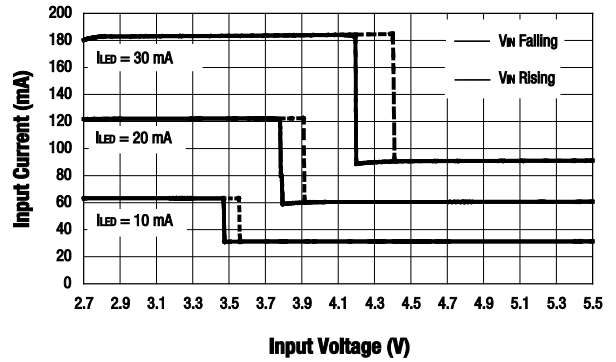


Figure 18. Input Current vs Input Voltage (Excluding AAT3192-4, PWM Option)

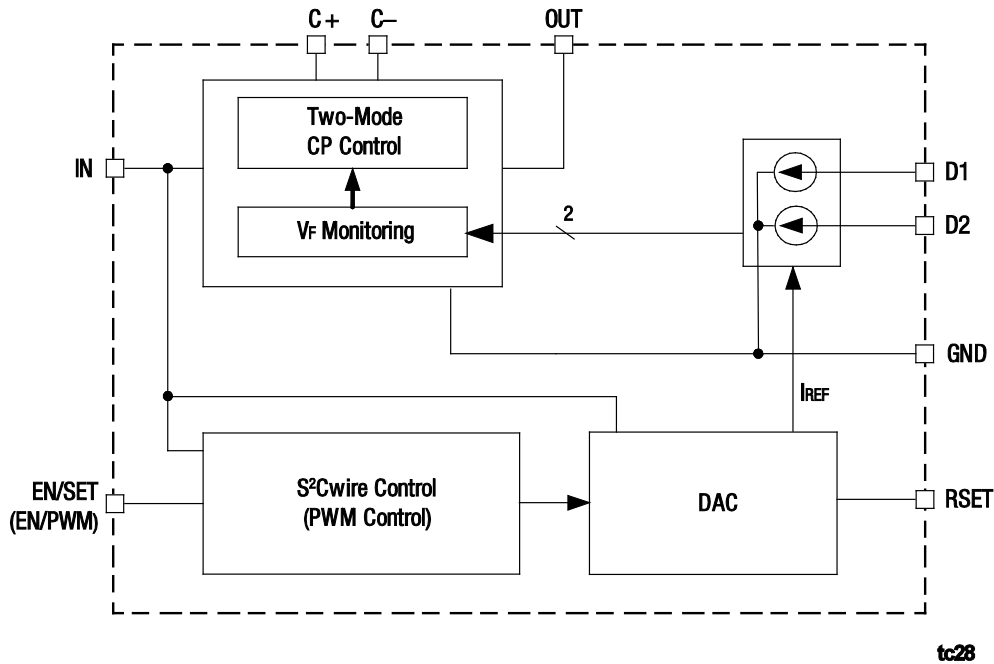


Figure 19. AAT3192 Functional Block Diagram

Functional Description

The AAT3192 is a low cost charge-pump solution designed to drive up to two white LEDs. The charge pump operates from a 2.7 V to 5.5 V power source and converts it to voltage levels necessary to drive the LEDs.

LED current is individually controlled through integrated current sinks powered from the output of the charge pump. Low 1X charge-pump output resistance and low-drop voltage current sinks allow the charge pump to stay in 1X mode with an input voltage as low as 3.75 V and LED forward voltages as high as 3.5 V. Once in 2X mode, the AAT3192-1/-2/-3 continuously monitors the input supply voltage and automatically switch back to 1X mode when there is sufficient input voltage. To support fast PWM response, the 2X mode is latched in the AAT3192-4 and the device, once there, stays in that mode. To reset the AAT3192-4 to the 1X mode, strobe EN/PWM low for 1 ms or longer.

The AAT3192 requires only four external components: one 1 μ F ceramic capacitor for the charge pump flying capacitors (CP), one 1 μ F ceramic input capacitor (C_{IN}), one 1 μ F ceramic output capacitor (C_{OUT}), and a resistor (RSET) to set the maximum LED current. The AAT3192 can drive two constant output sinks (D1 and D2) with up to 30 mA maximum current each.

Skyworks S²Cwire serial interface enables the AAT3192-1/-2/-3 and changes the current sink magnitudes through the EN/SET pin. The AAT3192-4 uses an external PWM signal to enable the device and to control the brightness of the LEDs.

A functional block diagram is provided in Figure 19.

Constant Current Control using RSET

The maximum current is programmed by an external resistor at the RSET pin. Using a 14.3 k Ω external resistor at the RSET pin, the AAT3192-1/-2/-4 includes an integrated serial LED current control that sets the full-scale LED current between 20 mA and 0.63 mA. For the AAT3192-3, an 11.5 k Ω external resistor at the RSET pin sets the full-scale LED current between 20 mA and 1.3 mA. The full-scale LED current can set higher or lower than 20 mA (see Tables 9 and 10). For maximum accuracy, a 1% tolerance resistor is recommended.

S²Cwire Serial Interface (AAT3192-1/-2/-3 Only)

The LED output current of the AAT3192 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 I/C to manage LED or display brightness, allowing the user to “set it and forget it.”

With its high-speed serial interface (1 MHz 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/SET rising edges, followed by a pause with EN/SET held high for at least t_{LAT} (500 μ s).

The programmed current is then seen at the current sink outputs. When EN/SET is held low for an amount of time longer than t_{OFF} (500 μ s), the AAT3192 enters into shutdown mode and draws less than 1 μ A from the input and the internal data register is reset to zero. Figure 20 shows the S²C serial interface timing.

The serial interface reduces the LED current on each rising pulse of the enable input. If the AAT3192 is in shutdown, the first rising edge of the EN/SET input turns on the LED driver to the maximum current.

Successive rising edges decrease the LED current as shown in Table 5 and Figure 21 for the AAT3192-1. For the AAT3192-2, Table 6 and Figure 22 illustrate an 8-step LED current control profile. For the AAT3192-3, Table 7 and Figure 23 illustrate a 4-step LED current control profile.

PWM Control (AAT3192-4 only)

PWM is an industry standard technique used to control LED brightness by modulating the conduction duty cycle of the LED current. LED brightness is determined by the average value of the PWM signal multiplied by the LED’s intensity where intensity is proportional to the LED drive current.

A PWM control signal can be applied to the EN/PWM pin of the AAT3192-4. By changing the duty cycle of the PWM signal from 100% (logic high) to 10%, LEDs sink current can be programmed from 20 mA to 2.4 mA. To save power when not used, AAT3192-4 can be shut down by holding the EN/PWM pin low for 1 ms.

Lastly, Table 8 and Figure 24 illustrate the AAT3192-4’s LED current control profile as a function of a PWM control signal.

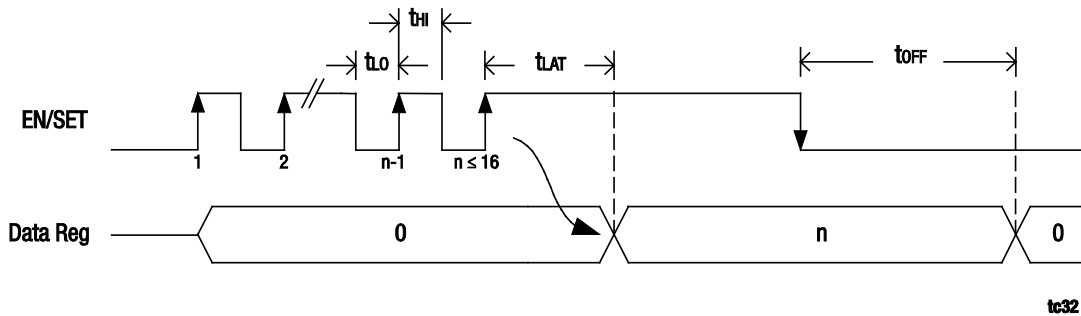


Figure 20. S²C Serial Interface Timing

Table 5. AAT3192-1 LED Current Settings

Data	EN Rising Edges	D1/D2 Current (mA)
1	1	20
2	2	18.7
3	3	17.3
4	4	16
5	5	14.7
6	6	13.3
7	7	12
8	8	10.7
9	9	9.3
10	10	8
11	11	6.7
12	12	5.3
13	13	4
14	14	2.7
15	15	1.3
16	16	0.63

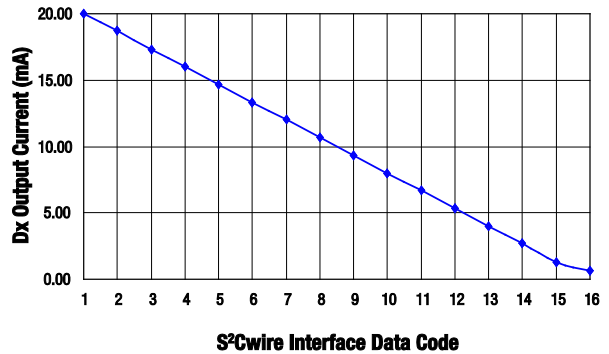


Figure 21. AAT3192-1 Current Control Profile

Table 6. AAT3192-2 LED Current Settings

Data	EN Rising Edges	D1/D2 Current (mA)
1	1	20
2	2	17.3
3	3	14.7
4	4	12
5	5	9.3
6	6	6.7
7	7	4
8	8	1.3

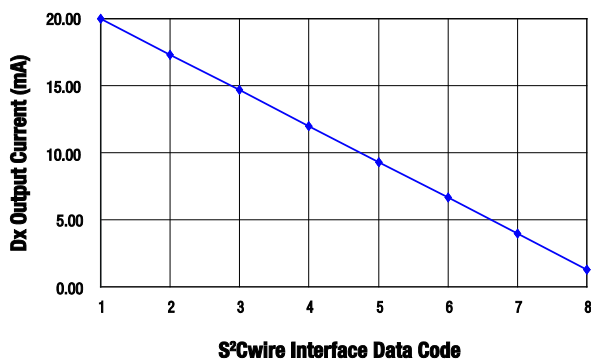


Figure 22. AAT3192-2 Current Control Profile

Table 7. AAT3192-3 LED Current Settings

Data	EN Rising Edges	D1/D2 Current (mA)
1	1	20
2	2	13.3
3	3	6.7
4	4	0.87

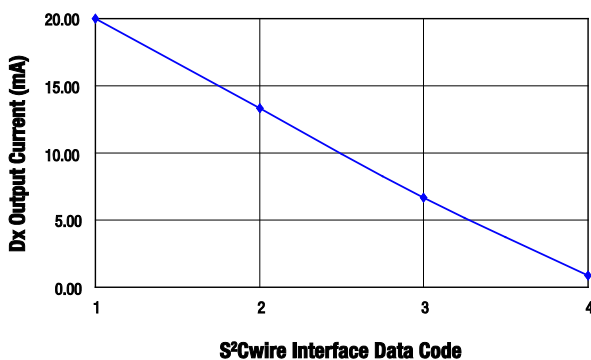
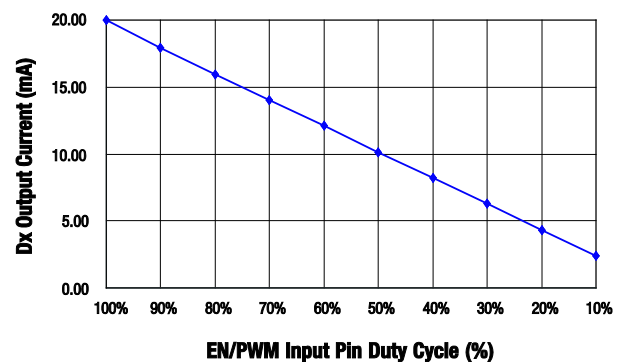


Figure 23. AAT3192-3 Current Control Profile

**Table 8. AAT3192-4 LED Current Settings
(RSET = 14.3 kΩ, fpWM = 50 kHz)**

EN/PWM Duty Cycle	D1/D2 Current (mA)
100%	20
90%	17.9
80%	15.9
70%	14
60%	12.1
50%	10.1
40%	8.2
30%	6.3
20%	4.3
10%	2.4



**Figure 24. AAT3192-4 Current Control Profile
(RSET = 14.3 kΩ, fpWM = 50 kHz)**

Application Information

LED Selection

The AAT3192 is specifically intended for driving white LEDs. However, the device design allows the AAT3192 to drive most types of LEDs with forward voltage specifications ranging from 2.2 V to 4.7 V. 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 to D2 constant current sinks are matched with negligible supply voltage dependence, the constant current channels are matched regardless of the specific LED forward voltage (Vf) levels.

The low dropout current sinks in the AAT3192 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.

Constant Current Setting

The LED current is controlled by the RSET resistor. For maximum accuracy, a 1% tolerance resistor is recommended. Table 9 shows RSET resistor values for AAT3192-1/2/4, and Table 10 shows RSET resistor values for AAT3192-3 for various LED full-scale current levels.

Table 9. Maximum LED Current and RSET Resistor Values (1% Resistor Tolerance) for the AAT3192-1/2/4

I _{LED} (mA)	R _{SET} (kΩ)
30	9.53
25	11.5
20	14.3
18	15.8
15	19.1
10	28.7

Table 10. Maximum LED Current and RSET Resistor Values (1% Resistor Tolerance) for the AAT3192-3

I _{LED} (mA)	R _{SET} (kΩ)
30	7.68
20	11.5
15	15.4
10	23.2

Device Switching Noise Performance

The AAT3192 operates at a fixed frequency of approximately 1 MHz to control noise and limit harmonics that can interfere with the RF operation of mobile communication devices. Back-injected noise appearing on the input pin of the charge pump is 20 mV peak-to-peak, typically ten times less than inductor-based DC/DC boost converter white LED backlight solutions. The AAT3192 soft-start feature prevents noise transient effects associated with inrush currents during start-up of the charge pump circuit.

Shutdown

Since the current switches are the only power returns for all loads, there is no leakage current when all sink switches are disabled. To activate the shutdown operation, the EN/SET input for the AAT3192-1/2/3 should be strobed low for longer than t_{OFF} (500 μs). For the 3192-4 PWM options, shutdown operation is enabled when the EN/PWM input is strobed low longer than 1 ms. In this state, the AAT3192 typically draws less than 1 μA from the input. Registers are reset to 0 in shutdown.

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 AAT3192, it is very difficult to measure efficiency in terms of a percent value comparing input power over output power.

Since the AAT3192 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 is maintained as a constant.

This makes quantifying output power a difficult task 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 percent efficiency.*

The AAT3192 efficiency may be quantified under very specific conditions and is dependent on the input voltage versus the output voltage across the loads applied to outputs D1 through D2 for a given constant current setting. Depending on the combination of V_{IN} and voltages sensed at the current sinks, the device operates in load switch mode. When any one of the voltages sensed at the current sinks nears dropout, the device operates in 2X charge pump mode. Each of these modes yields different efficiency values. Refer to the following two sections for explanations for each operational mode.

1X Mode Efficiency

The AAT3192 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, the 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:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_F \times I_{LED}}{V_{IN} \times I_{OUT}} \cong \frac{V_F}{V_{IN}}$$

Or:

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

2X Charge Pump Mode Efficiency

The AAT3192 contains a charge pump which boosts the input supply voltage in the event where 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 two times the input voltage. Efficiency (η) for an ideal 2X charge pump can typically be expressed as the output power divided by the input power.

$$\eta = \frac{P_F}{P_{IN}}$$

In addition, with an ideal 2X charge pump, the output current may be expressed as 1/3 of the input current. The expression to define the ideal efficiency (η) can be rewritten as:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_F \times I_{LED}}{V_{IN} \times 2 \times I_{OUT}} \approx \frac{V_F}{2 \times V_{IN}}$$

Or:

$$\eta(\%) = 100 \times \left(\frac{V_F}{2 \times V_{IN}} \right)$$

For a charge pump with an output of 5 V and a nominal input of 3.5 V, the theoretical efficiency is 71%. Due to internal switching losses and IC quiescent current consumption, the actual efficiency can be measured at 51%. The efficiency decreases substantially as load current drops below 1 mA or when the voltage level at V_{IN} approaches the voltage level at V_{OUT} .

Additional Applications

The current sinks of the AAT3192 can be combined to drive higher current levels through a single LED. As an example, a single LED can be driven at 60 mA total by combining together the D1 and D2 outputs, as shown in Figure 25.

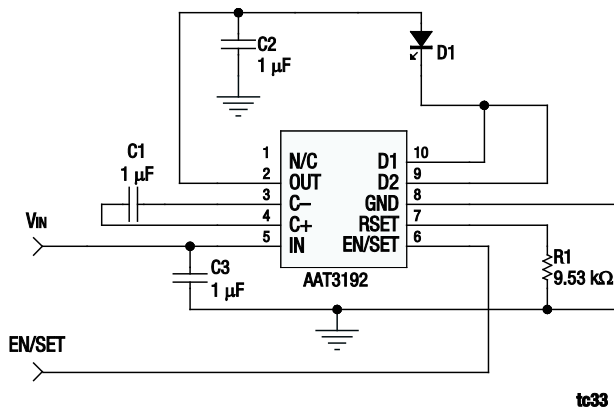


Figure 25. Higher Current, Single LED Application

For lower-cost applications, the flying capacitor can be removed, as shown in Figure 26. This forces the AAT3192 to operate in 1X mode. To maintain regulated LED current, the input supply voltage has to be higher than the charge-pump's dropout voltage in 1X mode.

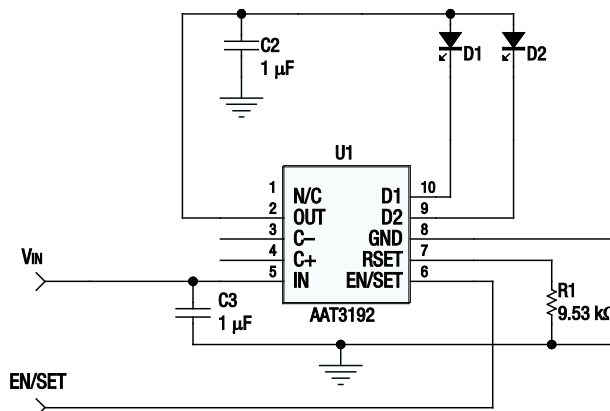


Figure 26. Lower Cost 1X Mode Application

Capacitor Selection

Careful selection of the three external capacitors C_{IN} , C_P , and C_{OUT} is important because they affect turn-on time, output ripple, and transient performance. The optimum performance is obtained when low Equivalent Series Resistance (ESR) ceramic capacitors are used. In general, low ESR may be defined as less than 100 mΩ. A value of 1 μF for all four capacitors is a good starting point when choosing capacitors. If the constant current sinks are only programmed for light current levels, then the capacitor size may be decreased.

Capacitor Characteristics

Ceramic composition capacitors are highly recommended over all other types of capacitors for use with the AAT3192. Ceramic capacitors offer many advantages over their tantalum and aluminum electrolytic counterparts. A ceramic capacitor typically has very low ESR, is the 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)

ESR is an important characteristic to consider when selecting a capacitor. ESR is the internal resistance of 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 0.1 μF 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 μF) are often available in low cost Y5V and Z5U dielectrics, but capacitors larger than 1 μF are not typically required for the AAT3192 applications.

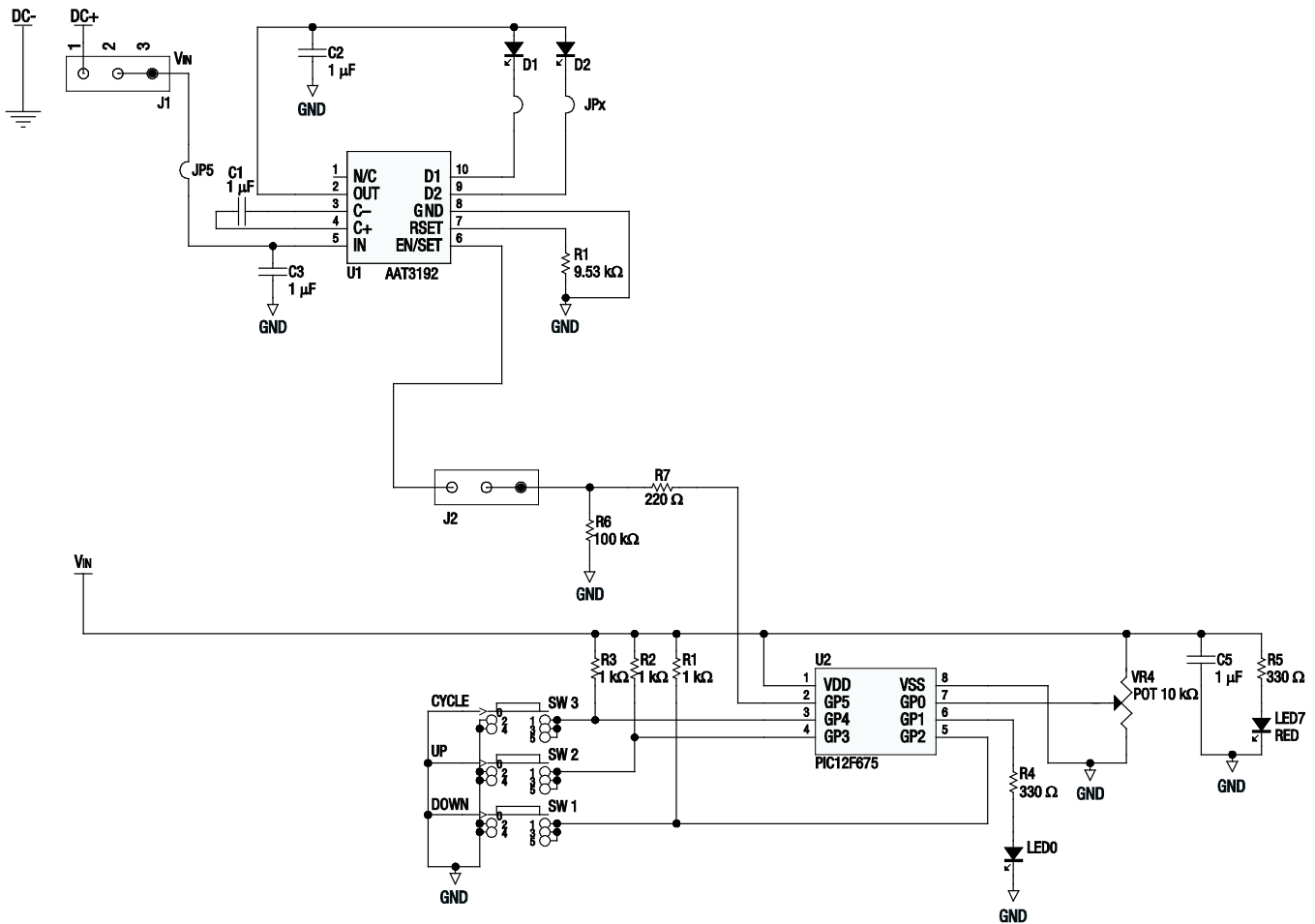
Capacitor area is another contributor to ESR. The capacitor that is physically large has a lower ESR when compared to a smaller capacitor with same material. These larger devices can improve circuit transient response when compared to an equal value capacitor in a smaller package size.

Evaluation Board Description

The AAT3192 Evaluation Board schematic diagram is provided in Figure 27. The PCB layer details are shown in Figure 28.

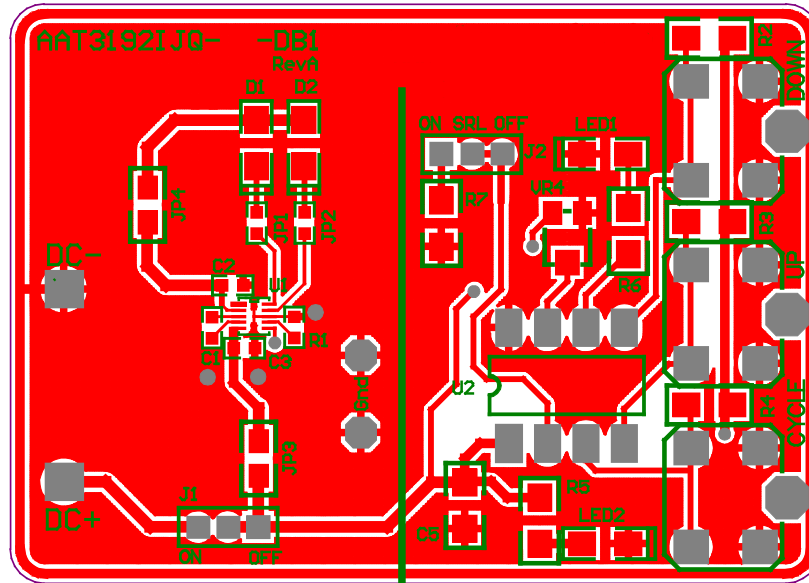
Package Information

Package dimensions for the SC70JW-10 are shown in Figure 29, and tape and reel dimensions are provided in Figure 30.

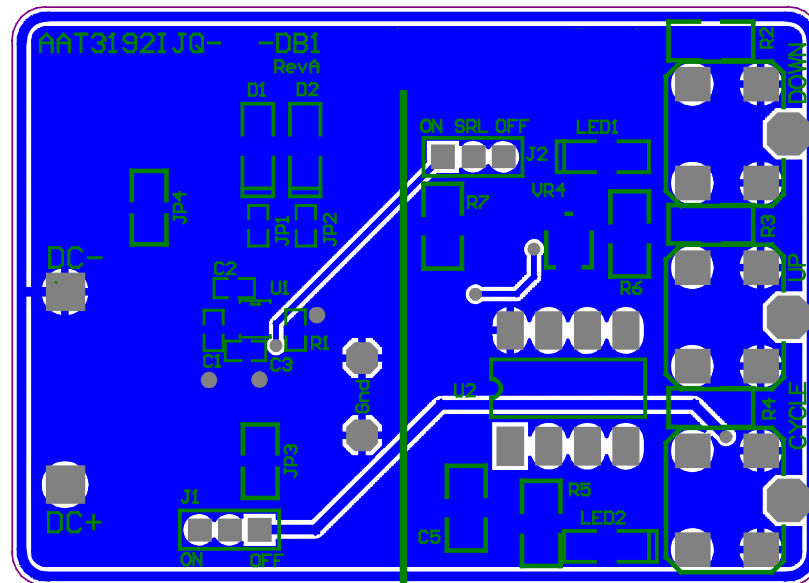


tc35

Figure 27. AAT3192 Evaluation Board Schematic



(a) Top Layer



(a) Bottom Layer

tc36

Figure 28. AAT3192 Evaluation Board Layout

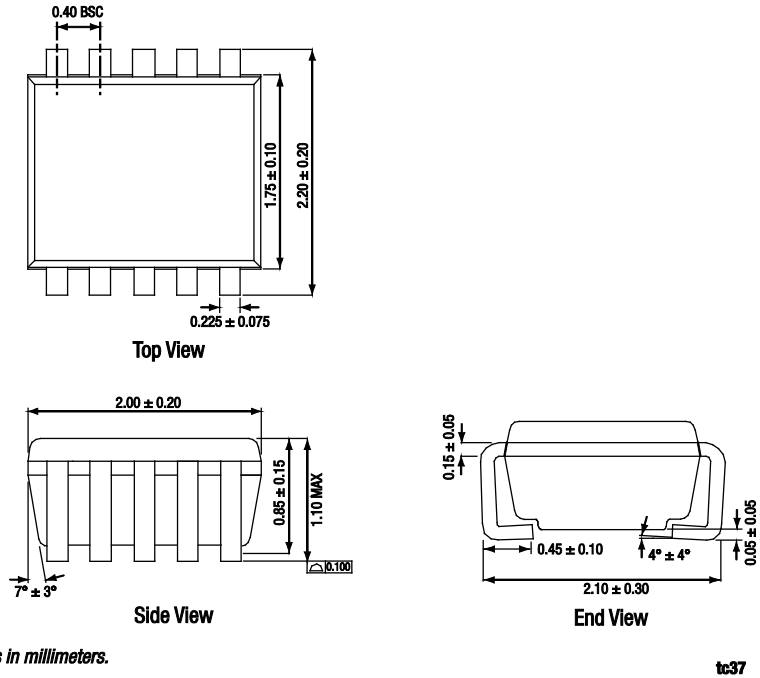


Figure 29. AAT3192 SC70JW-10 Package Dimensions

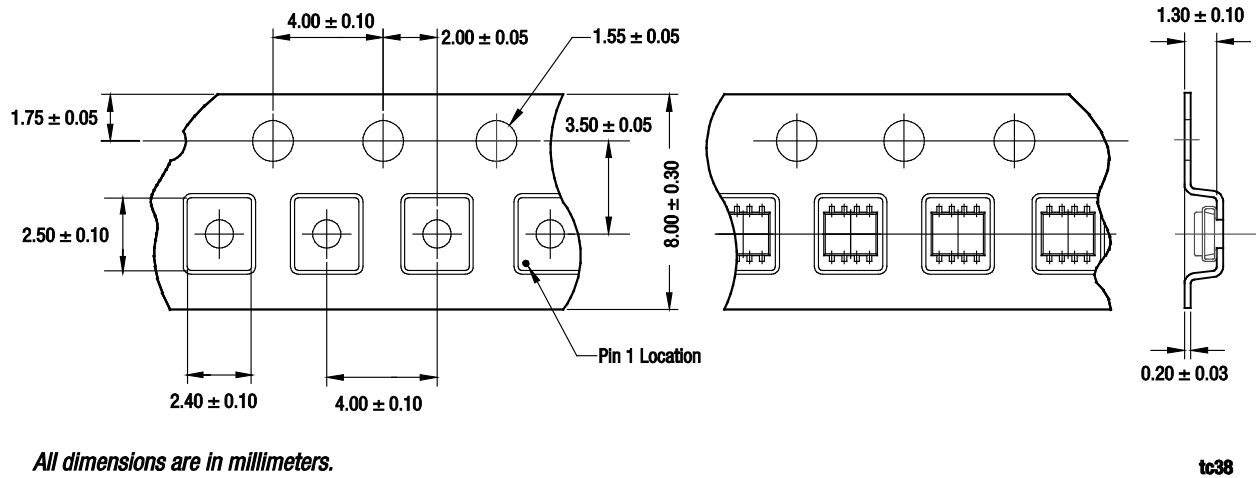


Figure 30. AAT3192 Tape and Reel Dimensions

Ordering Information

Model Name			Manufacturing Part Number (Note 1)	Evaluation Board Part Number
AAT3192 Two-Channel Charge Pump LED Driver	S ² Cwire	16-step	AAT3192IJQ-1-T1	AAT3192IJQ-1-T1-EVB
	S ² Cwire	8-step	AAT3192IJQ-2-T1	AAT3192IJQ-2-T1-EVB
	S ² Cwire	4-step	AAT3192IJQ-3-T1	AAT3192IJQ-3-T1-EVB
	PWM	Linear	AAT3192IJQ-4-T1	AAT3192IJQ-4-T1-EVB

Note 1: Sample stock is generally held on part numbers listed in **BOLD**.

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