NIPPON PRECISION CIRCUITS INC.

SM8122A

White LED Driver IC

OVERVIEW

The SM8122A is a high efficiency step-up DC/DC converter. Due to high voltage CMOS process realizing 25V output supply as maximum value, 2 to 6 lights of white LED connected in series can be lighted. By connecting in series, current variation among LED is eliminated. Current value sent to white LED can be set by external resistors. In addition, brightness can also be adjusted by control to FB pin or CE pin. Since the SM8122A has an over voltage protection circuit built-in, it dispenses with the existing external ZD (zener diode). Besides, the switching frequency of the SM8122A is higher (2.0MHz) than the existing product (SM8121A), so that it can respond to lower inductance value.

FEATURES

- Boost-up control using PWM
- 2 to 6 lights of white LED (connected in series) lighted
- Output current value can be set by external resistors (51Ω: 9.8mA, 33Ω: 15.2mA, 24Ω: 20.8mA)
- Brightness adjustable by control to FB pin or CE pin
- Current variation among LED decreased by high precision
- High efficient drive by step-up model
- Over voltage protection circuit built-in
- Supply voltage range: 2.3 to 5.5V
- Maximum output voltage: 25V
- Quiescent current: 820μA (typ)
- Standby current: 1.0μA (max)
- R_{ON} (Switching MOS-Tr): 2Ω (typ)
- Switching frequency: 2.0MHz (typ)
- Output current detection accuracy: ± 2%
- Package: SOT23-6W (SM8122AH)
  MSON-6 (SM8122AD)

APPLICATIONS

- Cellular phone
- Pager
- Digital still camera
- Handy terminal
- PDAs
- Portable games
- White LED drive
- LCD bias supply
- Flash memory supply

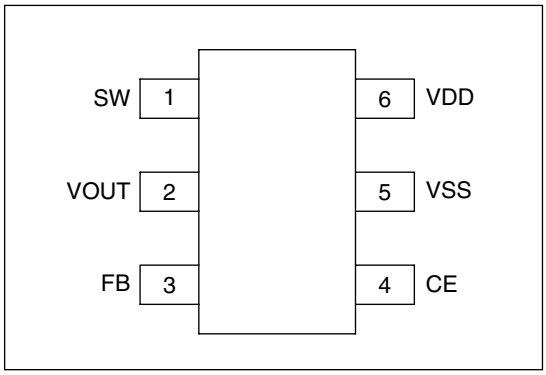
ORDERING INFORMATION

Device	Package
SM8122AH	SOT23-6W
SM8122AD	MSON-6

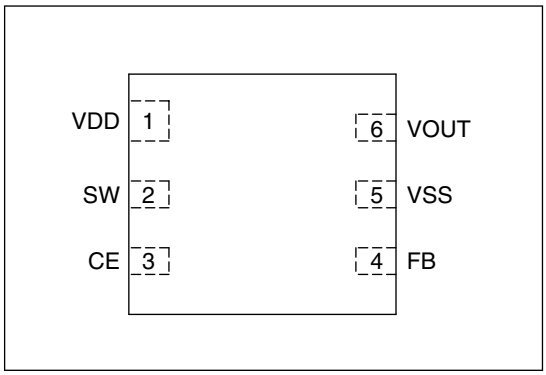
PINOUT

(Top view)

- SOT23-6W



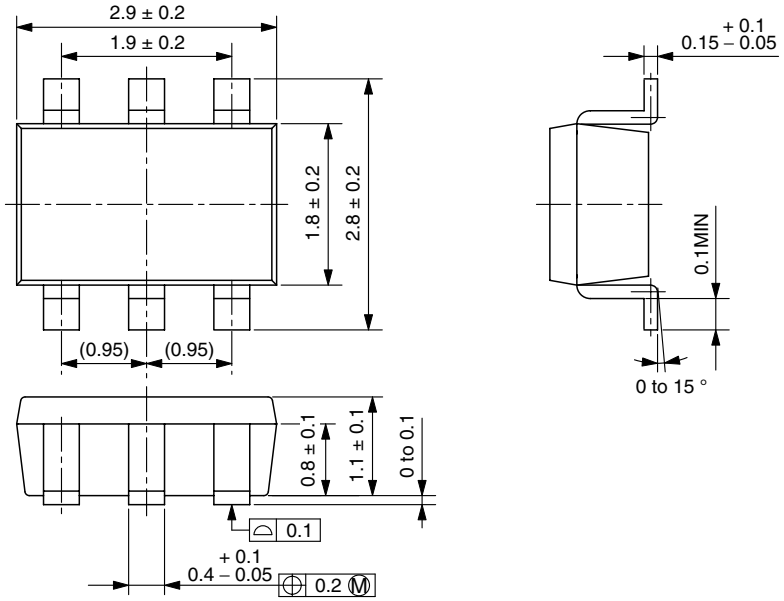
- MSON-6



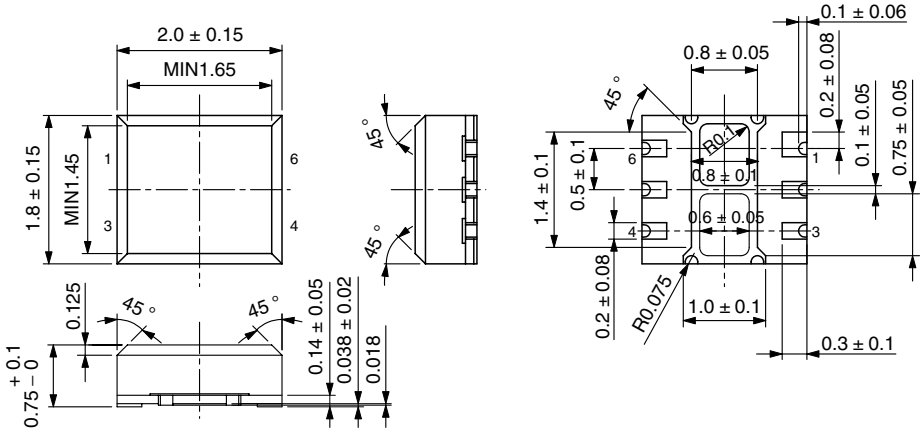
PACKAGE DIMENSIONS

(Unit: mm)

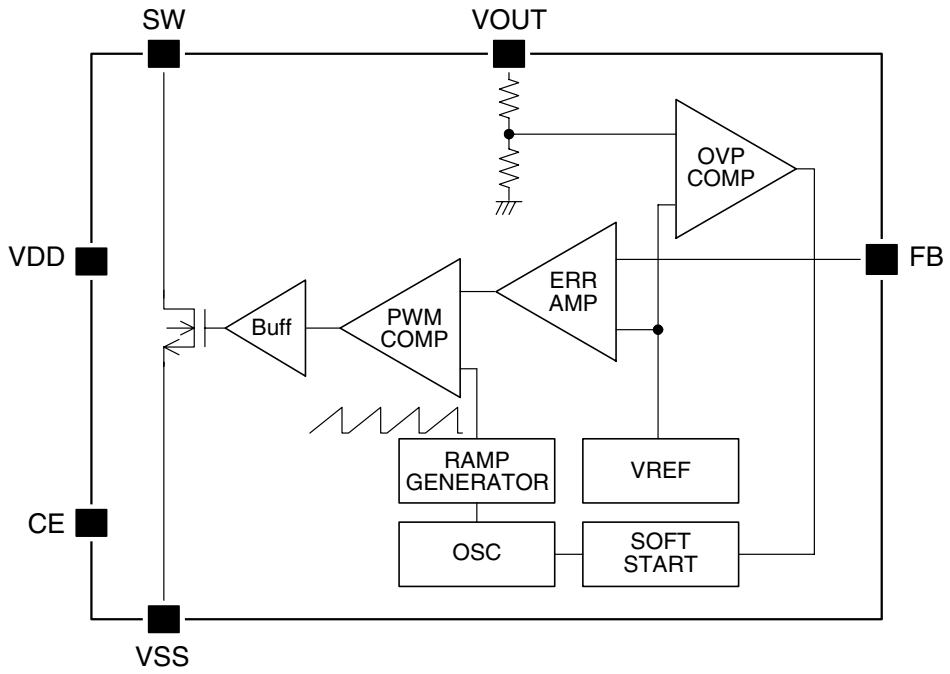
■ SOT23-6W



■ MSON-6



BLOCK DIAGRAM



PIN DESCRIPTION

Number		Name	I/O	Description
SOT23-6W	MSON-6			
1	2	SW	O	Coil switching
2	6	VOUT	I	Output voltage detection
3	4	FB	I	Feed back (Output current detection)
4	3	CE	Ip[1]	Chip enable (High active)
5	5	VSS	–	GND
6	1	VDD	–	Power supply

1. Input with built-in pull-down resistor

SPECIFICATIONS

Absolute Maximum Ratings

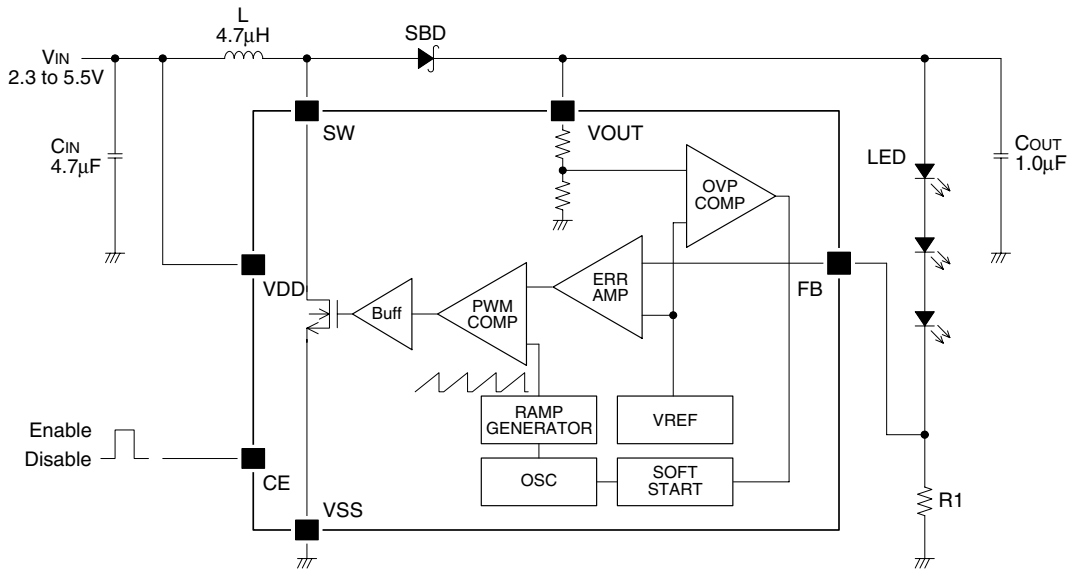
Parameter	Symbol	Rating	Unit
Supply voltage range	V_{DD}	–0.3 to 6.5	V
Input voltage range	V_{IN}	V_{SS} – 0.3 to V_{DD} + 0.3	V
SW output voltage range	V_{SW}	–0.3 to 30	V
SW input current	I_{SW}	500	mA
Power dissipation	P_D	250 (Ta = 25°C)	mW
Operating temperature range	T_{opr}	–40 to 85	°C
Storage temperature range	T_{stg}	–55 to 125	°C

Electrical Characteristics

V_{DD} = 3.6V, V_{SS} = 0V, Ta = 25°C unless otherwise noted

Parameter	Pin	Symbol	Condition	Rating			Unit
				min	typ	max	
Supply voltage	VDD	V_{DD}		2.3	3.6	5.5	V
Maximum output voltage	SW	V_{OUT}		–	–	25	V
Standby current	VDD	I_{STB}	V_{CE} = 0V	–	–	1.0	µA
Quiescent current	VDD	I_{DD}	V_{FB} = 1.0V	–	200	400	µA
			V_{FB} = 0V	–	820	1600	µA
SW-Tr ON resister	SW	R_{ON}	I_{SW} = 100mA, V_{DD} = 3.6V	–	2.0	3.0	Ω
SW-Tr leak current	SW	I_{LEAK}	V_{SW} = V_{DD}	–	–	1.0	µA
Switching frequency	SW	f_{OSC}	V_{FB} = 0V	1.8	2.0	2.2	MHz
Maximum duty	SW	Duty	V_{FB} = 0V	75	85	90	%
Input voltage	CE	V_{IH}		2.0	–	–	V
		V_{IL}		–	–	0.6	V
Input current	CE	I_{CE}	V_{CE} = 3.6V	–	5.0	10	µA
	FB	I_{FB}	V_{FB} = 0.5V	–1.0	–	1.0	µA
	VOUT	I_{VOUT}	V_{OUT} = 25V	60	82	120	µA
Soft-start time	SW	T_{SS1}	Switching stop time	10	20	70	µs
		T_{SS2}	Maximum duty restriction time	–	500	–	µs
FB voltage	FB	V_{FB}		0.49	0.50	0.51	V
Coil inductance	SW	L_{SW}		–	4.7	10	µH
Over voltage detection	VOUT	V_{OV}		25	30.5	36	V
Over voltage detection release		V_{OVR}		23	28.5	–	V

OPERATION OVERVIEW



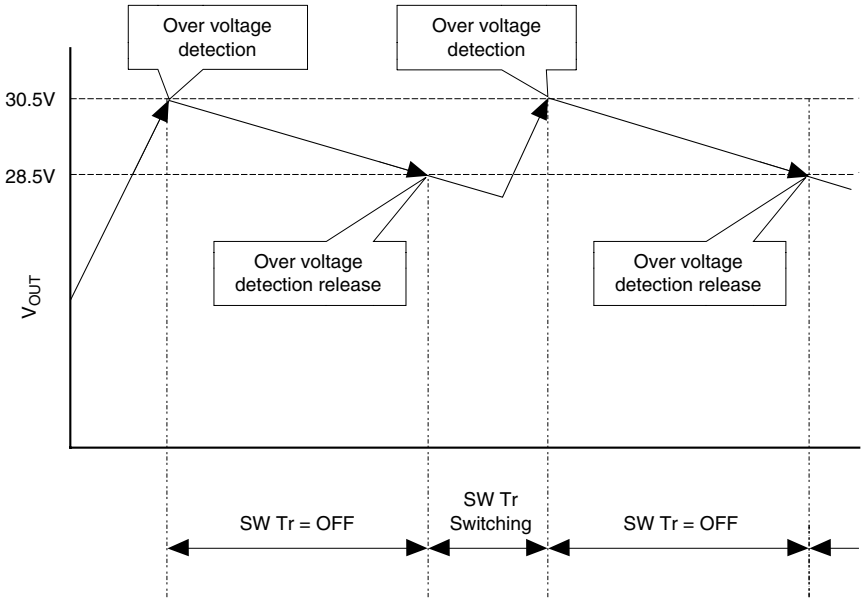
The SM8122A basic structure is a step-up DC/DC converter. The booster control employs Pulse Width Modulation (PWM) which controls the pulse duty cycle (85% max.) at constant frequency (2.0MHz typ.). The LED current is set by a current-setting resistor R1 connected between pins FB (with stable voltage of 0.5V typ.) and VSS.

When the switching transistor SW-Tr is ON, energy is stored in the inductor L. When SW-Tr is rapidly switched OFF, the energy stored in the inductor generates a voltage across the terminals of the inductor. The induced voltage, after being added to the input voltage, turns ON the Schottky barrier diode SBD and the stored energy is transferred to the output capacitor. This sequence of events continues repeatedly, boosting the output voltage.

The SM8122A features a built-in soft-start function. The soft-start time is approximately 500µs from after the chip enable input CE rising edge. During this interval, the maximum duty is restricted.

OVP (Over Voltage Protection)

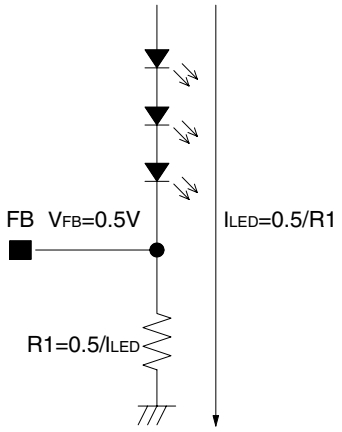
SM8122A is always monitoring the VOUT terminal voltage in order to protect itself from the stress of V_{OUT} over voltage. If SM8122A detects the V_{OUT} over voltage, it immediately stop the switching of the inductor drive transistor. After the VOUT terminal voltage decreases below the release voltage, SM8122A restarts switching the inductor drive transistor. The over voltage is set as approximately 30.5V, the release voltage is approximately 28.5V.



Selecting the Current-setting Resistor (R1)

The SM8122A control stabilizes the voltage on pin FB (0.5V typ.). Hence, the current-setting resistor R1 connected between FB and VSS sets the LED current I_{LED}, where the resistance R1 is given by the following equation.

$R1 = 0.5 / I_{LED}$



Selecting the Inductor (L)

The inductor DC resistance affects the power efficiency, therefore a low DC resistance inductor is recommended. Note also that the peak inductor current I_{peak} should not exceed the inductor maximum current rating. In pulsed current mode control, the peak inductor current I_{peak} is given by the following equation.

$I_{peak} = (V_{IN} \times T_{ON}) / L$

For example, if the input voltage V_{IN} is 3.6V, the inductance L is 4.7µH, and the SW-Tr ON time T_{ON} is 2MHz × 85% = 0.425µs, then the peak inductor current I_{peak} is $(3.6 \times 0.425 \times 10^{-6}) / (4.7 \times 10^{-6}) = 0.326A = 326mA$.

Selecting the Capacitors (C_{IN}, C_{OUT})

The recommended capacitances for use with the SM8122A are 4.7µF ceramic input capacitor C_{IN} and 1.0µF ceramic output capacitor C_{OUT}. The capacitor ESR ratings affect the ripple voltage, therefore capacitors with low ESR rating are recommended. The input capacitor should be mounted close to the SM8122A IC. Note that the capacitor voltage ratings should be selected to provide sufficient margin for the applied input and output voltages.

For example, if a lithium-ion battery (2.5 to 4.5V) is connected to the input and 3 white LEDs connected in series at the output draw 20mA, then the maximum input voltage is 4.5V and the maximum output voltage is (4.0V × 3 LEDs) + 0.5V = 12.5V. Therefore, the input capacitor should have a voltage rating of 6V, and the output capacitor should have a voltage rating of 16V.

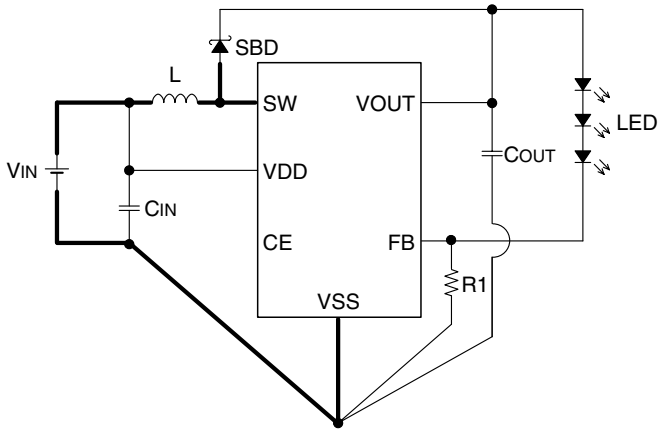
Selecting the Rectifier Schottky Barrier Diode (SBD)

The rectifier schottky barrier diode forward-direction voltage drop affects the power efficiency, therefore a Schottky barrier diode with low forward-direction voltage drop is recommended. Note that the diode should be selected to provide sufficient margin for the rated current and reverse-direction withstand voltage.

Board Layout Notes

The following precautions should be followed for stable device operation.

- The inductor L and Schottky barrier diode SBD should be connected close to the pin SW using thick, short circuit wiring.
- The input capacitor C_{IN} should be mounted close to the IC.
- The IC supply voltage V_{DD} wiring and inductor supply wiring should be isolated, reducing any common impedances.
- The ground wiring should be connected at a single point, reducing any common impedances.

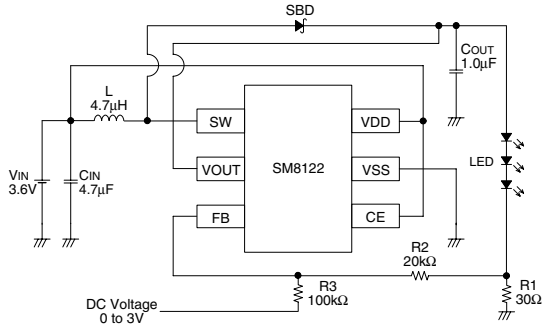


BRIGHTNESS ADJUSTMENT

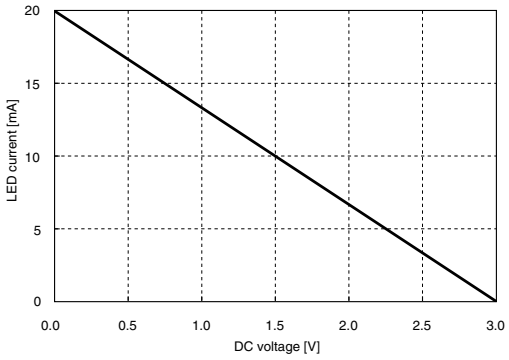
Brightness Adjustment using FB Pin

The LED brightness can be adjusted using an input DC control voltage connected through resistor R3 to the FB pin. Alternatively, the brightness can be controlled by a PWM signal by adding a low-pass filter comprising resistor R4 and capacitor C1. The PWM signal frequency range is determined by the low-pass filter coefficients. For example, the recommended values for resistor R4 (50kΩ) and capacitor C1 (0.1µF) provide a PWM signal frequency range of 1kHz to 1MHz.

Brightness adjustment using FB pin (DC voltage input)



Brightness adjustment circuit using FB pin (DC voltage input)



DC voltage vs. LED current

When the brightness is controlled by DC voltage (V_{DC}) connected to resistor R3, the LED current (I_{LED}) is given by equation 1.

$$I_{LED} = \frac{V_{FB} - \frac{R2 \times (V_{DC} - V_{FB})}{R3}}{R1} \quad \cdots (1)$$

If the values R1 = 30Ω, R2 = 20kΩ, R3 = 100kΩ, V_{FB} = 0.5V, and V_{DC} = 0V are inserted in equation 1, the LED current I_{LED} = 20mA, as shown in equation 2.

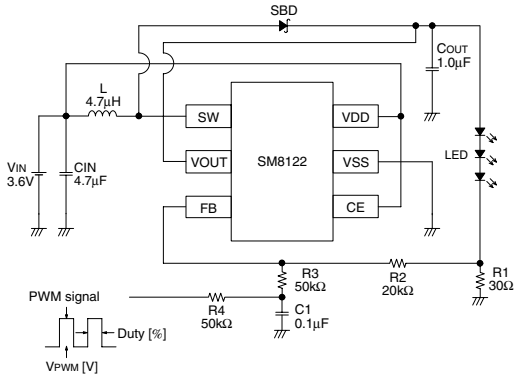
$$I_{LED} = \frac{0.5 - \frac{20{,}000 \times (0 - 0.5)}{100{,}000}}{30} = \frac{0.6}{30} = 20\text{mA} \quad \cdots (2)$$

If the values R1 = 30Ω, R2 = 20kΩ, R3 = 100kΩ, V_{FB} = 0.5V, and V_{DC} = 3V are inserted in equation 1, the LED current I_{LED} = 0mA, as shown in equation 3.

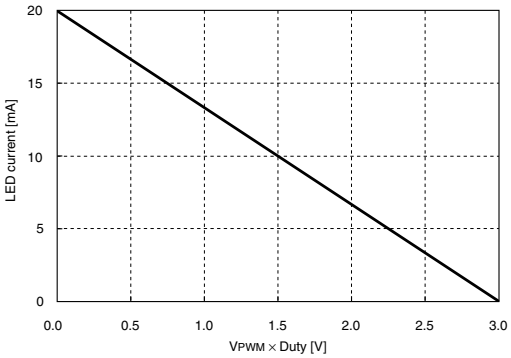
$$I_{LED} = \frac{0.5 - \frac{20{,}000 \times (3 - 0.5)}{100{,}000}}{30} = \frac{0}{30} = 0\text{mA} \quad \cdots (3)$$

Taking the above diagram as an example, inserting the values R1 = 30Ω, R2 = 20kΩ, R3 = 100kΩ, V_{FB} = 0.5V, and V_{DC} = 0 to 3V into equation 1 gives the maximum LED current I_{LED} of 20mA when V_{DC} = 0V (equation 2) and the minimum LED current I_{LED} of 0mA when V_{DC} = 3V (equation 3).

Brightness adjustment using FB pin (PWM signal input)



Brightness adjustment circuit using FB pin (PWM signal input)



PWM signal vs. LED current

When the brightness is controlled by PWM signal ($V_{PWM} \times$ Duty), the LED current (I_{LED}) is given by equation 4.

$$I_{LED} = \frac{V_{FB} - \dfrac{R2 \times (V_{PWM} \times Duty - V_{FB})}{R3 + R4}}{R1} \quad \cdots (4)$$

If the values R1 = 30Ω, R2 = 20kΩ, R3 = 50kΩ, R4 = 50kΩ, V_{FB} = 0.5V, V_{PWM} = 3V, and Duty = 0% are inserted in equation 4, the LED current I_{LED} = 20mA, as shown in equation 5.

$$I_{LED} = \frac{0.5 - \dfrac{20{,}000 \times (3 \times 0 - 0.5)}{50{,}000 + 50{,}000}}{30} = \frac{0.6}{30} = 20\text{mA} \quad \cdots (5)$$

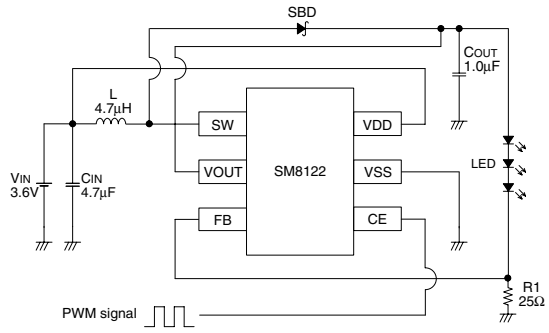
If the values R1 = 30Ω, R2 = 20kΩ, R3 = 50kΩ, R4 = 50kΩ, V_{FB} = 0.5V, V_{PWM} = 3V, and Duty = 100% are inserted in equation 4, the LED current I_{LED} = 0mA, as shown in equation 6.

$$I_{LED} = \frac{0.5 - \dfrac{20{,}000 \times (3 \times 1 - 0.5)}{50{,}000 + 50{,}000}}{30} = \frac{0}{30} = 0\text{mA} \quad \cdots (6)$$

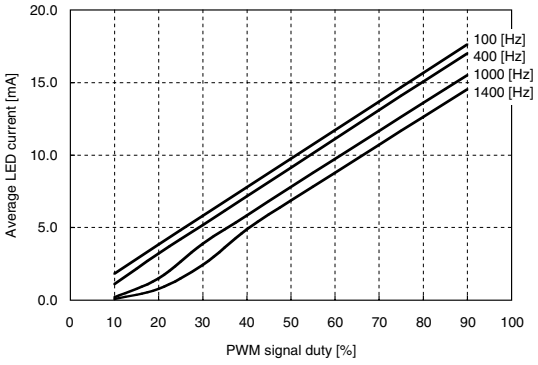
Taking the above diagram as an example, inserting the values R1 = 30Ω, R2 = 20kΩ, R3 = 50kΩ, R4 = 50kΩ, V_{FB} = 0.5V, V_{PWM} = 3V, and Duty = 0 to 100% into equation 4 gives the maximum LED current I_{LED} of 20mA when Duty = 0% (equation 5) and the minimum LED current I_{LED} of 0mA when Duty = 100% (equation 6).

Brightness Adjustment using CE Pin

The LED average current can be adjusted by controlling the duty of a PWM signal input on the CE pin. When CE goes from LOW to HIGH, the soft start function operates (with 500µs constant soft start time) and, therefore, the LED average current ratio for a given PWM signal duty falls with increasing PWM signal frequency. Taking this into consideration, the recommended PWM control signal has a frequency range of 100 to 400Hz with duty cycle range of 10 to 90%.



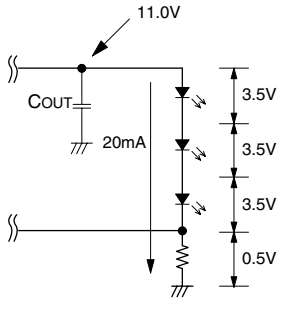
Brightness adjustment circuit using CE pin



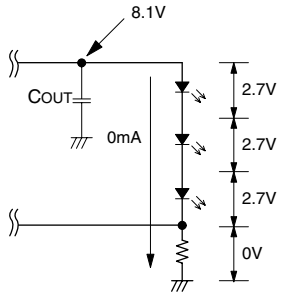
PWM signal duty vs. LED average current

When adjusting the brightness using the CE pin, a ripple voltage synchronized to the PWM signal is generated across the output capacitor C_{OUT}. The amplitude of the ripple voltage is determined by the number of LEDs and their forward-bias voltage drop characteristics. If a ceramic capacitor is used for the output capacitor C_{OUT}, an audible noise may be generated due to the ceramic capacitor's piezoelectric effect. The audible noise level depends on the ceramic capacitor (capacitance, bias dependency, withstand voltage etc.), LEDs (number, forward-bias voltage drop etc.), and mounting board (thickness, mounting conditions etc.), and thus should be verified under actual conditions.

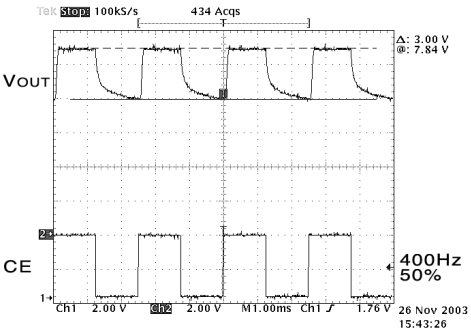
Alternatively, a tantalum capacitor or film capacitor with low piezoelectric effect can be used as the output capacitor C_{OUT} to minimize the noise level, or the brightness can be adjusted using the FB pin as described earlier. The audible noise generated when using the CE pin is not an inherent phenomena of the SM8122A device, but of the brightness adjustment method employed.



Output voltage with LEDs ON



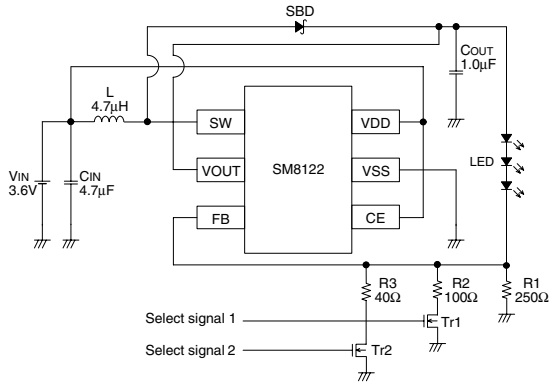
Output voltage with LEDs OFF



CE input signal and output ripple voltage

Current Switching using External Transistors

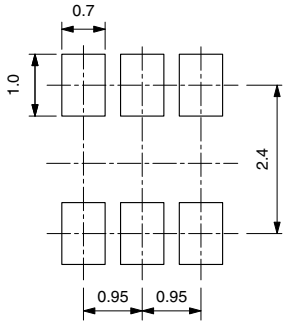
If only a few brightness steps are required, the LED current can be adjusted by switching the LED current setting resistance using external transistors (Tr).



Select signal 2	Select signal 1	I_{LED}
Low	Low	2mA
Low	High	2 + 5 = 7mA
High	Low	2 + 12.5 = 14.5mA
High	High	2 + 5 + 12.5 = 19.5mA

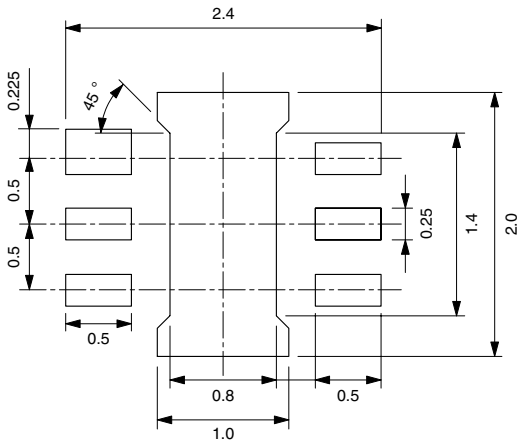
RECOMMEND PATTERN

SOT23-6W

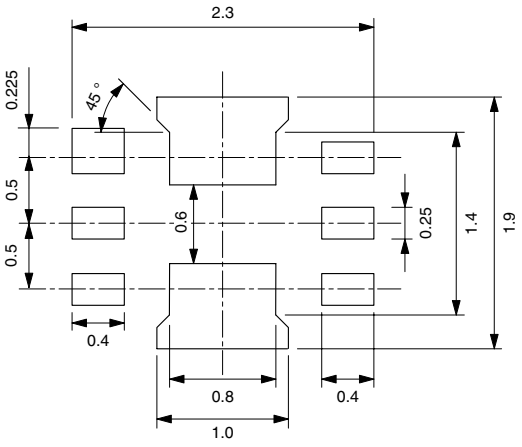


Footprint pattern

MSON-6



Footprint pattern



Metalmask pattern

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