SSL6203TW

120 V mains dimmable, 12 W linear LED driver

Rev. 2 — 5 March 2015 Product data sheet

1. General description

The SSL6203TW is a monolithic high-voltage Integrated Circuit (IC) that can drive and dim three high-voltage LED strings directly from the rectified mains. The high level of integration gives a low-cost and low component count application, which is especially suitable for retrofit Solid-State Lighting (SSL).

The IC operates as a linear high-voltage current source. The string current in the LEDs can easily be adjusted. A patented LED drive scheme ensures optimal LED utilization.

The application can be dimmed. It also runs on a leading-edge phase cut dimmer with the integrated smart bleeder current.

To guarantee correct and proper operation, the SSL6203TW incorporates many protection features.

A thermally enhanced small outline package gets rid of the heat and makes integration of the whole application on the LED plate possible.

2. Features and benefits

2.1 High-voltage integration

- Integrated 120 mA (120 V (AC) mains compatible) high-voltage current sources
- Integrated bleeder high-voltage current source
- Integrated low voltage supply regulator
- Two high-voltage current sources per output for optimal heat balancing
- Start up Junction Field Effect Transistor (JFET)
- Integrated floating switches for improving LED utilization
- Robust high-voltage IC with 330 V rating, compatible with 120 V (AC) mains voltage

2.2 Mains dimmable

- Leading-edge dimmer compatible (phase-cut)
- Adjustable bleeder current by a single resistor
- Adjustable LED current by a single resistor or controlled by a current source
- Low dimmer inrush current stress due to the absence of an electrolytic capacitor on the rectified mains

2.3 LED current

- For high-voltage LEDs
- Adjustable LED current using a single resistor or controlled by a current source
- Adjustable LED current ripple using external capacitors
- Drives three LED strings (typical string voltage ranges from approximately 43 V to 50 V (120 V (AC) mains))
- Overvoltage feedback for < 10 % line and load regulation
- Two high-voltage current sources per output for optimal heat balancing
- Patented LED drive scheme for optimal LED utilization (US 20130257282 A1)

2.4 Protections

- UnderVoltage LockOut (UVLO)
- Open LED protection on every LED string
- Protected against shorted LEDs
- OverTemperature Protection (OTP) on the high-voltage current sources

2.5 Thermal features

- Reduced IC dissipation because of the presence of dual LED current outputs per string, enabling the application of external heat dissipation resistors
- Thermally enhanced thin shrink small outline package ensuring the heat can be transported to the PCB easily
- Optimized start-up current for instantaneous on-light output

2.6 Mains current

- High power factor (> 0.9)
- Total Harmonic Distortion (THD) according to the IEC61000-3-2 standard
- No inrush current
- No EMI filter

2.7 Cost

- Low component count
- No inductors
- No mains electrolytic capacitor
- No EMI filter

2.8 Form factor

- Small form factor
- No inductors
- No EMI filter required as the SSL6203TW is a non-high-frequency switching converter
- High integration level

2.9 Smart lighting

- Setting the LED and BLEED pins to 0 V externally using a smart lighting system can switch off the IC.
- Externally controlling the LED pin with a current source using a smart lighting system can dim the LEDs.

3. Applications

- 120 V (AC) mains dimmable retrofit SSL lamps

4. Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
SSL6203TW	HTSSOP20	plastic thermal enhanced thin shrink small outline package; 20 leads; body width 4.4 mm; exposed die pad	SOT527-1

5. Block diagram

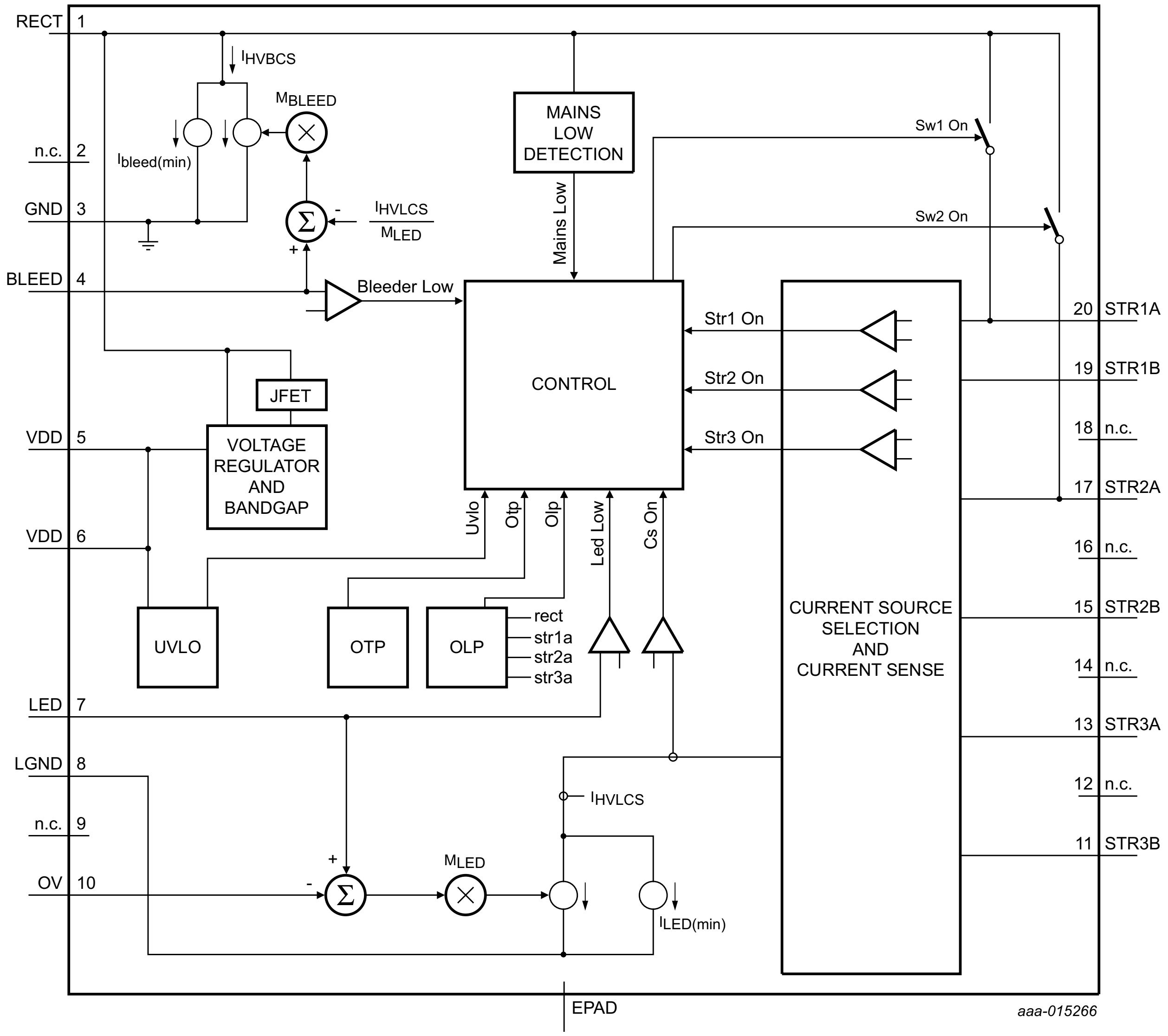


Fig 1. Block diagram

6. Pinning information

6.1 Pinning

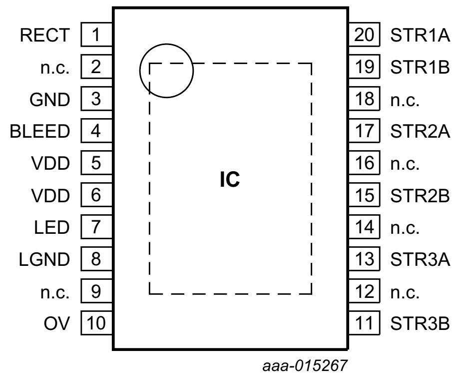


Fig 2. SSL6203TW pinning diagram

6.2 Pin description

Table 2. SSL6203TW pin description

Symbol	Pin	Description
RECT	1	rectified mains
n.c.	2	not connected
GND	3	ground
BLEED	4	bleeder reference current input
VDD	5	IC supply voltage
VDD	6	IC supply voltage
LED	7	LED reference current input
LGND	8	LED current source ground
n.c.	9	not connected
OV	10	overvoltage feedback
STR3B	11	string 3B connection
n.c.	12	not connected
STR3A	13	string 3A connection
n.c.	14	not connected
STR2B	15	string 2B connection
n.c.	16	not connected
STR2A	17	string 2A connection
n.c.	18	not connected
STR1B	19	string 1B connection
STR1A	20	string 1A connection

7. Functional description

7.1 Linear LED driver operation

The linear LED driver in the SSL6203TW operates as a high-voltage linear current source. This current source is used to drive the LEDs. Figure 3 shows a basic application diagram. Depending on the momentary value of the rectified mains voltage, the LED current flows through one or more LED strings.

To equalize the LED string on-times, integrated high-side switches short-circuit the LED strings at the appropriate moment. To set the required LED current ripple, additional capacitors can be added across every LED string. The application can be dimmed. Close to the mains zero crossing the LED current is off. To keep the dimmer in the on-state, a bleeder current starts to draw current.

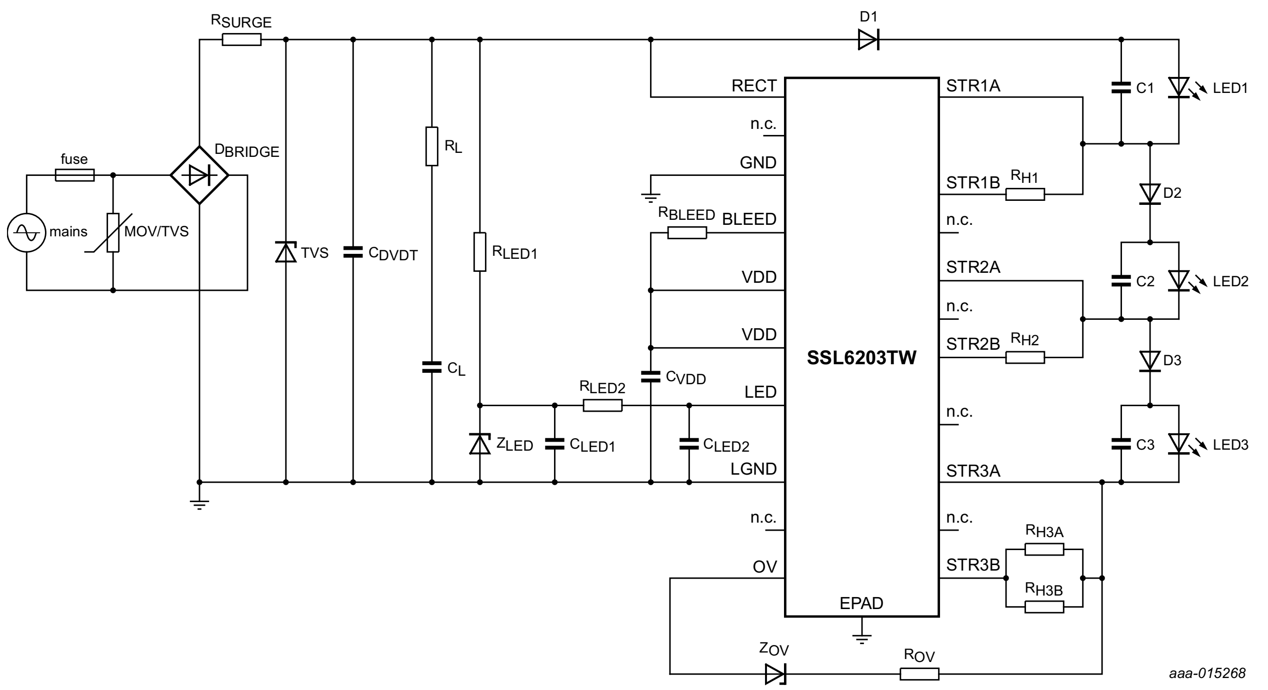


Fig 3. SSL6203TW basic application diagram

7.2 Protection mode and VDD supply generation

During start-up, the voltage on the VDD pin is < $V_{DD(stop)}$. The IC is in protection mode. When the mains voltage is applied to the SSL6203TW system (see Figure 1), an integrated JFET enables the supply voltage generation. The VDD control loop charges the external capacitor C_{VDD} and regulates the VDD voltage.

After C_{VDD} has been charged to > $V_{DD(start)}$ level, the IC proceeds to start-up mode. Should the voltage on the VDD pin drop to below $V_{DD(stop)}$, the IC enters the protection mode again.

7.3 Start-up mode

After the supply voltage has been ramped up and no other protections are active, the IC proceeds to start-up mode. To ensure a fast start-up without excessive dissipation in the IC, the charging current of the LED capacitor is dynamically adjusted to the mains voltage in start-up mode.

7.4 Normal mode

The IC proceeds to normal operation if none of the protections (UVLO, OTP, or OLP) are active and the LED capacitors have been sufficiently charged. Measuring the current into the OV pin detects that the LED capacitors are sufficiently charged. When the current into the OV drops to below $I_{th(OV)}$, the transition to normal mode can be made. In normal mode, the internal High-Voltage LED Current Source (HVLCS) is operational. The selected string output (STR1x, STR2x, STR3x) conducts.

The HVLCS current can be calculated with Equation 1:

$$I_{HVLCS} = I_{LED(min)} + max\{M_{LED} \cdot (I_{I(LED)} - I_{I(OV)}), 0\} \quad (1)$$

During normal operation, the bleeder system is enabled. The High-Voltage Bleeder Current Source (HVBCS) ensures that the dimmer is always biased with a minimum current (hold current). The HVBCS current can be calculated with Equation 2:

$$I_{HVBCS} = I_{bleed(min)} + max\left\{M_{BLEED} \cdot \left(I_{I(BLEED)} - \frac{I_{HVLCS}}{M_{LED}}\right), 0\right\} \quad (2)$$

The currents described by Equation 1 and Equation 2 reflect the DC values of the current. In an application with a leading-edge dimmer, the mains is phase-cut, resulting in a reduced average current because of a reduced duty cycle. The average LED current can drop to below a few percents of the maximum value.

7.5 IC dissipation reduction

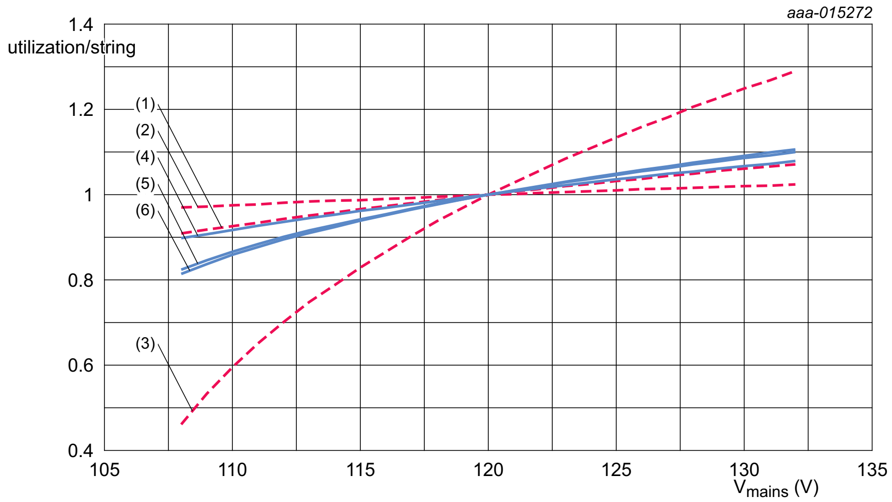
In normal operation, the number of series connected LED strings is selected according to the available RECT voltage. This selection maximizes the efficiency and minimizes the dissipation in the HVLCS.

Adding a series resistor to the STR1B, STR2B, and STR3B paths can further reduce the IC dissipation. The SSL6203TW prioritizes the HVLCS current through these paths so that dissipation takes place in the external resistors rather than in the IC. The remaining current flows into the STR1A, STR2A, and STR3A branches so that the total string current matches the LED current setting.

7.6 LED utility enhancement

The SSL6203TW optimizes the LED string switching pattern ensuring that at full power the average current of all the LED strings is almost identical. The optimization causes all LEDs to be used at maximum performance. Figure 4 shows the calculated normalized LED utilization per string for the SSL6203TW versus the average utilization per string in conventional solutions.

If insufficient voltage is available to operate the IC and three high-voltage LEDs, the conventional LED utilization scheme is used (see Figure 5).



V_{LED} = 47 V

(1) Without improved LED utilization: String 1

(2) Without improved LED utilization: String 2

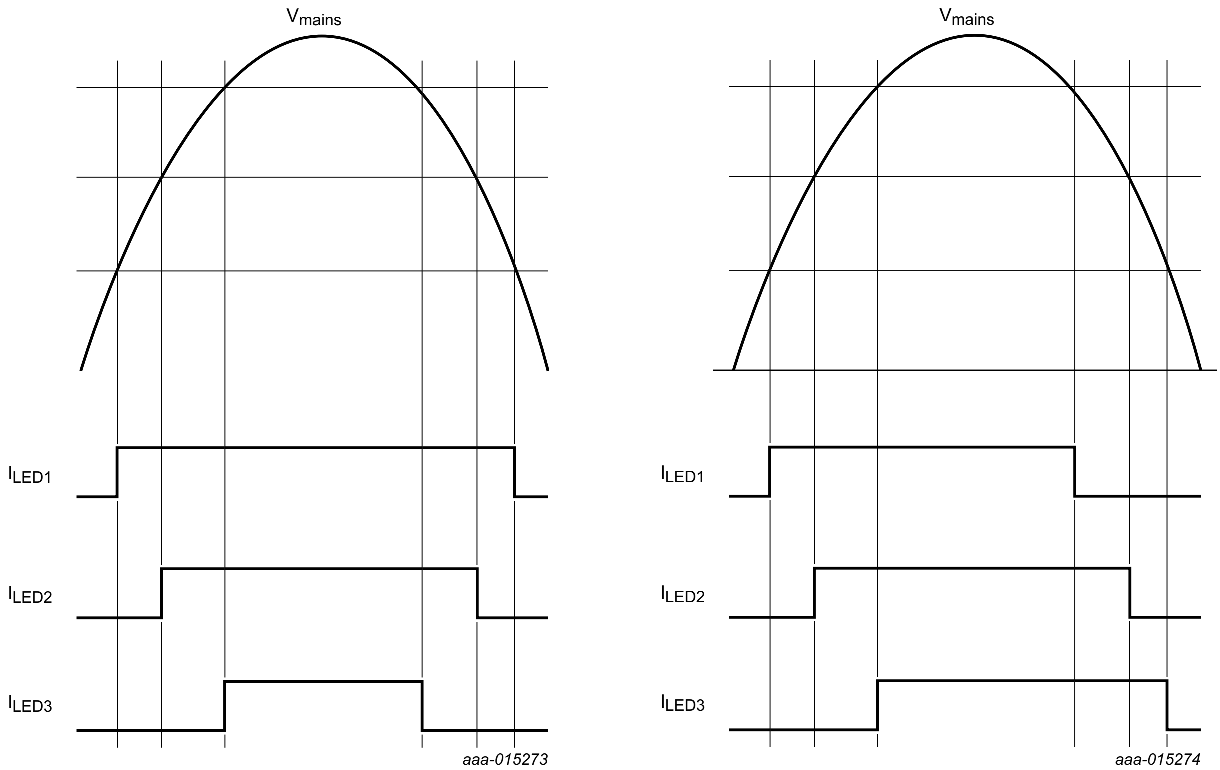
(3) Without improved LED utilization: String 3

(4) With improved LED utilization: String 1

(5) With improved LED utilization: String 2

(6) With improved LED utilization: String 3

Fig 4. Calculated LED utilization per string for SSL6203TW (blue) and conventional solutions (red) as function of mains voltage



a. Conventional LED utilization

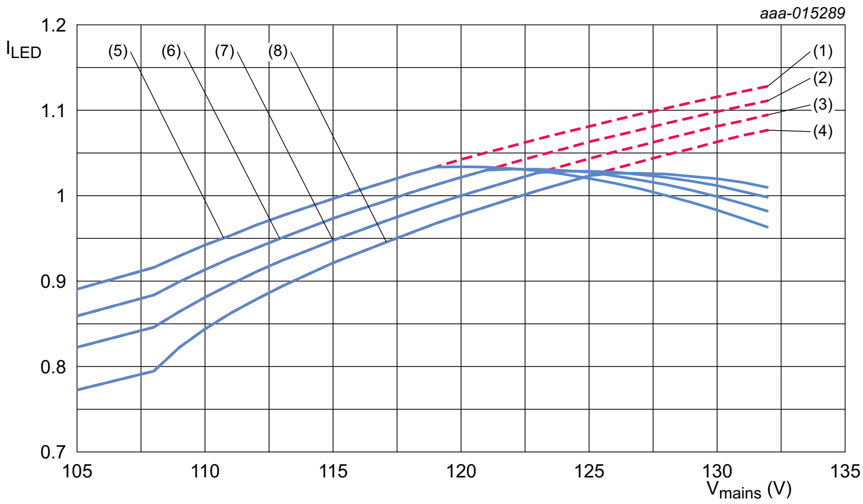
b. Optimized SSL6203TW LED utilization

Fig 5. Comparison of conventional and SSL6203TW LED utilization

7.7 Line/load regulation

A linear LED driver is sensitive to line and load variations as they affect the on-time of the LEDs (which influences the emitted light) and the dissipation in the IC. To get a more stable line/load regulation and a more constant IC dissipation, negative feedback is available through the OV pin. The feedback reduces the LED current as the mains current voltage increases, stabilizing the IC dissipation. Zener diode ZOV and resistor ROV (see Figure 3) can set the starting point and the sensitivity of the feedback.

Figure 6 shows the calculated effect of this feedback and with resulting line/load regulation.



(1) Without OV feedback; V_{LED} = 45 V

(2) Without OV feedback; V_{LED} = 46 V

(3) Without OV feedback; V_{LED} = 47 V

(4) Without OV feedback; V_{LED} = 48 V

(5) With OV feedback; V_{LED} = 45 V

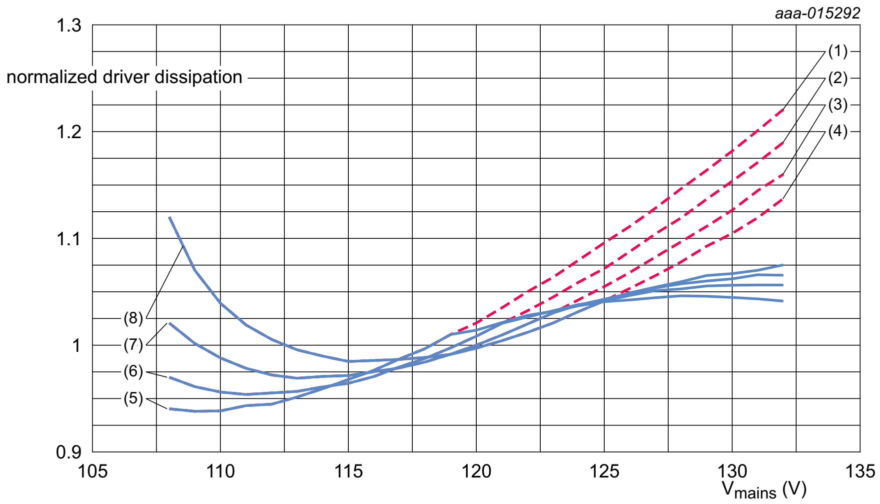
(6) With OV feedback; V_{LED} = 46 V

(7) With OV feedback; V_{LED} = 47 V

(8) With OV feedback; V_{LED} = 48 V

Fig 6. Calculated improvement of line regulation using OV feedback

The OV feedback also limits the driver dissipation at higher mains voltages. Figure 7 shows the effect.



(1) Without OV feedback; V_{LED} = 45 V
(2) Without OV feedback; V_{LED} = 46 V
(3) Without OV feedback; V_{LED} = 47 V
(4) Without OV feedback; V_{LED} = 48 V
(5) With OV feedback; V_{LED} = 45 V
(6) With OV feedback; V_{LED} = 46 V
(7) With OV feedback; V_{LED} = 47 V
(8) With OV feedback; V_{LED} = 48 V

Fig 7. Calculated normalized driver dissipation. Normalized to V_{mains} = 120 V; V_{LED} = 47 V

7.8 OverTemperature Protection (OTP)

The OTP is triggered when the die temperature reaches the $T_{th(act)otp}$ level. In that case, the IC changes to protection mode and the currents through the high-voltage current sources (both the LED and bleeder) are switched off. If the die temperature drops to below $T_{th(rel)otp}$, normal operation is resumed.

7.9 Open LED Protection (OLP)

If an LED string is open, the differential string voltage continues to rise. To protect the external buffer capacitor, an overvoltage threshold $V_{th(olp)}$ has been created. When the string voltage exceeds $V_{th(olp)}$, the IC enters the protection mode and the LED current is stopped, preventing further charging of the capacitor and destructive failure.

8. LED selection

8.1 Introduction

The SSL6203TW is designed to drive three LED strings in a 120 V (AC) mains application. For a proper operation of the application, it is important to select suitable LEDs. Below some guidelines are given. Detailed information can be found in the application note *AN11617, SSL6203TW 120 V 12 W linear LED driver*.

8.2 LED voltage rating

Suitable LEDs for use in an SSL6203TW application are 48 V high-voltage LEDs. A series connection of lower voltage LEDs, which sum up to about the same voltage level is also possible. Some considerations for selecting the LED voltage:

- When 10 % mains voltage variation is assumed, the minimum peak voltage of the mains in a 120 V (AC) system equals: $0.9 \times 120 \times \sqrt{2} = 152.7\ V$
- The bridge rectifier and the surge resistor have some voltage drop (see Figure 3)
- Voltage drop on series diodes D1, D2, and D3
- Voltage head room required for the SSL6203TW LED current source. For proper operation of the high-side switches, the IC must have 14 V on the internal LED current source
- LED voltage at its operating temperature

The remaining voltage must be high enough to accommodate three LED string voltages. The SSL6203TW incorporates an integrated Open LED Protection (OLP). The voltage of the selected LED must be lower than the $V_{th(olp)}$ level (see Section 12).

8.3 LED current rating

The maximum LED string current of the SSL6203TW can be set using the LED pin current biasing. The maximum set LED string current must be 120 mA or less. The selected LEDs must be able to handle the set LED string current. It is possible to place LEDs in parallel to divide the total string current over more LEDs.

9. Limiting values

Table 3. Limiting values
In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
Voltages					
$V_{I(RECT)}$	input voltage on pin RECT		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
$V_{I(STR1A)}$	input voltage on pin STR1A		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
$V_{I(STR1B)}$	input voltage on pin STR1B		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
$V_{I(STR2A)}$	input voltage on pin STR2A		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
$V_{I(STR2B)}$	input voltage on pin STR2B		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
$V_{I(STR3A)}$	input voltage on pin STR3A		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
$V_{I(STR3B)}$	input voltage on pin STR3B		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
$V_{I(OV)}$	input voltage on pin OV		–0.4	+200	V
		transient mains voltage; < 100 ms	–0.4	+330	V
V_{DD}	supply voltage		–0.4	+15.5	V
$V_{I(LED)}$	input voltage on pin LED		–0.4	V_{DD}	V
$V_{I(BLEED)}$	input voltage on pin BLEED		–0.4	V_{DD}	V
V_{LGND}	voltage on pin LGND		–0.4	+0.4	V
Currents					
$I_{I(RECT)}$	input current on pin RECT		-	120	mA
$I_{I(STR1A)}$	input current on pin STR1A		–120	+120	mA
$I_{I(STR1B)}$	input current on pin STR1B		-	120	mA
$I_{I(STR2A)}$	input current on pin STR2A		–120	+120	mA
$I_{I(STR2B)}$	input current on pin STR2B		-	120	mA
$I_{I(STR3A)}$	input current on pin STR3A		-	120	mA
$I_{I(STR3B)}$	input current on pin STR3B		-	120	mA
$I_{I(OV)}$	input current on pin OV		-	1	mA
$I_{I(BLEED)}$	input current on pin BLEED		-	45	μA
$I_{I(LED)}$	input current on pin LED		-	105	μA

Table 3. Limiting values *...continued*

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
General					
T_j	junction temperature	normal operation to the maximum junction temperature	–40	+125	°C
T_{stg}	storage temperature		–55	+150	°C
V_{ESD}	electrostatic discharge voltage	Human Body Model (HBM) [1]			
		pins RECT, STR1A, STR1B, STR2A, STR2B, STR3A, STR3B, OV	–800	+800	V
		all other pins	–2	+2	kV
		Charged Device Model (CDM): all pins [2]	–500	+500	V

[1] HBM: Equivalent to discharging a 100 pF capacitor through a 1.5 kΩ series resistor.

[2] CDM: Equivalent to charging the IC and the subsequent discharging of each pin down to 0 V over a 1 Ω resistor.

10. Recommended operating conditions

Table 4. Operating conditions

Symbol	Parameter	Conditions	Min	Max	Unit
$I_{I(LED)}$	input current on pin LED		-	105	μA
$I_{I(BLEED)}$	input current on pin BLEED		-	30	μA

11. Thermal characteristics

Table 5. Thermal characteristics

Symbol	Parameter	Conditions	Typ	Unit
$R_{th(j-c)}$	thermal resistance from junction to case	on NXP demo board	10	K/W

12. Characteristics

Table 6. Characteristics

T_{amb} = 25 °C; V_{DD} = 14.25 V; all voltages are measured with respect to ground (pin 3); currents are positive when flowing into the IC; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
High voltage						
$I_{ch(min)RECT}$	minimum charge current on pin RECT	internally regulated; $V_{I(RECT)}$ = 30 V; V_{DD} = 11 V	8	-	-	mA
$I_{ch(max)RECT}$	maximum charge current on pin RECT	internally regulated; $V_{I(RECT)}$ = 30 V; V_{DD} = 0 V	-	-	16	mA
Supply						
$V_{reg(VDD)}$	regulation voltage on pin VDD	$I_{I(VDD)}$ = −1 mA	13.5	14.25	15.5	V
$V_{DD(start)}$	start supply voltage		11.3	11.9	12.5	V
$V_{DD(stop)}$	stop supply voltage		9.3	9.8	10.3	V
I_{DD}	supply current	normal operation; $I_{I(BLEED)}$ = 30 μA; $I_{I(LED)}$ = 105 μA	0.5	0.8	1.1	mA
$I_{DD(pd)}$	power-down supply current	power-down; $V_{I(BLEED)} < V_{th(BLEED)}$; $V_{I(LED)} < V_{th(LED)}$	-	-	0.4	mA
Mains detection						
$V_{th(det)L(RECT)}$	LOW-level detection threshold voltage on pin RECT	falling RECT voltage	5.5	5.6	5.7	V
$V_{th(det)H(RECT)}$	HIGH-level detection threshold voltage on pin RECT	rising RECT voltage	8.9	9.0	9.1	V
Bleeder						
$V_{I(BLEED)}$	input voltage on pin BLEED	$I_{I(BLEED)}$ = 30 μA	1.65	1.75	1.85	V
$V_{th(BLEED)}$	threshold voltage on pin BLEED	to enable power-down mode	500	-	-	mV
M_{bleed}	bleeder multiplication	ratio between RECT bleeder current variation and input current variation on pin BLEED; $\Delta I_{I(BLEED)}$ = 4 μA around $I_{I(BLEED)}$ = 28 μA; $V_{I(RECT)}$ = 20 V	915	1040	1165	-
$I_{bleed(min)}$	minimum bleeder current	pin RECT; floating BLEED pin; $V_{I(RECT)}$ = 20 V	1.0	1.4	1.8	mA
$I_{bleed(startup)}$	start-up bleeder current	pin RECT; start-up state; $V_{I(RECT)}$ = 20 V	7	9	11	mA
LED string current						
$V_{I(LED)}$	input voltage on pin LED	$I_{I(LED)}$ = 105 μA	-	2.4	-	V
$V_{th(LED)}$	threshold voltage on pin LED	to enable power-down mode	500	-	-	mV

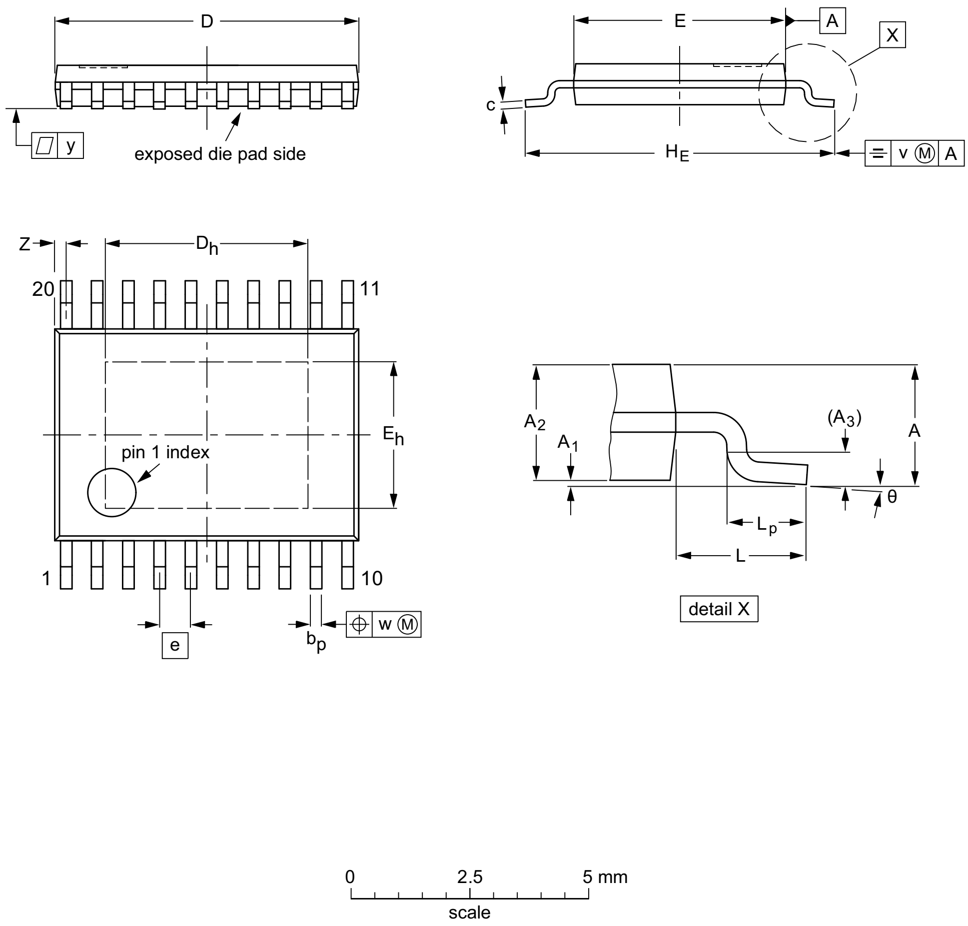
Table 6. Characteristics *…continued*

T_{amb} = 25 °C; V_{DD} = 14.25 V; all voltages are measured with respect to ground (pin 3); currents are positive when flowing into the IC; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
M_{LED}	LED multiplication	ratio between LED string current variation and input current variation on pin LED; $\Delta I_{I(LED)}$ = 10 µA around $I_{I(LED)}$ = 100 µA; $I_{I(OV)}$ = 0 µA; $V_{I(STRx)}$ = 13 V	945	985	1025	-
$I_{LED(min)}$	minimum LED current	current flowing in LED strings; $V_{I(RECT)}$ = 20 V; $V_{I(STR3A)}$ = 13 V; $I_{I(LED)}$ = 0 µA; $I_{I(OV)}$ = 0 µA	12	17	23	mA
Start-up state						
$I_{th(OV)}$	threshold current on pin OV		120	160	200	µA
$I_{startup(LED)}$	LED start-up current	current flowing in LED strings;				
		$V_{I(RECT)}$ = 20 V; $V_{I(STR3A)}$ = 13 V; $I_{I(OV)} > I_{th(OV)}$	12	17	23	mA
		$V_{I(RECT)}$ = 20 V; $V_{I(STR3A)}$ = 13 V; $I_{I(OV)} < I_{th(OV)}$	27	34	43	mA
Overvoltage feedback						
$I_{th(OV)}$	threshold current on pin OV	OV enabled	120	160	200	µA
$V_{I(OV)}$	input voltage on pin OV	$I_{I(OV)}$ = 60 µA; OV enabled	2.6	2.8	3.0	V
$V_{th(OV)}$	threshold voltage on pin OV		1.3	1.4	1.5	V
LED string short switches						
$V_{sw(RECT-STR1A)}$	switch voltage from pin RECT to pin STR1A	$I_{I(STR1A)}$ = −120 mA	-	-	5.5	V
$V_{sw(RECT-STR2A)}$	switch voltage from pin RECT to pin STR2A	$I_{I(STR2A)}$ = −120 mA	-	-	5.5	V
Open LED protection						
$V_{th(olp)}$	open load protection threshold voltage	open LED protection level on each string				
		$V_{I(RECT)}$ to $V_{I(STR1A)}$	57	64	71	V
		$V_{I(STR1A)}$ to $V_{I(STR2A)}$	57	64	71	V
		$V_{I(STR2A)}$ to $V_{I(STR3A)}$	57	64	71	V
Temperature protection						
$T_{th(act)otp}$	overtemperature protection activation threshold temperature		-	170	-	°C
$T_{th(rel)otp}$	overtemperature protection release threshold temperature		-	120	-	°C

13. Package outline

HTSSOP20: plastic thermal enhanced thin shrink small outline package; 20 leads; body width 4.4 mm; exposed die pad **SOT527-1**



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	D_h	$E^{(2)}$	E_h	e	H_E	L	L_p	v	w	y	$Z^{(1)}$	θ
mm	1.1	0.15 0.05	0.95 0.80	0.25	0.30 0.19	0.20 0.09	6.6 6.4	4.3 4.1	4.5 4.3	3.1 2.9	0.65	6.6 6.2	1	0.75 0.50	0.2	0.13	0.1	0.5 0.2	8° 0°

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic interlead protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT527-1		MO-153				~~03-04-07~~ 05-11-02

Fig 8. SOT527-1 (HTSSOP20)

14. Abbreviations

Table 7. Abbreviations

Acronym	Description
EMI	ElectroMagnetic Interference
HF	High Frequency
HVBCS	High-Voltage Bleeder Current Source
IC	Integrated Circuit
HVLCS	High-Voltage LED Current Source
JFET	Junction Field Effect Transistor
LED	Light-Emitting Diode
MOV	Metal Oxide Varistor
OLP	Open-LED Protection
OTP	OverTemperature Protection
PCB	Printed-Circuit Board
THD	Total Harmonic Distortion
TVS	Transient Voltage Suppressor
UVLO	UnderVoltage LockOut

15. Revision history

Table 8. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
SSL6203TW v.2	20150305	Product data sheet	-	SSL6203TW v.1
Modifications:	• The data sheet status has changed from Objective to Product • Text and graphics have been updated throughout the data sheet.			
SSL6203TW v.1	20141103	Objective data sheet	-	-

16. Legal information

16.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term ‘short data sheet’ is explained in section “Definitions”.

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

16.2 Definitions

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17. Contact information

For more information, please visit: **http://www.nxp.com**

For sales office addresses, please send an email to: **salesaddresses@nxp.com**

18. Contents

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