SSL21101T
GreenChip driver for LED lighting
Rev. 3 — 7 June 2012 **Product data sheet**

1.   General description

The SSL21101T is a Switch Mode Power Supply (SMPS) driver IC. It is designed to drive LED devices typically in flyback configurations. The device includes a high-voltage power switch and a circuit enabling start-up directly from the rectified mains voltage. It has accurate control of the output current.

2.   Features and benefits

- Small Printed-Circuit Board (PCB) footprint and compact solution with a small form factor
- Ease of integration
- Low component count (complete application with about 25 components)
- AC/DC offline non-dimmable LED driver from 100 V (AC) to 230 V (AC)
- Primary side sensing (no optocoupler required)
- True current source behavior:
    - LED current independent of mains voltage, LED voltage, temperature and coil variation
    - High LED current accuracy (±3 %)
- Efficiency up to 90 % depending on the application
- Smart Digital Control (SDC) to deal with all kind of applications:
    - High-Power Factor (PF; > 0.95) and low Total Harmonic Distortion Mode (THD down to 20 %)
    - Small form factor (low LED current mode ripple with small electrolytic capacitors) - compatible with exception clause IEC61000-3-2
- Internal protections:
    - Short-winding protection
    - Internal OverTemperature Protection (OTP)
    - LED short protection
    - LED open protection
    - UnderVoltage LockOut (UVLO)
- External temperature protection with built-in Negative Temperature Coefficient (NTC)
- Internal supply voltage generation enabling start-up from the rectified mains voltage
- Compatible with wall switches with built-in indication light during standby
- SO14 package

3. Applications

■ The SSL21101T is suitable for different power requirements:
  ◆ SSL, retrofit lamps (for example: small-size light bulbs, LED spots, up to 10 W or 12 W
  ◆ LED modules, mains AC/DC converter (for example: down-lights, up to 15 W)
  ◆ LED strings (for example: retail display; up to 15 W)

4. Quick reference data

Table 1. **Quick reference data**

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{CC}	supply voltage	functional	13	22	25.5	V
R_{DSon}	drain-source on-state resistance	T_j = 25 °C	-	6.8	-	Ω
		T_j = 125 °C	-	9.5	-	Ω
$f_{sw(max)}$	maximum switching frequency	DCM mode; main = 50 Hz; mode = 50 kHz	[1] 49.7	51.2	52.7	kHz
		DCM mode; main = 60 Hz; mode = 50 kHz	[1] 59.7	61.4	63.2	kHz
		DCM mode; modemain = 50 Hz; mode = 100 kHz	[1] 99.4	102.4	105.4	kHz
		DCM mode; main = 60 Hz; mode = 100 kHz	[1] 119.4	122.9	126.4	kHz
$I_{M(DRAIN)}$	peak current on pin DRAIN		0	-	1.2	A
V_{DRAIN}	voltage on pin DRAIN		−0.4	-	+700	V

[1] For a given $V_{I(ILEDREF)}$ and V_{NTC} > 1.25 V. See Table 5.

5. Ordering information

Table 2. **Ordering information**

Type number	Package		
	Name	Description	Version
SSL21101T/1	SO14	plastic small outline package; 14 leads; body width 3.9 mm	SOT108-1

6. Block diagram

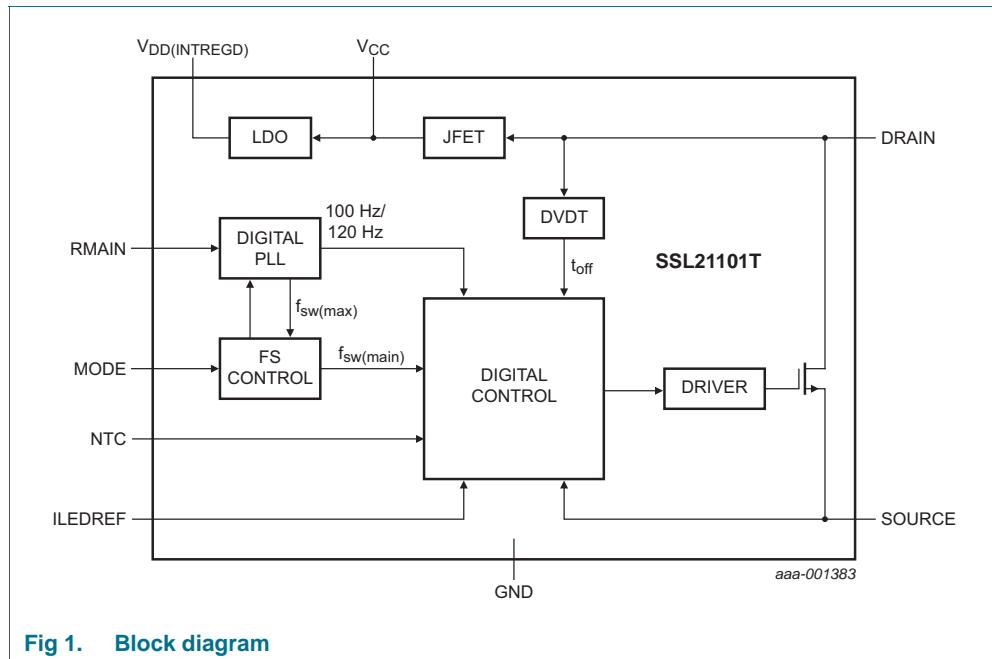

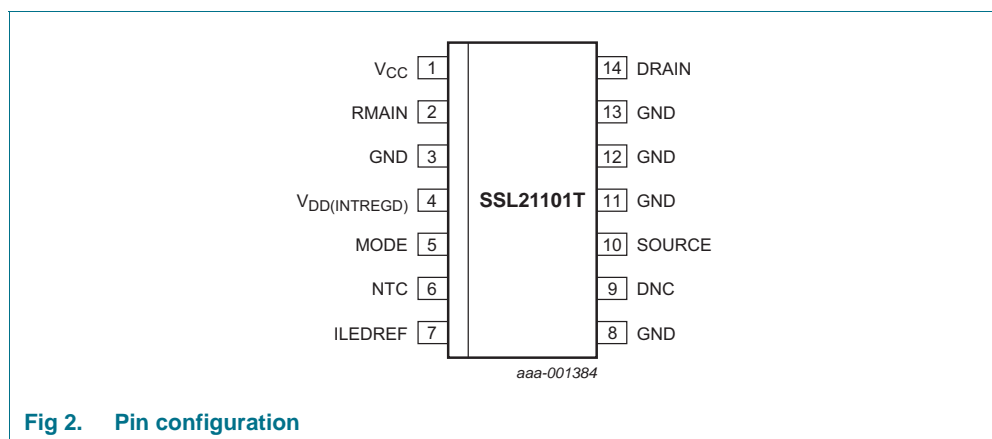**Fig 1. Block diagram**

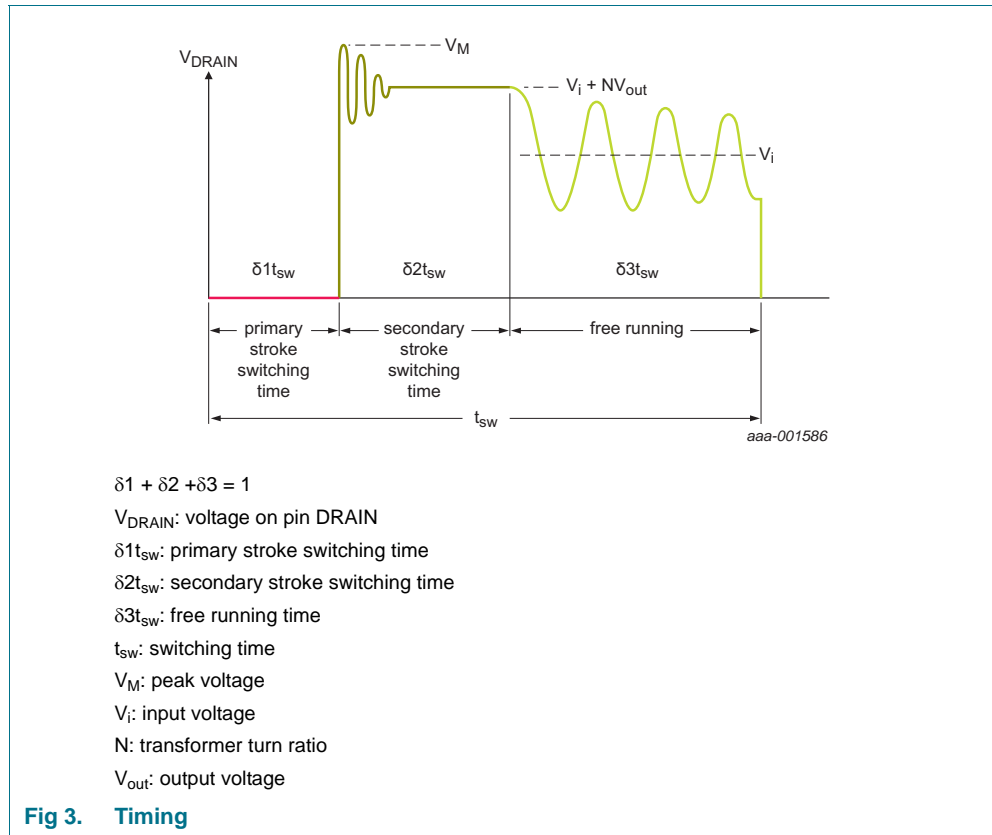## 7. Pinning information

7.1 Pinning

Fig 2. Pin configuration

7.2 Pin description

Table 3.   Pin description

Symbol	Pin	Description
V_{CC}	1	supply voltage
RMAIN	2	current source proportionally equivalent of V_{main}
GND	3	ground
$V_{DD(INTREGD)}$	4	internal regulated supply
MODE	5	power factor/THD and maximum switching frequency control input
NTC	6	LED temperature protection input
ILEDREF	7	LED current control input
GND	8	ground
DNC	9	do not connect
SOURCE	10	source of internal power switch
GND	11	ground
GND	12	ground
GND	13	ground
DRAIN	14	drain of internal power switch

8. Functional description

The SSL21101T is an integrated circuit intended for retrofit small form factor SSL lamps. It provides a controller with an internal high-voltage switch to drive LEDs. It operates directly from the rectified mains.

$\delta1 + \delta2 + \delta3 = 1$

V_{DRAIN}: voltage on pin DRAIN

$\delta1t_{sw}$: primary stroke switching time

$\delta2t_{sw}$: secondary stroke switching time

$\delta3t_{sw}$: free running time

t_{sw}: switching time

V_M: peak voltage

V_i: input voltage

N: transformer turn ratio

V_{out}: output voltage

Fig 3.   Timing

8.1 True current source behavior

The LED current (I_{LED}) of a flyback converter can be calculated with Equation 1:

$$I_{LED} = \frac{1}{2} \times N \times I_M \times \frac{\delta2t_{sw}}{t_{sw}}$$

(1)

Where:

- N is the turn ratio of the transformer
- I_M is the peak current
- $\delta2t_{sw}$ is the secondary stroke switching time
- t_{sw} is the switching period

The relationship between the LED current and pin ILEDREF can be calculated with Equation 2:

$$I_{LED} = \frac{0.45 \times N \times V_{I(ILEDREF)}}{V_{DD(INTREGD)} \times R_{SOURCE}}$$

(2)

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Where:

- $V_{I(ILEDREF)}$ is the voltage defined at the input of pin ILEDREF
- $V_{DD(INTREGD)}$ is the internal regulated voltage
- R_{SOURCE} is the resistor connected to pin SOURCE of the power MOS transistor.

The true current source behavior and the LED current accuracy are achieved using an internal digital control. The internal digital control compares the ILEDREF pin reference with the measurement of the average LED current over a half-main cycle. The primary peak current (I_M) is adjusted at each half-main cycle to achieve the expected LED current.

The expected primary peak current value on the application can be calculated with Equation 3:

$$I_M = \frac{V_{th(det)SOURCE}}{R_{SOURCE}} \tag{3}$$

Where:

- $V_{th(det)SOURCE}$ is the detection threshold voltage on pin SOURCE
- R_{SOURCE} is the resistor connected to pin SOURCE of the power MOS transistor

8.2 Leading-Edge Blanking (LEB)

The controller automatically adjusts LEB to avoid wrong detection of the primary peak current.

8.3 dV/dt detection

A dV/dt detector block is used on pin DRAIN to detect the end of demagnetization and possible valleys accurately. A valley switching concept is used for efficiency purposes.

8.4 Secondary stroke switching time ($\delta 2t_{sw}$)

A blanking time (t_{blank}) is applied at the beginning of $\delta 2t_{sw}$ before observing the demagnetization.

$\delta 2t_{sw}$ must have a value that allows the application to run in DCM mode.

For example, for a 100 kHz switching frequency the application design must provide a typical secondary stroke switching time ($\delta 2t_{sw}$) ranging from 4 μs to 6 μs.

8.5 Mains sensing

Pin RMAIN senses the mains voltage (V_{main} in Equation 4) in real time and transforms it to mains current (I_{main} in Equation 4):

$$I_{main} = \frac{V_{main} \times \sqrt{2}}{R_{RMAIN}} \tag{4}$$

Table 4. **Mains resistance/mains current dependency**

Mains voltage	Mains resistance	Mains current
220 V (AC)/230 V (AC)	1 MΩ	300 μA
100 V (AC)/120 V (AC)	470 kΩ	300 μA

8.6 Modulation type versus MODE pin input

Pin MODE enables the control of both the THD/LED ripple and the switching frequency operation mode. This input has a range of 0 V to $V_{DD(INTREGD)}$. Depending on the mains frequency (50 Hz or 60 Hz), the following modes can be selected to ensure a flexible application.

- Low THD mode: for example, THD ≈ 20 %; C_i = 200 nF for an 8 W application
- LR mode: C_i = 2.2 μF for an 8 W application

Selecting a maximum switching frequency (50 kHz/60 kHz or 100 kHz/120 kHz) is also possible.

Table 5. **MODE description**

MODE voltage range	Behavior	Maximum switching frequency
$V_{DD(INTREGD)} \geq V_{MODE} > 5 \times V_{DD(INTREGD)} / 6$	low THD	100 kHz/120 kHz
$5 \times V_{DD(INTREGD)} / 6 > V_{MODE} > 4 \times V_{DD(INTREGD)} / 6$	low THD	50 kHz/60 kHz
$4 \times V_{DD(INTREGD)} / 6 > V_{MODE} > 2 \times V_{DD(INTREGD)} / 6$	not functional	not applicable
$2 \times V_{DD(INTREGD)} / 6 > V_{MODE} > 1 \times V_{DD(INTREGD)} / 6$	low ripple	50 kHz/60 kHz
$1 \times V_{DD(INTREGD)} / 6 > V_{MODE} \geq 0$	low ripple	100 kHz/120 kHz

The SSL21101T IC can reach a high-power factor in combination with a low THD without an external PFC. It can also reduce the LED current ripple when the low ripple mode is selected. Controlling the switching frequency value over a main cycle gives the input current waveform.

The modulation controller takes into account the information of the Boundary Conduction Mode (BCM) detection. The chip has optimized performances in Discontinuous Conduction Mode (DCM). The IC prevents that the application enters Continuous Conduction Mode (CCM) and forces it to enter Boundary Conduction Mode (BCM).

Remark: Select specific values for external components, such as transformers and R_{SOURCE} to avoid forced BCM, otherwise THD and the LED current ripple performances are directly impacted.

8.7 Supply concept: V_{CC} and UnderVoltage LockOut (UVLO)

An integrated Junction gate Field-Effect Transistor (JFET), connected to the drain voltage, provides the start-up current.

The IC starts switching when the voltage on pin V_{CC} exceeds the $V_{CC(startup)}$ level. After start-up, an external supply is required, which an auxiliary winding connection can provide. When the voltage on pin V_{CC} drops below the $V_{CC(UVLO)}$ level, the IC stops switching and is reset.

The IC is compatible with a wall switch with built-in light that is activated when wall switch is in the off position.

8.8 Peak current detection

The cycle-by-cycle peak drain current limit circuit uses the external source resistor R_{SOURCE} to measure the primary peak current. The circuit is activated after the leading edge blanking time. The protection circuit limits the source voltage over resistor R_{SOURCE} to $V_{th(det)SOURCE}$, thus limiting the primary peak current.

8.9 Overheating protection of the LEDs

Input pin NTC ensures the protection of the LEDs against overheating. The target is:

Table 6.   NTC description

Temperature	LED current
$V_{NTC} > V_{det(H)(NTC)}$	LED current is 100 % of the expected LED current
$V_{det(H)(NTC)} > V_{NTC} > V_{det(L)(NTC)}$	Linear reduction of LED current: 25 %
$V_{det(L)(NTC)} > V_{NTC}$	Standby mode (LED current = 0)

Remark: After Standby mode, LED current only flows again when V_{NTC} exceeds $V_{det(H)(NTC)}$.

There are two detection levels on pin NTC:

- level 1 = $V_{det(H)(NTC)}$
- level 2 = $V_{det(L)(NTC)}$

These detection levels can be translated to temperature levels using an NTC resistor for which the levels have been optimized. Figure 4 shows an application using a 100 kΩ NTC resistor and equivalent temperature detection levels.
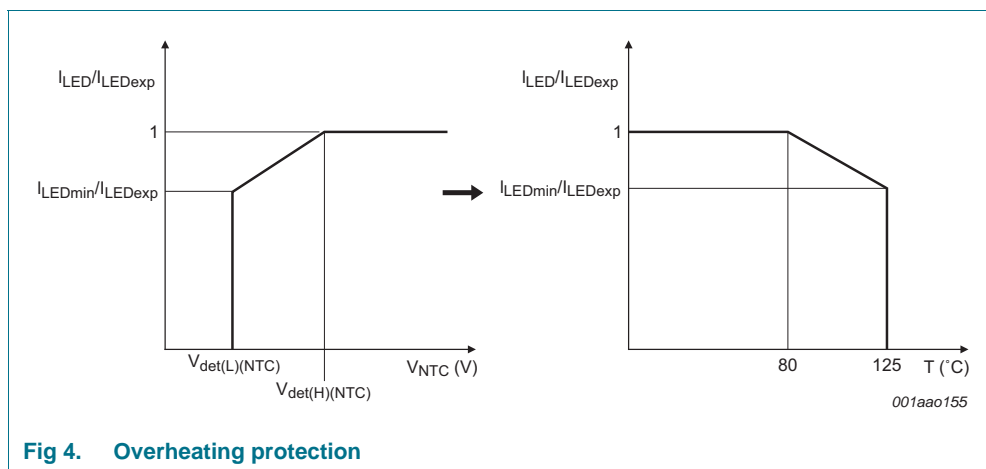

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Fig 4.   Overheating protection

8.10 Short-winding protection

The short-winding protection circuit is activated after the leading edge blanking time. If the source voltage exceeds the short-winding protection threshold voltage ($V_{th(swp)SOURCE}$), the IC stops switching. Only a power-on reset restarts normal operation (switching off the mains voltage).

8.11 Output LED short circuit protection

When during one rectified mains waveform the following conditions are true, the output short detection is activated and the IC enters Shutdown mode.

- $\delta 2 t_{sw} > t_{prot(sc)LED}$
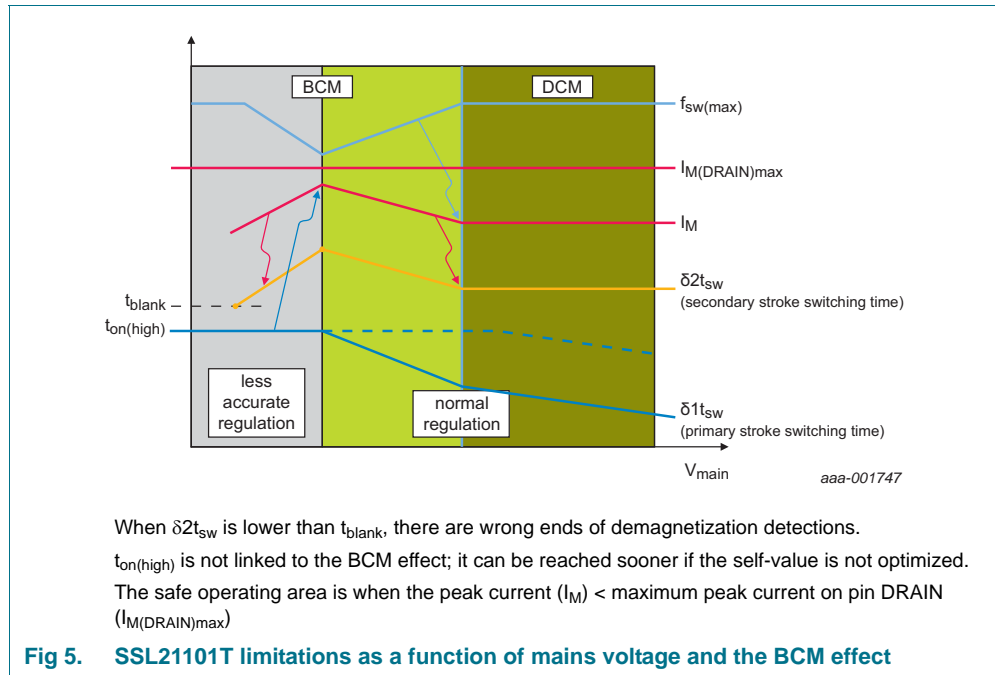- $\delta 1 t_{sw} < t_{on(high)}$

8.12 Output LED open circuit protection

If an open circuit occurs on the LEDs, the output voltage increases at each cycle of the AC/DC converter. Energy is no longer transferred to the LEDs. The energy accumulated at the primary side is transferred to the supply of the IC via the auxiliary winding. The IC enters Shutdown mode when V_{CC} reaches the $V_{prot(VCC)}$ value. Only a power-on reset restarts normal operation (switching off the mains voltage).

8.13 Limitations

The application must stay in DCM mode for normal functionality. During normal switching, the primary stroke switching time must stay under $t_{on(high)}$ to keep an accurate LED current.

When the application is working outside the defined main voltage range, meaning below the minimum mains voltage, the application can work in BCM mode. Figure 5 shows some of the effects that can be seen in this case.

When $\delta2t_{sw}$ is lower than t_{blank}, there are wrong ends of demagnetization detections.

$t_{on(high)}$ is not linked to the BCM effect; it can be reached sooner if the self-value is not optimized.

The safe operating area is when the peak current (I_M) < maximum peak current on pin DRAIN ($I_{M(DRAIN)max}$)

Fig 5. **SSL21101T limitations as a function of mains voltage and the BCM effect**

In BCM mode, the maximum frequency is not reached. The control first increases the peak current (I_M) and then the secondary stroke switching time ($\delta2t_{sw}$) to maintain the output power. When the mains voltage decreases, $\delta1t_{sw}$ increases. When $\delta1t_{sw}$ reaches $t_{on(high)}$, the LED current is less accurate.

9. Limiting values

Table 7.   Limiting values

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

Symbol	Parameter	Conditions		Min	Max	Unit
General						
P_{tot}	total power dissipation			-	0.8	W
T_{stg}	storage temperature			−55	+150	°C
T_j	junction temperature			−40	+150	°C
V_{ESD}	electrostatic discharge voltage	Human Body Model (HBM)	[1]			
		pins DRAIN and V_{CC}		−1000	+1000	V
		all other pins		−2000	+2000	V
		Charged Device Model (CDM)		−500	+500	V
Voltages						
V_{CC}	supply voltage	continuous		−0.4	+40	V
$V_{DD(INTREGD)}$	internal regulated supply voltage			−0.4	+5.5	V
V_{RMAIN}	voltage on pin RMAIN			−0.4	+1.7	V
V_{SOURCE}	voltage on pin SOURCE			−0.4	+5.5	V
V_{DRAIN}	voltage on pin DRAIN			−0.4	+700	V
$V_{ILEDREF}$	voltage on pin ILEDREF			−0.4	+5.5	V
V_{MODE}	voltage on pin MODE			−0.4	+5.5	V
V_{NTC}	voltage on pin NTC			−0.4	+5.5	V
Currents						
$I_{M(SOURCE)}$	peak current on pin SOURCE			−1.2	0	A
$I_{M(DRAIN)}$	peak current on pin DRAIN			0	1.2	A
$I_{M(RMAIN)}$	peak current on pin RMAIN			0	450	µA

[1]   Human body model: equivalent to discharging a 100 pF capacitor through a 1.5 kΩ series resistor.

10. Thermal characteristics

Table 8.   Thermal characteristics

Symbol	Parameter	Conditions	Typ	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air; SO14 package; PCB: 906 mm²; 2-layer; 35 µm Cu/layer	70	K/W

[1] $R_{th(j-a)}$ can be lower when the GND pins are connected to an area with sufficient copper on the printed-circuit board.

11. Characteristics

Table 9.   Characteristics

$T_{amb} = 25\ ^\circ C$

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supply						
I_{CC}	supply current	pin V_{CC}; $V_{DRAIN} > 60$ V; $V_{CC} = 22$ V; $T_j = 25\ ^\circ C$	0.15	0.8	1.4	mA
V_{CC}	supply voltage	functional	13	22	25.5	V
$I_{CC(startup)}$	start-up supply current	pin V_{CC}; $V_{DRAIN} > 60$ V; $V_{CC} = 15$ V; $T_j = 125\ ^\circ C$	-	-	1.46	mA
$V_{CC(startup)}$	start-up supply voltage		15	17	19	V
$V_{CC(UVLO)}$	undervoltage lockout supply voltage		9.5	11	13	V
$I_{startup(DRAIN)}$	start-up current on pin DRAIN	$V_{DRAIN} > 60$ V; $V_{CC} = 14$ V; $T_j = 125\ ^\circ C$	870	1200	1530	μA
		$V_{DRAIN} > 60$ V; $V_{CC} = 19$ V; $T_j = 125\ ^\circ C$	500	700	900	μA
$V_{BR(DRAIN)}$	breakdown voltage on pin DRAIN		-	-	700	V
Output stage						
R_{DSon}	drain-source on-state resistance	$T_j = 25\ ^\circ C$	-	6.8	-	Ω
		$T_j = 125\ ^\circ C$	-	9.5	-	Ω
$(dV/dt)_{r(DRAIN)}$	rise rate of change voltage on pin DRAIN		-	6	-	V/ns
$(dV/dt)_{f(DRAIN)}$	fall rate of change voltage on pin DRAIN		-	3	-	V/ns
$t_{on(high)}$	high on-time	MOSFET on-time limitation; main = 50 Hz; mode = 50 kHz	15.8	16.7	17.6	μs
		main = 60 Hz; mode = 50 kHz	13.1	13.9	14.7	μs
		main = 50 Hz; mode = 100 kHz	7.9	8.55	9.3	μs
		main = 60 Hz; mode = 100 kHz	6.5	7.1	7.7	μs

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Table 9. **Characteristics** *…continued*

$T_{amb} = 25$ °C

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{prot(sc)LED}$	LED short-circuit protection time	secondary stroke switching time;				
		main = 50 Hz	33.8	35.8	37.7	µs
		main = 60 Hz	28.1	29.8	31.5	µs
Temperature protection						
$T_{th(otp)}$	overtemperature protection threshold temperature	junction temperature	-	140	-	°C
$T_{otp(hys)}$	overtemperature protection trip hysteresis	junction temperature	-	20		°C
Regulator						
$V_{DD(INTREGD)}$	internal regulated supply voltage		4.6	4.9	5.2	V
$V_{DD(rst)}$	reset supply voltage	power-on reset	-	-	4.55	V
$V_{prot(VCC)}$	protection voltage on pin VCC		25.5	28	31	V
$V_{th(det)SOURCE}$	detection threshold voltage on pin SOURCE		0.65	-	0.85	V
$V_{th(swp)SOURCE}$	short-winding protection threshold voltage on pin SOURCE		-	$1.5 V_{th(det)SOURCE}$	-	V
Demagnetization						
t_{blank}	blanking time	main = 50 Hz	2.56	2.85	3.14	µs
		main = 60 Hz	2.14	2.37	2.62	µs
Frequency switching						
$f_{sw(max)}$	maximum switching frequency	DCM mode; main = 50 Hz; mode = 50 kHz	[1] 49.7	51.2	52.7	kHz
		DCM -mode; main = 60 Hz; mode = 50 kHz	[1] 59.7	61.4	63.2	kHz
		DCM mode; main = 50 Hz; mode = 100 kHz	[1] 99.4	102.4	105.4	kHz
		DCM mode; main = 60 Hz; mode = 100 kHz	[1] 119.4	122.9	126.4	kHz

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Table 9. **Characteristics** *…continued*

$T_{amb} = 25$ ℃

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
True current source (current accuracy)						
ΔI_o	output current variation	main variation: +10 % to −15 %	−3	-	+3	%
		output voltage variation: ±20 %	−3	-	+3	%
		temperature variation: $\Delta T_j = 140$ °C	−3	-	+3	%
		coil variation: ±20 %	−3	-	+3	%
NTC						
$V_{det(H)(NTC)}$	HIGH-level detection voltage on pin NTC		$0.23V_{DD(INTREGD)}$	$0.25V_{DD(INTREGD)}$	$0.27V_{DD(INTREGD)}$	V
$V_{det(L)(NTC)}$	LOW-level detection voltage on pin NTC		$0.115V_{DD(INTREGD)}$	$0.125V_{DD(INTREGD)}$	$0.135V_{DD(INTREGD)}$	V
I_{LED}/I_{LEDexp}	LED current to expected LED current ratio	[2]	-	1	-	
I_{LEDmin}/I_{LEDexp}	minimum LED current to expected LED current ratio	[2]	-	0.75	-	

[1]   See Table 5.

[2]   See Figure 4.

12. Application information

The two different types of application (LTHD mode and LR mode) are shown in Figure 6 and Figure 7. More information can be found in the application note *"SSL21101T flexible focus flyback LED driver application (AN11100)"*.

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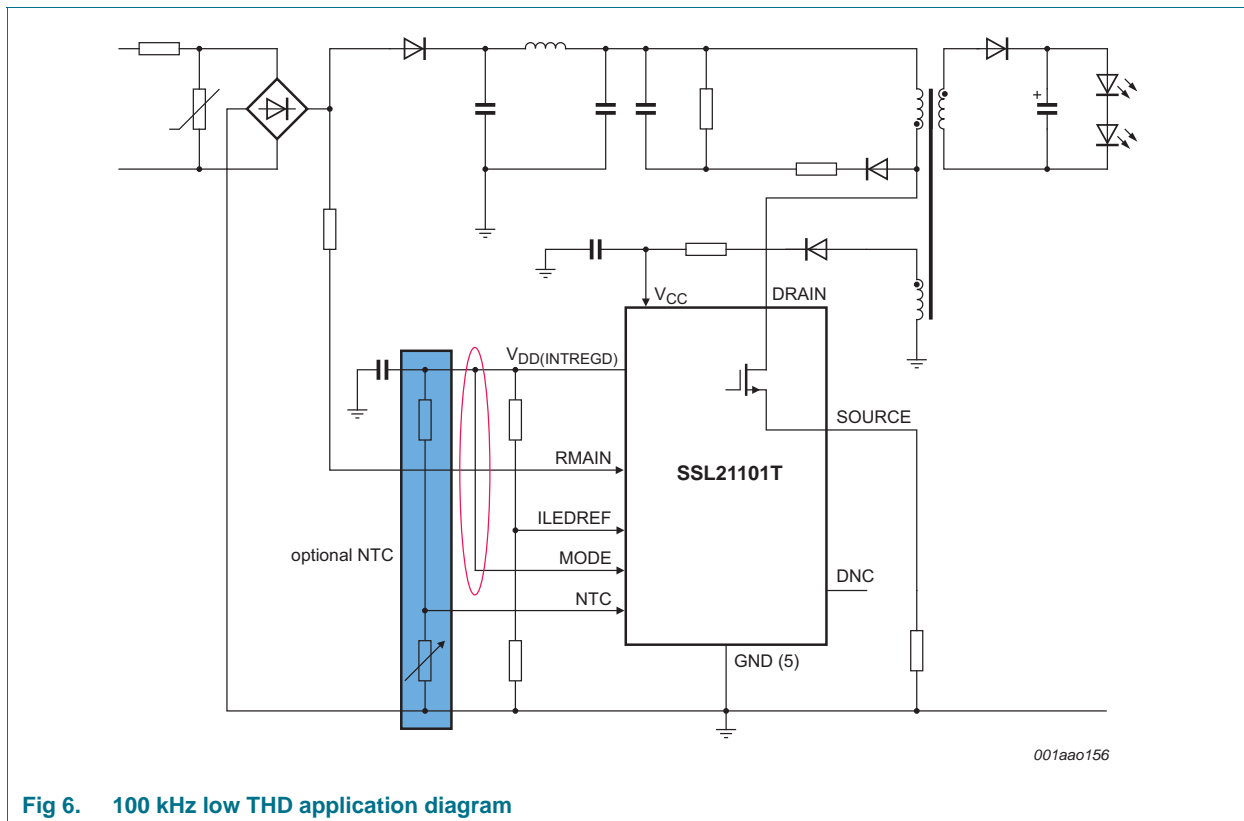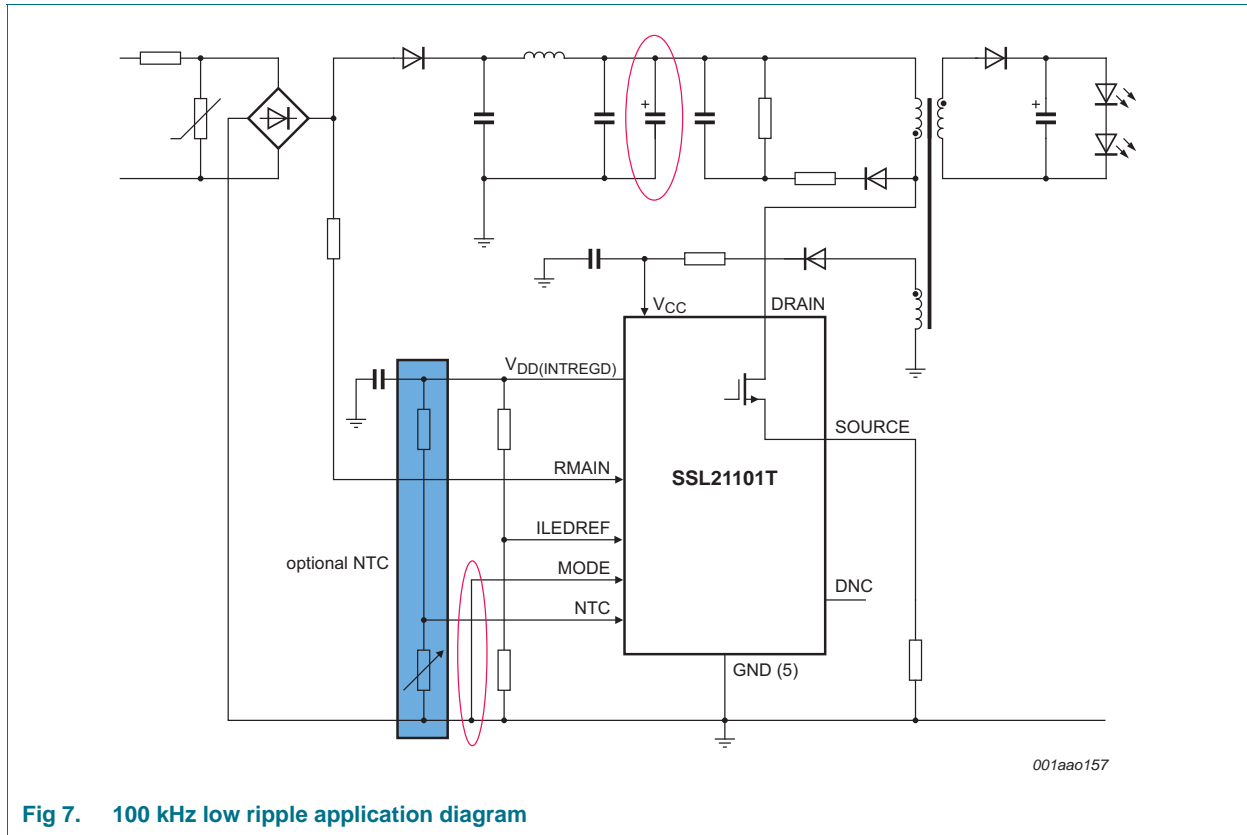
Fig 6.   100 kHz low THD application diagram

Fig 7.   **100 kHz low ripple application diagram**

13. Package outline

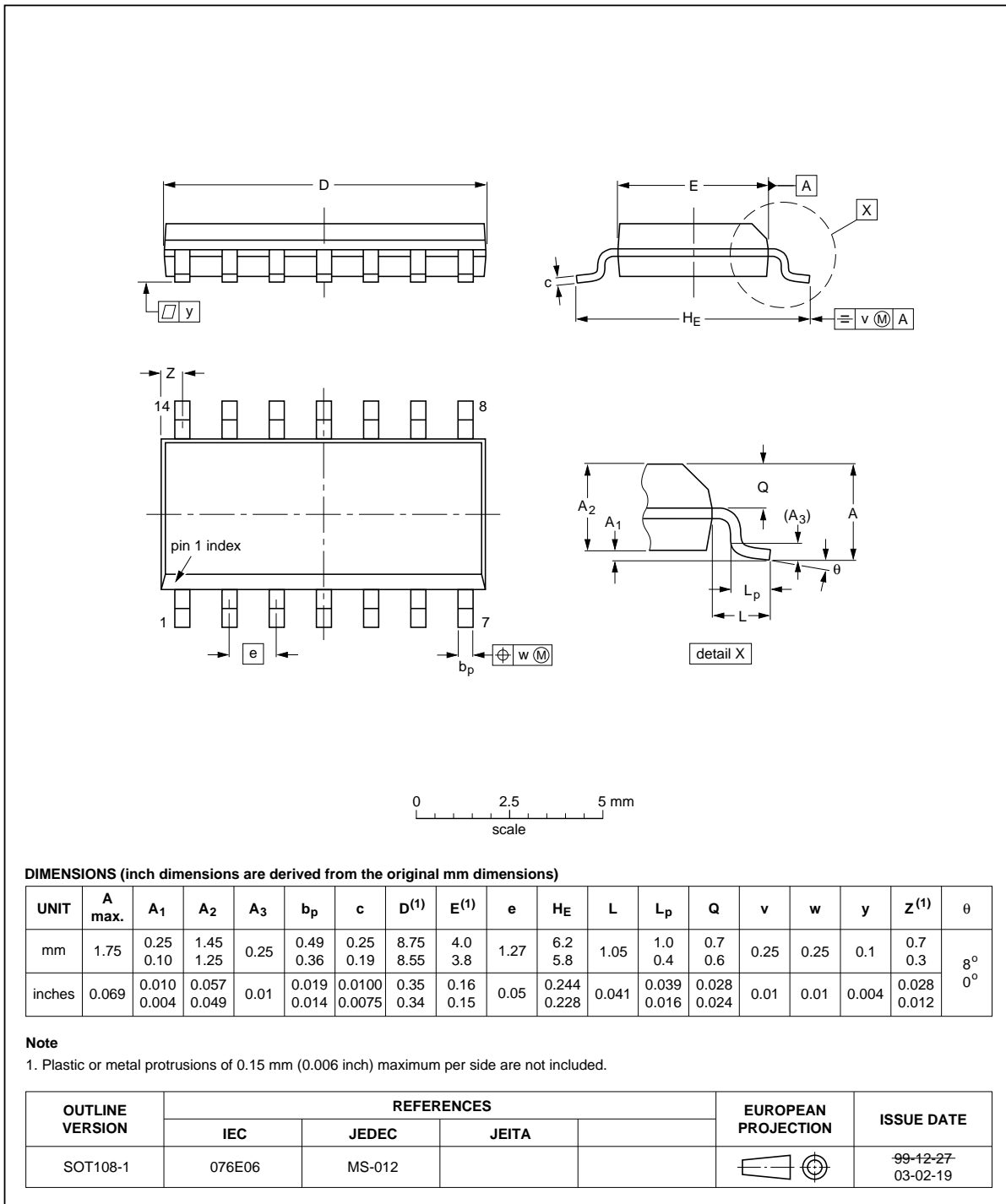**SO14: plastic small outline package; 14 leads; body width 3.9 mm** **SOT108-1**

DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A₁	A₂	A₃	bₚ	c	D[1]	E[1]	e	H_E	L	Lₚ	Q	v	w	y	Z[1]	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	8.75 8.55	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8° 0°
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.35 0.34	0.16 0.15	0.05	0.244 0.228	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

Note

1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT108-1	076E06	MS-012				99-12-27 03-02-19

Fig 8.   Package outline SOT108-1 (SO14)

14. Abbreviations

Table 10.   Abbreviations

Acronym	Description
BCM	Boundary Conduction Mode
CCM	Continuous Conduction Mode
CDM	Charged Device Model
DCM	Discontinuous Conduction Mode
JFET	Junction Field-Effect Transistor
LEB	Leading-Edge Blanking
LED	Light-Emitting Diode
LR	Low Ripple
LTHD	Low Total Harmonic Distortion
NTC	Negative Temperature Coefficient
OTP	OverTemperature Protection
SMPS	Switched Mode Power Supply
SDC	Smart Digital Control
SSL	Solid-State Light
THD	Total Harmonic Distortion
UVLO	UnderVoltage LockOut

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15. Revision history

Table 11. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
SSL21101T v.3	20120607	Product data sheet	-	SSL2110XT v.2
SSL21101T v.2	20120504	Objective data sheet	-	SSL2110XT v.1
SSL2110XT v.1	20110704	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.

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

SSL21101T

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18. Contents

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