SSL21081AT
Compact non-dimmable LED driver IC
Rev. 6 — 3 October 2013 **Product data sheet**

1. General description

The SSL21081AT is a high-voltage Integrated Circuit (IC) for driving LED lamps in general mains non-dimmable lighting applications.

The main benefits are:

- Small Printed-Circuit Board (PCB) footprint; compact solution
- High efficiency (up to 95 %)
- Ease of integration
- Low electronic Bill Of Material (BOM)

The IC incorporates a 300 V MOSFET.

The IC works as boundary conduction mode converters, typically in buck configuration. It has been designed to start up directly from the HV supply by an internal high-voltage current source. Thereafter, the dV/dt supply is used with capacitive coupling from the drain or any other auxiliary supply. This function provides full flexibility in the application design. The IC consumes 1.3 mA of supply current with an internal clamp limiting the supply voltage.

The IC provides accurate output current control with LED current accuracy within 5 %. It can be operated using Pulse-Width Modulation (PWM) current regulation. It includes many protection features including easy LED temperature feedback.

2. Features and benefits

- LED driver ICs for driving LED strings from a rectified mains supply
- High-efficiency switch mode buck driver product family:
    - drivers with integrated 300 V (DC) power switches
- Controller with power-efficient boundary conduction mode of operation with:
    - No reverse recovery losses in freewheel diode
    - Zero Current Switching (ZCS) for turn-on of switch
    - Zero voltage or valley switching for turn-on of switch
    - Minimal required inductance value and size
- Direct PWM current regulation possible
- Fast transient response through cycle-by-cycle current control:
    - Negligible AC mains ripple at LED current and minimal total capacitor value
    - No over or undershoots in the LED current

- Internal protections:
  - UnderVoltage LockOut (UVLO)
  - Leading-Edge Blanking (LEB)
  - OverCurrent Protection (OCP)
  - Internal OverTemperature Protection (OTP)
  - Brownout protection
  - Output Short Protection (OSP)
- Low component count LED driver solution (see Figure 3):
  - No Schottky diode required due to ZCS
  - Easy external temperature protection with a single NTC resistor
  - Option for soft-start function
  - Compatible with wall switches with built-in indication light during standby[1]
- IC lifetime easily matches or surpasses LED lamp lifetime

3. Applications

The SSL21081AT is intended for compact mains non-dimmable LED lighting applications with accurate fixed current output for single mains input voltages. Mains input voltages include 100 V (AC), 120 V (AC). The output signal can be modulated using a PWM signal.

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1. The Hotaru switch is a well-known wall switch with built-in light

4. Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{CC}	supply voltage	operating range	[1]	8	-	16	V
R_{DSon}	drain-source on-state resistance	$T_j = 25\ °C$		2.05	2.3	2.55	Ω
		$T_j = 125\ °C$		3.05	3.45	3.85	Ω
f_{conv}	conversion frequency			-	100	-	kHz
I_{DRAIN}	current on pin DRAIN			−2	-	+2	A
V_{DRAIN}	voltage on pin DRAIN			−0.4	-	+300	V

[1] An internal clamp sets the supply voltage. The current into the VCC pin must not exceed the maximum I_{DD} value (see Table 5).

5. Ordering information

Table 2. Ordering information

| Type number	Package		
	Name	Description	Version
SSL21081AT	SO8	plastic small package outline body; 8 leads; body width 3.9 mm	SOT96-1

5.1 Ordering options

Remark: All voltages are in V (AC) unless otherwise specified.
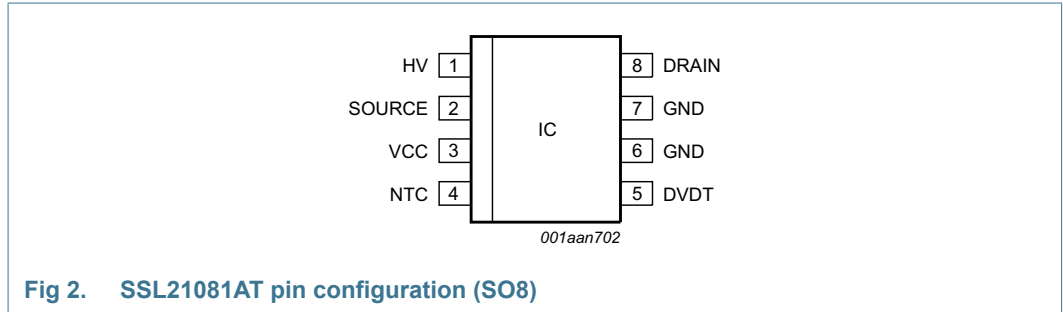
Table 3. Ordering options

Type	Input voltage	Internal MOSFET characteristics	Package
SSL21081AT	100 V; 120 V	300 V (DC); 2.3 Ω	SO8

6. Block diagram

Fig 1.   SSL21081AT block diagram
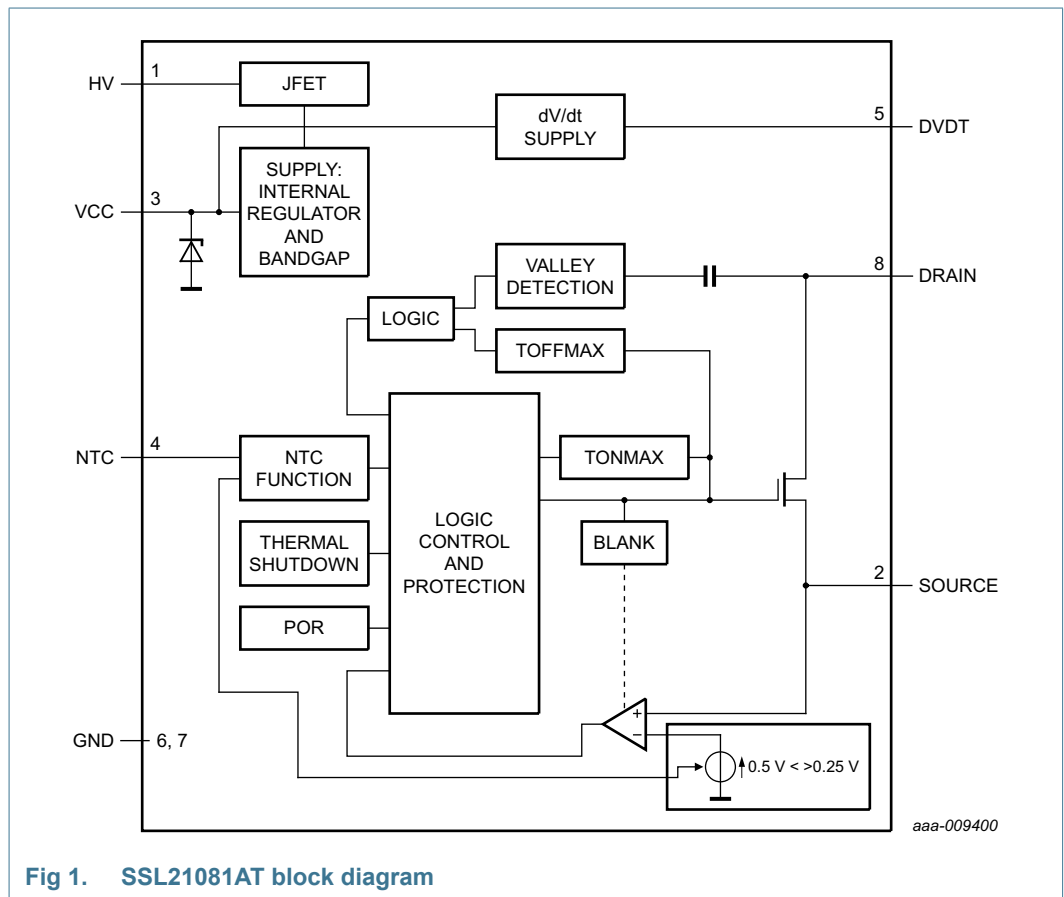
7. Pinning information

7.1 Pinning

Fig 2. **SSL21081AT pin configuration (SO8)**

7.2 Pin description

Table 4. **Pin description**

Symbol	Pin (SO8)	Description
HV	1	high-voltage supply pin
SOURCE	2	low-side internal switch
VCC	3	supply voltage
NTC	4	LED temperature protection input
DVDT	5	AC supply pin
GND	6; 7	ground
DRAIN	8	high-side internal switch

8. Functional description

8.1 Converter operation

The converter in the SSL21081AT is a Boundary Conduction Mode (BCM), peak current controlled system. Figure 3 shows the basic application diagram. Figure 4 shows the waveforms. This converter type operates at the boundary between continuous and discontinuous mode. Energy is stored in inductor L each period that the switch is on. The inductor current I_L is zero when the internal MOSFET switch is switched on. Thereafter, the amplitude of the current build-up in L is proportional to $V_{IN} - V_{OUT}$ and the time that the internal MOSFET switch is on. When the internal MOSFET switch is switched off, the current continues to flow through the freewheel diode and the output capacitor. The current then falls at a rate proportional to the value of V_{OUT}. The LED current I_{LED} is almost equal to half the peak switch current. As soon as the inductor current I_L is zero, a new cycle is started.
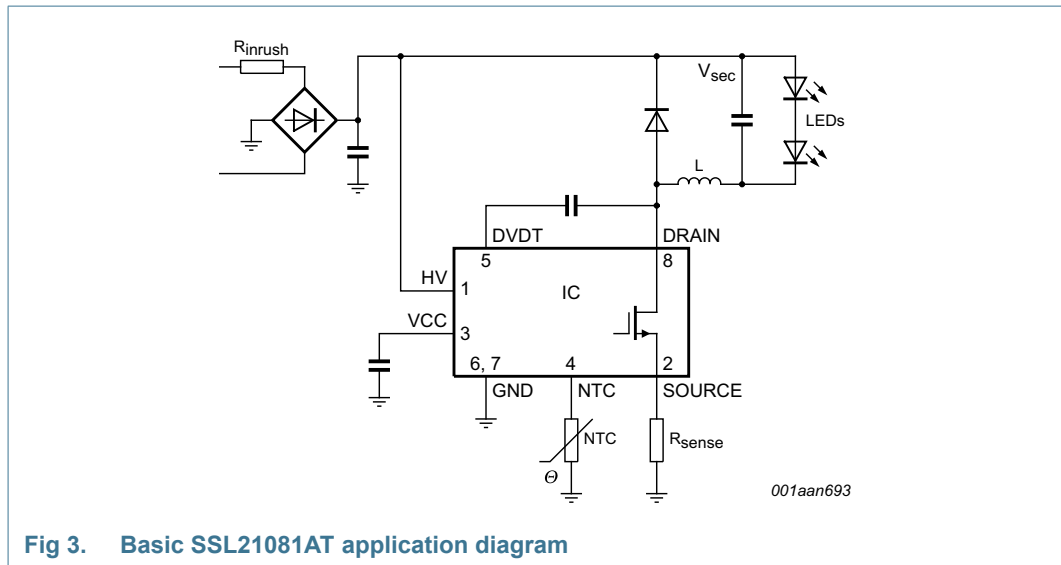

Fig 3. Basic SSL21081AT application diagram

SSL21081AT

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8.2 Valley detection

A new cycle is started when the primary switch is switched on (see Figure 4). Following time t_1, when the peak current is detected on the SOURCE pin, the switch is turned off and the secondary stroke starts (3). When the secondary stroke is complete and the coil current at t_3 equals zero, the drain voltage starts to oscillate around the $V_{IN} - V_{OUT}$ level. The amplitude equals V_{OUT}. A special feature, called valley detection is an integrated part of the SSL21081AT circuitry. Dedicated built-in circuitry connected to the DRAIN pin, senses when the voltage on the drain of the switch has reached its lowest value. The next cycle is then started and as a result the capacitive switching losses are reduced.

If both the frequency of the oscillations and the voltage swing are within the range specified (f_{ring} and $\Delta V_{vrec(min)}$) for detection, a valley is detected and accepted. If a valid valley is not detected, the secondary stroke is continued until the maximum off-time ($t_{off(high)}$) is reached. Then the next cycle is started.
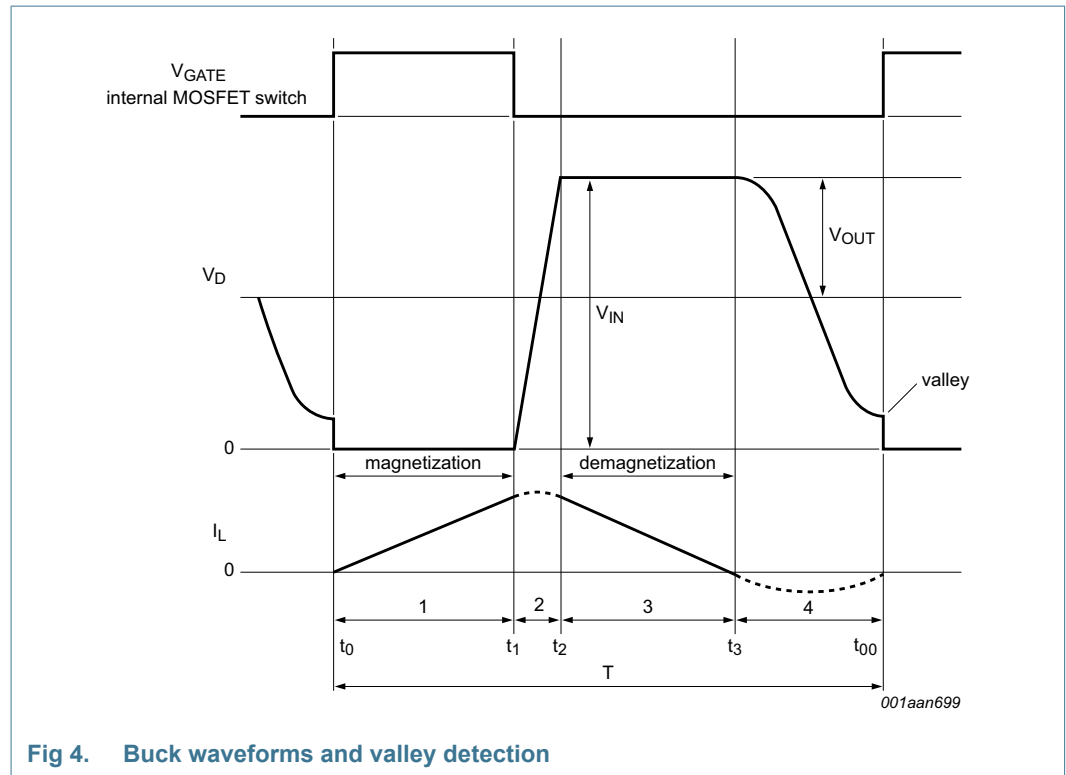

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Fig 4. Buck waveforms and valley detection

8.3 Protective features

The IC has the following protective features:

- UnderVoltage LockOut (UVLO)
- Leading-Edge Blanking (LEB)
- OverCurrent Protection (OCP)
- Internal OverTemperature Protection (OTP)
- Brownout protection
- Output Short Protection (OSP)
- LED overtemperature control and protection

The OSP is a latched protection. This protection causes the IC to halt until a reset (a result of power cycling) is executed. When V_{CC} drops to below $V_{CC(rst)}$, the IC resets the latch protection mode. The internal OTP and LED overtemperature protections are safe-restart protections. The IC halts, causing V_{CC} to drop to below $V_{CC(stop)}$, triggering a start-up. When V_{CC} drops to below $V_{CC(rst)}$, the IC resets the latch protection mode. Switching starts only when a no fault condition exists.

8.3.1 UnderVoltage LockOut (UVLO)

When the voltage on the VCC pin drops to below $V_{CC(stop)}$, the IC stops switching. An attempt is made to restart by supplying V_{CC} from the HV pin voltage.

8.3.2 Leading-Edge Blanking (LEB)

To prevent false detection of overcurrent, a blanking time following switch-on is implemented. When the internal MOSFET switch switches on, there can be a short current spike due to capacitive discharge of voltage over the drain and source and the charging of the gate to source capacitance. During the LEB time (t_{leb}), the spike is disregarded.

8.3.3 OverCurrent Protection (OCP)

The SSL21081AT contains a highly accurate built-in peak current detector. It triggers when the voltage at the SOURCE pin reaches the peak-level $V_{th(ocp)SOURCE}$. The current through the switch is sensed using a resistor connected to the SOURCE pin. The sense circuit is activated following LEB time t_{leb}. As the LED current is half the peak current (by design), it automatically provides protection for maximum LED current during operation. There is a propagation delay ($t_{d(ocp-swoff)}$) between the overcurrent detection and the actual switching off of the switch. Due to the delay, the actual peak current is slightly higher than the OCP level set by the resistor in series to the SOURCE pin.

8.3.4 OverTemperature Protection (OTP)

When the internal OTP function is triggered at a certain IC temperature ($T_{th(act)otp}$), the converter stops operating. The safe-restart protection is triggered and the IC restarts with switching resuming when the IC temperature drops lower than $T_{th(rel)otp}$.

8.3.5 Brownout protection

Brownout protection is designed to limit the lamp power when the input voltage drops close to the output voltage level. The input power has to remain constant. The input current would otherwise increase to a level that is too high for the input circuitry. For the

SSL21081AT, there is a maximum limit on the on-time $t_{on(high)}$. The rate of current rise in the coil during the on-phase is proportional to the difference between input voltage and output voltage. Therefore, the peak current cannot be reached before $t_{on(high)}$. As a result the average output current to the LEDs is reduced.

8.3.6 Output Short-circuit Protection (OSP)

During the secondary stroke (switch-off time), if a valley is not detected within the off-time limit ($t_{off(high)}$), then typically the output voltage is less than the minimum limit allowed in the application. This condition can occur either during start-up or due to a short-circuit. A timer $t_{det(sc)}$ is started when $t_{off(high)}$ is detected. Timer $t_{det(sc)}$ is reset when a valid valley detection occurs in one of the subsequent cycles or when V_{CC} drops to below $V_{CC(stop)}$.

The timer can also be reset if the maximum limit on the on-time of the switch ($t_{on(high)}$) is reached, which is usually the case at start-up (brownout protection). If no valley is detected and ($t_{on(high)}$) is not reached before $t_{det(sc)}$, then it is concluded that a real short-circuit exists. The IC enters latched protection. If V_{CC} drops to below $V_{CC(rst)}$, the IC resets the latched protection mode (see Figure 5).
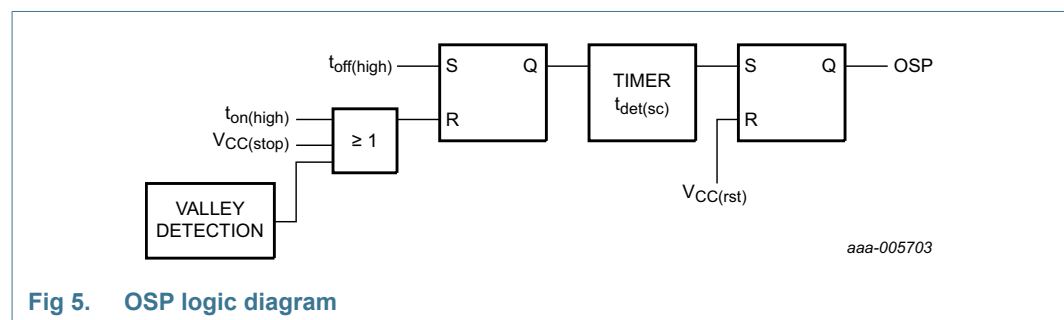

Fig 5.   OSP logic diagram

8.4 VCC supply

The SSL21081AT is supplied using three methods:

- Under normal operation, the voltage swing on the DVDT pin is rectified within the IC providing current towards the VCC pin

- At start-up, there is an internal current source connected to the HV pin. The current source provides internal power until either the dV/dt supply or an external current on the VCC pin provides the supply

- Using an auxiliary winding, the voltage can be rectified and connected to the VCC pin via a series resistor.

The IC starts up when the voltage at the VCC pin exceeds $V_{CC(startup)}$. The IC locks out (stops switching) when the voltage at the VCC pin is < $V_{CC(stop)}$. The hysteresis between the start and stop levels allows the IC to be supplied by a buffer capacitor until the dV/dt supply is settled. The SSL21081AT has an internal V_{CC} clamp, which is an internal active Zener (or shunt regulator). This internal active Zener limits the voltage on the supply VCC pin to the maximum value of V_{CC}. If the maximum current of the dV/dt supply minus the current consumption of the IC (determined by the load on the gate drivers) is lower than the maximum value of I_{DD}, no external Zener diode is required in the dV/dt supply circuit.

8.5 DVDT pin supply (dV/dt)

The DVDT pin is connected to an internal single-sided rectification stage. When a different voltage with sufficient amplitude is supplied to the pin, the IC can be powered without any other external power connection. This provides an effective method to prevent additional high power losses, which are the result if a regulator were used for continuously powering the IC. Unlike an auxiliary supply, additional inductor windings are not required.

8.6 VCC regulator

During supply dips, the input voltage can drop so much that it can no longer supply the required IC current through the DVDT pin. Under these conditions, if the VCC voltage drops to below the $V_{CC(swon)reg}$ level, another regulator with a current capability of up to $I_{sup(high)HV}$ is started. The job of the regulator is to fill in the required supply current, which the dV/dt supply does not deliver, thus preventing that the IC enters UVLO. When the VCC voltage exceeds the $V_{CC(swon)reg}$ level, the regulator is turned off.

8.7 NTC functionality and PWM regulation

The NTC pin can be used as a control method for LED thermal protection. Alternatively, the pin can be used as an input to disable/enable light output using a digital signal (PWM regulation). The pin has an internal current source that generates the current of $I_{offset(NTC)}$. An NTC resistor to monitor the LED temperature can be connected directly to the NTC pin. Depending on the resistance value and the corresponding voltage on the NTC pin, the converter reacts as shown in Figure 6.

During start-up, before V_{CC} reaches $V_{CC(startup)}$ the voltage on the NTC pin must be less than the minimum value of $V_{act(tmr)NTC}$. This is valid when the voltage on the NTC pin is derived from the V_{CC} using a resistive divider and a PTC in series with the resistor between pins VCC and NTC.

If an NTC resistor is connected between the NTC pin and ground, the voltage on the NTC pin is 0 V when V_{CC} reaches $V_{CC(startup)}$.
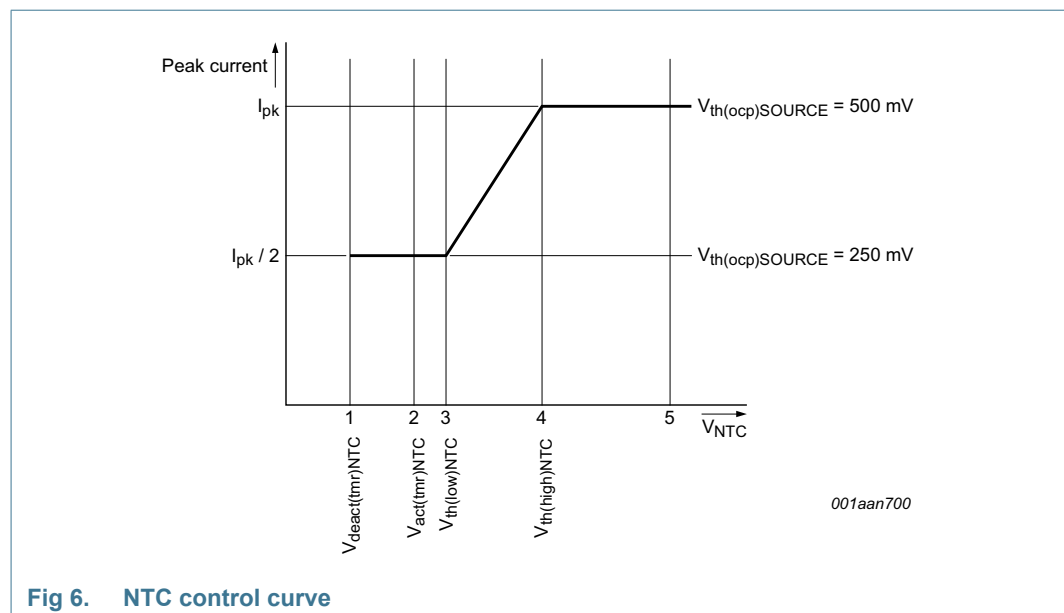

Fig 6.   NTC control curve

When the voltage on the NTC pin exceeds $V_{th(high)NTC}$ (see Figure 6 (4)), the converter delivers nominal output current. When the voltage is lower than this level, the peak current is gradually reduced until $V_{th(low)NTC}$ is reached (see Figure 6 (3)). The peak current is now half the peak current of nominal operation. When $V_{act(tmr)NTC}$ is passed (see Figure 6 (2)), a timer starts to run to distinguish between the following situations:

- If the low-level $V_{deact(tmr)NTC}$ is not reached within time $t_{to(deact)NTC}$ (see Figure 6 (1)), LED overtemperature is detected. The IC stops switching and attempts to restart from the HV pin voltage. The converter restarts from an NTC protection shutdown when the voltage on the NTC pin exceeds $V_{th(high)NTC}$ (see Figure 6 (4)). It is assumed that the reduction in peak current does not result in a lower NTC temperature and LED OTP is activated.

- If the low-level $V_{deact(tmr)NTC}$ is reached within the time $t_{to(deact)NTC}$ (see Figure 6 (1)) it is assumed that the pin is pulled down externally. The restart function is not triggered. Instead, the output current is reduced to zero. PWM regulation and consequently LED output current regulation can be implemented this way. The output current rises again when the voltage exceeds $V_{th(low)NTC}$.

8.7.1 Soft-start function

The NTC pin can be used to make a soft start function. During switch-on, the level on the NTC pin is low. By connecting a capacitor (in parallel with the NTC resistor), a time constant can be defined. The time constant causes the level on the NTC pin to increase slowly. When passing level $V_{th(low)NTC}$ (see Figure 6 (3)), the converter starts with half of the maximum current. The output current slowly increases to maximum when $V_{th(high)NTC}$ (see Figure 6 (4)) is reached.

8.8 Heat sink

The copper of the PCB acts as the heat sink for SSL21081AT applications.

Equation 1 shows the relation between the maximum allowable power dissipation P and the thermal resistance from junction to ambient.

$$R_{th(j-a)} = (T_{j(max)} - T_{amb})/P \qquad (1)$$

Where:

$R_{th(j-a)}$ = thermal resistance from junction to ambient

$T_{j(max)}$ = maximum junction temperature

T_{amb} = ambient temperature

P = power dissipation

9. Limiting values

Table 5.   Limiting values
In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions		Min	Max	Unit
General						
SR	slew rate	on pin DRAIN		−5	+5	V/ns
P_{tot}	total power dissipation	SO8 package		-	0.6	W
T_{amb}	ambient temperature			−40	+125	°C
T_j	junction temperature			−40	+150	°C
T_{stg}	storage temperature			−55	+150	°C
Voltages						
V_{CC}	supply voltage	continuous	[1]	−0.4	+20	V
V_{DRAIN}	voltage on pin DRAIN			−0.4	+300	V
V_{HV}	voltage on pin HV	current limited		−0.4	+300	V
V_{SOURCE}	voltage on pin SOURCE	current limited		−0.4	+5.2	V
V_{NTC}	voltage on pin NTC	current limited		−0.4	+5.2	V
Currents						
I_{DD}	supply current	at pin VCC	[2]	-	20	mA
I_{DRAIN}	current on pin DRAIN			−2	+2	A
I_{SOURCE}	current on pin SOURCE			−2	+2	A
I_{DVDT}	current on pin DVDT	duration 20 μs maximum		-	1.3	A
V_{ESD}	electrostatic discharge voltage	human body model; pins DRAIN and HV	[3]	−1	+1	kV
		human body model; all other pins		−2	+2	kV
		charged device	[4]	−500	+500	V

[1] The current into the VCC pin must not exceed the maximum I_{DD} value.

[2] An internal clamp sets the supply voltage.

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

[4] Charged device model: equivalent to charging the IC up to 1 kV and the subsequent discharging of each pin down to 0 V over a 1 Ω resistor.

10. Thermal characteristics

Table 6.   Thermal characteristics

Symbol	Parameter	Conditions	Typ	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air; SO8 package, PCB: 2 cm × 3 cm, 2-layer, 35 μm Cu per layer	142	K/W
		in free air; SO8 package; PCB: JEDEC 2s2p	72	K/W
$\Psi_{j\text{-top}}$	thermal characterization parameter from junction to top of package	top package temperature measured at the warmest point on top of the case; SO8 package	3.4	K/W

11. Characteristics

Table 7.   Characteristics

Values specified at T_{amb} = 25 °C unless otherwise stated; all voltages are measured with respect to ground; currents are positive. when flowing into the IC.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{conv}	conversion frequency		-	100	-	kHz
High-voltage						
$I_{leak(DRAIN)}$	leakage current on pin DRAIN	V_{DRAIN} = 300 V (DC)	-	-	10	μA
$I_{leak(HV)}$	leakage current on pin HV	V_{HV} = 300 V (DC)	-	-	30	μA
Supply						
V_{CC}	supply voltage	operating range [1]	8	-	16	V
$V_{CC(startup)}$	start-up supply voltage		11	12	13	V
$V_{CC(stop)}$	stop supply voltage		8	9	10	V
$V_{CC(hys)}$	hysteresis of supply voltage	between $V_{CC(startup)}$ and $V_{CC(stop)}$	2	-	-	V
$V_{CC(rst)}$	reset supply voltage		4.5	5	5.5	V
$V_{CC(swon)reg}$	regulator switch-on supply voltage	insufficient dV/dt supply	8.75	9.25	9.75	V
$V_{CC(swoff)reg}$	regulator switch-off supply voltage	insufficient dV/dt supply	9.5	10	10.5	V
$V_{CC(reg)hys}$	regulator supply voltage hysteresis	$V_{CC(swoff)reg} - V_{CC(swon)reg}$	0.3	-	-	V
$V_{CC(regswon-stop)}$	supply voltage difference between regulator switch-on and stop	$V_{CC(swon)reg} - V_{CC(stop)}$	0.3	-	-	V
Consumption						
$I_{stb(HV)}$	standby current on pin HV	during start-up or in protection; V_{HV} = 100 V	300	350	400	μA
I_{CC}	supply current	normal operation	-	1.3	-	mA
Capability						
$I_{sup(high)HV}$	high supply current on pin HV	Standby: V_{HV} = 40 V; $V_{CC} < V_{CC(stop)}$	1	1.3	1.6	mA
		Regulator On: V_{HV} = 40 V; $V_{CC} < V_{CC(swon)reg}$ after start-up	2	2.3	2.6	mA
Current protection						
$V_{th(ocp)SOURCE}$	overcurrent protection threshold voltage on pin SOURCE	$\Delta V/\Delta t$ = 0.1 V/μs	480	500	520	mV
		$\Delta V/\Delta t$ = 0.1 V/μs; V_{NTC} = 0.325 V	230	250	270	mV
$t_{d(ocp-swoff)}$	delay time from overcurrent protection to switch-off	$\Delta V/\Delta t$ = 0.1 V/μs	-	75	100	ns
t_{leb}	leading edge blanking time	overcurrent protection	260	300	340	ns

Table 7.   Characteristics *…continued*

Values specified at T_{amb} = 25 °C unless otherwise stated; all voltages are measured with respect to ground; currents are positive. when flowing into the IC.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Valley detection						
$(\Delta V/\Delta t)_{vrec}$	valley recognition voltage change with time	on pin DRAIN	−30	−20	−10	V/μs
f_{ring}	ringing frequency	[2]	200	550	1000	kHz
$\Delta V_{vrec(min)}$	minimum valley recognition voltage difference	voltage drop on pin DRAIN	15	20	25	V
$t_{d(vrec-swon)}$	valley recognition to switch-on delay time		-	100	-	ns
Brownout detection						
$t_{on(high)}$	high on-time		12.5	15	17.5	μs
MOSFET output stage						
$V_{BR(DRAIN)}$	breakdown voltage on pin DRAIN	T_j > 0 °C	300	-	-	V
R_{DSon}	drain-source on-state resistance	T_j = 25 °C	2.05	2.3	2.55	Ω
		T_j = 125 °C	3.05	3.45	3.85	Ω
$(dV/dt)_{f(DRAIN)}$	fall rate of change of voltage on pin DRAIN	C_{DRAIN} = 150 pF, R_{SOURCE} = 2.2 Ω [2]	-	1.2	-	V/ns
NTC functionality						
$V_{th(high)NTC}$	high threshold voltage on pin NTC		0.47	0.5	0.53	V
$V_{th(low)NTC}$	low threshold voltage on pin NTC		0.325	0.35	0.375	V
$V_{act(tmr)NTC}$	timer activation voltage on pin NTC		0.26	0.29	0.325	V
$V_{deact(tmr)NTC}$	timer deactivation voltage on pin NTC		0.17	0.2	0.23	V
$t_{to(deact)NTC}$	deactivation time-out time on pin NTC		33	46	59	μs
$I_{offset(NTC)}$	offset current on pin NTC		-	−47	-	μA
OSP						
$t_{det(sc)}$	short-circuit detection time		16	20	24	ms
$t_{off(high)}$	high off-time		30	36	42	μs
Temperature protections						
$T_{th(act)otp}$	overtemperature protection activation threshold temperature		160	170	180	°C
$T_{th(rel)otp}$	overtemperature protection release threshold temperature		90	100	110	°C

[1]   An internal clamp sets the supply voltage. The current into the VCC pin must not exceed the maximum I_{DD} value (see Table 5).

[2]   This parameter is not tested during production, by design it is guaranteed.
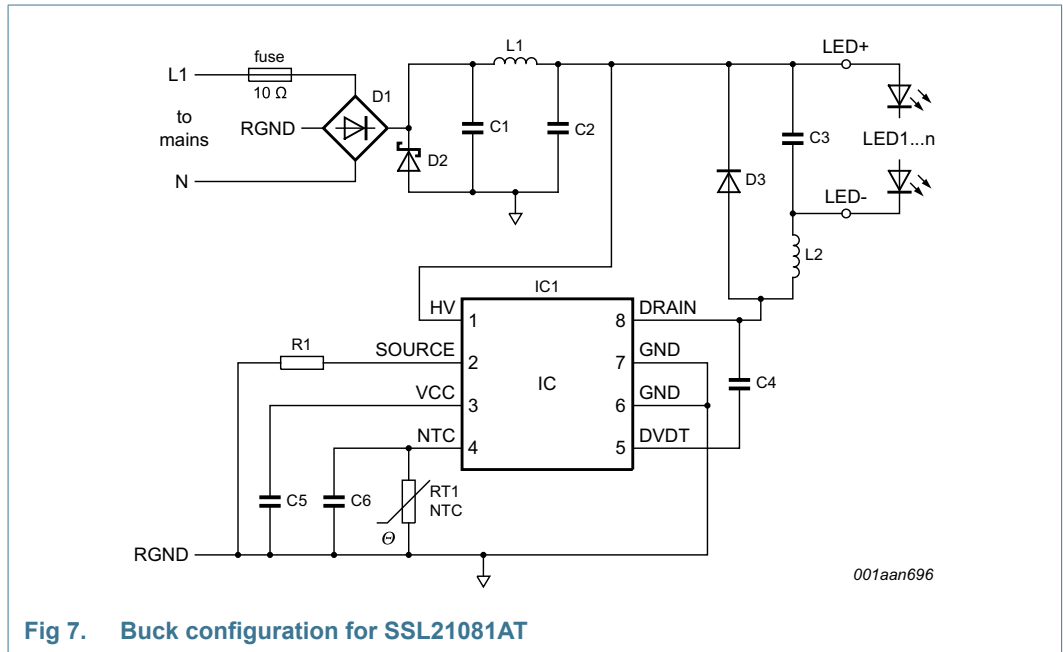
12. SSL21081AT buck configuration

Fig 7.   Buck configuration for SSL21081AT

13. Package outline

SO8: plastic small outline package; 8 leads; body width 3.9 mm   **SOT96-1**

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

UNIT	A max.	A₁	A₂	A₃	bₚ	c	D[1]	E[2]	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	5.0 4.8	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	0.20 0.19	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	

Notes

1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm (0.01 inch) maximum per side are not included.

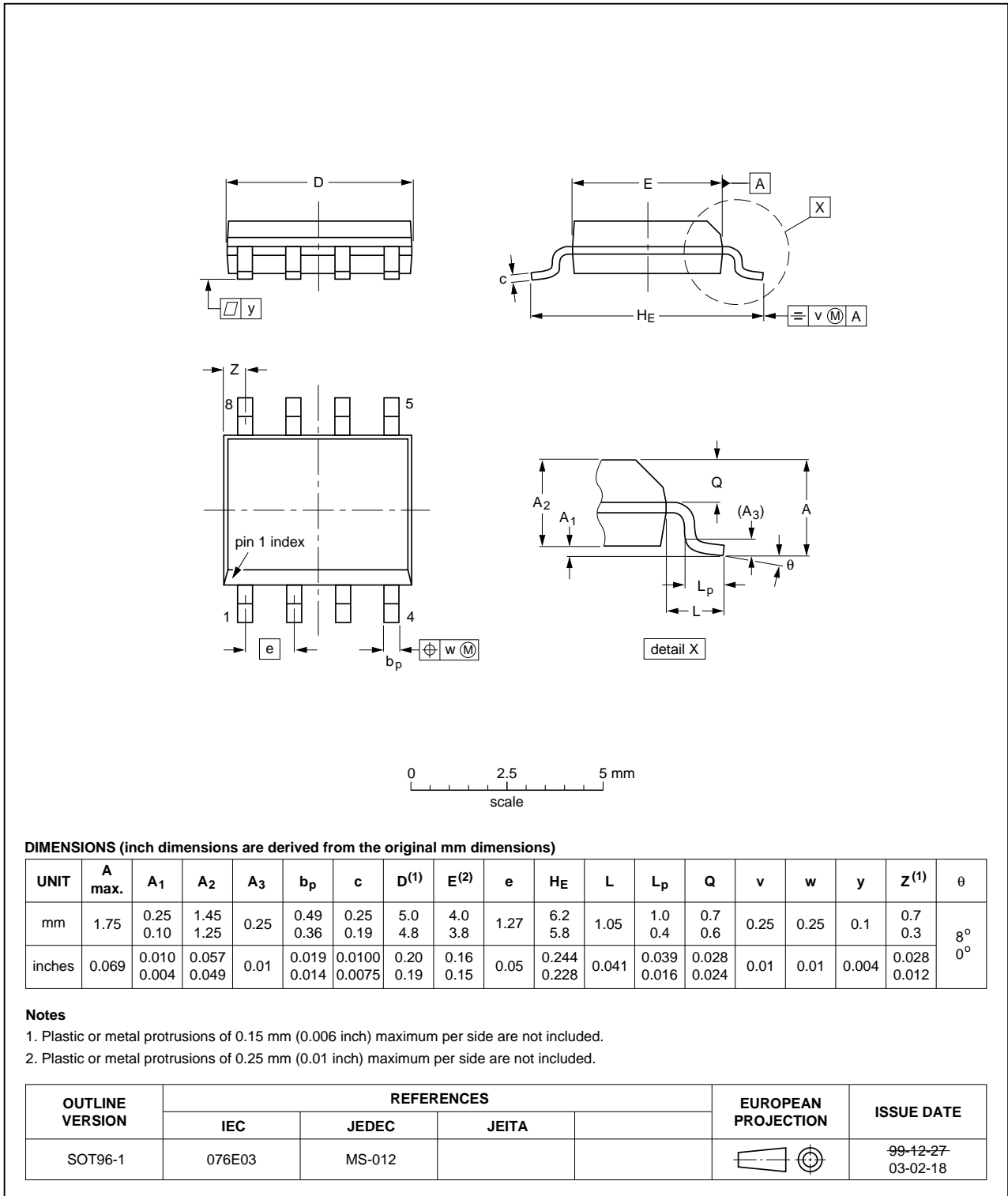| OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT96-1	076E03	MS-012				99-12-27 03-02-18

Fig 8.   Package outline SOT96-1 (SOT8)