

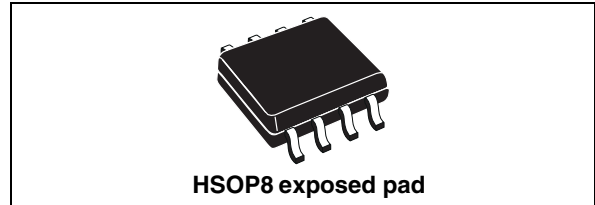
2 A switch step down switching regulator

Features

- 2 A internal switch
- Operating input voltage from 4 V to 36 V
- 3.3 V / ($\pm 2\%$) reference voltage
- Output voltage adjustable from 1.235 V to 35 V
- Low dropout operation: 100% duty cycle
- 500 kHz Internally fixed frequency
- Voltage feedforward
- Zero load current operation
- Internal current limiting
- Inhibit for zero current consumption
- Synchronization
- Protection against feedback disconnection
- Thermal shutdown

Applications

- Consumer: STB, DVD, TV, VCR, car radio, LCD monitors
- Networking: XDSL, modems, DC-DC modules
- Computer: printers, audio/graphic cards, optical storage, hard disk drive
- Industrial: chargers, car battery, DC-DC converters



Description

The L5973AD is a step down monolithic power switching regulator with a switch current limit of 2 A so it is able to deliver more than 1.5 A DC current to the load depending on the application conditions.

The output voltage can be set from 1.235 V to 35 V. The high current level is also achieved thanks to an SO8 package with exposed frame, that allows to reduce the R_{thJA} down to approximately 40 °C/W.

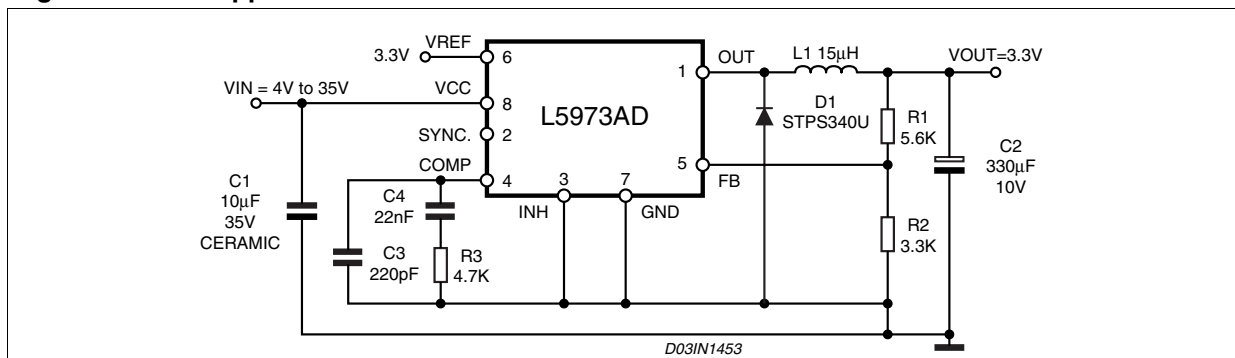
The device uses an internal P-Channel D-MOS transistor (with a typical of 200 m Ω) as switching element to avoid the use of bootstrap capacitor and guarantee high efficiency.

An internal oscillator fixes the switching frequency at 500 kHz to minimize the size of external components.

Having a minimum input voltage of 4 V only, it is particularly suitable for 5 V bus, available in all computer related applications.

Pulse by pulse current limit with the internal frequency modulation offers an effective constant current short circuit protection.

Figure 1. Test application circuit



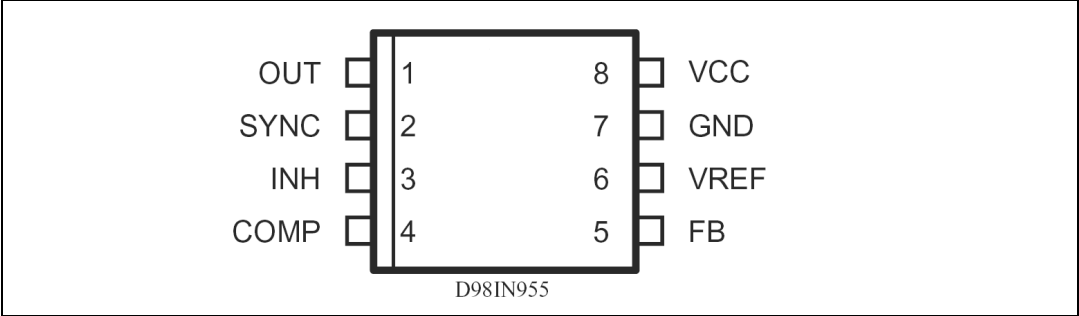
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1 Pin settings

1.1 Pin connection

Figure 2. Pin connection (top view)



1.2 Pin description

Table 1. Pin description

N°	Type	Description
1	OUT	Regulator output.
2	SYNC	Master/slave synchronization. When it is open, a signal synchronous with the turn-off of the internal power is present at the pin. When connected to an external signal at a frequency higher than the internal one, then the device is synchronized by the external signal. Connecting together the SYNC pin of two devices, the one with the higher frequency works as master and the other one, works as slave.
3	INH	A logical signal (active high) disables the device. With IHN higher than 2.2 V the device is OFF and with INH lower than 0.8V, the device is ON. If INH is not used the pin must be grounded. When it is open, an internal pull-up disables the device.
4	COMP	E/A output to be used for frequency compensation.
5	FB	Stepdown feedback input. Connecting the output voltage directly to this pin results in an output voltage of 1.235 V. An external resistor divider is required for higher output voltages (the typical value for the resistor connected between this pin and ground is 4.7 K).
6	VREF	Reference voltage of 3.3 V. No filter capacitor is needed to stability.
7	GND	Ground.
8	VCC	Unregulated DC input voltage.

2 Electrical data

2.1 Maximum ratings

Table 2. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_8	Input voltage	40	V
V_1	Output DC voltage Output peak voltage at $t = 0.1 \mu\text{s}$	-1 to 40 -5 to 40	V V
I_1	Maximum output current	int. limit.	
V_4, V_5	Analog pins	4	V
V_3	INH	-0.3V to V_{CC}	
V_2	SYNC	-0.3 to 4	V
P_{TOT}	Power dissipation at $T_A \leq 60^\circ\text{C}$	2.25	W
T_J	Operating junction temperature range	-40 to 150	$^\circ\text{C}$
T_{STG}	Storage temperature range	-55 to 150	$^\circ\text{C}$

2.2 Thermal data

Table 3. Thermal data

Symbol	Parameter	HSOP8 Exposed pad	Unit
R_{thJA}	Maximum thermal resistance junction-ambient	40 ⁽¹⁾	$^\circ\text{C/W}$

1. Package mounted on board

3 Electrical characteristics

$T_J = 25\text{ }^{\circ}\text{C}$, $V_{CC} = 12\text{ V}$, unless otherwise specified

Table 4. Electrical characteristics

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
V _{CC}	Operating input voltage range	V _O = 1.235 V; I _O = 2 A	4		36	V
R _{DS(on)}	MOSFET on resistance			0.250	0.5	Ω
I _I	Maximum limiting current	V _{CC} = 4.4 V to 36 V	2	2.3	3.5	A
f _s	Switching frequency			500		kHz
	Duty cycle		0		100	%
Dynamic characteristics (see test circuit).						
V ₅	Voltage feedback	4.4 V < V _{CC} < 36 V, 20 mA < I _O < 2 A	1.220	1.235	1.25	V
η	Efficiency	V _O = 5 V, V _{CC} = 12 V		90		%
DC characteristics						
I _{qop}	Total operating quiescent current			5	7	mA
I _q	Quiescent current	Duty cycle = 0; V _{FB} = 1.5 V			2.7	mA
I _{qst-by}	Total stand-by quiescent current	V _{inh} > 2.2 V		50	100	μA
Inhibit						
	INH threshold voltage	Device ON			0.8	V
		Device OFF	2.2			V
Error amplifier						
V _{OH}	High level output voltage	V _{FB} = 1 V	3.5			V
V _{OL}	Low level output voltage	V _{FB} = 1.5 V			0.4	V
I _{O source}	Source output current	V _{COMP} = 1.9 V; V _{FB} = 1 V	200	300		μA
I _{O sink}	Sink output current	V _{COMP} = 1.9 V; V _{FB} = 1.5 V	1	1.5		mA
I _b	Source bias current			2.5	4	μA
	DC open loop gain	R _L = ∞	50	57		dB

Table 4. Electrical characteristics (continued)

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
gm	Transconductance	$I_{\text{comp}} = -0.1 \text{ mA to } 0.1 \text{ mA}$ $V_{\text{COMP}} = 1.9 \text{ V}$		2.3		mS
Sync function						
	High input voltage	$V_{\text{CC}} = 4.4 \text{ V to } 36 \text{ V}$	2.5		V_{REF}	V
	Low input voltage	$V_{\text{CC}} = 4.4 \text{ V to } 36 \text{ V}$			0.74	V
	Slave sink current	$V_{\text{sync}} = 0.74 \text{ V}^{(1)}$ $V_{\text{sync}} = 2.33 \text{ V}$	0.11 0.21		0.25 0.45	mA mA
	Master output amplitude	$I_{\text{source}} = 3 \text{ mA}$	2.75	3		V
	Output pulse width	no load, $V_{\text{sync}} = 1.65 \text{ V}$	0.20	0.35		μs
Reference section						
	Reference voltage		3.234	3.3	3.366	V
		$I_{\text{REF}} = 0 \text{ to } 5 \text{ mA}$ $V_{\text{CC}} = 4.4 \text{ V to } 36 \text{ V}$	3.2	3.3	3.399	V
	Line regulation	$I_{\text{REF}} = 0 \text{ mA}$ $V_{\text{CC}} = 4.4 \text{ V to } 36 \text{ V}$		5	10	mV
	Load regulation	$I_{\text{REF}} = 0 \text{ to } 5 \text{ mA}$		8	15	mV
	Short circuit current		10	18	30	mA

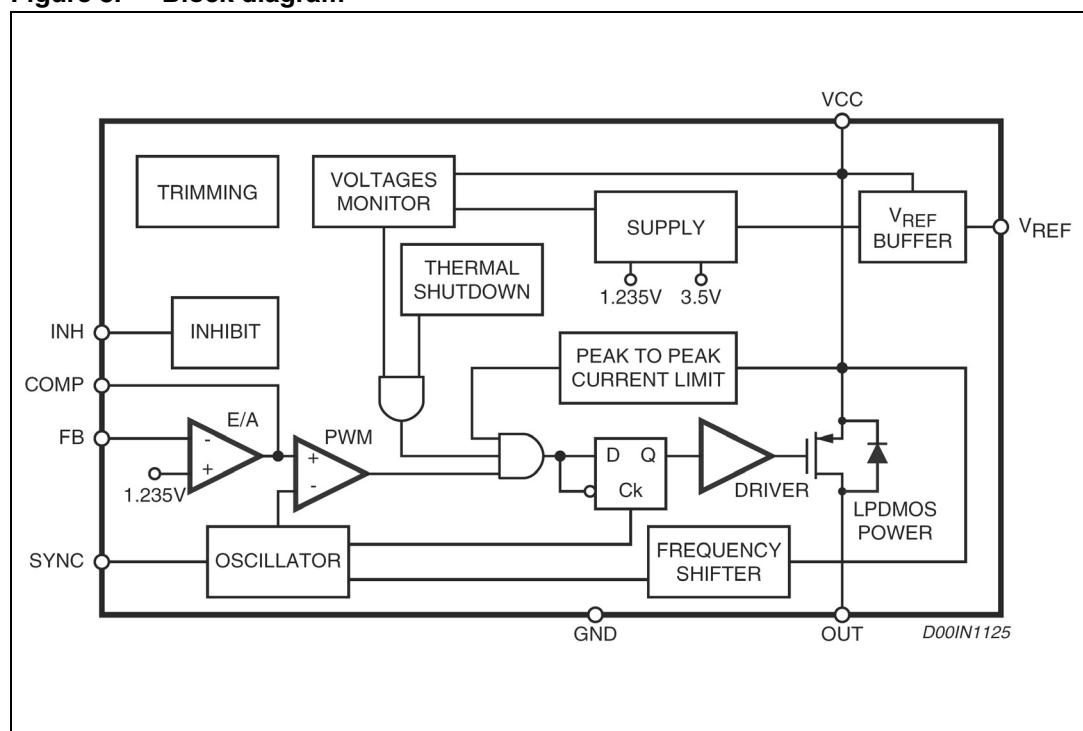
1. Guaranteed by design.

4 Functional description

The main internal blocks are shown in [Figure 3](#), where is reported the device block diagram. They are:

- A voltage regulator that supplies the internal circuitry. From this regulator, a 3.3 V reference voltage is externally available.
- A voltage monitor circuit that checks the input and internal voltages.
- A fully integrated sawtooth oscillator whose frequency is 500 kHz
- Two embedded current limitations circuitries which control the current that flows through the power switch. The Pulse by Pulse Current Limit forces the power switch OFF cycle by cycle if the current reaches an internal threshold, while the Frequency Shifter reduces the switching frequency in order to strongly reduce the duty cycle.
- A transconductance error amplifier.
- A pulse width modulator (PWM) comparator and the relative logic circuitry necessary to drive the internal power.
- An high side driver for the internal P-MOS switch.
- An inhibit block for stand-by operation.
- A circuit to realize the thermal protection function.

Figure 3. Block diagram



4.1 Power supply and voltage reference

The internal regulator circuit (shown in [Figure 4](#)) consists of a start-up circuit, an internal voltage pre-regulator, the Bandgap voltage reference and the Bias block that provides current to all the blocks.

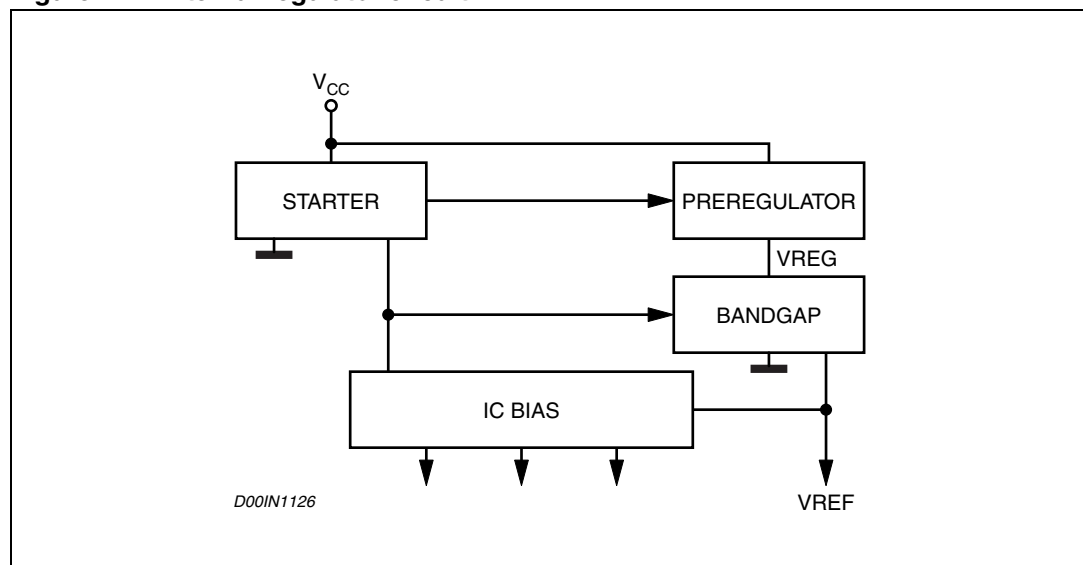
The Starter gives the start-up currents to the whole device when the input voltage goes high and the device is enabled (inhibit pin connected to ground).

The pre-regulator block supplies the Bandgap cell with a pre-regulated voltage V_{REG} that has a very low supply voltage noise sensitivity.

4.2 Voltages monitor

An internal block senses continuously the V_{CC} , V_{ref} and V_{bg} . If the voltages go higher than their thresholds, the regulator starts to work. There is also an hysteresis on the V_{CC} (UVLO).

Figure 4. Internal regulator circuit



4.3 Oscillator and synchronization

[Figure 5](#) shows the block diagram of the oscillator circuit.

The clock generator provides the switching frequency of the device that is internally fixed at 500 kHz. The frequency shifter block acts reducing the switching frequency in case of strong overcurrent or short circuit. The clock signal is then used in the internal logic circuitry and is the input of the ramp generator and synchronization blocks.

The ramp generator circuit provides the sawtooth signal, used to realize the PWM control and the internal voltage feed forward, while the Synchronization circuit generates the synchronization signal. In fact the device has a synchronization pin that can work both as Master and Slave.

As Master to synchronize external devices to the internal switching frequency.

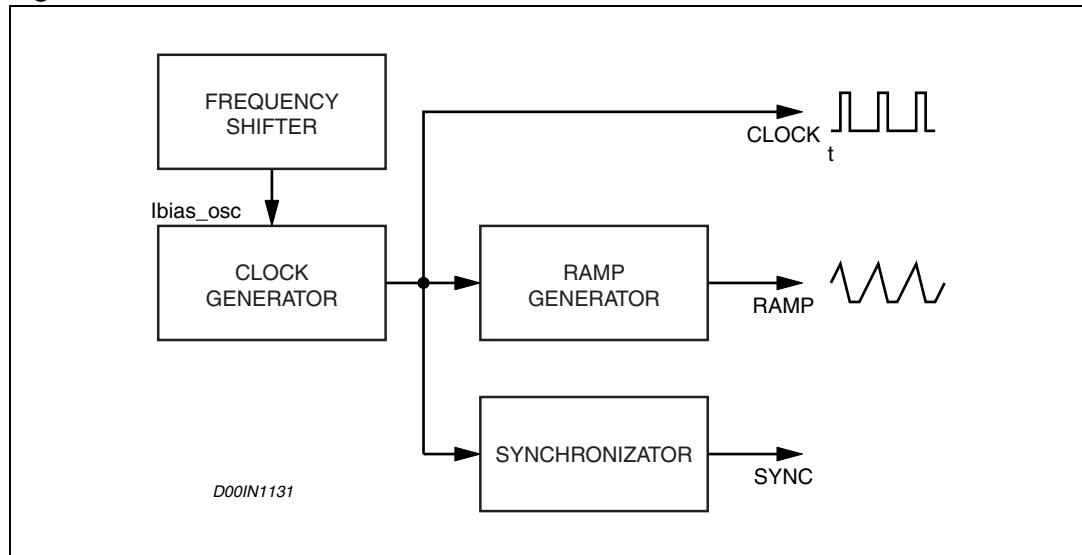
As Slave to synchronize itself by external signal.

In particular, connecting together two devices, the one with the lower switching frequency works as Slave and the other one works as Master.

To synchronize the device, the SYNC pin has to pass from a low level to a level higher than the synchronization threshold with a duty cycle that can vary approximately from 10% to 90%, depending also on the signal frequency and amplitude.

The frequency of the synchronization signal must be at least higher than the internal switching frequency of the device (500 kHz).

Figure 5. Oscillator circuit



4.4 Current protection

The L5973AD has two current limit protections, pulse by pulse and frequency fold back.

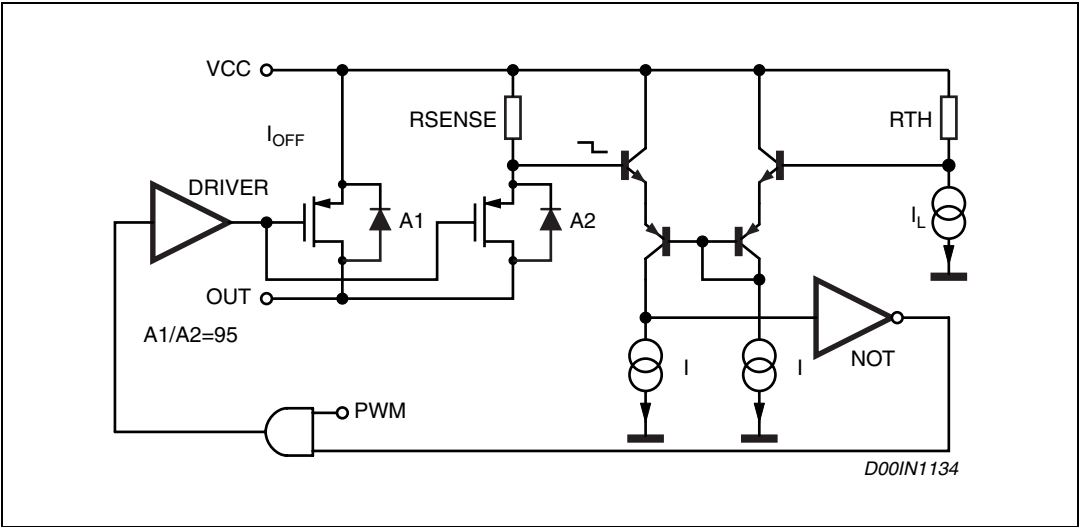
The schematic of the current limitation circuitry for the pulse by pulse protection is shown in [Figure 6](#).

The output power PDMOS transistor is split in two parallel PDMOS. The smallest one has a resistor in series, R_{SENSE} . The current is sensed through R_{sense} and if reaches the threshold, the mirror is unbalanced and the PDMOS is switched off until the next falling edge of the internal clock pulse.

Due to this reduction of the ON time, the output voltage decreases.

Since the minimum switch ON time (necessary to avoid false overcurrent signal) is not enough to obtain a sufficiently low duty cycle at 500 kHz, the output current, in strong overcurrent or short circuit conditions, could increase again. For this reason the switching frequency is also reduced, so keeping the inductor current under its maximum threshold. The Frequency Shifter (see [Figure 5](#)) depends on the feedback voltage. As the feedback voltage decreases (due to the reduced duty cycle), the switching frequency decreases too.

Figure 6. Current limitation circuitry



4.5 Error amplifier

The voltage error amplifier is the core of the loop regulation. It is a transconductance operational amplifier whose non inverting input is connected to the internal voltage reference (1.235 V), while the inverting input (FB) is connected to the external divider or directly to the output voltage. The output (COMP) is connected to the external compensation network.

The uncompensated error amplifier has the following characteristics:

Table 5. Uncompensated error amplifier

Transconductance	2300 μS
Low frequency gain	65 dB
Minimum sink/source voltage	1500 μA /300 μA
Output voltage swing	0.4 V/3.65 V
Input bias current	2.5 μA

The error amplifier output is compared with the oscillator sawtooth to perform PWM control.

4.6 PWM comparator and power stage

This block compares the oscillator sawtooth and the error amplifier output signals generating the PWM signal for the driving stage. The power stage is a very critical block cause it has to guarantee a correct turn on and turn OFF of the PDMOS. The turn ON of the power element, or better, the rise time of the current at turn on, is a very critical parameter to compromise.

At a first approach, it looks like the faster it is the rise time, the lower are the turn on losses. But there is a limit introduced by the recovery time of the recirculation diode. In fact when the current of the power element equals the inductor current, the diode turns off and the drain of the power is free to go high. But during its recovery time, the diode can be considered as an high value capacitor and this produces a very high peak current, responsible of many problems:

- Spikes on the device supply voltage that cause oscillations (and thus noise) due to the board parasitic.
- Turn ON overcurrent causing a decrease of the efficiency and system reliability.
- Big EMI problems.
- Shorter freewheeling diode life.

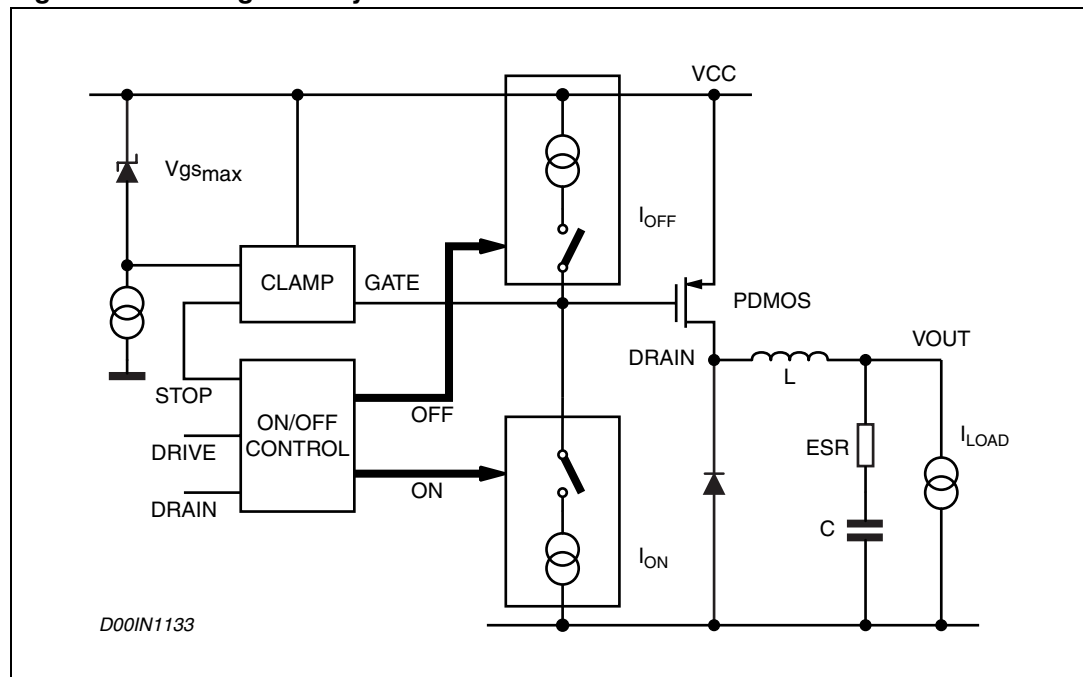
The fall time of the current during the turn off is also critical. In fact it produces voltage spikes (due to the parasites elements of the board) that increase the voltage drop across the PDMOS.

In order to minimize all these problems, a new topology of driving circuit has been used and its block diagram is shown in [Figure 7](#).

The basic idea is to change the current levels used to turn on and off the power switch, according with the PDMOS status and with the gate clamp status.

This circuitry allow to turn off and on quickly the power switch and to manage the above question related to the freewheeling diode recovery time problem.

The gate clamp is necessary to avoid that V_{gs} of the internal switch goes higher than V_{gsmax} . The ON/OFF Control block avoids any cross conduction between the supply line and ground.

Figure 7. Driving circuitry

4.7 Inhibit function

The inhibit feature allows to put in stand-by mode the device. With INH pin higher than 2.2 V the device is disabled and the power consumption is reduced to less than 100 μ A. With INH pin lower than 0.8 V, the device is enabled. If the INH pin is left floating, an internal pull up ensures that the voltage at the pin reaches the inhibit threshold and the device is disabled. The pin is also Vcc compatible.

4.8 Thermal shutdown

The shutdown block generates a signal that turns off the power stage if the temperature of the chip goes higher than a fixed internal threshold (150 $^{\circ}$ C). The sensing element of the chip is very close to the PDMOS area, so ensuring an accurate and fast temperature detection. An hysteresis of approximately 20 $^{\circ}$ C avoids that the devices turns on and off continuously

5 Additional features and protections

5.1 Feedback disconnection

In case of feedback disconnection, the duty cycle increases versus the maximum allowed value, bringing the output voltage close to the input supply. This condition could destroy the load.

To avoid this dangerous condition, the device is turned off if the feedback pin remains floating.

5.2 Output overvoltage protection

The overvoltage protection, OVP, is realized by using an internal comparator, which input is connected to the feedback, that turns off the power stage when the OVP threshold is reached. This threshold is typically 30% higher than the feedback voltage.

When a voltage divider is requested for adjusting the output voltage (see test application circuit), the OVP intervention will be set at:

Equation 1

$$V_{OVP} = 1.3 \cdot \frac{R_1 + R_2}{R_2} \cdot V_{FB}$$

Where R_1 is the resistor connected between the output voltage and the feedback pin, while R_2 is between the feedback pin and ground.

5.3 Zero load

Due to the fact that the internal power is a PDMOS, no bootstrap capacitor is required and so, the device works properly also with no load at the output. In this condition it works in burst mode, with random repetition rate of the burst.

5.4 Application circuit

In [Figure 8](#) is shown the demo board application circuit, where the input supply voltage, V_{CC} , can range from 4 V to 25 V due to the rated voltage of the input capacitor and the output voltage is adjustable from 1.235 V to V_{CC} .

Figure 8. Demo board application circuit

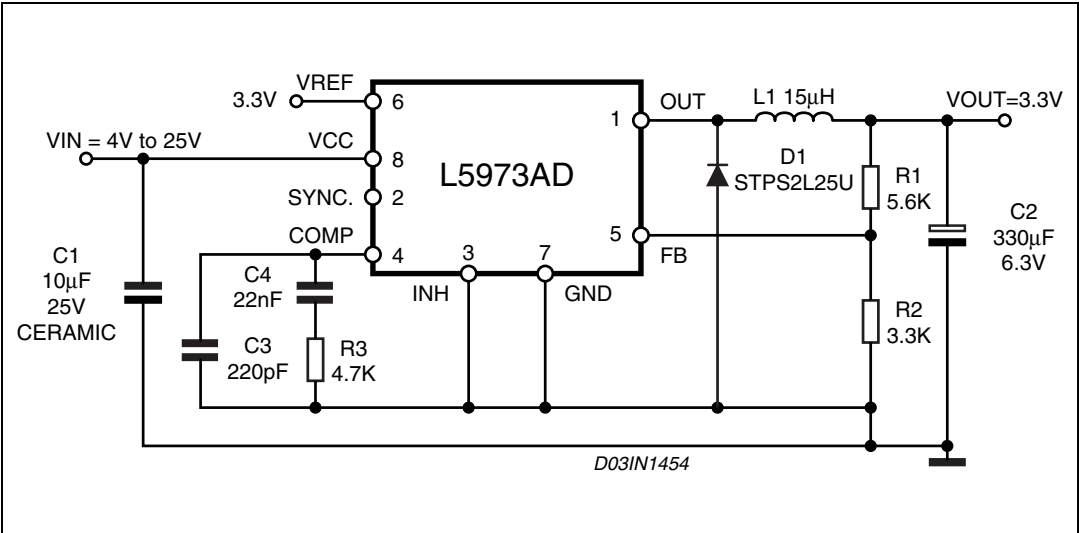


Table 6. Component List

Reference	Part Number	Description	Manufacturer
C1	GRM32DR61E106KA12L	10 μ F, 25 V	MURATA
C2	POSCAP 6TPB330M	330 μ F, 6.3 V	Sanyo
C3	C1206C221J5GAC	220 pF, 5%, 50 V	KEMET
C4	C1206C223K5RAC	22 nF, 10%, 50 V	KEMET
R1		5.6 K, 1%, 0.1 W 0603	Neohm
R2		3.3 K, 1%, 0.1 W 0603	Neohm
R3		4.7 K, 1%, 0.1 W 0603	Neohm
D1	STPS2L25U	2 A, 25 V	ST
L1	DO3316P-153	15 μ H, 3 A	COILCRAFT

Figure 9. Junction temperature vs output current

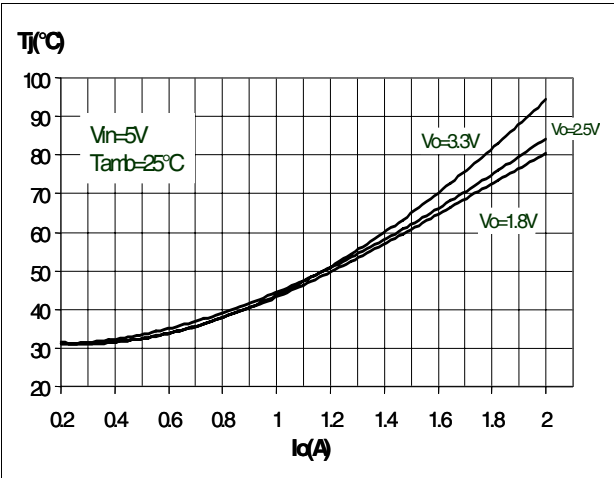


Figure 10. Junction temperature vs output current

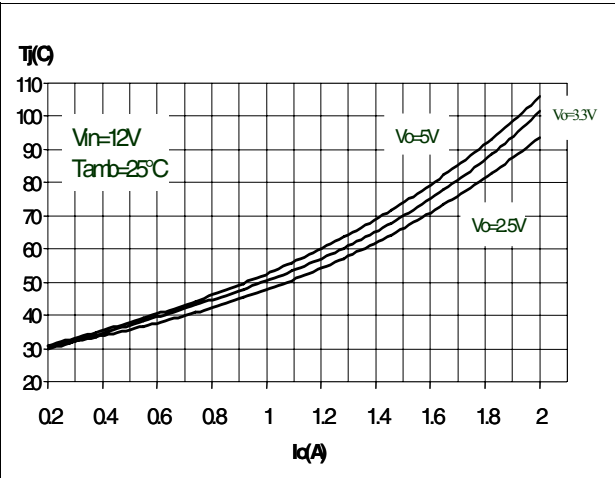


Figure 11. Efficiency vs output current

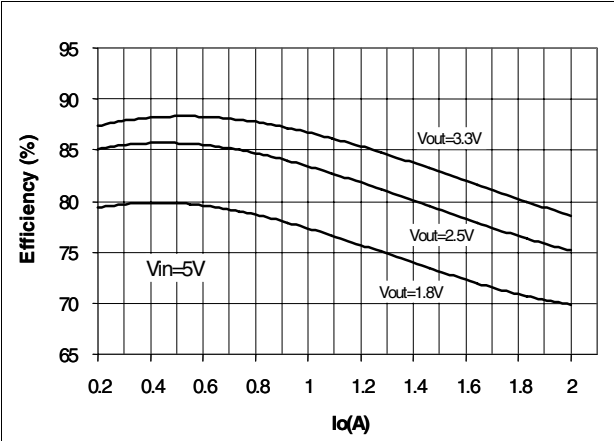
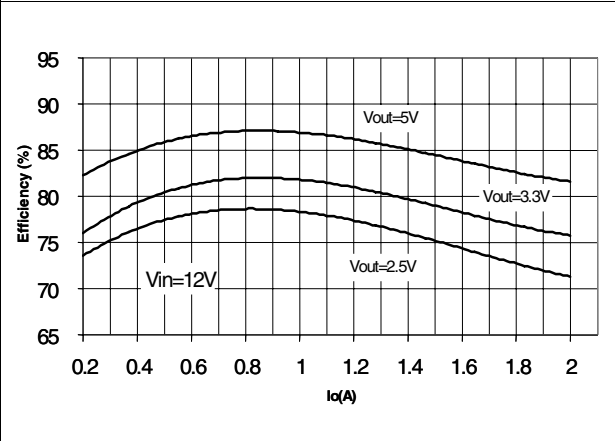


Figure 12. Efficiency vs output current



6 Application ideas

Figure 13. Positive buck-boost regulator

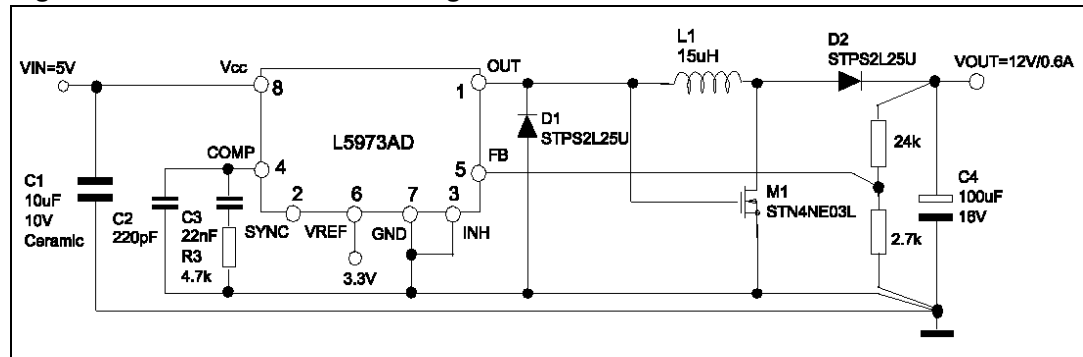


Figure 14. Buck-boost regulator

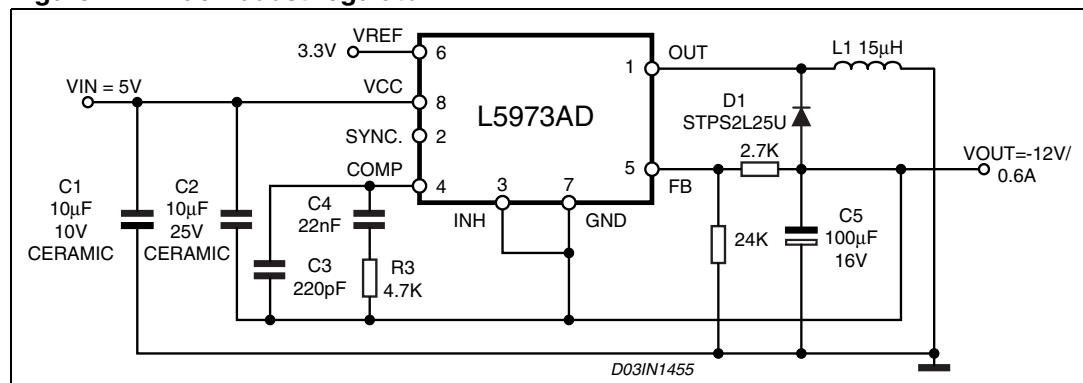
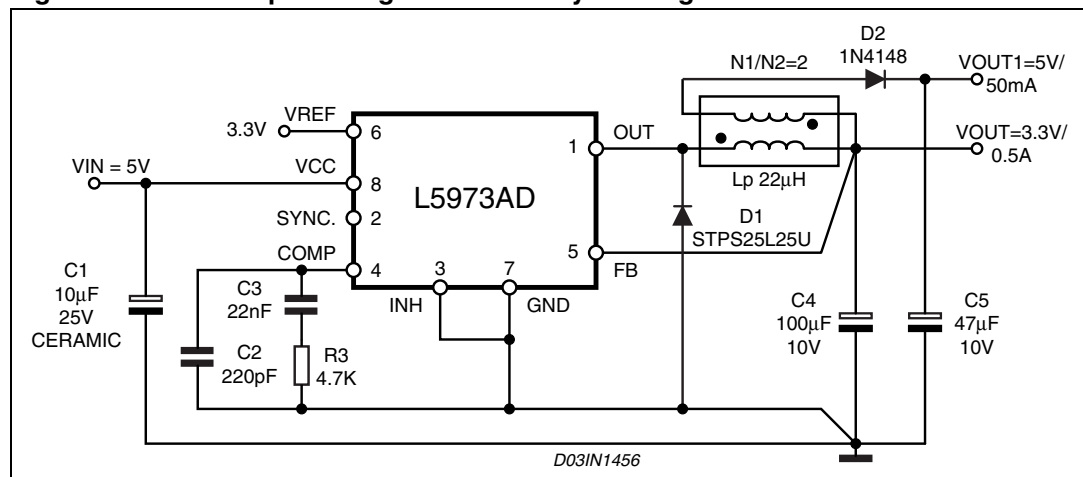


Figure 15. Dual output voltage with auxiliary winding



Refer to L5973AD application note (AN1723) to have additional information, details, and more application ideas.

L5973AD belongs to L597x family.

Related part numbers are:

- L5970D: 1.5 A (I_{SW}), 250 kHz step down DC-DC Converter in SO8
- L5972D: 2 A (I_{SW}), 250 kHz step down DC-DC Converter in SO8
- L5973D: 2.5 A (I_{SW}), 250 kHz step down DC-DC Converter in HSOP8

In case higher current is needed, the nearest DC-DC Converter family is L497x.

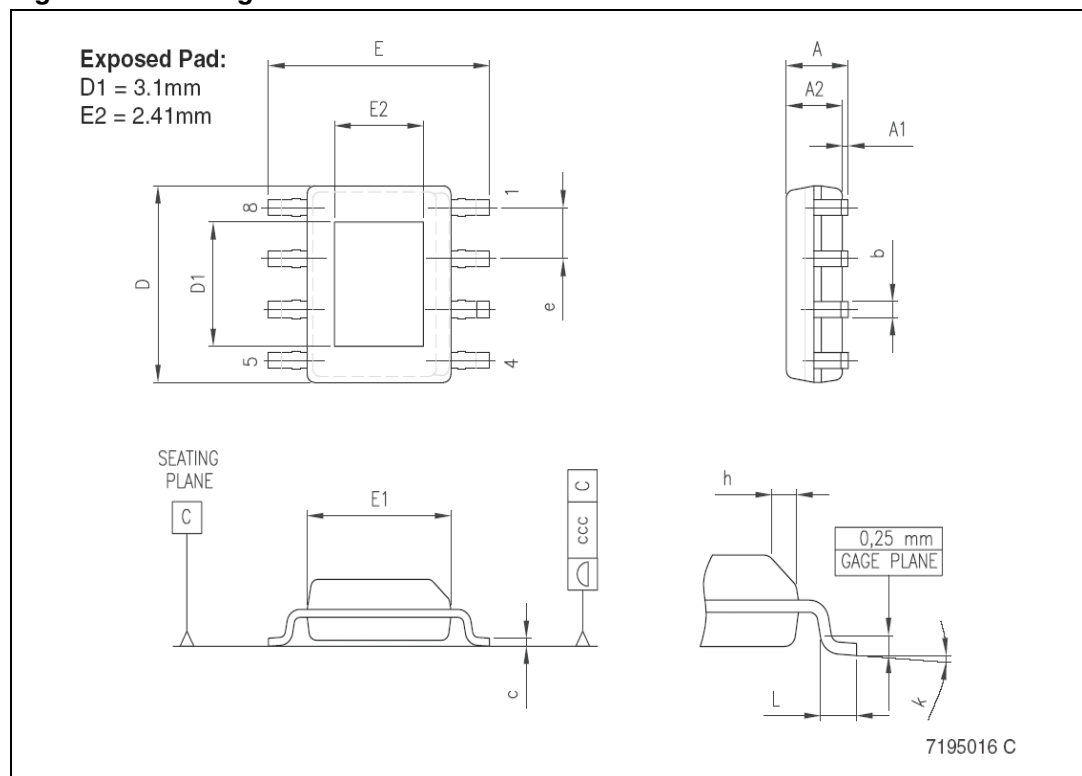
7 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

Table 7. HSOP8 mechanical data

Dim.	mm.			inch		
	Min	Typ	Max	Min	Typ	Max
A			1.70			0.0669
A1	0.00		0.15		0.00	0.0059
A2	1.25			0.0492		
b	0.31		0.51	0.0122		0.0201
c	0.17		0.25	0.0067		0.0098
D	4.80	4.90	5.00	0.1890	0.1929	0.1969
D1	3	3.1	3.2	0.118	0.122	0.126
E	5.80	6.00	6.20	0.2283		0.2441
E1	3.80	3.90	4.00	0.1496		0.1575
E2	2.31	2.41	2.51	0.091	0.095	0.099
e		1.27				
h	0.25		0.50	0.0098		0.0197
L	0.40		1.27	0.0157		0.0500
k	0		8			0.3150
ccc			0.10			0.0039

Figure 16. Package dimensions



8 Order code

Table 8. Ordering information

Order code	Package	Packaging
L5973AD	HSOP8 (Exposed pad)	Tube
L5973ADTR	HSOP8 (Exposed pad)	Tape and reel

9 Revision history

Table 9. Document revision history

Date	Revision	Changes
December 2003	1	First Issue
January 2004	2	Migration to EDOCS
December 2004	3	Added D1 and E1 dimensions in HSOP8 package information.
November 2005	4	Updated the package information section.
14-Dec-2006	5	V _{CC} value updated to 4V in Table 4 on page 5 , the document has been reformatted.
15-Jan-2007	6	Modified V _{CC} value in Table 4 on page 5 , added part number for C1 Table 6 on page 14 .
11-Oct-2007	7	Updated Table 6: Component List on page 14
24-Oct-2007	8	Updated Table 7 on page 19
01-Nov-2009	9	Updated Table 7 on page 19 and Table 4 on page 5

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