TSM1051

Constant voltage and constant current controller for battery chargers and adaptors

Features

- Constant voltage and constant current control
- Low voltage operation
- Precision internal voltage reference
- Low external component count
- Current sink output stage
- Easy compensation
- Low AC mains voltage rejection

Description

The device is is a highly integrated solution for SMPS applications requiring CV (constant voltage) and CC (constant current) mode.

It integrates one voltage reference, two operational amplifiers (with ORed outputs - common collectors), and a current sensing circuit.

The voltage reference combined with one operational amplifier makes it an ideal voltage controller; the current sensing circuit and the other operational amplifier make up the current control loop.

SO-8   **SOT23-6**
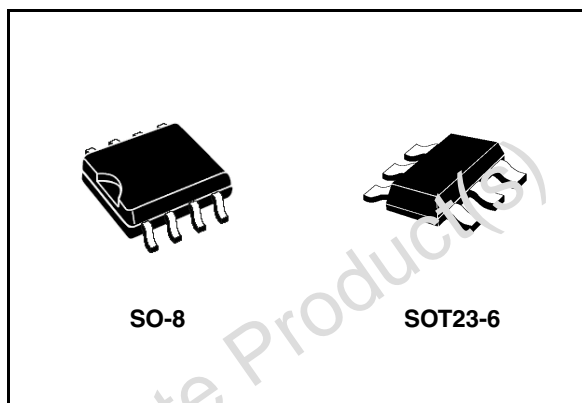
The only external components are:

- A resistor divider to be connected to the output of the power supply (adaptor, battery charger) to set the voltage regulation by dividing the desired output voltage to match the internal voltage reference value.
- A sense resistor having a value and allowable dissipation power which need to be chosen according to the internal voltage threshold.
- Optional compensation components (RC).

Housed in one of the smallest package available, it is ideal for space-shrunk applications such as adaptors and battery chargers.

Applications

- Adaptors
- Battery chargers

Table 1.   Device summary

Order codes	Package	Packaging
TSM1051CLT	SOT23-6	Tape and reel
TSM1051CD	SO-8	Tube
TSM1051CDT	SO-8	Tape and reel

Contents

1   Description

1.1   Pin connection

Figure 1.   Pin connection (top view)
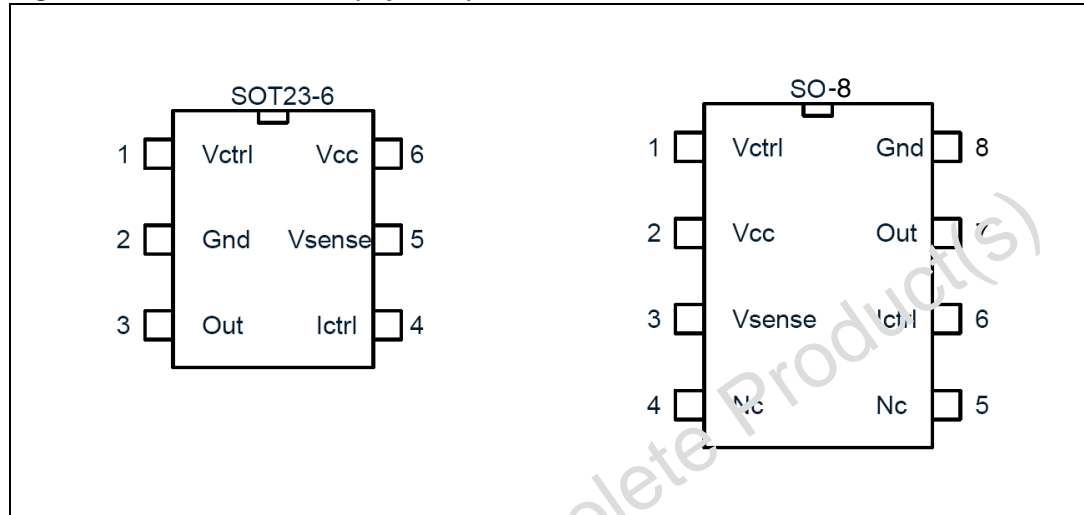
1.2   Pin description

Table 2.   Pin out

Name	Pin out		Type	Function
	SOT23 - 6	**SO-8**		
V_{ctrl}	1	1	Analog input	Input pin of the voltage control loop
Gnd	2	8	Power supply	Ground line. 0 V reference for all voltages
Out	3	7	Current sink output	Output pin. sinking current only
I_{ctrl}	4	6	Analog input	Input pin of the current control loop
V_{sense}	5	3	Analog input	Input pin of the current control loop
V_{CC}	6	2	Power supply	Positive power supply line
Nc		5		Not internally connected
Nc		4		Not internally connected.

1.3 Absolute maximum ratings

Table 3. **Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V_{CC}	DC supply voltage	14	V
V_I	Input voltage	-0.3 to Vcc	V
T_J	Maximum junction temperature	150	°C

1.4 Thermal data

Table 4. **Thermal data**

Symbol	Parameter	SOT23 - 6	SO-8	Unit
R_{thJA}	Thermal resistance junction ambient	250	130	°C/W

1.5 Operating conditions

Table 5. **Recommended operating conditions**

Symbol	Parameter	Value	Unit
V_{CC}	DC supply conditions	2.5 to 12	V
T_A	Ambient temperature range	0 to 85	°C

2   Electrical characteristics

T_A = 25 °C and V_{CC} = +5 V (unless otherwise specified)

Table 6.   Electrical characteristics

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
Total current consumption						
I_{CC}	Total supply current - not taking the output sinking current into account			1.1	2	mA
		0 < T_A < 85 °C		1.2		
Voltage control loop						
Gmv	Transconduction gain (Vctrl). sink current only [1]		1	3.5		mA/mV
		0 < T_A < 85 °C		2.5		
V_{ref}	Voltage control loop reference [2]		1.198	1.21	1.222	V
		0 < T_A < 85 °C	1.186		1.234	
Iibv	Input bias current (Vctrl)			50		nA
		0 < T_A < 85 °C		100		
Current control loop						
Gmi	Transconduction Gain (Ictrl). Sink Current Only [3]			1.5	7	mA/mV
V_{SENSE}	Current control loop reference [4]	I_O = 2.5 mA	196	200	204	mV
		0 < T_A < 85 °C I_O = 2.5 mA	192		208	
Iibi	Current out of pin ICTRL at -200 mV			25		µA
		0 < T_A < 85 °C		50		
Output stage						
V_{OL}	Low output voltage at 10 mA sinking current			200		mV
I_{OS}	Output short circuit current. output to vcc. sink current only			27	50	mA
		0 < T_A < 85 °C		35		

1. If the voltage on V_{CTRL} (the negative input of the amplifier) is higher than the positive amplifier input(V_{ref} = 1.210 V), and it is increased by 1mV, the sinking current at the output OUT will be increased by 3.5 mA.

2. The internal Voltage Reference is set at 1.210 V (bandgap reference). The voltage control loop precision takes into account the cumulative effects of the internal voltage reference deviation as well as the input offset voltage of the trans-conductance operational amplifier. The internal Voltage Reference is fixed by bandgap, and trimmed to 0.5 % accuracy at room temperature.

3. When the positive input at I_{CTRL} is lower than -200 mV, and the voltage is decreased by 1mV, the sinking current at the output OUT will be increased by 7 mA.

4. The internal current sense threshold is set to -200 mV. The current control loop precision takes into account the cumulative effects of the internal voltage reference deviation as well as the input offset voltage of the trans-conduction operational amplifier.
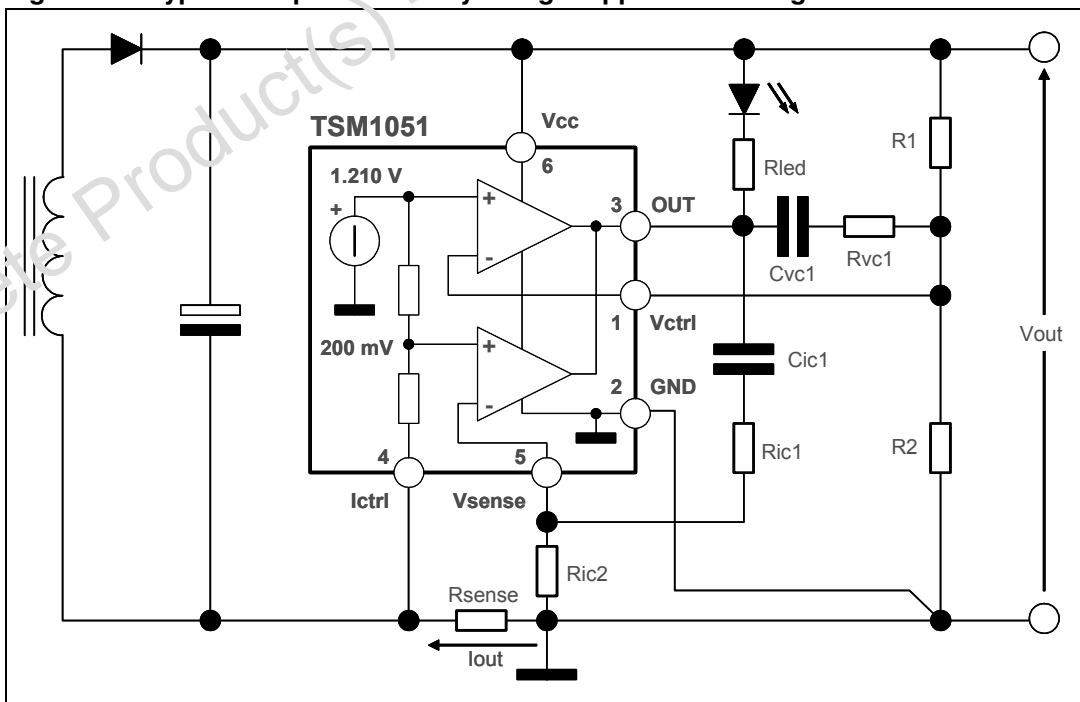
3 Schematics

3.1 Internal schematic

Figure 2. Block diagram
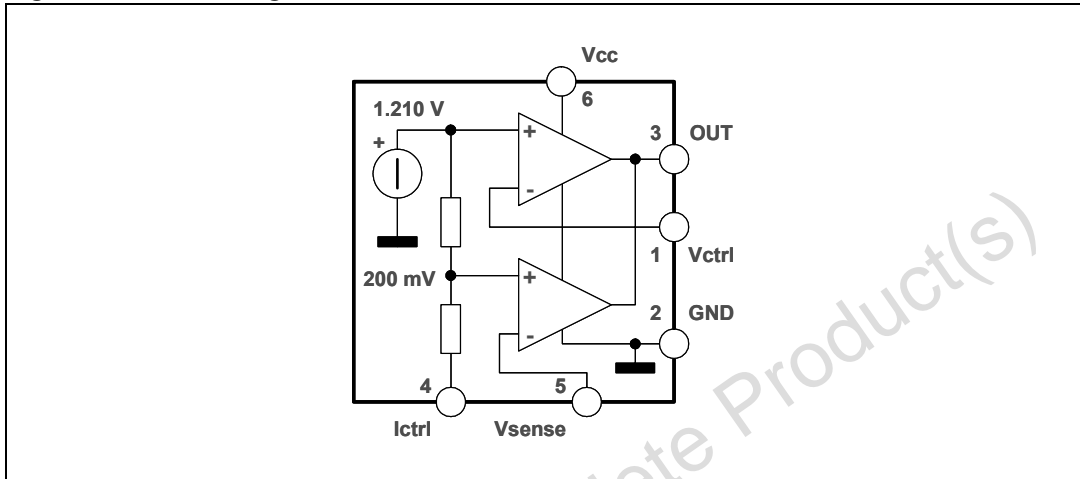
## 3.2 Typical application circuit

**Figure 3. Typical adaptor or battery charger application using the device**

In the above application schematic, the device is used on the secondary side of a flyback adaptor (or battery charger) to provide an accurate control of voltage and current. The above feedback loop is made with an optocoupler.
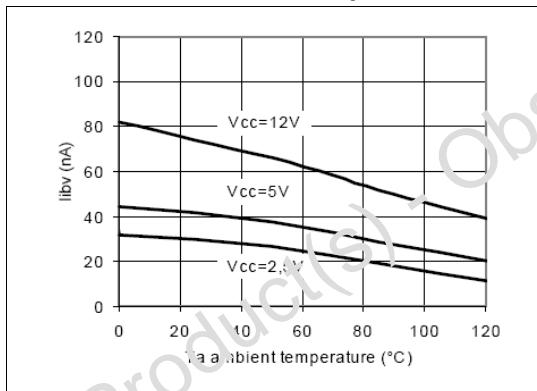
4 Typical electrical performance

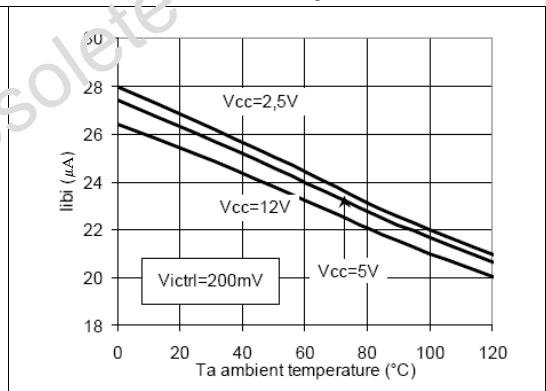**Figure 4. Vref vs ambient temperature**
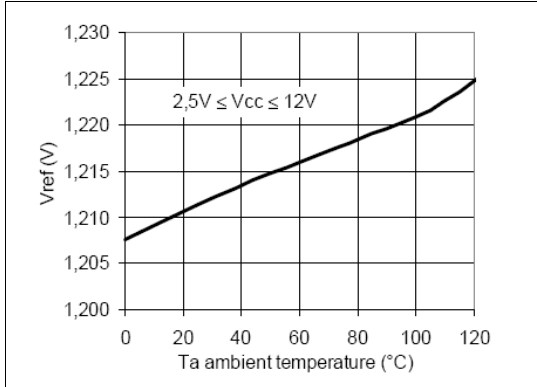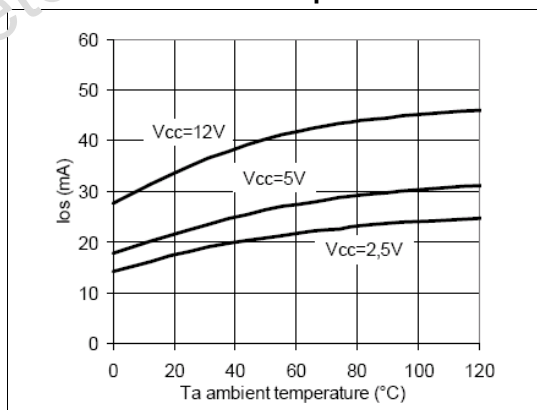
Figure 5. Vsense vs ambient temp.
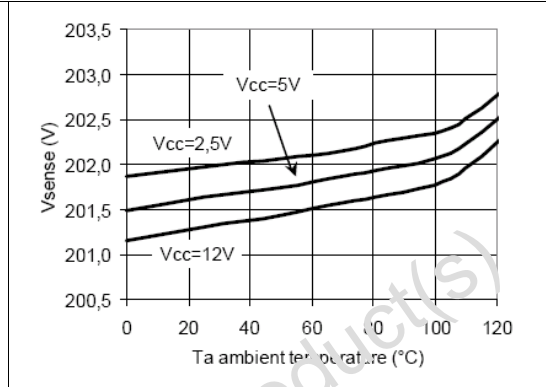
Figure 6. Vsense pin input bias current vs ambient temperature
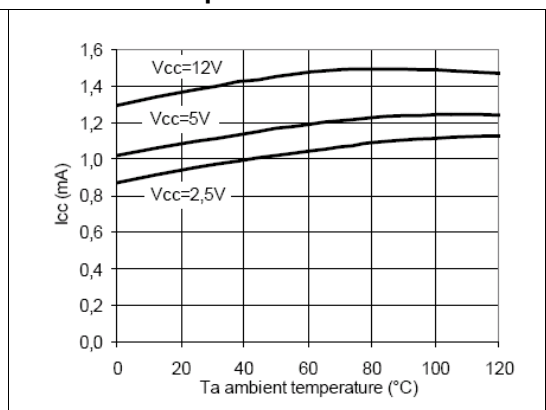
Figure 7. Ictrl pin input bias current vs ambient temperature

Figure 8. Output short circuit current vs ambient temperature

Figure 9. Supply current vs ambient temperature

5 Application information

5.1 Voltage and current control

5.1.1 Voltage control

The voltage loop is controlled via a first transconductance operational amplifier, the voltage divider R_1, R_2, and the optocoupler which is directly connected to the output. Its possible to choose the values of R1 and R2 resistors using Equation 1.

$$R_1 = R_2 \cdot \frac{(V_{OUT} - V_{REF})}{V_{REF}} \qquad \text{Eq:1}$$

where Vout is the desired output voltage.

To avoid the discharge of the load, the voltage divider R_1, R_2 should be highly resistive. For this type of application, it is suggested a total value of 100 kΩ (or more) for resistors R1 and R2

As an example, with R_2 = 33 kΩ, V_{OUT} = 5 V, V_{REF} = 1.210 V, then R_1 = 103.4 kΩ

Please note that if a low drop diode is inserted between the load and the voltage divider of the voltage control loop in order to avoid current flowing from the load through the voltage divider, the diode voltage drop should be taken into account in the computation of Equation 1 replacing V_{out} with V_{out} + V_{drop}.

5.1.2 Current control

The current loop is controlled via the second trans-conductance operational amplifier, the sense resistor Rsense, and the optocoupler.

The control equation verifies:

   Rsense x Ilim = Vsense   Eq:2

   Rsense = Vsense / Ilim   Eq:2a

where Ilim is the desired limited current, and Vsense is the threshold voltage for the current control loop. As an example, with Ilim = 1 A, Vsense = -200 mV, then Rsense = 200 mΩ.

Note that the Rsense resistor should be chosen taking into account the maximum dissipation (Plim) through it during full load operation.

   Plim = Vsense x Ilim.   Eq:3

As an example, with Ilim = 1 A, and Vsense = 200 mV, Plim = 200 mW.

Therefore, for most adaptor and battery charger applications, a quarter-watt, or half-watt resistor to make the current sensing function is sufficient. Vsense threshold is achieved internally by a voltage divider tied to the Vref voltage reference. Its middle point is tied to the positive input of the current control operational amplifier, and its foot is to be connected to lower potential point of the sense resistor as shown in *Figure 3.* The resistors of this voltage divider are matched to provide the best precision possible. The current sinking outputs of the two trans-conductance operational amplifiers are common (to the output of the IC). This makes an ORing function which ensures that whenever the current or the voltage reaches too high values, the optocoupler is activated. The relation between the controlled current and the controlled output voltage can be described with a square characteristic as shown in the following V/I output-power graph. (with power supply of the device indipendent from the output voltage)

Figure 10.   Output voltage versus output current
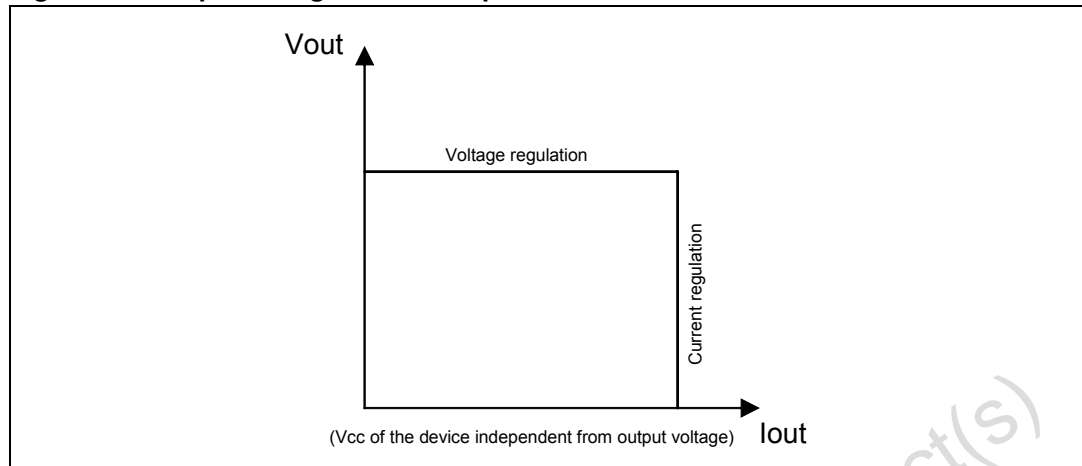
5.2   Compensation

The voltage-control trans-conductance operational amplifier can be fully compensated. Both of its output and negative input are directly accessible for external compensation components.

An example of a suitable compensation network is shown in *Figure 3.* It consists of a capacitor Cvc1 = 2.2 nF and a resistor Rvc1 = 470 kΩ in series.

The current-control trans-conductance operational amplifier can be fully compensated. Both its output and negative input are directly accessible for external compensation components.

An example of a suitable compensation network is shown in *Figure 3.* It consists of a capacitor Cic1 = 2.2 nF and a resistor Ric1 = 22 kΩ in series. In order to reduce the dissipation of the device (especially with V_{CC} voltage values close to 12 V) and to increase the stability of the application it is suggested to limit the current flowing in the OUT pin of the device adding a resistor in series with the opto-coupler.

An example of a suitable R_{LED} value could be 330 Ω in series with the opto-coupler in case V_{CC} = 12 V.

5.3   Start up and short circuit conditions

Under start-up or short-circuit conditions the device is not provided with a high enough supply voltage. This is due to the fact that the chip has its power supply line in common with the power supply line of the system.

Therefore, the current limitation can only be ensured by the primary PWM module, which should be chosen accordingly.

If the primary current limitation is considered not to be precise enough for the application, then a sufficient supply for the device has to be ensured under any condition. It would then be necessary to add some circuitry to supply the chip with a separate power line. This can be achieved in numerous ways, including an additional winding on the transformer.

The following schematic shows how to realize a low-cost power supply for the device (with no additional windings).

This solution allow a costant current regulation till output goes to 0 V.

Attention has to be payed to V_{CC} of the device that cannot be higher than Absolute Maximum Rating.

Figure 11. Application circuit able to supply the device even with $V_{OUT} = 0$
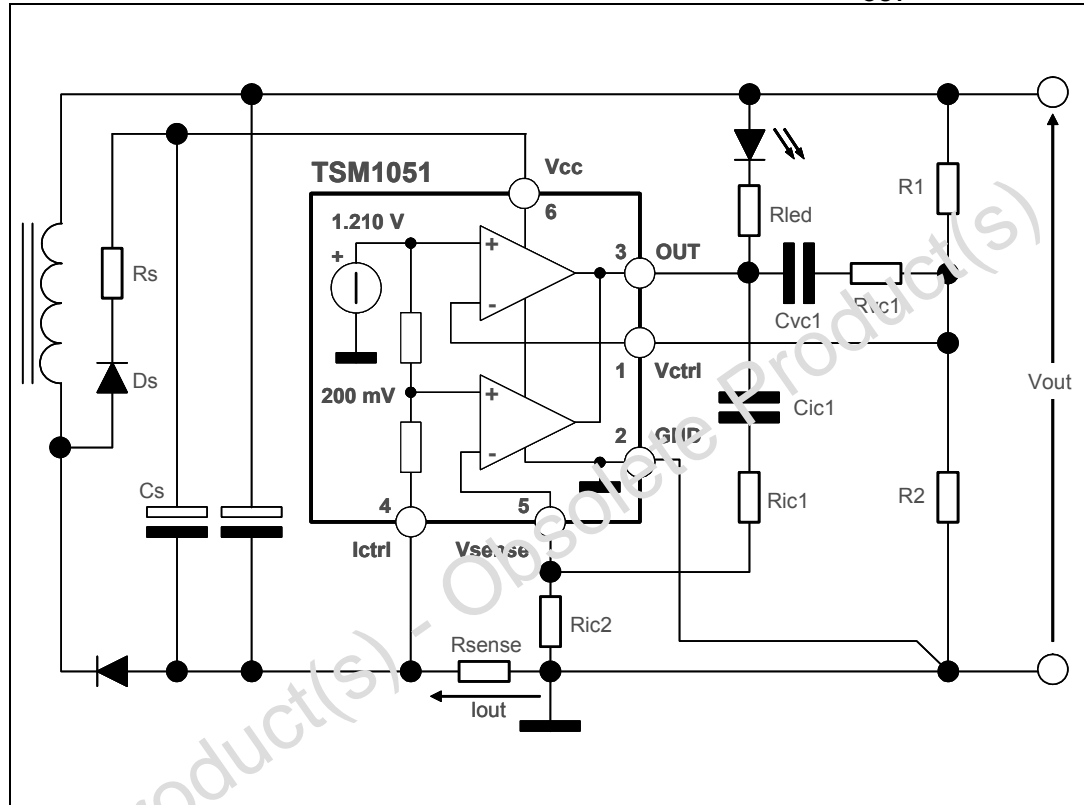
6   Package mechanical data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.

Table 7.   SOT23-6 mechanical data

Dim.	mm.			inch		
	Min	Typ	Max	Min	Typ	Max
A		0.9	1.45		0.035	0.057
A1		0	0.1		0	0.0039
A2		0.9	1.3		0.035	0.0512
b		0.35	0.5		0.014	0.02
c		0.09	0.2		0.004	0.008
D		2.8	3.05		0.11	0.120
E		1.5	1.75		0.059	0.0689
e	0.95			0.037		
H		2.6	3		0.102	0.118
L		0.1	0.6		0.004	0.024
θ		0	10°		0	10°

Note: Dimensions per JEDEC MO178AB

Figure 12.   Package dimensions
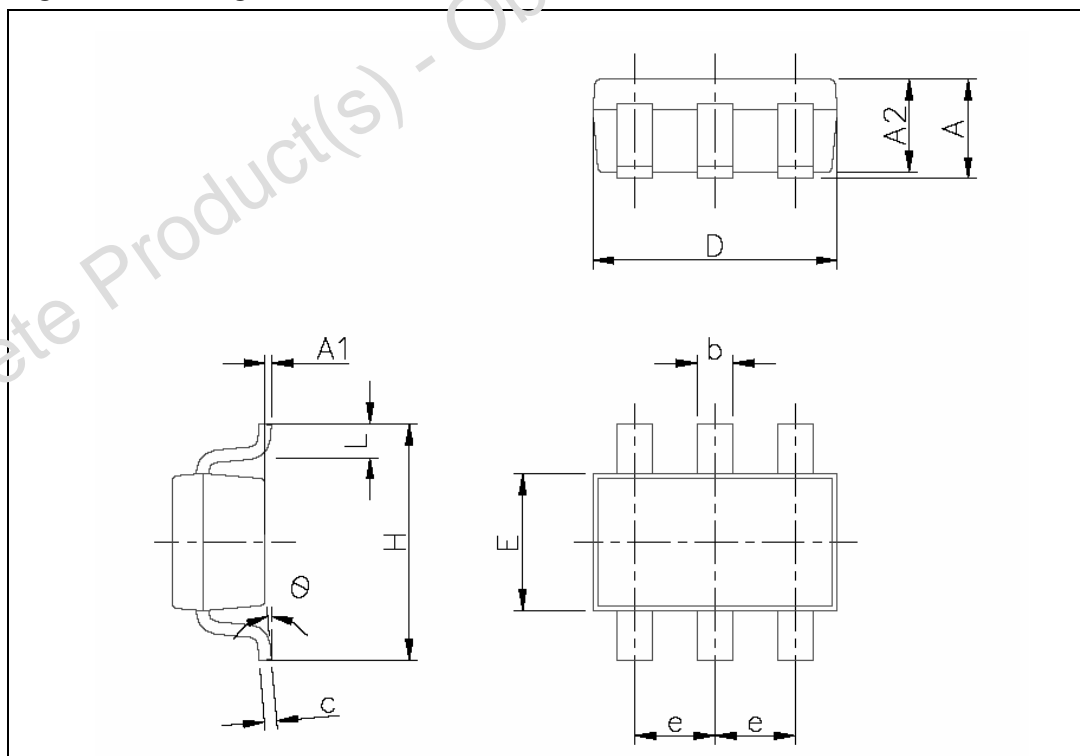
Table 8. SO-8 mechanical data

Dim.	mm.			inch		
	Min	Typ	Max	Min	Typ	Max
A	1.35		1.75	0.053		0.069
A1	0.1		0.25	0.004		0.010
A2	1.1		1.65	0.043		0.065
B	0.33		0.51	0.013		0.020
C	0.19		0.25	0.007		0.010
D	4.8		5	0.189		0.197
E	3.8		4	0.150		0.157
e		1.27		0.000	0.050	0.000
H	5.8		6.2	0.228		0.244
h	0.25		0.5	0.010		0.020
L	0.4		1.27	0.016		0.050
k	8° (max.)					
ddd			0.1			0.004

Figure 13. Package dimensions
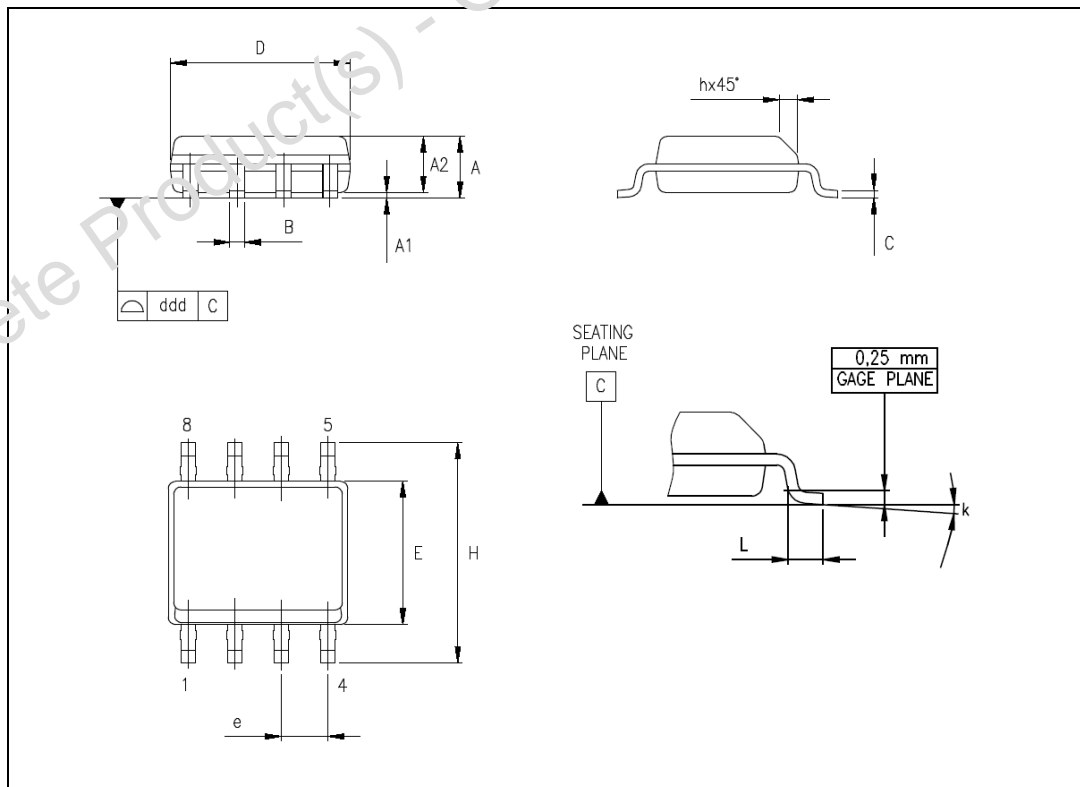
7   Revision history

Table 9.   Document revision history

Date	Revision	Changes
8-Jan-2002	1	Initial release.
18-Apr-2006	2	New Template, few updates
12-Feb-2008	3	Updated: *Section 6: Package mechanical data on page 11*

Please Read Carefully:

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

www.st.com