



# TSM1051

## Constant voltage and constant current controller for battery chargers and adaptors

### Features

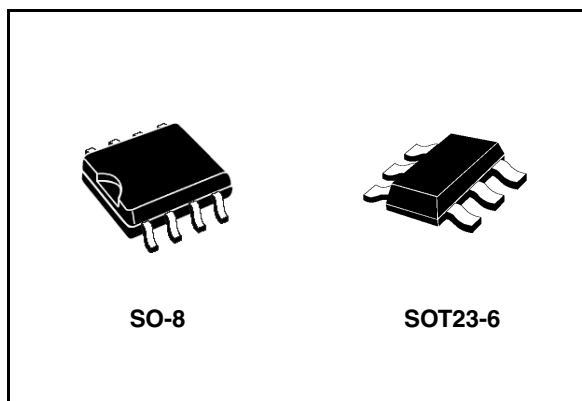
- Constant voltage and constant current control
- Low voltage operation
- Precision internal voltage reference
- Low external component count
- Current sink output stage
- Easy compensation
- Low AC mains voltage rejection

### Description

The device is 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.



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 |

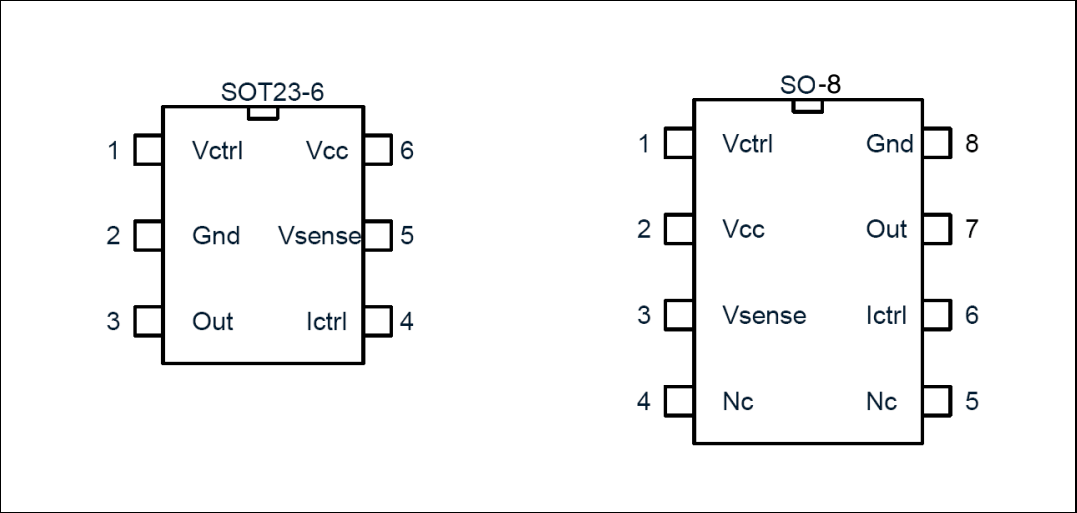
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# 1 Description

## 1.1 Pin connection

Figure 1. Pin connection (top view)



## 1.2 Pin description

Table 2. Pin out

| Name               | Pin n°    |      | Type                | Function                                    |
|--------------------|-----------|------|---------------------|---------------------------------------------|
|                    | SOT23 - 6 | SO-8 |                     |                                             |
| V <sub>ctrl</sub>  | 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 <sub>ctrl</sub>  | 4         | 6    | Analog input        | Input pin of the current control loop       |
| V <sub>sense</sub> | 5         | 3    | Analog input        | Input pin of the current control loop       |
| V <sub>CC</sub>    | 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 $V_{CC}$ | 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

$T_A = 25\text{ }^{\circ}\text{C}$  and  $V_{CC} = +5\text{ V}$  (unless otherwise specified)

**Table 6. Electrical characteristics**

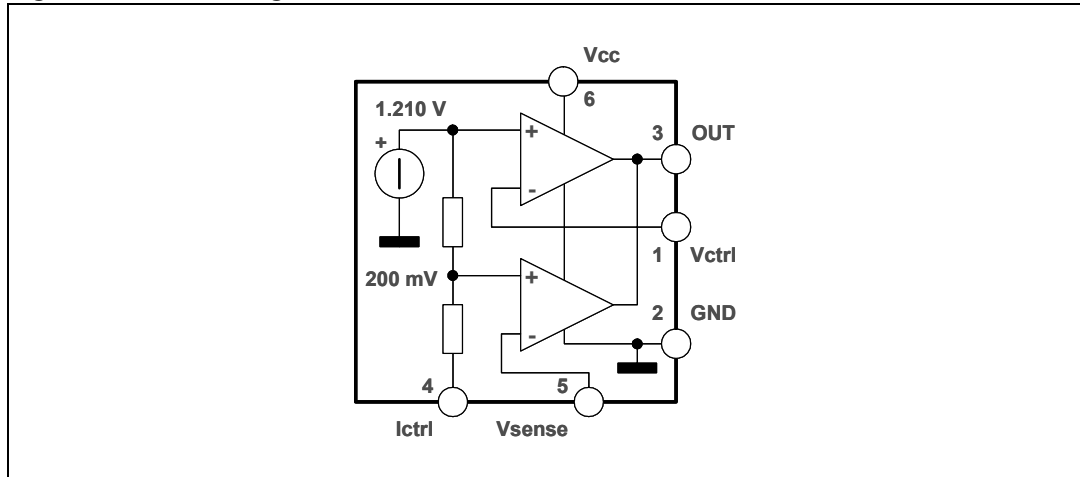
| Symbol                    | Parameter                                                                   | Test condition                                        | Min   | Typ  | Max   | Unit  |
|---------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------|-------|------|-------|-------|
| Total current consumption |                                                                             |                                                       |       |      |       |       |
| I <sub>CC</sub>           | Total supply current - not taking the output sinking current into account   |                                                       |       | 1.1  | 2     | mA    |
|                           |                                                                             | 0 < T <sub>A</sub> < 85 °C                            |       | 1.2  |       |       |
| Voltage control loop      |                                                                             |                                                       |       |      |       |       |
| G <sub>mv</sub>           | Transconduction gain (V <sub>ctrl</sub> ). sink current only <sup>(1)</sup> |                                                       | 1     | 3.5  |       | mA/mV |
|                           |                                                                             | 0 < T <sub>A</sub> < 85 °C                            |       | 2.5  |       |       |
| V <sub>ref</sub>          | Voltage control loop reference <sup>(2)</sup>                               |                                                       | 1.198 | 1.21 | 1.222 | V     |
|                           |                                                                             | 0 < T <sub>A</sub> < 85 °C                            | 1.186 |      | 1.234 |       |
| libv                      | Input bias current (V <sub>ctrl</sub> )                                     |                                                       |       | 50   |       | nA    |
|                           |                                                                             | 0 < T <sub>A</sub> < 85 °C                            |       | 100  |       |       |
| Current control loop      |                                                                             |                                                       |       |      |       |       |
| G <sub>mi</sub>           | Transconduction Gain (I <sub>ctrl</sub> ). Sink Current Only <sup>(3)</sup> |                                                       | 1.5   | 7    |       | mA/mV |
| V <sub>SENSE</sub>        | Current control loop reference <sup>(4)</sup>                               | I <sub>O</sub> = 2.5 mA                               | 196   | 200  | 204   | mV    |
|                           |                                                                             | 0 < T <sub>A</sub> < 85 °C<br>I <sub>O</sub> = 2.5 mA | 192   |      | 208   |       |
| libi                      | Current out of pin ICTRL at -200 mV                                         |                                                       |       | 25   |       | μA    |
|                           |                                                                             | 0 < T <sub>A</sub> < 85 °C                            |       | 50   |       |       |
| Output stage              |                                                                             |                                                       |       |      |       |       |
| V <sub>OL</sub>           | Low output voltage at 10 mA sinking current                                 |                                                       |       | 200  |       | mV    |
| I <sub>OS</sub>           | Output short circuit current. output to vcc. sink current only              |                                                       |       | 27   | 50    | mA    |
|                           |                                                                             | 0 < T <sub>A</sub> < 85 °C                            |       | 35   |       |       |

1. If the voltage on  $V_{CTRL}$  (the negative input of the amplifier) is higher than the positive amplifier input ( $V_{ref} = 1.210\text{ V}$ ), 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

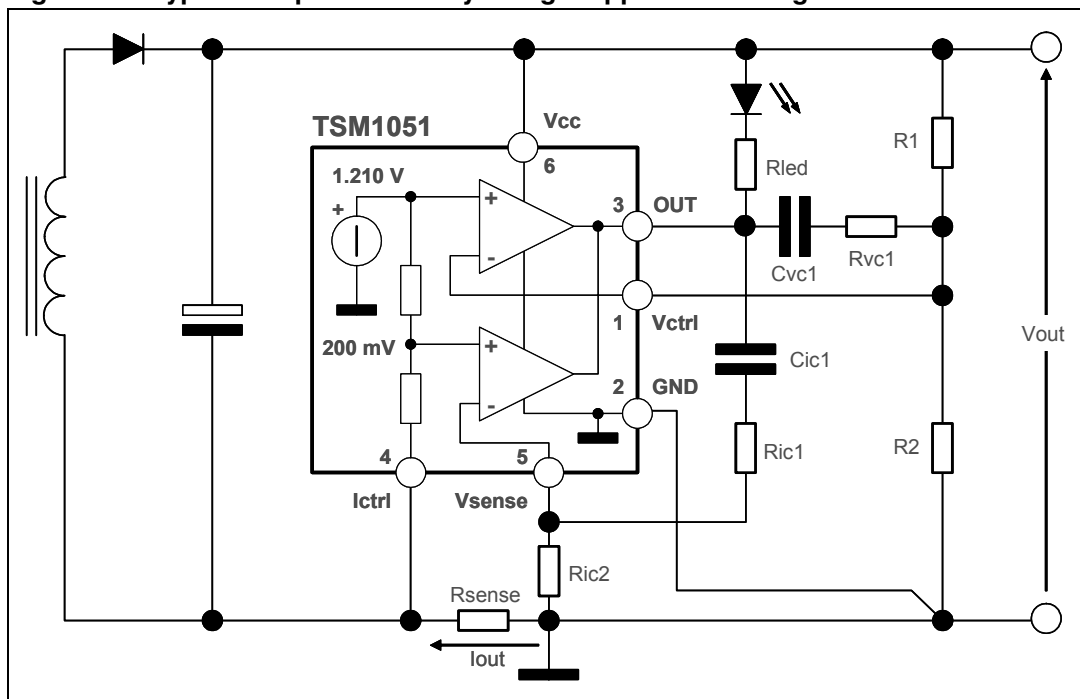
### 3.1 Internal schematic

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

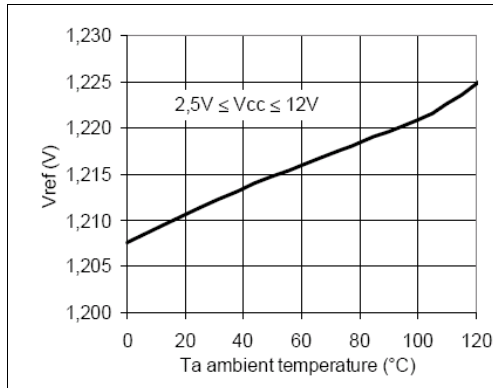


Figure 5. Vsense vs ambient temp.

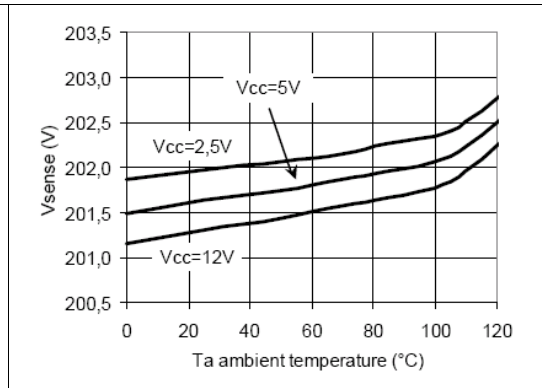


Figure 6. Vsense pin input bias current vs ambient temperature

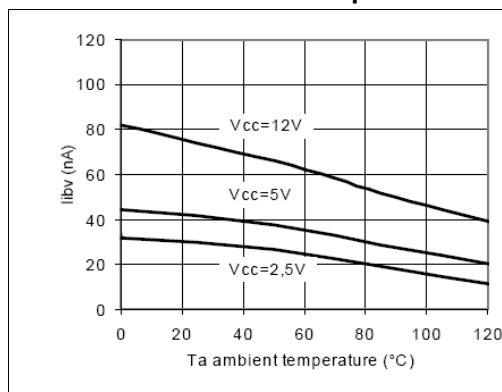


Figure 7. Ictrl pin input bias current vs ambient temperature

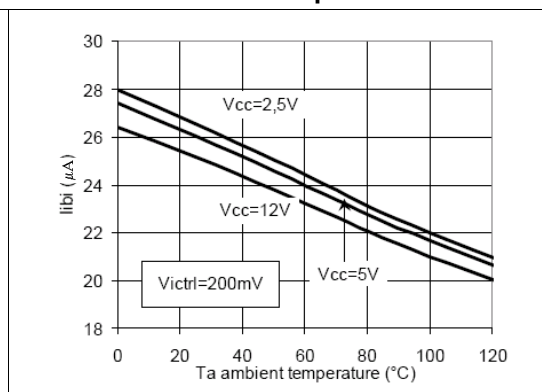


Figure 8. Output short circuit current vs ambient temperature

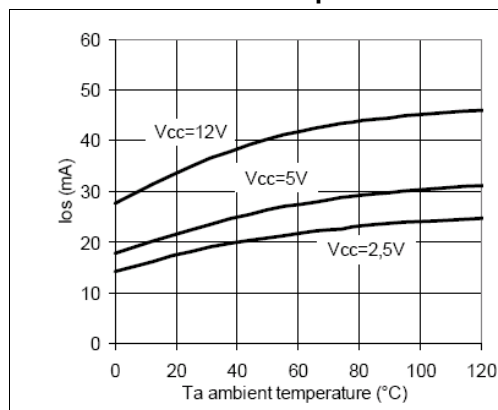
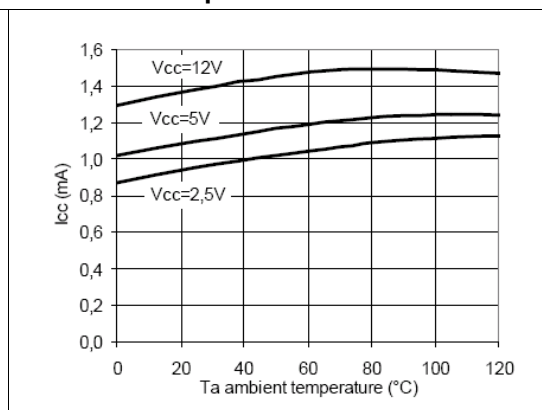


Figure 9. Supply current vs ambient temperature



## 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  $R_1$  and  $R_2$  resistors using Equation 1.

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

where  $V_{out}$  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 k $\Omega$  (or more) for resistors  $R_1$  and  $R_2$

As an example, with  $R_2 = 33 \text{ k}\Omega$ ,  $V_{OUT} = 5 \text{ V}$ ,  $V_{REF} = 1.210 \text{ V}$ , then  $R_1 = 103.4 \text{ k}\Omega$

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  $R_{sense}$ , and the optocoupler.

The control equation verifies:

$$R_{sense} \times I_{lim} = V_{sense} \quad \text{Eq:2}$$

$$R_{sense} = V_{sense} / I_{lim} \quad \text{Eq:2a}$$

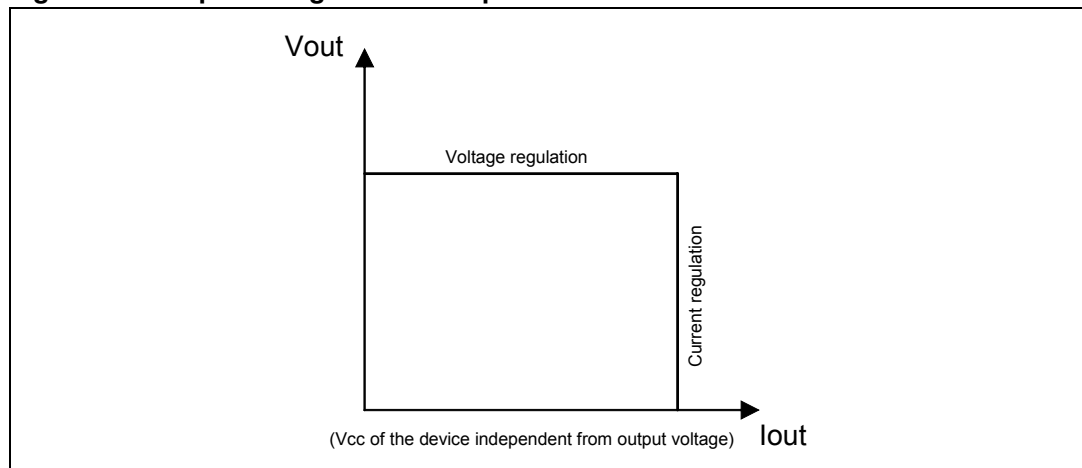
where  $I_{lim}$  is the desired limited current, and  $V_{sense}$  is the threshold voltage for the current control loop. As an example, with  $I_{lim} = 1 \text{ A}$ ,  $V_{sense} = -200 \text{ mV}$ , then  $R_{sense} = 200 \text{ m}\Omega$ .

Note that the  $R_{sense}$  resistor should be chosen taking into account the maximum dissipation ( $P_{lim}$ ) through it during full load operation.

$$P_{lim} = V_{sense} \times I_{lim}. \quad \text{Eq:3}$$

As an example, with  $I_{lim} = 1 \text{ A}$ , and  $V_{sense} = 200 \text{ mV}$ ,  $P_{lim} = 200 \text{ mW}$ .

Therefore, for most adaptor and battery charger applications, a quarter-watt, or half-watt resistor to make the current sensing function is sufficient.  $V_{sense}$  threshold is achieved internally by a voltage divider tied to the  $V_{ref}$  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 independent 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  $C_{vc1} = 2.2 \text{ nF}$  and a resistor  $R_{cv1} = 470 \text{ k}\Omega$  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  $C_{ic1} = 2.2 \text{ nF}$  and a resistor  $R_{ic1} = 22 \text{ k}\Omega$  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  $330 \text{ }\Omega$  in series with the opto-coupler in case  $V_{CC} = 12 \text{ V}$ .

## 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).

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

The diagram shows a power supply and a feedback control system. A transformer provides input to a diode bridge rectifier. The output of the rectifier is filtered by a capacitor  $C_s$ . A resistor  $R_s$  is connected between the input and the rectifier. The output of the rectifier is connected to the  $V_{cc}$  pin of the TSM1051. The TSM1051 is a dual operational amplifier. The first op-amp has its non-inverting input (+) connected to a 1.210V reference and its inverting input (-) connected to a feedback network consisting of a resistor  $R_{led}$  and a capacitor  $C_{vc1}$ . The output of the first op-amp is connected to the  $V_{ctrl}$  pin. The second op-amp has its non-inverting input (+) connected to a 200mV reference and its inverting input (-) connected to a feedback network consisting of a resistor  $R_{ic1}$  and a capacitor  $C_{ic1}$ . The output of the second op-amp is connected to the  $V_{sense}$  pin. The  $V_{sense}$  pin is also connected to a resistor  $R_{ic2}$  and a resistor  $R_{sense}$ . The output of the  $R_{sense}$  resistor is labeled  $I_{out}$ . The output of the  $R_{ic2}$  resistor is connected to the  $V_{ctrl}$  pin. The output of the  $V_{ctrl}$  pin is connected to the  $V_{cc}$  pin. The output of the  $V_{cc}$  pin is connected to the  $V_{out}$  terminal. The output of the  $V_{out}$  terminal is connected to the  $V_{out}$  terminal.

## 6 Package mechanical data

In order to meet environmental requirements, ST offers these devices in ECOPACK<sup>®</sup> 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](http://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

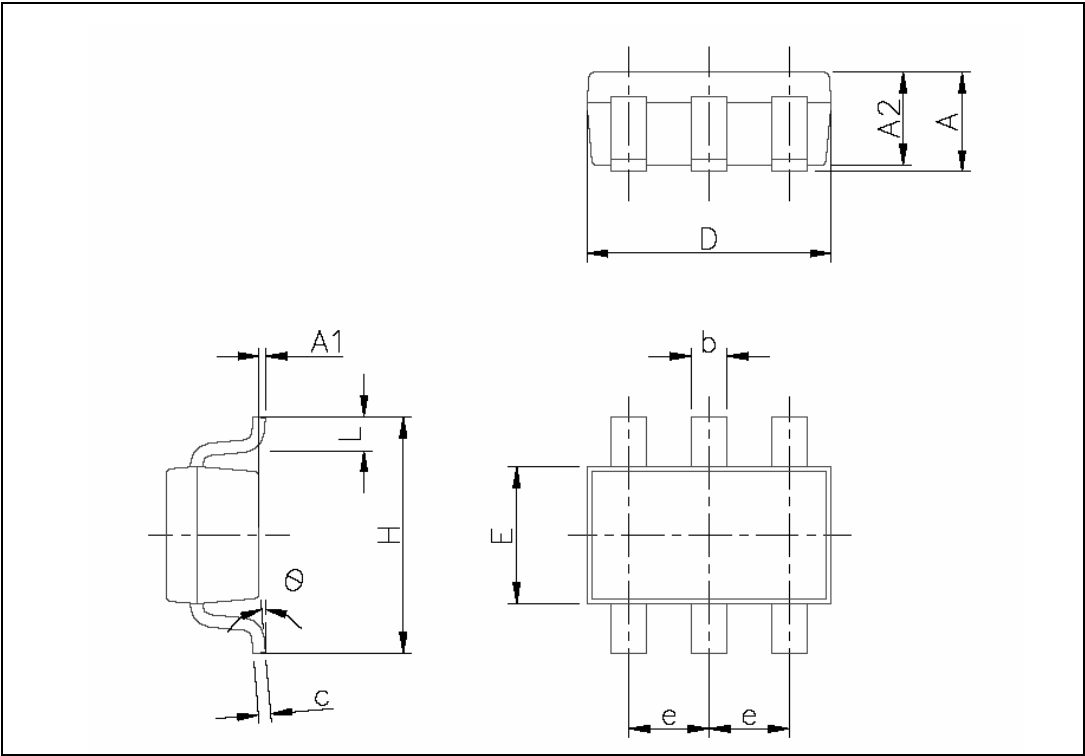
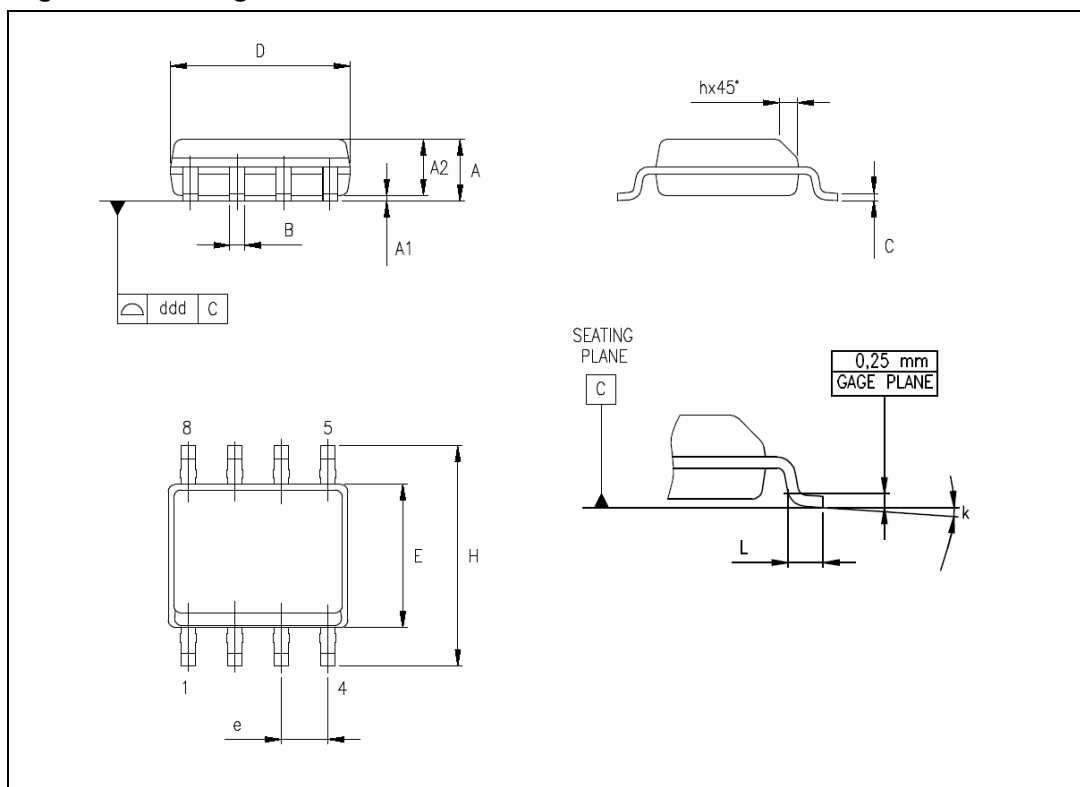


Table 8. SO-8 mechanical data

| 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: <a href="#">Section 6: Package mechanical data on page 11</a> |

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