



TSM1013

Constant Voltage and Constant Current Controller for Battery Chargers and Adaptors

- Constant voltage and constant current control
- Low voltage operation
- Low external component count
- Current sink output stage
- Easy compensation

VOLTAGE REFERENCE

- Fixed output voltage reference 2.5V
- 0.5% and 1% Voltage precision

DESCRIPTION

TSM1013 is a highly integrated solution for SMPS applications requiring CV (constant voltage) and CC (constant current) mode.

TSM1013 integrates one voltage reference and two operational amplifiers.

The voltage reference combined with one operational amplifier makes it an ideal voltage controller. The other operational, combined with few external resistors and the voltage reference, can be used as a current limiter.

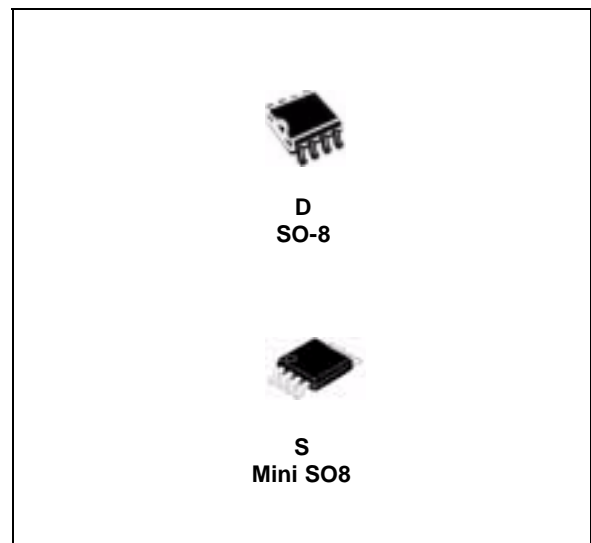
APPLICATIONS

- Adapters
- Battery Chargers

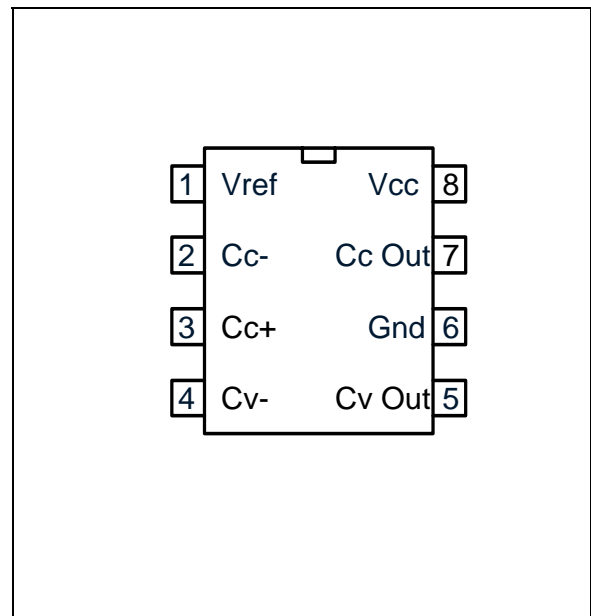
ORDER CODE

| Part Number | Temperature Range | Package | | Marking |
|-------------|-------------------|---------|---|---------|
| | | S | D | |
| TSM1013I | 0 to 105°C | | 2 | M1013 |
| TSM1013AI | 0 to 105°C | | 2 | M1013A |
| TSM1013I | 0 to 105°C | 2 | | M806 |
| TSM1013AI | 0 to 105°C | 2 | | M807 |

Note: S: MiniSO only available in Tape & Reel with T suffix
D: SO is available in Tube (D) and in Tape & Reel (DT)



PIN CONNECTIONS (top view)



1 PIN DESCRIPTION

SO8 & Mini SO8 Pinout

| Name | Pin # | Type | Function |
|--------|-------|---------------|--|
| Vref | 1 | Analog Output | Voltage Reference |
| Cc- | 2 | Analog Input | Input pin of the operational amplifier |
| Cc+ | 3 | Analog Input | Input pin of the operational amplifier |
| Cv- | 4 | Analog Input | Input pin of the operational amplifier |
| Cv Out | 5 | Analog Output | Output of the operational amplifier |
| Gnd | 6 | Power Supply | Ground Line. 0V Reference For All Voltages |
| Cc Out | 7 | Analog Output | Output of the operational amplifier |
| Vcc | 8 | Power Supply | Power supply line. |

ABSOLUTE MAXIMUM RATINGS

| Symbol | DC Supply Voltage | Value | Unit |
|--------|---|-------------|------|
| Vcc | DC Supply Voltage (50mA =< Icc) | -0.3V to Vz | V |
| Vi | Input Voltage | -0.3 to Vcc | V |
| Tstg | Storage temperature | -55 to 150 | °C |
| Tj | Junction temperature | 150 | °C |
| Iref | Voltage reference output current | 10 | mA |
| ESD | Electrostatic Discharge | 2 | KV |
| Rthja | Thermal Resistance Junction to Ambient Mini SO8 package | 180 | °C/W |
| Rthja | Thermal Resistance Junction to Ambient SO8 package | 175 | °C/W |

OPERATING CONDITIONS

| Symbol | Parameter | Value | Unit |
|--------|-------------------------|-----------|------|
| Vcc | DC Supply Conditions | 4.5 to Vz | V |
| Toper | Operational temperature | 0 to 105 | °C |

2 ELECTRICAL CHARACTERISTICS

T_{amb} = 25°C and V_{cc} = +18V (unless otherwise specified)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|--|--|--|----------------|-----------------|----------------------------------|-------|
| Total Current Consumption | | | | | | |
| I _{cc} | Total Supply Current, excluding current in Voltage Reference. | V _{cc} = 18V, no load T _{min.} < T _{amb} < T _{max.} | | | 1 | mA |
| V _z | V _{cc} clamp voltage | I _{cc} = 50mA | | 28 | | V |
| Operator 1 : Op-amp with non-inverting input connected to the internal Vref | | | | | | |
| V _{ref} +V _{io} | Input Offset Voltage + Voltage reference TSM1013 TSM1013A | T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} | | 2.5446 2.545 | 2.574 2.575 2.553 2.560 | V |
| DV _{io} | Input Offset Voltage Drift | | | 7 | | μV/°C |
| Operator 2 | | | | | | |
| V _{io} | Input Offset Voltage TSM1013 TSM1013A | T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} | | 1 0.5 | 4 5 2 3 | mV |
| DV _{io} | Input Offset Voltage Drift | | | 7 | | μV/°C |
| I _{io} | Input Offset Current | T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} | | 2 | 30 50 | nA |
| I _{ib} | Input Bias Current | T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} | | 20 50 | 150 200 | nA |
| SVR | Supply Voltage Rejection Ratio | V _{CC} = 4.5V to 28V | 65 | 100 | | dB |
| V _{icm} | Input Common Mode Voltage Range | | 0 | | V _{cc} -1.5 | V |
| CMR | Common Mode Rejection Ratio | T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} | 70 60 | 85 | | dB |
| Output stage | | | | | | |
| G _m | Transconductance Gain. Sink Current Only ¹ | T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} | 1 | 3.5 2.5 | | mA/mV |
| V _{ol} | Low level output voltage at 10 mA sinking current | | | 200 | 600 | mV |
| I _{os} | Output Short Circuit Current. Output to V _{cc} . Sink Current Only | T _{amb} = 25°C T _{min.} ≤ T _{amb} ≤ T _{max.} | | 27 | 50 | mA |
| Voltage reference | | | | | | |
| V _{ref} | Reference Input Voltage, I _{load} =1mA TSM1013 1% precision TSM1013A 0.5% precision | T _{amb} = 25°C | 2.519 2.532 | 2.545 | 2.57 2.557 | V |
| ΔV _{ref} | Reference Input Voltage Deviation Over Temperature Range | T _{min.} ≤ T _{amb} ≤ T _{max.} | | 20 | 30 | mV |
| RegLine | Reference input voltage deviation over V _{cc} range. | I _{load} = 5mA | | | 20 | mV |
| RegLoad | Reference input voltage deviation over output current. | V _{cc} = 18V, 0 < I _{load} < 10mA | | | 10 | mV |

- 1) The current depends on the difference voltage between the negative and the positive inputs of the amplifier. If the voltage on the minus input is 1mV higher than the positive amplifier, the sinking current at the output OUT will be increased by 3.5mA.

Fig. 1: Internal Schematic

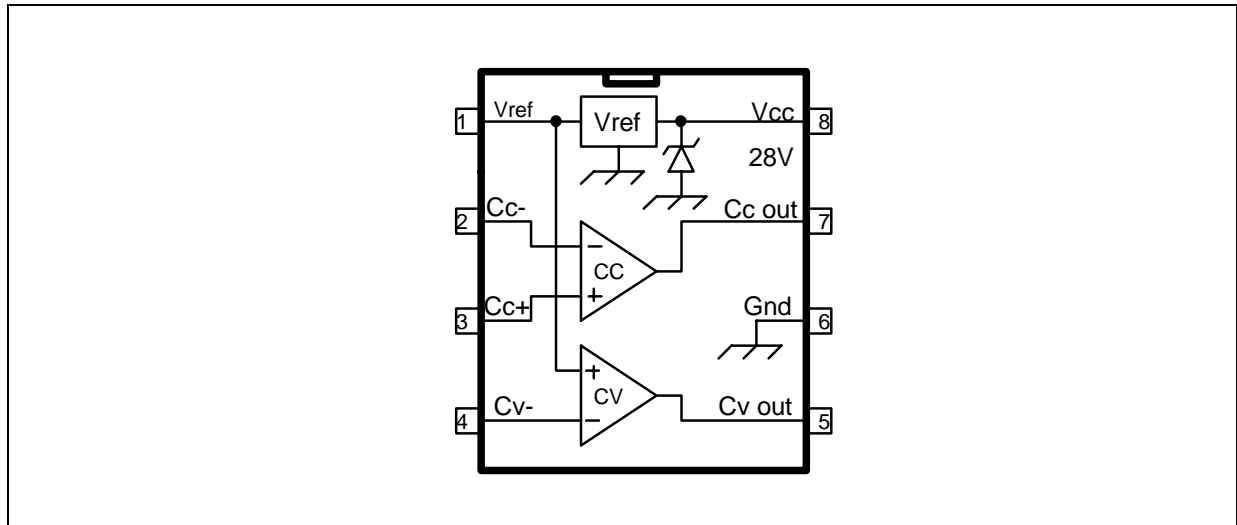
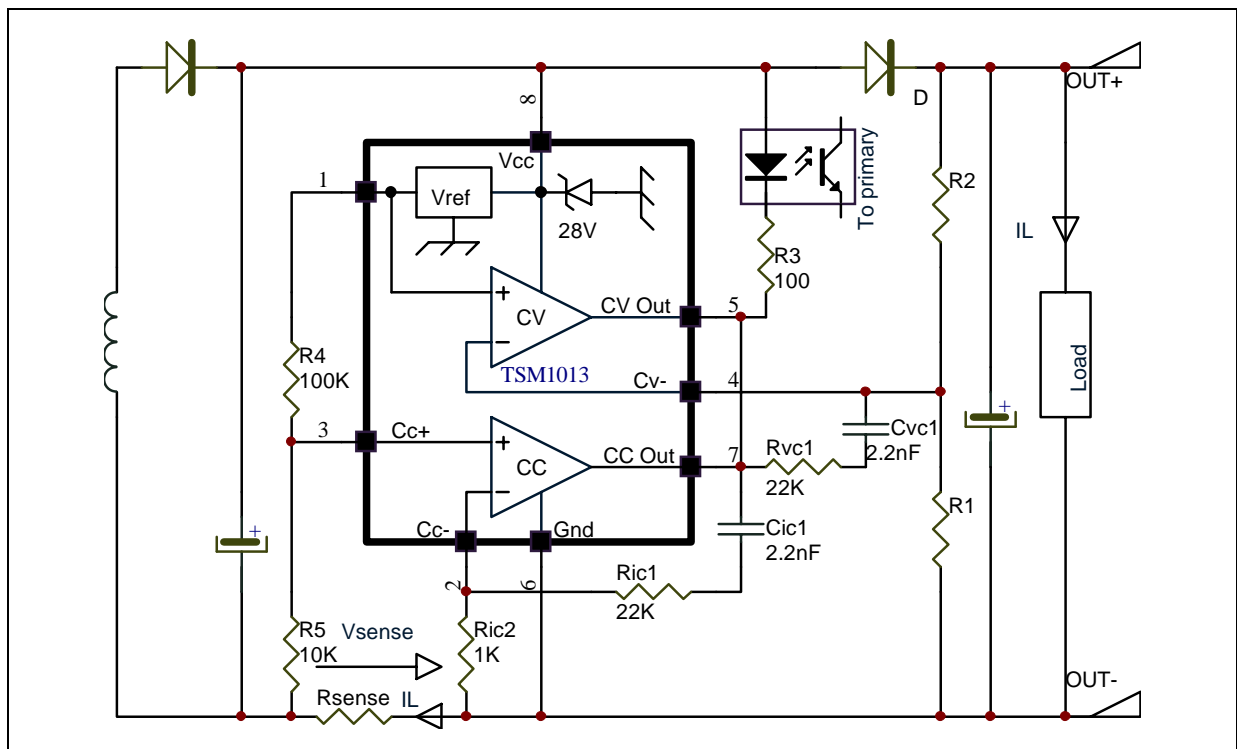


Fig. 2: Typical Adapter Application Using TSM1013



In the above application schematic, the TSM1013 is used on the secondary side of a flyback adapter (or battery charger) to provide an accurate control of voltage and current. The above feedback loop is made with an optocoupler.

Principle of Operation and Application Hints

3 VOLTAGE AND CURRENT CONTROL

3.1 Voltage Control

The voltage loop is controlled via a first transconductance operational amplifier, the resistor bridge R1, R2, and the optocoupler which is directly connected to the output.

The relation between the values of R1 and R2 should be chosen as written in Equation 1.

$$R1 = R2 \times V_{ref} / (V_{out} - V_{ref}) \quad \text{Equation 1}$$

Where V_{out} is the desired output voltage.

To avoid the discharge of the load, the resistor bridge R1, R2 should be highly resistive. For this type of application, a total value of 100K Ω (or more) would be appropriate for the resistors R1 and R2.

As an example, with $R2 = 100K\Omega$, $V_{out} = 4.10V$, $V_{ref} = 2.5V$, then $R1 = 41.9K\Omega$.

Note that if the low drop diode should be inserted between the load and the voltage regulation resistor bridge to avoid current flowing from the load through the resistor bridge, this drop should be taken into account in the above calculations by replacing V_{out} by $(V_{out} + V_{drop})$.

3.2 Current Control

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

V_{sense} threshold is achieved externally by a resistor bridge 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 on the following figure. The resistors of this bridge are matched to provide the best precision possible

The control equation verifies:

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

$$V_{sense} = R5 \times V_{ref} / (R4 + R5)$$

$$I_{lim} = R5 \times V_{ref} / (R4 + R5) \times R_{sense} \quad \text{Equation 3}$$

where I_{lim} is the desired limited current, and V_{sense} is the threshold voltage for the current control loop.

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

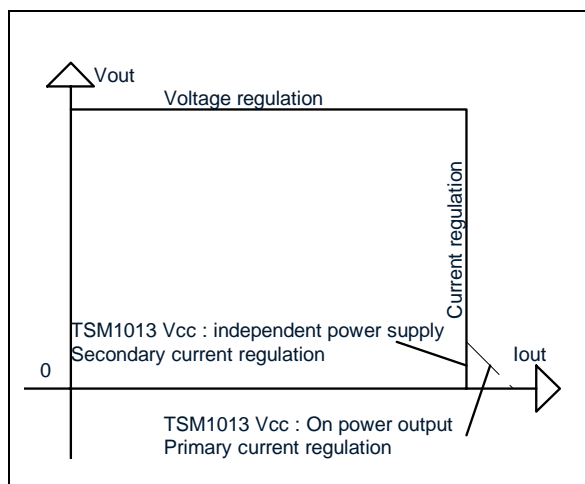
$$P_{lim} = V_{sense} \times I_{lim}. \quad \text{Equation 4}$$

Therefore, for most adapter and battery charger applications, a quarter-watt, or half-watt resistor to make the current sensing function is sufficient.

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.

Fig. 3: Output voltage versus output current



4 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 Fig.2. It consists of a capacitor $C_{vc1}=2.2nF$ and a resistor $R_{cv1}=22K\Omega$ in series.

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5 START UP AND SHORT CIRCUIT CONDITIONS

Under start-up or short-circuit conditions the TSM1013 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 TSM1013 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.

6 VOLTAGE CLAMP

The following schematic shows how to realise a low-cost power supply for the TSM1013 (with no additional windings). Please pay attention to the fact that in the particular case presented here, this low-cost power supply can reach voltages as high as twice the voltage of the regulated line. Since the Absolute Maximum Rating of the TSM1013 supply voltage is 28V. In the aim to protect the TSM1013 against such high voltage values a internal zener clamp is integrated.

$$R_{limit} = (V_{cc} - V_z) / I_{Vz}$$

Fig. 4: Clamp voltage

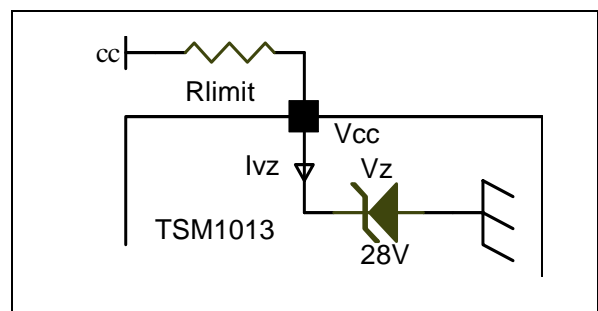
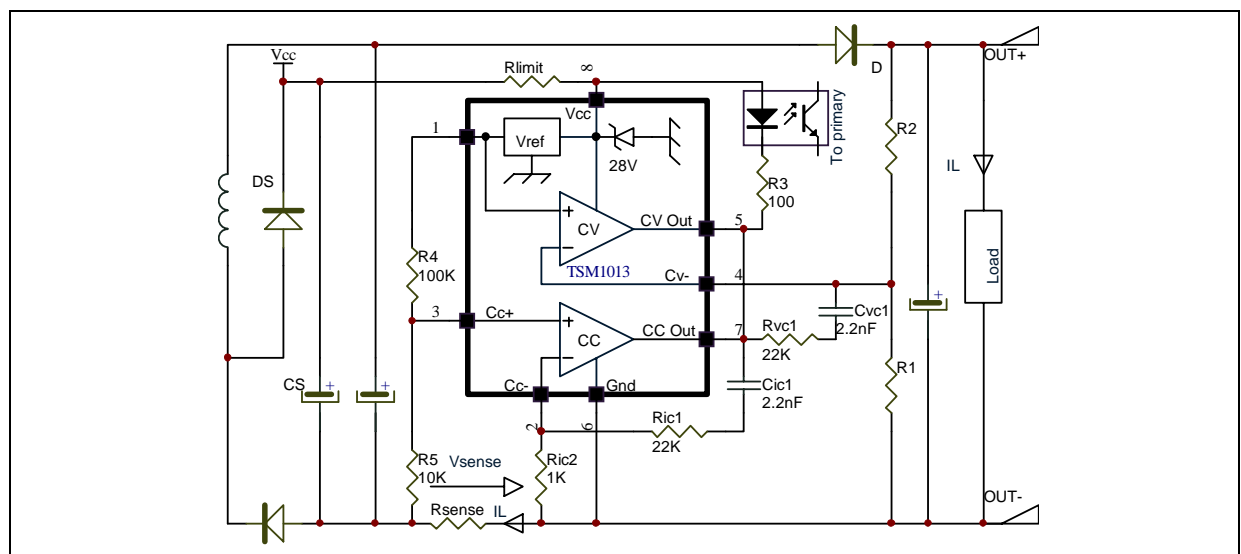


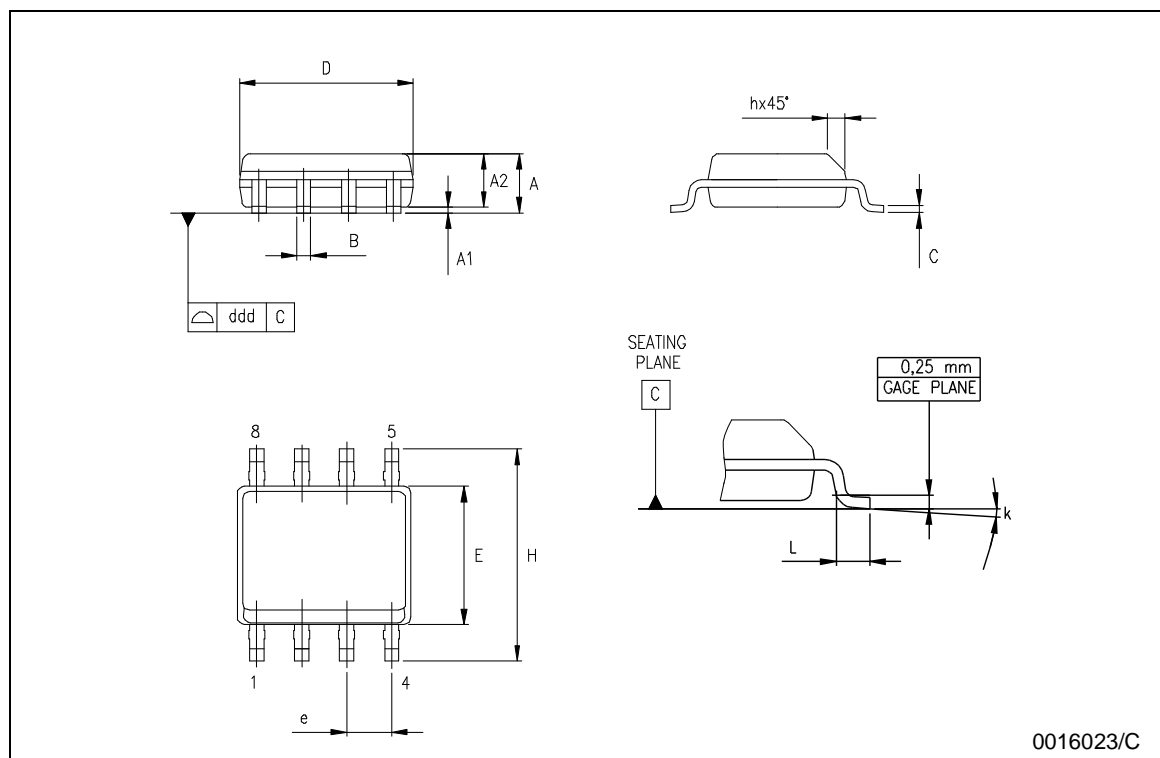
Fig. 5:



7 PACKAGE MECHANICAL DATA

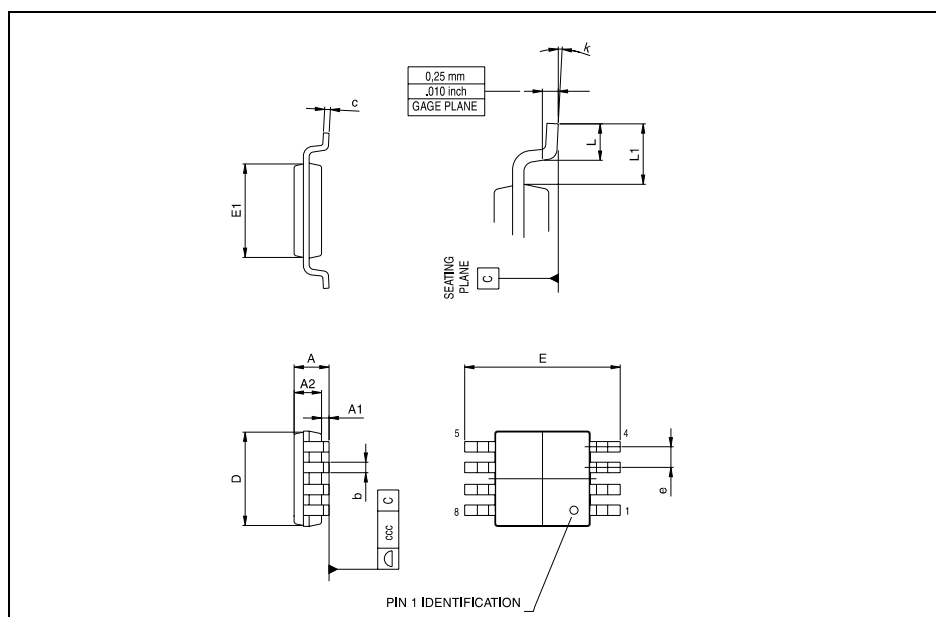
SO-8 MECHANICAL DATA

| DIM. | mm. | | | inch | | |
|------|-----------|------|------|-------|-------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | 1.35 | | 1.75 | 0.053 | | 0.069 |
| A1 | 0.10 | | 0.25 | 0.04 | | 0.010 |
| A2 | 1.10 | | 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 | 4.80 | | 5.00 | 0.189 | | 0.197 |
| E | 3.80 | | 4.00 | 0.150 | | 0.157 |
| e | | 1.27 | | | 0.050 | |
| H | 5.80 | | 6.20 | 0.228 | | 0.244 |
| h | 0.25 | | 0.50 | 0.010 | | 0.020 |
| L | 0.40 | | 1.27 | 0.016 | | 0.050 |
| k | 8° (max.) | | | | | |
| ddd | | | 0.1 | | | 0.04 |



miniSO-8 MECHANICAL DATA

| DIM. | mm. | | | inch | | |
|------|------|------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.1 | | | 0.043 |
| A1 | 0.05 | 0.10 | 0.15 | 0.002 | 0.004 | 0.006 |
| A2 | 0.78 | 0.86 | 0.94 | 0.031 | 0.031 | 0.037 |
| b | 0.25 | 0.33 | 0.40 | 0.010 | 0.13 | 0.013 |
| c | 0.13 | 0.18 | 0.23 | 0.005 | 0.007 | 0.009 |
| D | 2.90 | 3.00 | 3.10 | 0.114 | 0.118 | 0.122 |
| E | 4.75 | 4.90 | 5.05 | 0.187 | 0.193 | 0.199 |
| E1 | 2.90 | 3.00 | 3.10 | .0114 | 0.118 | 0.122 |
| e | | 0.65 | | | 0.026 | |
| K | 0° | | 6° | 0° | | 6° |
| L | 0.40 | 0.55 | 0.70 | 0.016 | 0.022 | 0.028 |
| L1 | | | 0.10 | | | 0.004 |



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