TSM105

CONSTANT VOLTAGE AND CONSTANT CURRENT CONTROLLER FOR BATTERY CHARGERS AND ADAPTORS

- ■ **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

TSM105 is a highly integrated solution for SMPS applications requiring CV (constant voltage) and CC (constant current) mode.

TSM105 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, and the other low voltage reference combined with the other operational amplifier makes it an ideal current limiter for output low side current sensing.

The current threshold is fixed, and precise.

The only external components are:

* a resistor bridge to be connected on the output of the power supply (adapter, battery charger) to set the voltage regulation by dividing the desired output voltage to match the internal voltage reference value.

* a sense resistor whose value and allowable dissipation power need to be chosen according to the internal voltage threshold.

* optional compensation components (R and C).

TSM105, housed in one of the smallest package available, is ideal for space shrinked applications such as adapters and battery chargers.
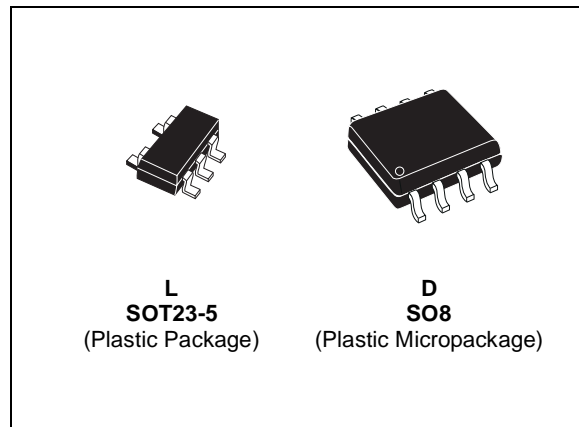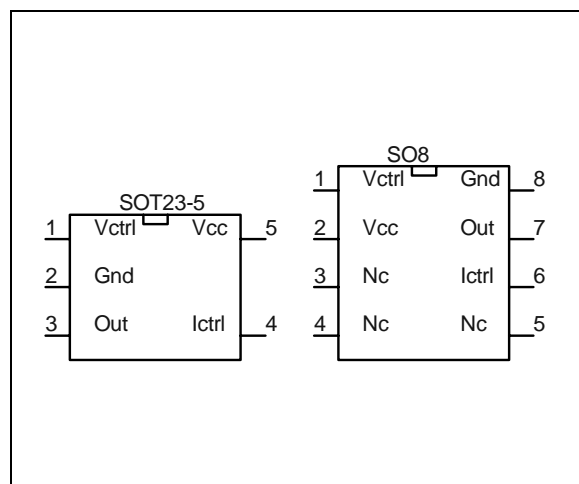
APPLICATIONS

- ■ **ADAPTERS**
- ■ **BATTERY CHARGERS**

ORDER CODE

Part Number	Temperature Range	Package		Marking
		L	D	
TSM105CLT	0 to 85°C	●		M105
TSM105CD	0 to 85°C		●	TSM105

L = Tiny Package (SOT23-5) - only available in Tape & Reel (LT)
D = Small Outline Package (SO) - also available in Tape & Reel (DT)

L
SOT23-5
(Plastic Package)

D
SO8
(Plastic Micropackage)

PIN CONNECTIONS (top view)

SOT23-5

1	Vctrl	Vcc	5
2	Gnd		
3	Out	Ictrl	4

SO8

1	Vctrl	Gnd	8
2	Vcc	Out	7
3	Nc	Ictrl	6
4	Nc	Nc	5

PIN DESCRIPTION

SOT23-5 Pinout

Name	Pin #	Type	Function
Vcc	5	Power Supply	Positive Power Supply Line
Gnd	2	Power Supply	Ground Line. 0V Reference For All Voltages
Vctrl	1	Analog Input	Input Pin of the Voltage Control Loop
Ictrl	4	Analog Input	Input Pin of the Current Control Loop
Out	3	Current Sink Output	Output Pin. Sinking Current Only

SO8 Pinout

Name	Pin #	Type	Function
Vcc	2	Power Supply	Positive Power Supply Line
Gnd	8	Power Supply	Ground Line. 0V Reference For All Voltages
Vctrl	1	Analog Input	Input Pin of the Voltage Control Loop
Ictrl	6	Analog Input	Input Pin of the Current Control Loop
Out	7	Current Sink Output	Output Pin. Sinking Current Only
NC	3		
NC	4		
NC	5		

ABSOLUTE MAXIMUM RATINGS

Symbol	DC Supply Voltage	Value	Unit
Vcc	DC Supply Voltage	14	V
Vi	Input Voltage	-0.3 to Vcc	V
Top	Operating Free Air Temperature Range	-55 to 125	°C
Tj	Maximum Junction Temperature	150	°C
Rthja	Thermal Resistance Junction to Ambient SO8 package	130	°C/W
Rthja	Thermal Resistance Junction to Ambient SOT23-5 package	250	°C/W

OPERATING CONDITIONS

Symbol	Parameter	Value	Unit
Vcc	DC Supply Conditions	2.8 to 12	V

ELECTRICAL CHARACTERISTICS

Tamb = 25°C and Vcc = +5V (unless otherwise specified)

Symbol	Parameter	Test Condition	Min	Typ	Max	Unit
Total Current Consumption						
Icc	Total Supply Current - not taking the output sinking current into account	Tamb 0 < Tamb < 85°C		1.05 1.2	2	mA
Voltage Control Loop						
Gmv	Transconduction Gain (Vctrl). Sink Current Only [1]	Tamb 0 < Tamb < 85°C	1	3.5 2.5		mA/mV
Vref	Voltage Control Loop Reference [2]	Tamb 0 < Tamb < 85°C	1.198 1.186	1.21	1.222 1.234	V
Iibv	Input Bias Current (Vctrl)	Tamb 0 < Tamb < 85°C		50 100		nA
Current Control Loop						
Gmi	Transconduction Gain (Ictrl). Sink Current Only [3]	Tamb 0 < Tamb < 85°C	1.5	7 4		mA/mV
Vsense	Current Control Loop Reference [4]	Iout = 2.5mA Tamb 0 < Tamb < 85°C	196 192	200	204 208	mV
Iibi	Current out of pin ICTRL at -200mV	Tamb 0 < Tamb < 85°C		25 50		µA
Output Stage						
Vol	Low output voltage at 10 mA sinking current	Tamb		200		mV
Ios	Output Short Circuit Current. Output to Vcc. Sink Current Only	Tamb 0 < Tamb < 85°C		27 35	50	mA

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

2. The internal Voltage Reference is set at 1.210V (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 temperaure.

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

4. The internal current sense threshold is set to -200mV. 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-conductance operational amplifier.

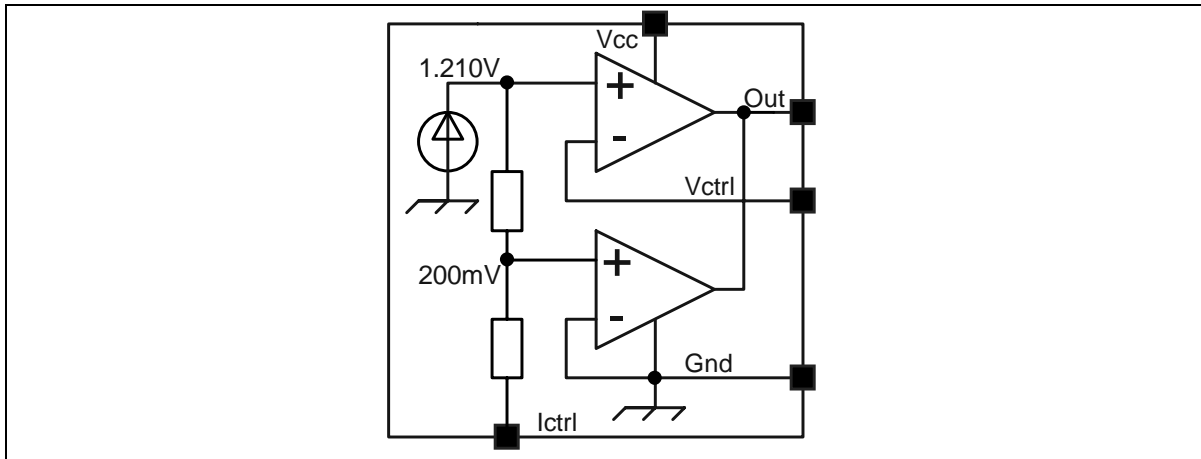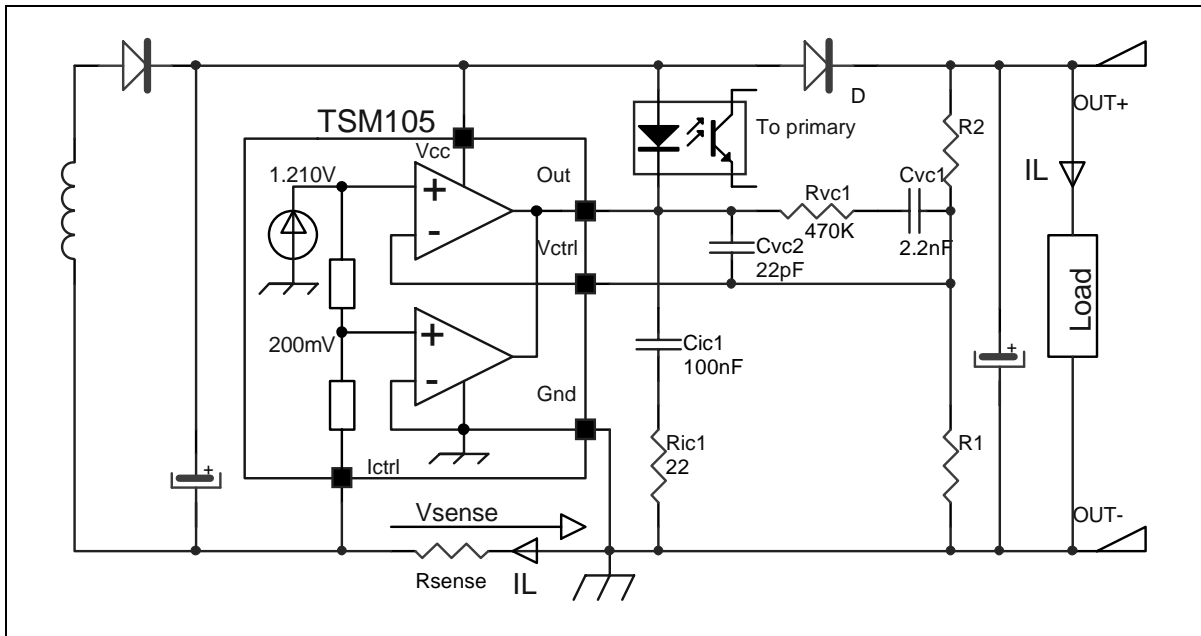**Figure 1 :** Internal Schematic

Figure 2 : Typical Adapter or Battery Charger Application Using TSM105

In the above application schematic, the TSM105 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

1. Voltage and Current Control

1.1. 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 writen in Equation 1.

$$R1 = R2 \times Vref / (Vout - Vref) \qquad Eq1$$

where Vout 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 100KΩ (or more) would be appropriate for the resistors R1 and R2.

As an example, with R2 = 100KΩ, Vout = 4.10V, Vref = 1.210V, then R1 = 41.9KΩ.

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 Vout by (Vout + Vdrop).

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:

$$Rsense \times Ilim = Vsense \qquad eq2$$
$$Rsense = Vsense / Ilim \qquad eq2'$$

where Ilim is the desired limited current, and Vsense is the threshold voltage for the current control loop.

As an example, with Ilim = 1A, Vsense = -200mV, then Rsense = 200mΩ.

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

$$Plim = Vsense \times Ilim. \qquad eq3$$

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

Therefore, for most adapter 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 resistor bridge 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 on the following figure. The resistors of this bridge are matched to provide the best precision possible

The current sinking outputs of the two trans-connuctance 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.

Figure 3 : Output voltage versus output current
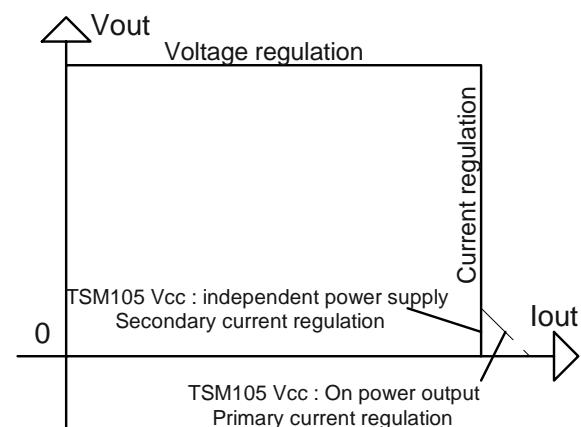
2. Compensation

The voltage-control trans-conductance operational amplifier can be fully compensated. Both its output and the 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 Cvc1=2.2nF and a resistor Rcv1=470KΩ in series, connected in parallel with another capacitor Cvc2=22pF.

The current-control trans-conductance operational amplifier has to be compensated in a different way, since its negative input is connected to ground. A series connection of a capacitor Cic1=100nF and a resistor Ric1=22Ω can be put between OUT and GND to stabilize the global regulation loop.

3. Start Up and Short Circuit Conditions

Under start-up or short-circuit conditions the TSM105 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 TSM105 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 realise a low-cost power supply for the TSM105 (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 TSM105 supply voltage is 14 V, this low-cost auxiliary power supply can only be used in applications where the regulated line voltage does not exceed 7 V.

Figure 4 :

MACROMODEL

The model is centred at a typical supply voltage of 5 V and at an ambient temperature of 70°C (the typical temperature within a battery pack).
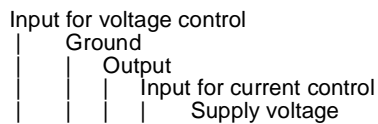To obtain the right values for amplifier gain, it is RECOMMENDED TO SET THE SIMULATION TEMPERATURE TO 70°C.

SUPPLY CURRENT: 1.15 mA
VOLTAGE REFERENCE: 1.210 V

AMPLIFIER CHARACTERISTICS:

TCA (Amplifier for voltage control)
Gain: gm = 3.6 mA/mV
1st dominant pole: 1E5 Hz
UGBW: 8E6 Hz

TCAFC (Amplifier for current control)
Gain: gm = 8.1 mA/mV
1st dominant pole: 1E5 Hz
UGBW: 2E7 Hz

CONNECTIONS:

```
        Input for voltage control
        |   Ground
        |   |   Output
        |   |   |   Input for current control
        |   |   |   |   Supply voltage
        |   |   |   |   |
.SUBCKT TSM105 N1VCRTL N2GND N3OUT N4ICTRL
N5VCC
XI60  N2GND N3OUT N5VCC N2GND NET32 TCAFC
XI59  N2GND N3OUT N5VCC N1VCRTL NET22 TCA
VV48 NET22 N2GND 1.21
RR46 NET32 NET22 48.7K
RR47 N4ICTRL NET32 8K
II63 N5VCC N2GND 651u
.ENDS TSM105
```

Amplifier for current control
```
.SUBCKT TCAFC GR OUT VC VM VP
VV169 NET128 GR 3
VV171 NET227 GR 3
MM165 NET62 NET75 GR GR MOSFET105 W=1u L=1u
DD153 NET153 NET117 D_B105 AREA=1
DDM NET61 NET70 D_A105 AREA=1
DD151 NET58 NET127 D_B105 AREA=1
DD155 NET65 NET151 D_B105 AREA=1
DD159 NET168 GR D_B105 AREA=1
DD157 NET71 NET132 D_B105 AREA=1
DDP NET61 NET78 D_A105 AREA=1
DD179 GR NET71 D_C105 AREA=1
VF147 NET78 VP 0
FF147 VP NET151 VF147 0.99967
VF152 NET113 NET58 0
FF152 VC NET113 VF152 0.9832
VF158 NET52 NET71 0
FF158 NET128 NET52 VF158 0.9832
VF148 NET70 VM 0
FF148 VM NET117 VF148 0.99967
VF154 NET127 NET153 0
FF154 NET113 NET127 VF154 0.9819
VF144 NET227 NET62 0
FF144 NET125 GR VF144 -40000
VF140 OUT NET125 0
FF140 NET227 NET75 VF140 1
VF160 NET132 NET168 0
FF160 NET125 NET132 VF160 0.9832
VF156 NET127 NET65 0
FF156 NET52 NET127 VF156 0.9819
```

```
CC1 NET125 NET52 15p
CC2 NET125 NET132 2p
RR120 GR NET117 1.4K
RR142 GR NET75 28
RR121 GR NET151 1.4K
RR122 GR NET132 70K
II116 VC NET113 25u
II115 VC NET61 287u
II117 VC NET52 25u
II138 VC NET125 25u
.ENDS TCAFC
```

Amplifier for voltage control
```
.SUBCKT TCA GR OUT VC VM VP
II167 VC NET79 94.5u
II138 VC NET26 25u
RR122 GR NET18 70K
RR121 GR NET20 4K
RR142 GR NET22 30
RR120 GR NET24 4K
CC2 NET26 NET18 500f
CC1 NET26 NET31 25p
VF156 NET32 NET77 0
FF156 NET31 NET32 VF156 0.9804
VF160 NET18 NET75 0
FF160 NET26 NET18 VF160 0.9804
VF140 OUT NET26 0
FF140 NET42 NET22 VF140 1
VF144 NET42 NET85 0
FF144 NET26 GR VF144 -40000
VF154 NET32 NET81 0
FF154 NET47 NET32 VF154 0.9804
VF147 NET62 VP 0
FF147 VP NET31 VF147 0.99894
VF158 NET31 NET68 0
FF158 NET59 NET31 VF158 0.9804
VF170 NET47 NET67 0
FF170 VC NET47 VF170 0.9804
VF148 NET50 VM 0
FF148 VM NET47 VF148 0.99894
DD153 NET81 NET24 D_B105 AREA=1
DDM NET79 NET50 D_A105 AREA=1
DD155 NET77 NET20 D_B105 AREA=1
DD159 NET75 GR D_B105 AREA=1
DD157 NET68 NET18 D_B105 AREA=1
DDP NET79 NET62 D_A105 AREA=1
DD185 GR NET68 D_C105 AREA=1
DD169 NET67 NET32 D_B105 AREA=1
MM165 NET85 NET22 GR GR MOSFET105 W=1u L=1u
VV177 NET42 GR 3
VV175 NET59 GR 3
.ENDS TCA
```
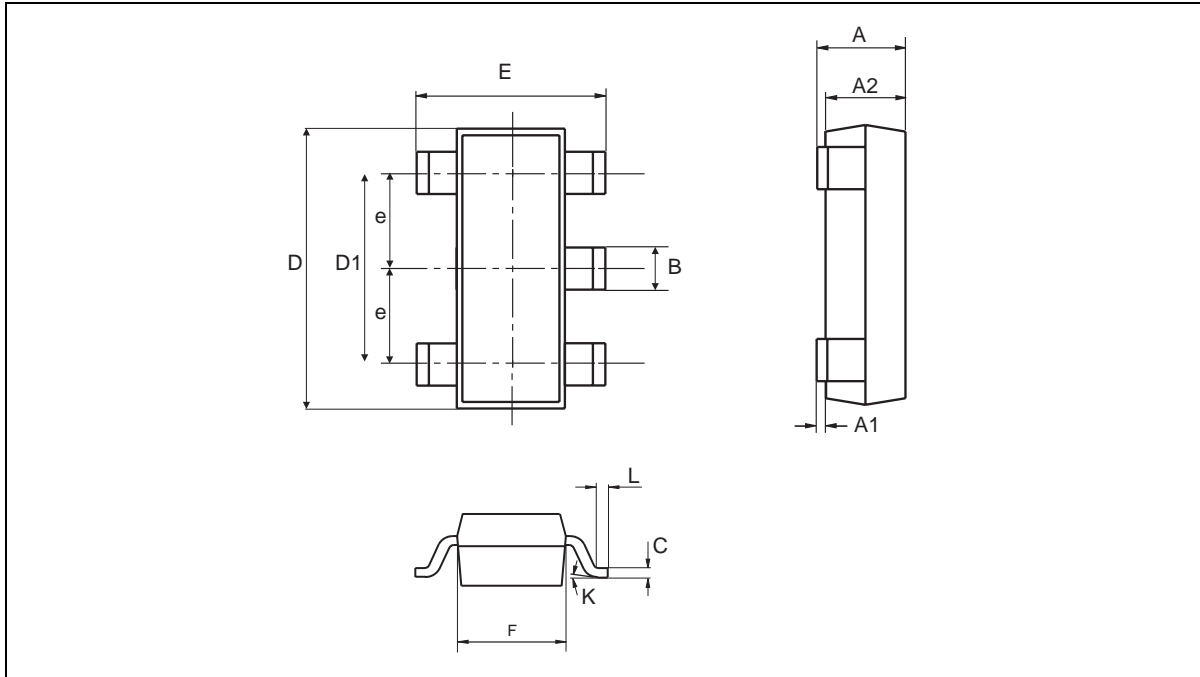
Models
```
.model D_A105 D(IS=1.459E-17)
.model D_B105 D(IS=7.0E-18)
.model D_C105 D(IS=2.0E-12)
.model MOSFET105 NMOS VT0=1.0 KP=1.3E-3 LEVEL=1
```

## PACKAGE MECHANICAL DATA
5 PINS - PLASTIC PACKAGE SOT23-5

Dim.	Millimeters			Inches		
	Min.	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**
A	0.90	1.20	1.45	0.035	0.047	0.057
A1	0		0.15			0.006
A2	0.90	1.05	1.30	0.035	0.041	0.051
B	0.35	0.40	0.50	0.014	0.016	0.020
C	0.09	0.15	0.20	0.004	0.006	0.008
D	2.80	2.90	3.00	0.110	0.114	0.118
D1		1.90			0.075	
e		0.95			0.037	
E	2.60	2.80	3.00	0.102	0.110	0.0118
F	1.50	1.60	1.75	0.059	0.063	0.069
L	0.10	0.5	0.60	0.004	0.014	0.024
K	0d		10d	0d		10d

PACKAGE MECHANICAL DATA
8 PINS - PLASTIC MICROPACKAGE (SO8)
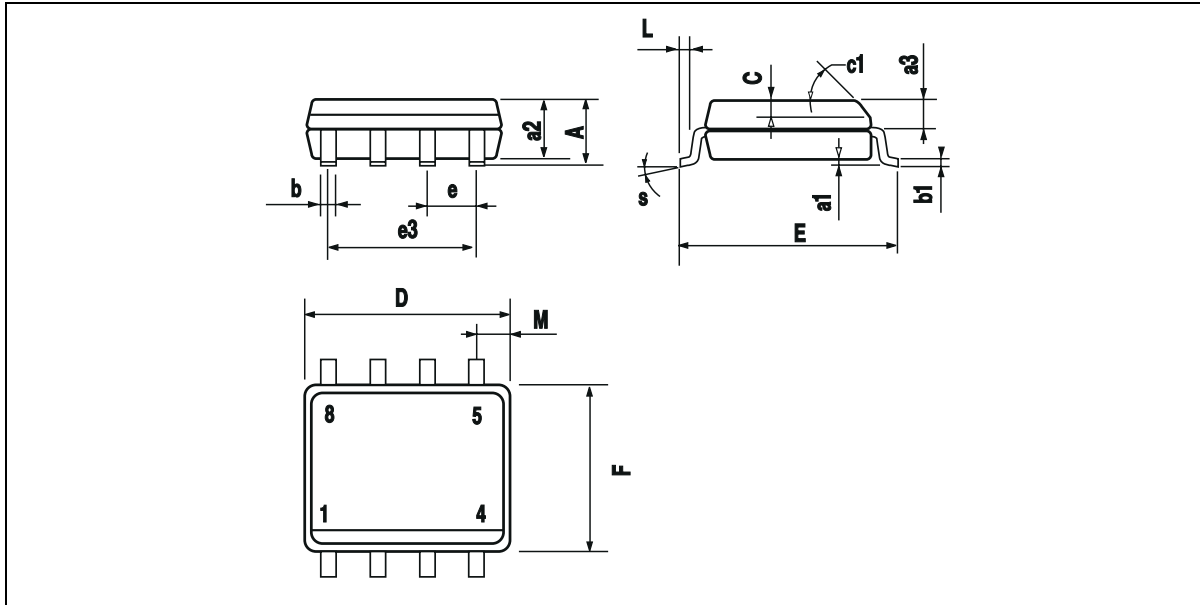
Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.6			0.024
S	8° (max.)					