1. Introduction

The Smartec temperature sensor is a sophisticated full silicon temperature sensor with a digital output. The one wire (duty cycle) output can be connected to all kind of micro-controllers directly without the need of A/D conversion. The temperature range is -45 °C to 150 °C. The sensor is available in various housing like TO18, TO92, TO220 and for high volume production in SOIC.

2. Smart temperature sensor

Most important features

- No A-D converter necessary
- Absolute accuracy ± .7 °C
- Linear output within .2 °C
- Output fully digital interpretable
- Output fully analogue interpretable
- Calibrated on chip.
- TTL, CMOS compatible
- Temperature range 175 °C (-45 to + 130 °C)
- Directly connectable to data input of micro processor
- Easy multiplexing when using more sensors to one micro processor
- Low power consumption (< 1 mW)

Typical applications

- Heater systems
- Air conditioners
- Climatizing units
- Washing machines
- Overheating protection
- Appliances

Product highlights

1. The SMART TEMPERATURE SENSOR represents a significant totally new development in transducer technology. Its new on-chip interface responds to the progressively stringent demands of both the consumer and industrial electronics sectors for a temperature sensor directly connectable to microprocessor input and thus capable of direct and reliable communication with microprocessors.

2. The SMART TEMPERATURE SENSOR features a duty-cycle modulated square-wave output voltage with linear response to temperatures in the -45 °C to +130 °C range to an accuracy of better than 1.2 °C. In the range from -30 to +100 °C the linearity is better than 0.2 °C. (TO18)

3. The SMART TEMPERATURE SENSOR is calibrated during test and burn-in of the chip. The integral modulator ensures that the sensor unit can communicate effectively with low-cost processors without the need of (onboard) A-D convertors.

4. The SMART TEMPERATURE SENSOR combines digital output and on-chip calibration to ensure major cost reductions and performance-related advantages.

5. Direct connection of the sensor output to the microprocessor input reduces the number of components and terminals to a minimum, cutting costs and boosting reliability.

6. In applications where more sensors are used, easy multiplexing can be obtained by using more micro processor inputs or by using simple and cheap digital multiplexers.

7. Since the sensor requires no subsequent calibration, optimal cost savings are recorded both during manufacturing and in the course of after-sales servicing.

3. Pin-out and housing

SO8L housing
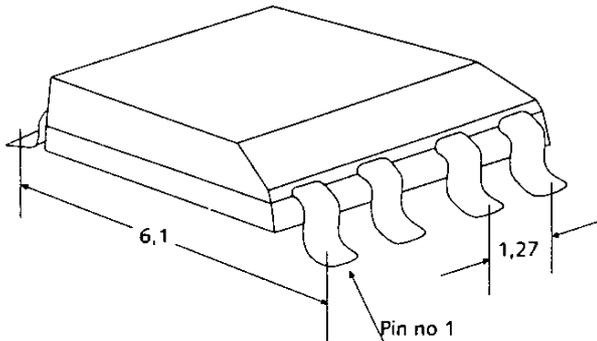
pin 1   + V_{cc}
pin 7   GND
pin 8   Out

HE housing
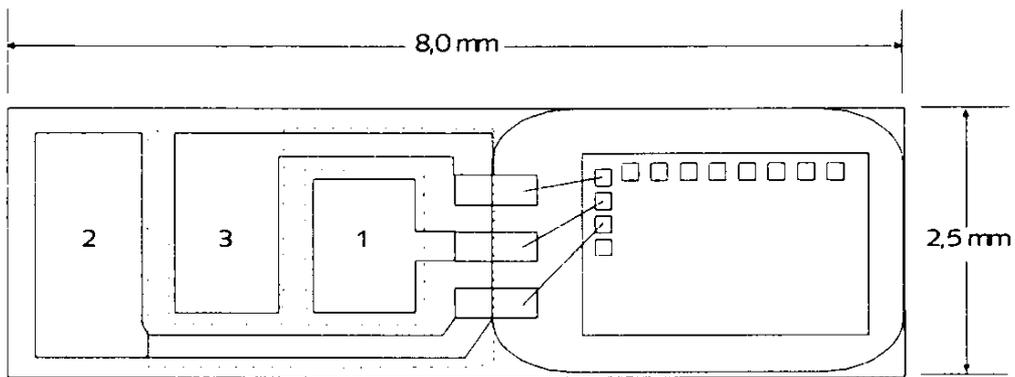
DIE SIZE: 1.55X2.5 mm

pin 1   Output
pin 2   +V_{cc}
pin 3   GND

TO-92 housing   **TO-18 housing**   **TO-220 housing**
                                bottom view

pin 1   Output
pin 2   + V_{cc}
pin 3   GND

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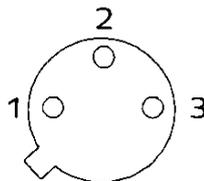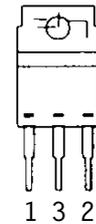
4. Product description

The SMT160-30 is a three terminal integrated temperature sensor, with a duty-cycle output. Two terminals are used for the power supply of 5 Volts and the third terminal carries the output signal. A duty cycle modulated output is used because this output is interpretable by a micro-processor without A-D converter, while the analogue information is still available.

The SMT160-30 (TO18 model) has an overall accuracy of 0.7 °C in the range from -30 C to +100 °C and an accuracy of 1.2 °C from -45 to +130 °C. This makes the sensor especially useful in all applications where "human" (climate control, food processing etc.) conditions are to be controlled.

The C-mos output of the sensor can handle cable length up to 20 meters. This makes the SMT160-30 very useful in remote sensing and control applications.

Parameters	Value	unit
Supply voltage	4.75 - 7	V
Supply current	max 200	μA
Short circuit protection	infinite (within supply voltage range)	-
Operating temperature range	-45 to +130	°C
Storage temperature	-50 to +150	°C

5. Specifications

parameters	TO18			TO92	TO220	HE	S08	units
	min.	typ	max.	max. [1]	max.	max.	max.	
Supply voltage [2]	4.75	5	7	•	•	•	•	V.
Supply current	160		200	•	•	•	•	µA.
temperature range [3]	-45	-	130	•	•	•	•	°C
Total accuracy [4]	-30 +100 °C -45 +130 °C		0.7 1.2	1.2 2.0	1.7 1.7	1.5 1.5	1.0 1.5	°C
Non-linearity [5]			0.2	0.4	0.5	1.0	1.0	°C
Supply voltage sensitivity			0.1	•	•	•	•	°C/V
Repeatability			0.1	0.2	0.2	0.2	0.2	°C
Long term drift			0.05	-	-	-	0.05	°C
Output:								
- duty cycle =	0.320 + 0.00470*t (t = temperature in °C)							
- frequency	1	-	4	•	•	•	•	Khz
- noise			0.005	•	•	•	•	°C
- Impedance			200	•	•	•	•	Ohm

[1] All not mentioned specifications are the same as TO18
[2] Case connected to ground
[3] The SMT 30-160-18 can be used from -65 to +160 °C for a short periods without physical damage to the device. The specified accuracy applies only to the rated performance temperature range.
[4] Total accuracy includes all errors.
[5] Applicable from -30 to +100 °C

6. Understanding the specifications.

The way in which the SMT160-30 is specified makes it easy to apply in a wide variety of different applications. It is important to understand the meaning of the various specifications and their effects on accuracy. The SMT160-30 is basically a bipolar temperature sensor, with accurate electronics to convert the sensor signal into a duty cycle. During production the devices are calibrated.

The output signal

As stated in the specifications the output is a square wave with a well-defined temperature-dependent duty cycle. The duty cycle of the output signal is linearly related to the temperature according to the equation:

$$D.C. = 0.320 + 0.00470*t \qquad \begin{aligned} &D.C. = \text{duty cycle} \\ &t = \text{Temperature in } °C \end{aligned}$$

Easy calculation shows that for instance that at 0 °C the
D.C. = 0.320 or 32.0 % and at 130 °C the
D.C.= 0.931 or 93.1 %

Total accuracy

The above mentioned equation is the nominal one. The maximum deviation from the nominal equation is defined as total accuracy. With temperatures above 100 °C the accuracy decreases.

Non linearity

Non-linearity as it applies to the SMT160-30 is the deviation from the best-fit straight line over the whole temperature range. For the temperature range of -30 °C to +100 °C the non-linearity is less than 0.2 °C (TO18).

Long-term drift

This drift strongly depends on the operating condition. At room temperature the drift is very low (< 0.05 °C). However at higher temperatures the drift will be worse, mainly because of changes in mechanical stresses. This drift is partly irreversible and causes non-ideal repeatability and long-term effects. At temperatures above 100 °C but in the operating range a long-term drift better than 0.1 °C is to be expected.

Noise

The resolution is better than 0.005 °C. The standarddeviation of the noiselevel (measured over a 20 ms. period) is below this 0.005 °C.

Time constants

The time constants of the sensor is measured under different circumstances. To compare this with other types of sensors the same kind of measurements were done. The time constant is defined as the time required to reach 63% of an instantaneous temperature change.

condition	time constant (sec) (TO18)
mounted in an alu block of a certain temperature (mean value of different measurements)	0.6
in a bath filled with oil that was stirred (mean value of different measurements)	1.4
Moving air with a speed of about 3 m/s - without heatsink	13.5
Moving air with a speed of about 3 m/s - with heatsink	5.0
Non moving air - without heatsink	60
Non moving air - with heatsink	100

The above mentioned figures are hard to measure, an accuracy of around 5 % is a reasonable estimation. These figures only concern the sensor built in a TO-18 housing and not the TO-92 nor the chip itself.

7. General operation

An easy way of measuring a duty cycle is to use a microcontroller. It is only necessary to connect the sensors output to one of the microcontrollers inputs. With help of a small program it is possible to sense that input wether it is high or low. The speed of this sampling is limited due to the instruction time of the controller. So to achieve the wished accuracy it is necessary to sample over more than one sensor period. This way of working has also the advantage to filter noise. From the theory of signal processing it can be derived that there is a fixed ratio between the sensors signal frequency, the sampling rate and the sampling noise. This sampling noise limits the accuracy and amounts to:

$$T_{error} = \frac{200 * t_s}{\sqrt{6 * t_m * t_p}}$$

T_{error} = measurement error (= standard deviation of the sampling noise)

t_s = microcontrollers sampling rate

t_m = total measurement time

t_p = output signal periodicity of the sensor

Microcontrollers can sample at a high frequency so with a small program it is possible to measure the sensor's duty cycle within 50 ms and a resolution of .01 °C.

NOTE:
The above mentioned error has in principle nothing to do with the accuracy of the sensor; it gives only an impression of the accuracy of measuring duty cycles with microcontrollers (standard deviation).

For more information how to measure duty cycles with microcontrollers we refer to our application notes.