ANALOG DEVICES

±1°C Accurate PWM Temperature Sensor in 5-Lead SC-70

Preliminary Technical Data

TMP05/TMP06

FEATURES

Modulated Serial Digital Output
- Proportional to Temperature
±1°C Accuracy from 0°C to 70°C
±3°C over entire temperature range
Two Grades Available
Operation from -40°C to 150°C
Operation from 2.7V to 5.5V
Power Consumption TBD mW Max at 5.5 V
CMOS/TTL-Compatible Output on TMP05
Flexible Open Drain output on TMP06
Small Low Cost 5-Pin SC-70 and SOT-23 Packages.

APPLICATIONS

Isolated Sensors
Environmental Control Systems
Computer Thermal Monitoring
Thermal Protection
Industrial Process Control
Power System Monitors

GENERAL DESCRIPTION

The TMP05/TMP06 are monolithic temperature sensors that generate a modulated serial digital output (PWM) that varies in direct proportion to the temperature of the devices. The high period (T1) of the PWM remains static over all temperature while the low period (T2) varies. The B-Grade versions offer a higher temperature accuracy of ±1°C from 0°C to +70°C, with excellent transducer linearity. The digital output of the TMP05/06 is CMOS/ TTL compatible, and is easily interfaced to the serial inputs of most popular microprocessors. The flexible open-drain output of the TMP06 is capable of sinking 3mA.

The TMP05/TMP06 is specified for operation at supply voltages from 2.7 V to 5.5 V. Operating at 3.3 V the supply current (unloaded) is typically 230 µA.

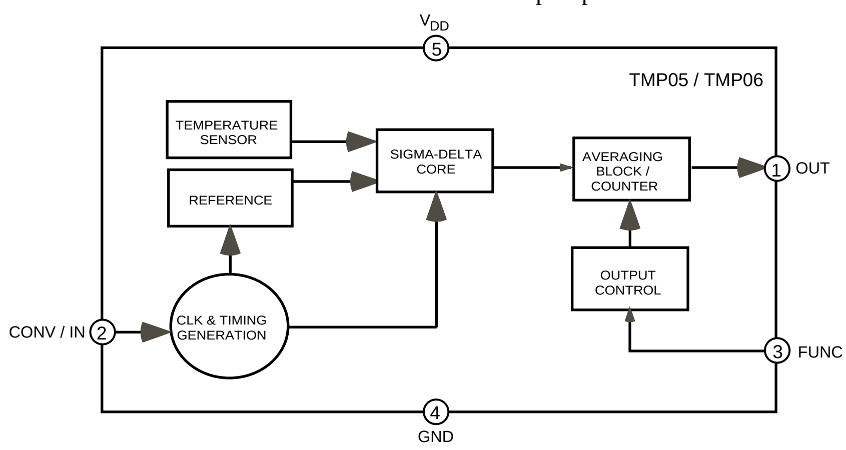
The TMP05/TMP06 is rated for operation over the -40°C to +150°C temperature range. It is packaged in low cost, low area SC-70 and SOT-23 packages.

The TMP05/TMP06 has 3 modes of operation. These are Continuously Converting, Daisy Chain and One Shot Mode. A tri-state FUNC input determines which mode the TMP05/TMP06 operates in.

The CONV / IN input pin is used to determine the rate with which the TMP05/TMP06 measures temperature in Continuously Converting and in One Shot mode. In Daisy Chain Mode the CONV / IN pin operates as the input to the daisy chain.

PRODUCT HIGHLIGHTS

1. The TMP05/06 has an on-chip temperature sensor that allows an accurate measurement of the ambient temperature. The measurable temperature range is –40°C to +150°C.
2. Supply voltage of +2.7 V to +5.5 V.
3. Space-saving 5-lead SOT-23 and SC-70 packages.
4. Temperature accuracy of ±1°C.
5. 0.02°C temperature resolution.
6. The TMP05/TMP06 features a One Shot mode that reduces the power consumption to 2.57 µW at one sample per second.



FUNCTIONAL BLOCK DIAGRAM

REV. Pr.H 05/'03

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700   World Wide Web Site: http://www.analog.com
Fax: 781/326-8703

TMP05A/TMP06A–SPECIFICATIONS[1]

($T_A = T_{MIN}$ to T_{MAX}, V_{DD} = +2.7 V to +5.5 V, unless otherwise noted)

Parameter	Min	Typ	Max	Units	Test Conditions/Comments
TEMPERATURE SENSOR AND ADC					
Accuracy @ V_{DD} = +3.3 V (±10%)			±1	°C	T_A = 25°C.
			±2	°C	T_A = 0°C to 70°C.
			±3	°C	T_A = –40°C to +85°C.
			±4	°C	T_A = –40°C to +125°C.
			±5[2]	°C	T_A = –40°C to +150°C.
Accuracy @ V_{DD} = +5 V (±10%)			±1	°C	T_A = 25°C.
			±2	°C	T_A = 0°C to 70°C.
			±3	°C	T_A = –40°C to +85°C.
			±4	°C	T_A = –40°C to +125°C.
			±5[2]	°C	T_A = –40°C to +150°C.
Temperature Resolution		0.02		°C	
T1 Pulse Width		40		ms	T_A = 40°C. Nominal Conversion Rate.
T2 Pulse Width		80		ms	T_A = 40°C. Nominal Conversion Rate.
Power Supply Rejection Ratio		0.3	0.6	°C/V	T_A = +25°C
SUPPLIES					
Supply Voltage	2.7		5.5	V	
Supply Current					
Normal Mode[6] @ 3.3 V		230	450	µA	Continuously Coverting, Daisy Chain and One Shot Modes at Nominal Conversion Rates.
Normal Mode[6] @ 5 V		300	500	µA	Continuously Coverting, Daisy Chain and One Shot Modes at Nominal Conversion Rates.
Quiescent[6] @ 3.3 V		3	8	µA	Device not converting. Output is high.
Quiescent[6] @ 5.5 V		5	10	µA	Device not converting. Output is high.
One Shot Mode @ 1 sps				µA	V_{DD} = 2.7 V to 3.3 V. Nominal Conversion Rate.
One Shot Mode @ 1 sps				µA	V_{DD} = 4.5 V to 5.5 V. Nominal Conversion Rate.
Power Dissipation		759		µW	V_{DD} = +3.3 V, Continuously Converting at Nominal Conversion Rates.
Power Dissipation 1 sps				µW	Average Power Dissipated for V_{DD} = +3.3 V. One Shot Mode.
TMP05 OUTPUT (Push-Pull)[3]					
Output High Voltage, V_{OH}	V_{DD}-0.3			V	I_{OH} = 800 µA
Output Low Voltage, V_{OL}			0.4	V	I_{OL} = 800 µA
Output High Current, I_{OUT}			2	mA	
Pin Capacitance		10		pF	
Device Turn-On Time		20		mS	
Rise Time[4], t_{LH}		50		nS	
Fall Time[4], t_{HL}		50		nS	
R_{ON} Resistance (Low Output)		55		Ω	Supply and temperature dependent.
TMP06 OUTPUT (Open Drain)[3]					
Output Low Voltage, V_{OL}			0.4	V	I_{OL} = 1.6 mA
Output Low Voltage, V_{OL}			1.2	V	I_{OL} = 5 mA
Sink Current, I_{SINK}			3	mA	
Pin Capacitance		10		pF	
High Output Leakage Current, I_{OH}		0.1	0.5	µA	PWM_{OUT} = 5.5V
Device Turn-On Time		20		mS	
Fall Time[5], t_{HL}		30		nS	
R_{ON} Resistance (Low Output)		55		Ω	Supply and temperature dependent.

NOTES

[1] All A-Grade specifications apply for –40°C to +150°C unless otherwise stated.

[2] It is not recommended to operate the device at tempereatures above +125°C for greater than 5% of the lifetime of the device. Any exposure beyond this limit will affect device reliability.

[3] Guaranteed by design and characterization, not production tested.

[4] Test load circuit is 100pF to GND.

[5] Test load circuit is 100pF to GND, 10KΩ to 5.5 V.

[6] Normal mode current relates to current during T2. TMP05/06 is not converting during T1 so quiescent current relates to current during T1.

Specifications subject to change without notice.

TMP05B/TMP06B–SPECIFICATIONS[1]

($T_A = T_{MIN}$ to T_{MAX}, V_{DD} = +2.7 V to +5.5 V, unless otherwise noted)

Parameter	Min	Typ	Max	Units	Test Conditions/Comments
TEMPERATURE SENSOR AND ADC					
Accuracy @ V_{DD} = +3.3 V (±10%)			±0.5	°C	T_A = 25°C.
			±1	°C	T_A = 0°C to 70°C.
			±2	°C	T_A = –40°C to +85°C.
			±3	°C	T_A = –40°C to +125°C.
			±4[2]	°C	T_A = –40°C to +150°C.
Accuracy @ V_{DD} = +5 V (±10%)			±0.5	°C	T_A = 25°C.
			±1	°C	T_A = 0°C to 70°C.
			±2	°C	T_A = –40°C to +85°C.
			±3	°C	T_A = –40°C to +125°C.
			±4[2]	°C	T_A = –40°C to +150°C.
Temperature Resolution		0.02		°C	
T1 Pulse Width		40		ms	T_A = 40°C. Nominal Conversion Rate.
T2 Pulse Width		80		ms	T_A = 40°C. Nominal Conversion Rate.
Power Supply Rejection Ratio		0.3	0.6	°C/V	T_A = +25°C
SUPPLIES					
Supply Voltage	2.7		5.5	V	
Supply Current					
Normal Mode[6] @ 3.3 V		230	450	µA	Continuously Coverting, Daisy Chain and One Shot Modes at Nominal Conversion Rates.
Normal Mode[6] @ 5 V		300	500	µA	Continuously Coverting, Daisy Chain and One Shot Modes at Nominal Conversion Rates.
Quiescent[6] @ 3.3 V		3	8	µA	Device not converting. Output is high.
Quiescent[6] @ 5.5 V		5	10	µA	Device not converting. Output is high.
One Shot Mode @ 1 sps				µA	V_{DD} = 2.7 V to 3.3 V. Nominal Conversion Rate.
One Shot Mode @ 1 sps				µA	V_{DD} = 4.5 V to 5.5 V. Nominal Conversion Rate.
Power Dissipation		759		µW	V_{DD} = +3.3 V, Continuously Converting at Nominal Conversion Rates.
Power Dissipation 1 sps				µW	Average Power Dissipated for V_{DD} = +3.3 V. One Shot Mode.
TMP05 OUTPUT (Push-Pull)[3]					
Output High Voltage, V_{OH}	V_{DD}-0.3			V	I_{OH} = 800 µA
Output Low Voltage, V_{OL}			0.4	V	I_{OL} = 800 µA
Output High Current, I_{OUT}			2	mA	
Pin Capacitance		10		pF	
Device Turn-On Time		20		mS	
Rise Time[4], t_{LH}		50		nS	
Fall Time[4], t_{HL}		50		nS	
R_{ON} Resistance (Low Output)		55		Ω	Supply and temperature dependent.
TMP06 OUTPUT (Open Drain)[3]					
Output Low Voltage, V_{OL}			0.4	V	I_{OL} = 1.6 mA
Output Low Voltage, V_{OL}			1.2	V	I_{OL} = 5 mA
Sink Current, I_{SINK}			3	mA	
Pin Capacitance		10		pF	
High Output Leakage Current, I_{OH}		0.1	0.5	µA	PWM_{OUT} = 5.5V
Device Turn-On Time		20		mS	
Fall Time[5], t_{HL}		30		nS	
R_{ON} Resistance (Low Output)		55		Ω	Supply and temperature dependent.

NOTES

[1] All B-Grade specifications apply for –40°C to +150°C unless otherwise stated.

[2] It is not recommended to operate the device at tempereatures above +125°C for greater than 5% of the lifetime of the device. Any exposure beyond this limit will affect device reliability.

[3] Guaranteed by design and characterization, not production tested.

[4] Test load circuit is 100pF to GND.

[5] Test load circuit is 100pF to GND, 10KΩ to 5.5 V.

[6] Normal mode current relates to current during T2. TMP05/06 is not converting during T1 so quiescent current relates to current during T1.

Specifications subject to change without notice.

TIMING CHARACTERISTICS[1]

($T_A = T_{MIN}$ to T_{MAX}, V_{DD} = +2.7 V to +5.5 V, unless otherwise noted)

Parameter	Limit	Units	Comments
T_1	40	ms typ	PWM High Time @ 40°C under Nominal Conversion Rate.
T_2	80	ms typ	PWM Low Time @ 40°C under Nominal Conversion Rate.
t_3[2]	50	ns typ	TMP05 Output Rise Time.
t_4[2]	50	ns typ	TMP05 Output Fall Time.
t_4[3]	30	ns typ	TMP06 Output Fall Time.
t_5	42	µs min	Daisy Chain Warm-Up Pulse Width.
t_6	34	µs max	Daisy Chain START Pulse Width.

NOTES
[1] Guaranteed by design and characterization, not production tested.
[2] Test load circuit is 100pF to GND.
[3] Test load circuit is 100pF to GND, 10kΩ to 5.5 V

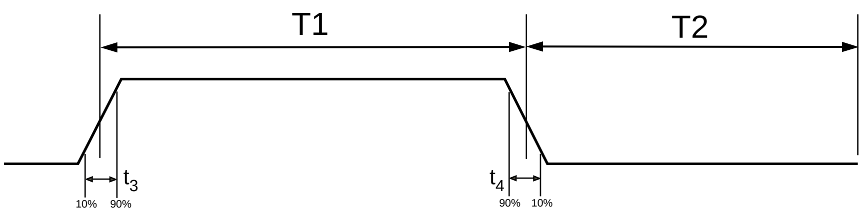


Figure 1. PWM Output Nominal Timing Diagram (40°C)

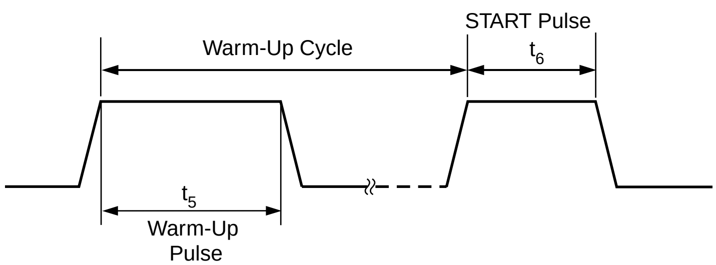


Figure 2. Daisy Chain Start and Stop Timing

ABSOLUTE MAXIMUM RATINGS[1]

V_{DD} to GND . . . . –0.3 V to +7 V
Digital Input Voltage to GND . . –0.3 V to V_{DD} + 0.3 V
Maximum Output Current (OUT) . . . . ±10 mA
Operating Temperature Range[2] . . . . . –40°C to +150°C
Storage Temperature Range . . . . –65°C to +160°C
Max Junction Temperature, T_{JMAX} . . . . +150°C
5-Lead SOT-23 . . . .
Power Dissipation[3] . . . . $W_{MAX} = (T_{JMAX} - T_A^4)/\theta_{JA}$
Thermal Impedance[5]
θ_{JA}, Junction-to-Ambient . . . . 270°C/W
θ_{JC}, Junction-to-Case . . . . .102°C/W
5-Lead SC-70 . . . .
Power Dissipation[3] . . . . $W_{MAX} = (T_{JMAX} - T_A^4)/\theta_{JA}$
Thermal Impedance[5]
θ_{JA}, Junction-to-Ambient . . . . 211.4°C/W
θ_{JC}, Junction-to-Case . . . . 177.4°C/W
IR Reflow Soldering
Peak Temperature . . . . +220°C (-0/+5°C)
Time at Peak Temperature . . . . 10 to 20 secs
Ramp-up Rate . . . . 2-3°C/sec
Ramp-down Rate . . . . -6°C/sec

1 Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

2 It is not recommended to operate the device at tempereatures above +125°C for greater than 5% of the lifetime of the device. Any exposure beyond this limit will affect device reliability.

3 Values relate to package being used on a 4-layer pcb. Reference Figure 4. for a plot of max power dissipation vs. ambient temperature (T_A).

4 T_A = Ambient Temperature.

5 Junction-to-Case resistance is applicable to components featuring a preferential flow direction, eg. components mounted on a heat sink. Junction-to-Ambient resistance is more useful for air-cooled PCB-mounted components.

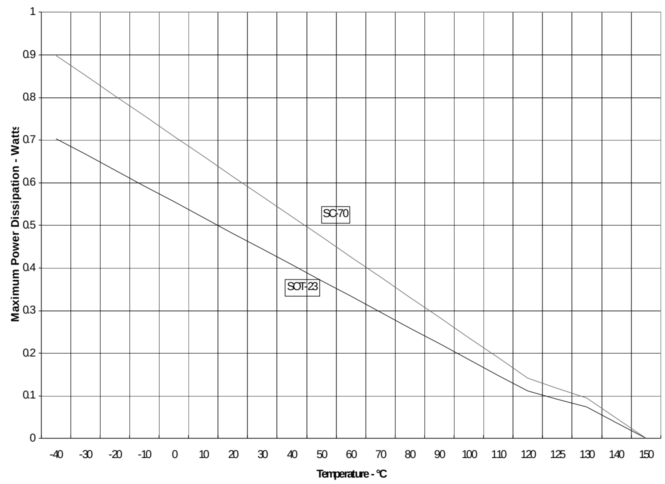


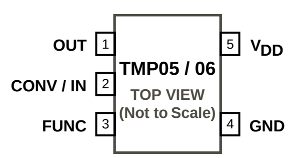
Figure 4. Plot of Maximum Power Dissipation vs. Temperature

PIN FUNCTION DESCRIPTION

Pin Mnemonic	Pin No.	Description
OUT	1	Digital Output. Pulse Width Modulated (PWM) output gives a square wave whose ratio of high to low period is proportional to temperature.
CONV/IN	2	Digital Input. In Continuously Converting and One-Shot operating modes a high, low or float input determines the temperature measurement rate. In Daisy Chain operating mode it is the input pin for the PWM signal from the previous part.
FUNC	3	Digital Input. A high, low or float input on this pin gives three different modes of operation.
GND	4	Analog and Digital Ground.
V_{DD}	5	Positive Supply Voltage, 2.7 V to 5.5 V.

PIN CONFIGURATIONS

SOT-23/SC-70



CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the TMP05/06 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

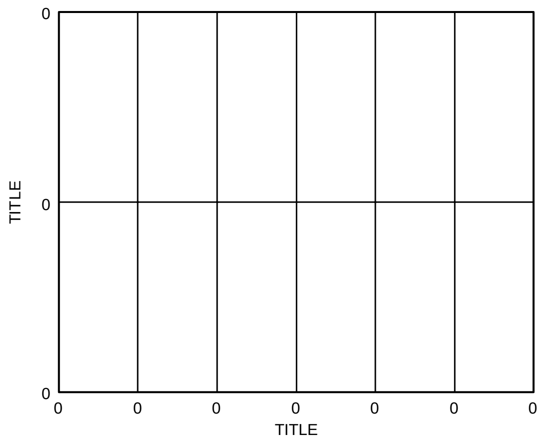
ORDERING GUIDE

Model	Temperature Range[1]	Temperature Accuracy[2]	Package Description	Branding Information	Package Option	Minimum Quantities/Reel
TMP05AKS-500REEL7	–40°C to +150°C	±2°C	5-Lead SC-70		KS-5	500
TMP05AKS-REEL	–40°C to +150°C	±2°C	5-Lead SC-70		KS-5	10000
TMP05AKS-REEL7	–40°C to +150°C	±2°C	5-Lead SC-70		KS-5	3000
TMP05ART-500REEL7	–40°C to +150°C	±2°C	5-Lead SOT-23		RJ-5	500
TMP05ART-REEL	–40°C to +150°C	±2°C	5-Lead SOT-23		RJ-5	10000
TMP05ART-REEL7	–40°C to +150°C	±2°C	5-Lead SOT-23		RJ-5	3000
TMP05BKS-500REEL7	–40°C to +150°C	±1°C	5-Lead SC-70		KS-5	500
TMP05BKS-REEL	–40°C to +150°C	±1°C	5-Lead SC-70		KS-5	10000
TMP05BKS-REEL7	–40°C to +150°C	±1°C	5-Lead SC-70		KS-5	3000
TMP05BRT-500REEL7	–40°C to +150°C	±1°C	5-Lead SOT-23		RJ-5	500
TMP05BRT-REEL	–40°C to +150°C	±1°C	5-Lead SOT-23		RJ-5	10000
TMP05BRT-REEL7	–40°C to +150°C	±1°C	5-Lead SOT-23		RJ-5	3000
TMP06AKS-500REEL7	–40°C to +150°C	±2°C	5-Lead SC-70		KS-5	500
TMP06AKS-REEL	–40°C to +150°C	±2°C	5-Lead SC-70		KS-5	10000
TMP06AKS-REEL7	–40°C to +150°C	±2°C	5-Lead SC-70		KS-5	3000
TMP06ART-500REEL7	–40°C to +150°C	±2°C	5-Lead SOT-23		RJ-5	500
TMP06ART-REEL	–40°C to +150°C	±2°C	5-Lead SOT-23		RJ-5	10000
TMP06ART-REEL7	–40°C to +150°C	±2°C	5-Lead SOT-23		RJ-5	3000
TMP06BKS-500REEL7	–40°C to +150°C	±1°C	5-Lead SC-70		KS-5	500
TMP06BKS-REEL	–40°C to +150°C	±1°C	5-Lead SC-70		KS-5	10000
TMP06BKS-REEL7	–40°C to +150°C	±1°C	5-Lead SC-70		KS-5	3000
TMP06BRT-500REEL7	–40°C to +150°C	±1°C	5-Lead SOT-23		RJ-5	500
TMP06BRT-REEL	–40°C to +150°C	±1°C	5-Lead SOT-23		RJ-5	10000
TMP06BRT-REEL7	–40°C to +150°C	±1°C	5-Lead SOT-23		RJ-5	3000

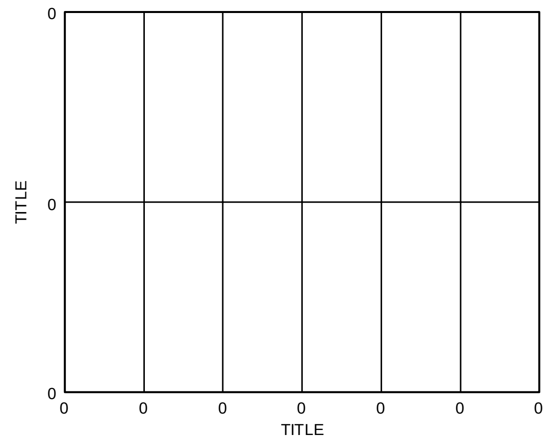
[1] It is not recommended to operate the device at tempereatures above +125°C for greater than 5% of the lifetime of the device. Any exposure beyond this limit will affect device reliability.

[2] Temperature accuracy is over 0°C to +70°C temperature range.

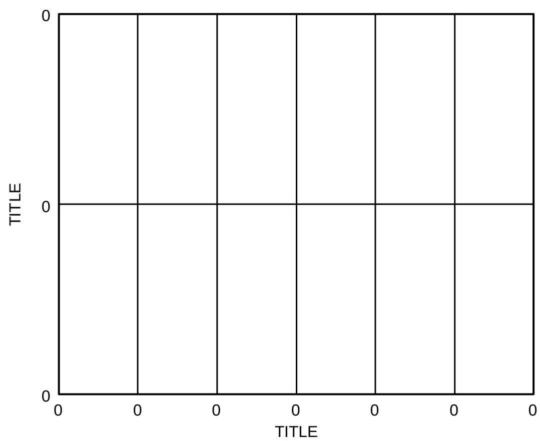
TYPICAL PERFORMANCE CURVES



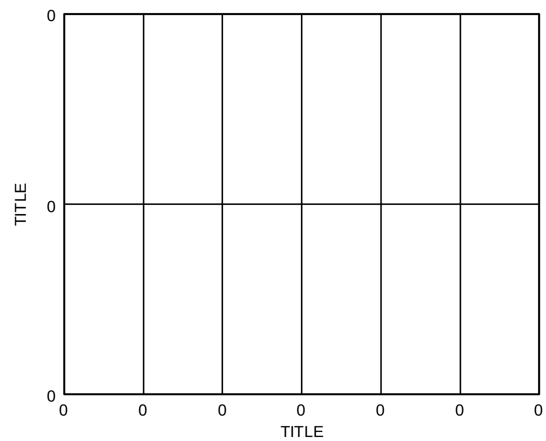
TPC 1. PWM O/P Frequence vs. Temperature



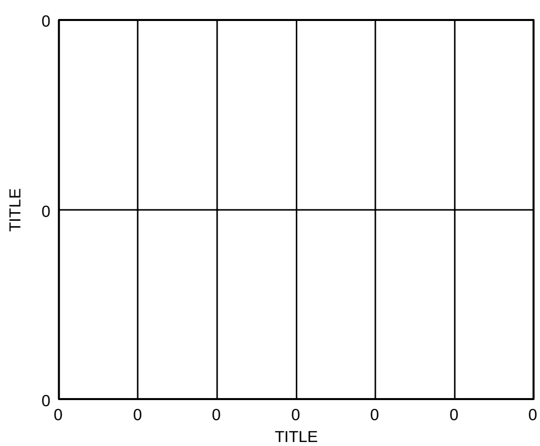
TPC 2. PWM O/P Frequency vs. Supply Voltage



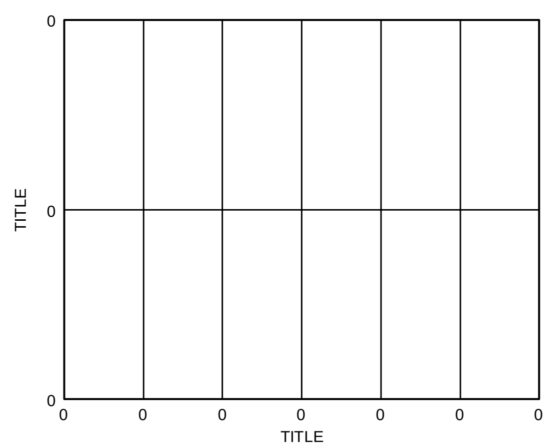
TPC 3. T1 and T2 Times vs. Temperature



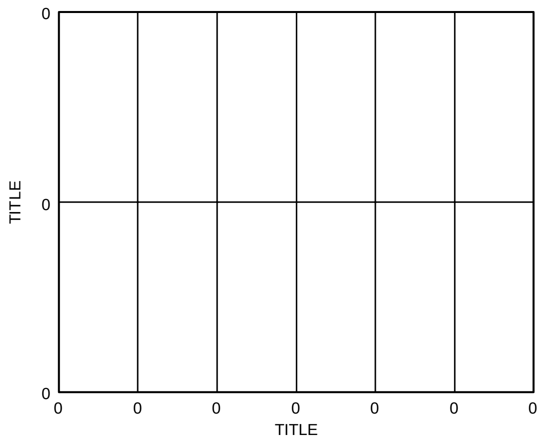
TPC 4. TMP05 Output Rise Time at +25°C



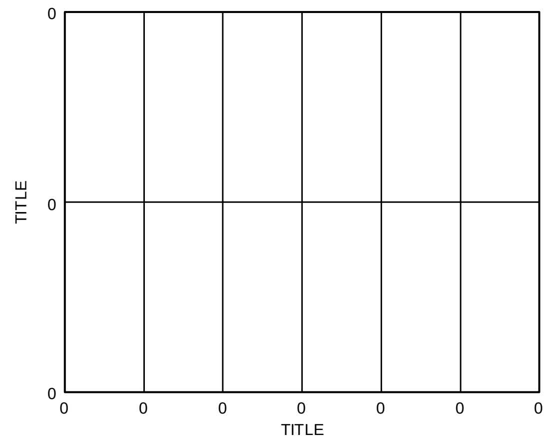
TPC 5. TMP05 Output Fall Time at +25°C



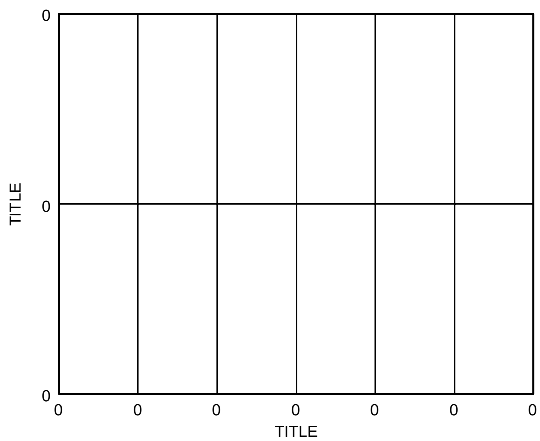
TPC 6. TMP06 Output Fall Time at +25°C



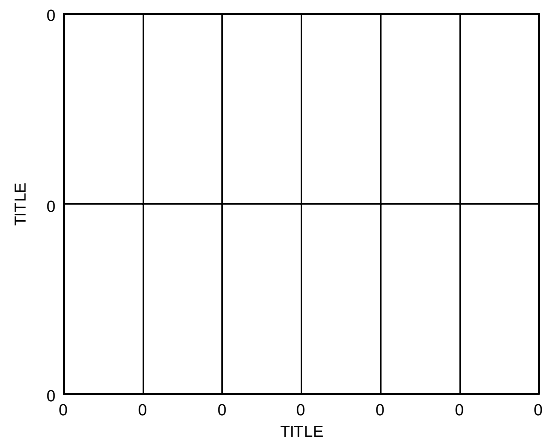
TPC 7. TMP05 Output Rise and Fall Times vs Capacitive Load



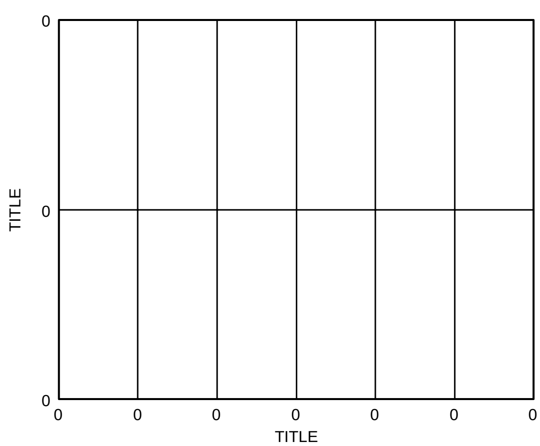
TPC 8. Output Low Voltage vs Temperature



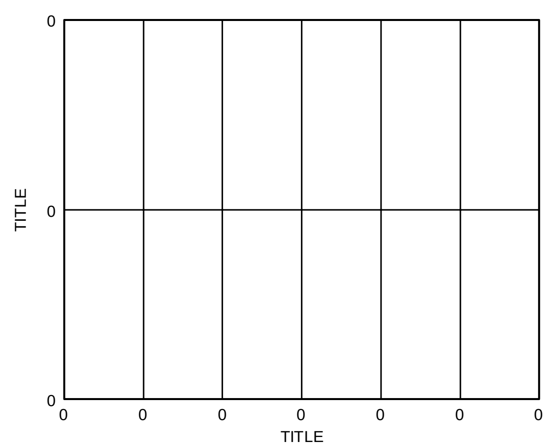
TPC 9. Output High Voltage vs Temperature



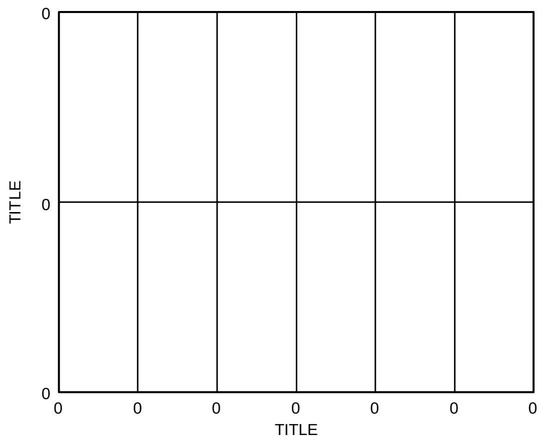
TPC 10. TMP06 Open Collector Sink Current vs Temperature.



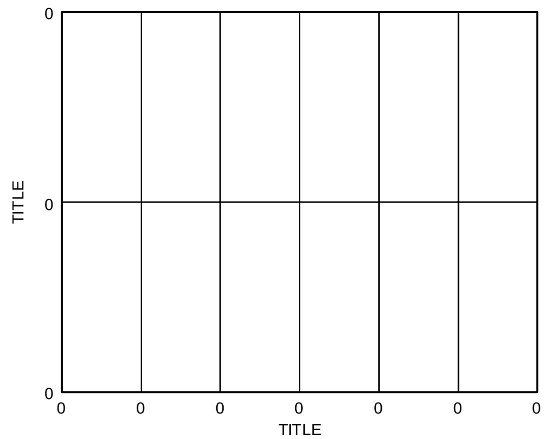
TPC 11. TMP06 Open Collector Output Voltage vs Temperature



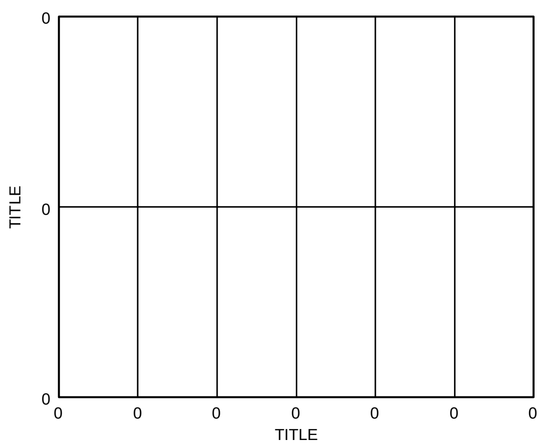
TPC 12. Output Accuracy vs. Temperature



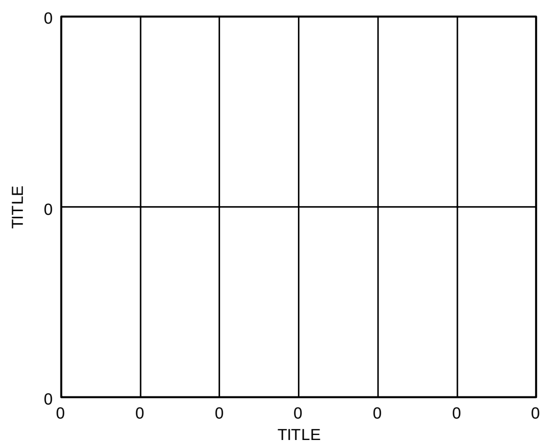
TPC 13. Supply Current vs. Temperature



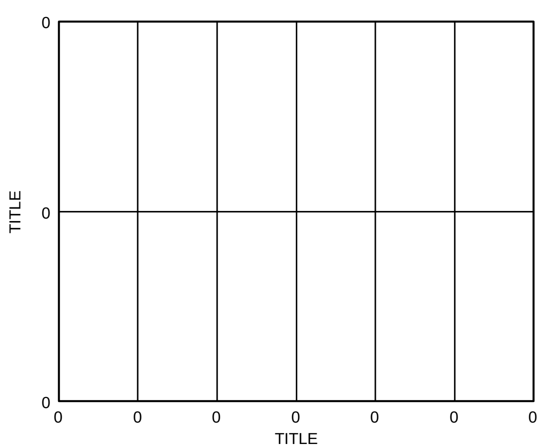
TPC 14. Supply Current vs. Supply Voltage



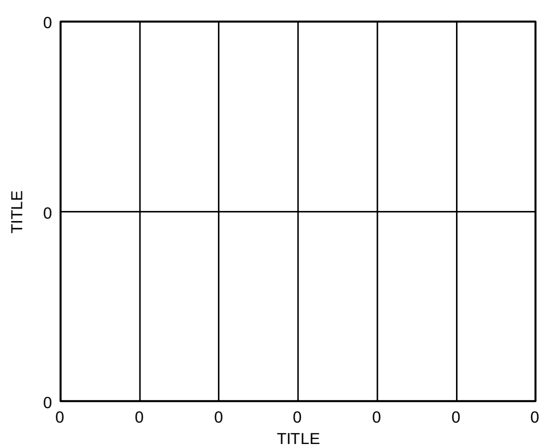
TPC 15. Power Supply Rejection vs. Temperature



TPC 16. Power Supply Rejection vs. Frequency



TPC 17. Response to Thermal Shock



TPC 18. TMP05 Temperature Error vs Load Current

CIRCUIT INFORMATION

The TMP05/TMP06 is a monolithic temperature sensor that generates a modulated serial digital output that varies in direct proportion with the temperature of the device. An onboard sensor generates a voltage precisely proportional to absolute temperature which is compared to an internal voltage reference and input to a precision digital modulator. The ratiometric encoding format of the serial digital output is independent of the clock drift errors common to most serial modulation techniques such as voltage-to-frequency converters. Overall accuracy is ±1°C from 0°C to +70°C, with excellent transducer linearity. The digital output of the TMP05 is CMOS/TTL compatible, and is easily interfaced to the serial inputs of most popular microprocessors. The open drain output on the TMP06 is capable of sinking 3mA.

The onboard temperature sensor has excellent accuracy and linearity over the entire rated temperature range without correction or calibration by the user.

The sensor output is digitized by a first-order sigma-delta modulator, also known as the “charge balance” type analog-to-digital converter. This type of converter utilizes time-domain oversampling and a high accuracy comparator to deliver 12 bits of effective accuracy in an extremely compact circuit.

CONVERTER DETAILS

The sigma-delta modulator consists of an input sampler, a summing network, an integrator, a comparator, and a 1-bit DAC. Similar to the voltage-to-frequency converter, this architecture creates in effect a negative feedback loop whose intent is to minimize the integrator output by changing the duty cycle of the comparator output in response to input voltage changes. The comparator samples the output of the integrator at a much higher rate than the input sampling frequency, this is called oversampling. This spreads the quantization noise over a much wider band than that of the input signal, improving overall noise performance and increasing accuracy.

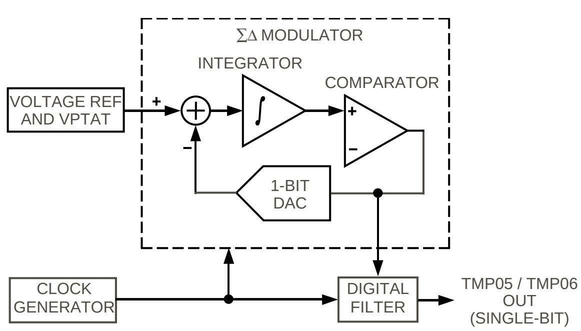


Figure 6. First-Order Sigma-Delta Modulator

The modulated output of the comparator is encoded using a circuit technique, which results in a serial digital signal with a mark-space ratio format that is easily decoded by any microprocessor into either degrees centigrade or degrees Fahrenheit values, and readily transmitted or modulated over a single wire. More importantly, this encoding method neatly avoids major error sources common to other modulation techniques, as it is clock-independent.

FUNCTIONAL DESCRIPTION

The output of the TMP05/TMP06 is a square wave with a typical period of 120ms at 40°C (i.e. Conv / In pin is left floating). The high period, T1, is constant while the low period, T2, varies with measured temperature. The output format for the nominal conversion rate is readily decoded by the user as follows:

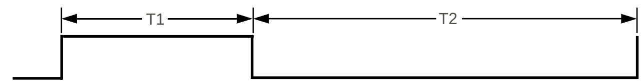


Figure 7. TMP05/TMP06 Output Format

$$\text{Temperature } (°C) = 406 - (731 \times (T1 / T2))$$

The time periods T1 (high period) and T2 (low period) are values easily read by a microprocessor timer/counter port, with the above calculations performed in software. Since both periods are obtained consecutively, using the same clock, performing the division indicated in the above formulas, results in a ratiometric value that is independent of the exact frequency or drift of either the originating clock of the TMP05/TMP06 or the user’s counting clock.

OPERATING MODES

The user can program the TMP05/TMP06 to operate in three different modes by configuring the FUNC pin to be either high, low or floating on power-up.

TABLE 1. OPERATING MODES

FUNC PIN	OP-MODE
LOW	One Shot
FLOAT	Continuously Converting
HIGH	Daisy Chain

Continuously Converting:

In this mode the TMP05/TMP06 continuously outputs a square wave representing temperature. The nominal frequency at which this square wave is outputed is determined by the state of the CONV /IN pin on power up. Any change to the state of the CONV pin after power up is not reflected until the TMP05/TMP06 is powered down and back up again.

One Shot Mode:

In this mode the TMP05/TMP06 outputs one square wave representing temperature when requested by the microcontroller. The microcontroller pulls the OUT pin low and then releases it to indicate to the TMP05/TMP06 that an output is required. The temperature measurement is outputed when the OUT line is released by the microcontroller.

The advantages of the One Shot mode include lower average power consumption and the microcontroller knows that the first low to high transition will occur after the micro releases the OUT pin.

In Continuously Converting and One-Shot Mode the state of the CONV / IN pin on power up determines the rate at which the TMP05/TMP06 measures temperature. The available conversion rates are shown in Table 1.

TABLE 2. CONVERSION RATES

CONV / IN PIN	Conversion Rate	T1/T2 (40°C)
LOW	Quarter Period (T1 ÷ 4, T2 ÷ 4)	10/20 (ms)
FLOAT	Nominal	40/80 (ms)
HIGH	Double High (T1 x 2) Quarter Low (T2 ÷ 4)	80/20 (ms)

The TMP05 (push-pull output) advantage when using the high state conversion rate is lower power consumption. However the trade off is loss of resolution on the low time. Depending on the state of the CONV/IN pin, two different temperature equations need to be used.

The temperature equation for the low and float states conversion rates is :

$$\text{Temperature (°C)} = 406 - (731 \times (T1 / T2))$$

The temperature equation for the high state conversion rate is :

$$\text{Temperature (°C)} = 406 - (91 \times (T1 / T2))$$

Daisy Chain:

Setting the FUNC pin to a high state allows multiple TMP05/TMP06's to be connected together and thus allow one input line of the microcontroller to be the sole receiver of all temperature measurements. In this mode the CONV/ IN pin now operates as the input of the daisy chain and conversions take place at the nominal conversion rate i.e. T1/T2 = 40ms/80ms at 40°C.

Therefore the temperature equation for the Daisy Chain mode of operation is :

$$\text{Temperature (°C)} = 406 - (731 \times (T1 / T2))$$

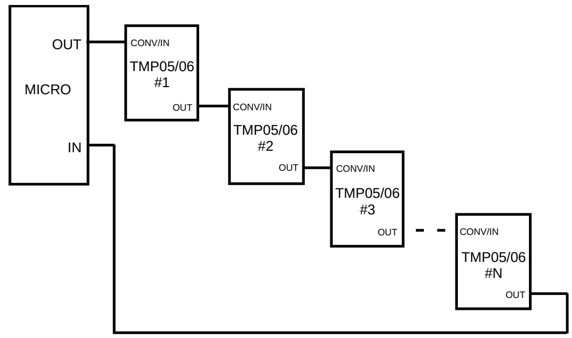


Figure 8. Daisy Chain Operation

A second microcontroller line is needed to generate the conversion START pulse on the CONV/IN pin. The pulse width of the START pulse should be less than 34µs. The START Pulse on the CONV/IN pin lets the TMP05/ TMP06 know that it should start a conversion and output its own temperature now. Once the TMP05/ TMP06 has outputed its own temperature, it will then output a START pulse for the next TMP05/06 on the Daisy Chain link. The pulse width of the START pulse from each TMP05/06 will be typically 17µs. Figure 9 shows the pulse output by the TMP05/TMP06 #1.

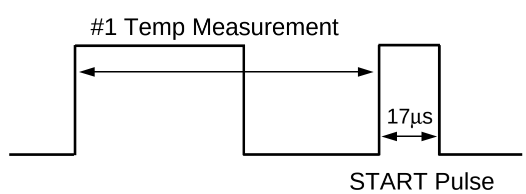


Figure 9. TMP05/06 #1 Temperature measurement and START pulse output

Every TMP05/06 in the Daisy Chain acts a buffer for the proceeding temperature measurement signals. The part monitors the PWM signal for the START pulse from the previous TMP05/06. Once the part detects the START pulse, it initiates a conversion and inserts the result at the end of the Daisy Chain PWM signal. It then inserts a START pulse for the next TMP05/06 in the link. The

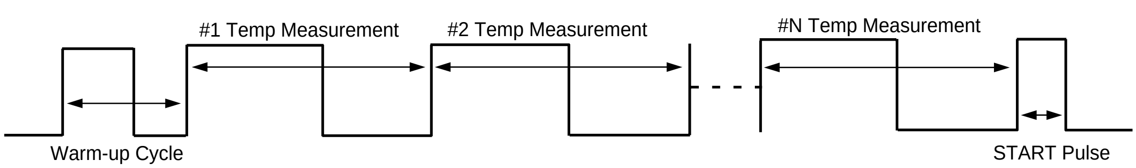


Figure 10. Daisy Chain Signal at input to the microcontroller with Warm-up Cycle.

final signal input to the microcontroller should look like Figure 10.

Improvement in the temperature accuracy measurement is possible by issueing a warm-up cycle prior to the START pulse. The warm-up pulse gives the TMP05/TMP06 an opportunity to power-up and let the oscillator stabilize before generating a temperature output. The warm-up pulse high time should be greater than 42us, the low time can be any value. However if the input goes high and remains high, the TMP05/TMP06 will timeout between 0.3 and 1.2 seconds later and will power down. It will therefore require another START pulse or warmup cycle to generate a temperature measurement. This warmup cycle is recommended but not necessary. It improves the accuracy of the TMP05/TMP06 by a small percent.

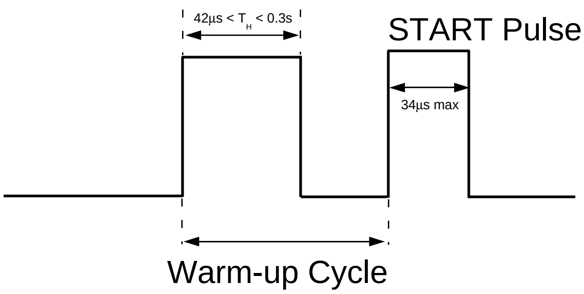


Figure 11. Warm-up pulse generated by the microcontroller

TMP05 OUTPUT

The TMP05 has a push-pull CMOS output (Figure 12) and provides rail-to-rail output drive for logic interfaces. The rise and fall times of the TMP05 output are closely matched, so that errors caused by capacitive loading are minimized. If load capacitance is large, for example when driving a long cable, an external buffer may improve accuracy.

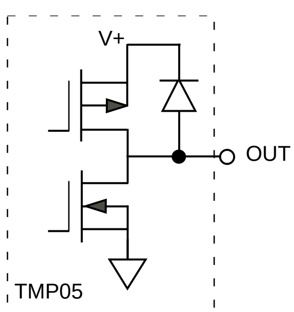


Figure 12. TMP05 Digital Output Structure

TMP06 OUTPUT

The TMP06 has an open drain output. Since the output source current is set by the pull up resistor, output capacitance should be minimised in TMP06 applications otherwise unequal rise and fall times will skew the pulse width and introduce measurement errors.

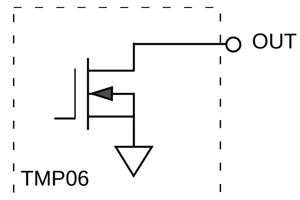


Figure 13. TMP06 Digital Output Structure

APPLICATION HINTS

THERMAL RESPONSE TIME

The time required for a temperature sensor to settle to a specified accuracy is a function of the thermal mass of, and the thermal conductivity between, the sensor and the object being sensed. Thermal mass is often considered equivalent to capacitance. Thermal conductivity is commonly specified using the symbol θ, and can be thought of as thermal resistance. It is commonly specified in units of degrees per watt of power transferred across the thermal joint. Thus, the time required for the TMP05/TMP06 to settle to the desired accuracy is dependent on the package selected, the thermal contact established in that particular application, and the equivalent power of the heat source. In most applications, the settling time is probably best determined empirically. The TMP05/TMP06 output operates with a nominal period of 120ms at 40°C, so the minimum settling time resolution is TBD ms.

SELF-HEATING EFFECTS

The temperature measurement accuracy of the TMP05/TMP06 may be degraded in some applications due to self-heating. Errors introduced are from the quiescent dissipation and power dissipated when converting i.e. during T2. The magnitude of these temperature errors is dependent on the thermal conductivity of the TMP05/TMP06 package, the mounting technique, and effects of airflow. Static dissipation in the TMP05/TMP06 is typically 10 µW operating at 3.3 V with no load. In the 5 lead SC-70 package mounted in free air, this accounts for a temperature increase due to self-heating of:

$$\Delta T = P_{DISS} \times \theta_{JA} = 10\ \mu W \times 211.4\ °C/W = 0.0021\ °C$$

In addition, power is dissipated by the digital output which is capable of sinking 800 µA continuously (TMP05). Under an 800 µA load, the output may dissipate:

$$P_{DISS} = (0.4V)(0.8mA)((T2) / (T1 + T2))$$

For example with T2 = 80 ms and T1 = 40 ms, the power dissipation due to the digital output is approximately

0.21 mW. In a free standing SC-70 package this accounts for a temperature increase due to self-heating of

$$\Delta T = P_{DISS} \times \theta_{JA} = 0.21\ mW \times 211.4\ °C/W = 0.044\ °C$$

This temperature increase adds directly to that from the quiescent dissipation and affects the accuracy of the TMP05/TMP06 relative to the true ambient temperature.

It is recommended that current dissipated through the device is kept to a minimum as it has a proportional affect on the temperature error.

SUPPLY DECOUPLING

The TMP05/06 should be decoupled with a 0.1 µF ceramic capacitor between V_{DD} and GND. This is particularly important if the TMP05/06 is mounted remote from the power supply. Precision analog products, such as the TMP05/TMP06, require a well filtered power source. Since the TMP05/TMP06 operates from a single supply, it seems convenient to simply tap into the digital logic power supply. Unfortunately, the logic supply is often a switch-mode design, which generates noise in the 20 kHz to 1 MHz range. In addition, fast logic gates can generate glitches hundred of millivolts in amplitude due to wiring resistance and inductance.

If possible, the TMP05/TMP06 should be powered directly from the system power supply. This arrangement, shown in Figure 14, will isolate the analog section from the logic switching transients. Even if a separate power supply trace is not available, however, generous supply bypassing will reduce supply-line induced errors. Local supply bypassing consisting of a 0.1 µF ceramic capacitor is recommended.

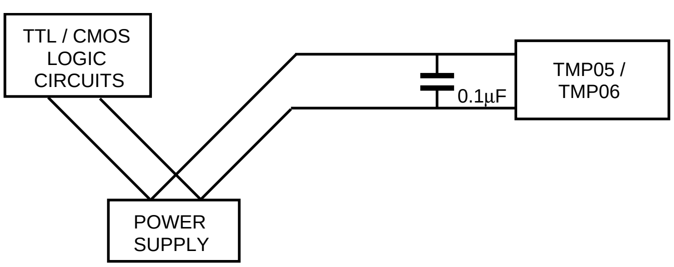


Figure 14. Use Separate Traces to Reduce Power Supply Noise

TEMPERATURE MONITORING

The TMP05/TMP06 is ideal for monitoring the thermal environment within electronic equipment. For example, the surface mounted package will accurately reflect the exact thermal conditions which affect nearby integrated circuits.

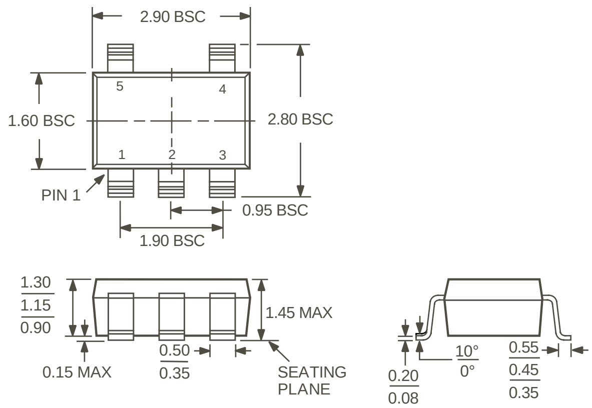
The TMP05/TMP06 measures and converts the temperature at the surface of their own semiconductor chip. When the TMP05/TMP06 is used to measure the temperature of a nearby heat source, the thermal impedance between the heat source and the TMP05/TMP06 must be considered. Often, a thermocouple or other temperature sensor is used to measure the temperature of the source while the TMP05/TMP06 temperature is monitored by measuring T1 and T2. Once the thermal impedance is determined, the temperature of the heat source can be inferred from the TMP05/TMP06 output.

One example of using the TMP05/TMP06 unique properties is in monitoring a high power dissipation microprocessor. The TMP05/TMP06, in a surface mount package, is mounted directly beneath the microprocessor's pin grid array (PGA) package. In a typical application, the TMP05/TMP06's output would be connected to an ASIC where the pulsewidth would be measured. The TMP05/TMP06 pulse output provides a significant advantage in this application because it produces a linear temperature output while needing only one I/O pin and without requiring an A/D converter.

OUTLINE DIMENSIONS

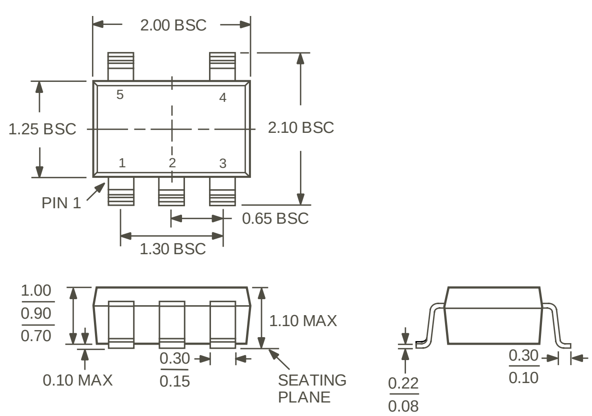
Dimensions shown in mm.

5-Lead SOT-23
(RJ-5)



COMPLIANT TO JEDEC STANDARDS MO-178-AA

5-Lead SC-70
(KS-5)



COMPLIANT TO JEDEC STANDARDS MO-203