MCP9700/9700A
MCP9701/9701A

Low-Power Linear Active Thermistor ICs

Features

- Tiny Analog Temperature Sensor
- Available Packages:
  - SC70-5, SOT-23-3, TO-92-3
- Wide Temperature Measurement Range:
  - -40°C to +125°C (Extended Temperature)
  - -40°C to +150°C (High Temperature) **(MCP9700,** SOT-23-3 and SC70-5 only**)**
- Accuracy:
  - ±2°C (max.), 0°C to +70°C **(MCP9700A/9701A)**
  - ±4°C (max.), 0°C to +70°C **(MCP9700/9701)**
- Optimized for Analog-to-Digital Converters (ADCs):
  - 10.0 mV/°C (typical) **(MCP9700/9700A)**
  - 19.5 mV/°C (typical) **(MCP9701/9701A)**
- Wide Operating Voltage Range:
  - V_{DD} = 2.3V to 5.5V **(MCP9700/9700A)**
  - V_{DD} = 3.1V to 5.5V **(MCP9701/9701A)**
- Low Operating Current: 6 µA (typical)
- Optimized to Drive Large Capacitive Loads

Typical Applications

- Hard Disk Drives and Other PC Peripherals
- Entertainment Systems
- Home Appliance
- Office Equipment
- Battery Packs and Portable Equipment
- General Purpose Temperature Monitoring

General Description

MCP9700/9700A and MCP9701/9701A sensors with Linear Active Thermistor Integrated Circuit (IC) comprise a family of analog temperature sensors that convert temperature to analog voltage.

The low-cost, low-power sensors feature an accuracy of ±2°C from 0°C to +70°C (MCP9700A/9701A) and ±4°C from 0°C to +70°C (MCP9700/9701) while consuming 6 µA (typical) of operating current.

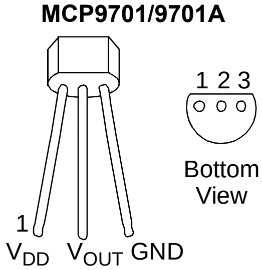
Unlike resistive sensors, e.g., thermistors, the Linear Active Thermistor IC does not require an additional signal-conditioning circuit. Therefore, the biasing circuit development overhead for thermistor solutions can be avoided by implementing a sensor from these low-cost devices. The Voltage Output pin (V_{OUT}) can be directly connected to the ADC input of a microcontroller. The MCP9700/9700A and MCP9701/9701A temperature coefficients are scaled to provide a 1°C/bit resolution for an 8-bit ADC with a reference voltage of 2.5V and 5V, respectively. The MCP9700/9700A output 0.1°C/bit for a 12-bit ADC with 4.096V reference.

The MCP9700/9700A and MCP9701/9701A provide a low-cost solution for applications that require measurement of a relative change of temperature. When measuring relative change in temperature from +25°C, an accuracy of ±1°C (typical) can be realized from 0°C to +70°C. This accuracy can also be achieved by applying system calibration at +25°C.

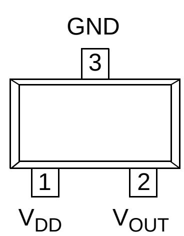
In addition, this family of devices is immune to the effects of parasitic capacitance and can drive large capacitive loads. This provides printed circuit board (PCB) layout design flexibility by enabling the device to be remotely located from the microcontroller. Adding some capacitance at the output also helps the output transient response by reducing overshoots or undershoots. However, capacitive load is not required for the stability of sensor output.

Package Types

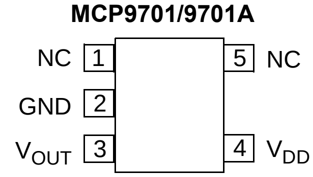
3-Pin TO-92
MCP9700/9700A
MCP9701/9701A



3-Pin SOT-23
MCP9700/9700A
MCP9701/9701A



5-Pin SC70
MCP9700/9700A
MCP9701/9701A



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD} 6.0V
Storage Temperature......................... -65°C to +150°C
Ambient Temp. with Power Applied... -40°C to +150°C
Output Current ....±30 mA
Junction Temperature (T_J)................................. 150°C
ESD Protection on All Pins (HBM:MM) ..... (4 kV:200V)
Latch-Up Current at Each Pin .... ±200 mA

† Notice: Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load

Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions
Power Supply						
Operating Voltage Range	V_{DD} V_{DD}	2.3 3.1	— —	5.5 5.5	V V	**MCP9700/9700A** **MCP9701/9701A**
Operating Current	I_{DD}	—	6	12	µA	
	I_{DD}	—	—	15	µA	T_A = 150°C (**Note 1**)
Line Regulation	$\Delta°C/\Delta V_{DD}$	—	0.1	—	°C/V	
Sensor Accuracy (Notes 2, 3)						
T_A = +25°C	T_{ACY}	—	±1	—	°C	
T_A = 0°C to +70°C	T_{ACY}	-2.0	±1	+2.0	°C	**MCP9700A/9701A**
T_A = -40°C to +125°C	T_{ACY}	-2.0	±1	+4.0	°C	**MCP9700A**
T_A = -10°C to +125°C	T_{ACY}	-2.0	±1	+4.0	°C	**MCP9701A**
T_A = 0°C to +70°C	T_{ACY}	-4.0	±2	+4.0	°C	**MCP9700/9701**
T_A = -40°C to +125°C	T_{ACY}	-4.0	±2	+6.0	°C	**MCP9700**
T_A = -10°C to +125°C	T_{ACY}	-4.0	±2	+6.0	°C	**MCP9701**
T_A = -40°C to +150°C	T_{ACY}	-4.0	±2	+6.0	°C	**High Temperature (Note 1)**
Sensor Output						
Output Voltage, T_A = 0°C	$V_{0°C}$	—	500	—	mV	**MCP9700/9700A**
Output Voltage, T_A = 0°C	$V_{0°C}$	—	400	—	mV	**MCP9701/9701A**
Temperature Coefficient	T_C	—	10.0	—	mV/°C	**MCP9700/9700A**
	T_C	—	19.5	—	mV/°C	**MCP9701/9701A**
Output Nonlinearity	V_{ONL}	—	±0.5	—	°C	T_A = 0°C to +70°C (**Note 3**)

Note 1: MCP9700 with SC70-5 and SOT-23-3 packages only. The MCP9700 High Temperature is not available with TO-92 package.
2: The MCP9700/9700A family accuracy is tested with V_{DD} = 3.3V, while the MCP9701/9701A accuracy is tested with V_{DD} = 5.0V.
3: The MCP9700/9700A and MCP9701/9701A family is characterized using the first-order or linear equation, as shown in Equation 4-2. Also refer to Figure 2-16.
4: The MCP9700/9700A and MCP9701/9701A family is characterized and production tested with a capacitive load of 1000 pF.
5: SC70-5 package thermal response with 1x1 inch, dual-sided copper clad, TO-92-3 package thermal response without PCB (leaded).

DC ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load

Parameter	Sym.	Min.	Typ.	Max.	Unit	Conditions
Output Current	I_{OUT}	—	—	100	µA	
Output Impedance	Z_{OUT}	—	20	—	Ω	I_{OUT} = 100 µA, f = 500 Hz
Output Load Regulation	$\Delta V_{OUT}/\Delta I_{OUT}$	—	1	—	Ω	T_A = 0°C to +70°C I_{OUT} = 100 µA
Turn-On Time	t_{ON}	—	800	—	µs	
Typical Load Capacitance	C_{LOAD}	—	—	1000	pF	**Note 4**
SC-70 Thermal Response to 63%	t_{RES}	—	1.3	—	s	30°C (Air) to +125°C (Fluid Bath) (**Note 5**)
TO-92 Thermal Response to 63%	t_{RES}	—	1.65	—	s	

Note 1: MCP9700 with SC70-5 and SOT-23-3 packages only. The MCP9700 High Temperature is not available with TO-92 package.

2: The MCP9700/9700A family accuracy is tested with V_{DD} = 3.3V, while the MCP9701/9701A accuracy is tested with V_{DD} = 5.0V.

3: The MCP9700/9700A and MCP9701/9701A family is characterized using the first-order or linear equation, as shown in Equation 4-2. Also refer to Figure 2-16.

4: The MCP9700/9700A and MCP9701/9701A family is characterized and production tested with a capacitive load of 1000 pF.

5: SC70-5 package thermal response with 1x1 inch, dual-sided copper clad, TO-92-3 package thermal response without PCB (leaded).

TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Specified Temperature Range (**Note 1**)	T_A	-40	—	+125	°C	**MCP9700/9700A**
	T_A	-10	—	+125	°C	**MCP9701/9701A**
	T_A	-40	—	+150	°C	High Temperature (**MCP9700,** SOT23-3 and SC70-5 only**)**
Operating Temperature Range	T_A	-40	—	+125	°C	Extended Temperature
	T_A	-40	—	+150	°C	High Temperature
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, 5LD SC70	θ_{JA}	—	331	—	°C/W	
Thermal Resistance, 3LD SOT-23	θ_{JA}	—	308	—	°C/W	
Thermal Resistance, 3LD TO-92	θ_{JA}	—	146	—	°C/W	

Note 1: Operation in this range must not cause T_J to exceed Maximum Junction Temperature (+150°C).

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin No. SC70	Pin No. SOT-23	Pin No. TO-92	Symbol	Function
1	—	—	NC	No Connect (this pin is not connected to the die.)
2	3	3	GND	Power Ground Pin
3	2	2	V_{OUT}	Output Voltage Pin
4	1	1	V_{DD}	Power Supply Input
5	—	—	NC	No Connect (this pin is not connected to the die.)

3.1 Power Ground Pin (GND)

GND is the system ground pin.

3.2 Output Voltage Pin (V_{OUT})

The sensor output can be measured at V_{OUT}. The voltage range over the operating temperature range for the MCP9700/9700A is 100 mV to 1.75V. The voltage range over the operating temperature range for the MCP9701/9701A is 200 mV to 3V.

3.3 Power Supply Input (V_{DD})

The operating voltage as specified in the **DC Electrical Characteristics** table is applied to V_{DD}.

3.4 No Connect Pin (NC)

This pin is not connected to the die. It can be used to improve thermal conduction to the package by connecting it to a printed circuit board (PCB) trace from the thermal source.

4.0 APPLICATIONS INFORMATION

The Linear Active Thermistor™ IC uses an internal diode to measure temperature. The diode electrical characteristics have a temperature coefficient that provides a change in voltage based on the relative ambient temperature from -40°C to 150°C. The change in voltage is scaled to a temperature coefficient of 10.0 mV/°C (typical) for the MCP9700/9700A and 19.5 mV/°C (typical) for the MCP9701/9701A. The output voltage at 0°C is also scaled to 500 mV (typical) and 400 mV (typical) for the MCP9700/9700A and MCP9701/9701A, respectively. This linear scale is described in the first-order transfer function shown in Equation 4-1 and Figure 2-16.

EQUATION 4-1: SENSOR TRANSFER FUNCTION

$$V_{OUT} = T_C \times T_A + V_{0°C}$$

Where:

T_A = Ambient Temperature

V_{OUT} = Sensor Output Voltage

$V_{0°C}$ = Sensor Output Voltage at 0°C (see **DC Electrical Characteristics** table)

T_C = Temperature Coefficient (see **DC Electrical Characteristics** table)

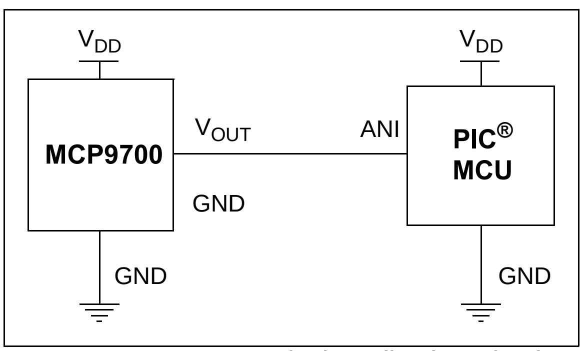


FIGURE 4-1: *Typical Application Circuit.*

4.1 Improving Accuracy

The MCP9700/9700A and MCP9701/9701A accuracy can be improved by performing a system calibration at a specific temperature. For example, calibrating the system at +25°C ambient improves the measurement accuracy to a ±0.5°C (typical) from 0°C to +70°C, as shown in Figure 4-2. Therefore, when measuring relative temperature change, this family of devices measures temperature with higher accuracy.

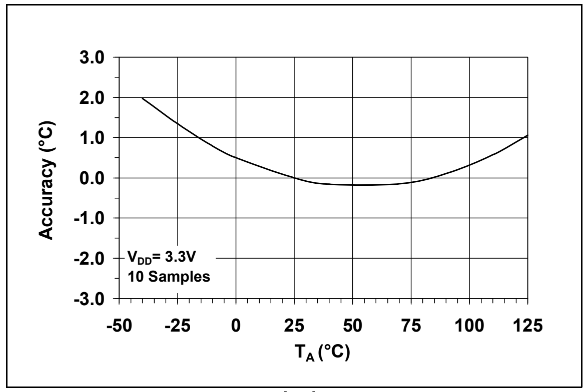


FIGURE 4-2: *Relative Accuracy to +25°C vs. Temperature.*

The change in accuracy from the calibration temperature is due to the output nonlinearity from the first-order equation, as specified in Equation 4-2. The accuracy can be further improved by compensating for the output nonlinearity.

For higher accuracy using a sensor compensation technique, refer to Application Note AN1001, *"IC Temperature Sensor Accuracy Compensation with a PIC® Microcontroller"* (DS00001001). The application note shows that if the device is compensated in addition to room temperature calibration, the sensor accuracy can be improved to ±0.5°C (typical) accuracy over the operating temperature (Figure 4-3).

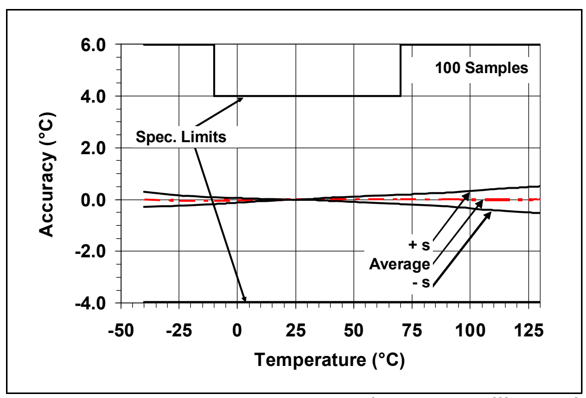


FIGURE 4-3: *MCP9700/9700A Calibrated Sensor Accuracy.*

The compensation technique provides a linear temperature reading. The application note includes compensation firmware so that a look-up table can be generated to compensate for the sensor error.

4.2 Shutdown Using Microcontroller I/O Pin

The 6 µA (typical) low operating current of the MCP9700/9700A and MCP9701/9701A family makes it ideal for battery-powered applications. However, for applications that require a tighter current budget, this device can be powered using a microcontroller Input/Output (I/O) pin. The I/O pin can be toggled to shut down the device. In such applications, the microcontroller internal digital switching noise is emitted to the MCP9700/9700A and MCP9701/9701A as power supply noise. However, this switching noise compromises measurement accuracy, therefore a decoupling capacitor and series resistor will be necessary to filter out the system noise.

4.3 Layout Considerations

The MCP9700/9700A and MCP9701/9701A family of sensors does not require any additional components to operate. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the V_{DD} and GND pins. In high-noise applications, connect the power supply voltage to the V_{DD} pin using a 200Ω resistor with a 1 µF decoupling capacitor. A high frequency ceramic capacitor is recommended. It is necessary that the capacitor is located as close as possible to the V_{DD} and GND pins in order to provide effective noise protection. In addition, avoid tracing digital lines in close proximity to the sensor.

4.4 Thermal Considerations

The MCP9700/9700A and MCP9701/9701A family measures temperature by monitoring the voltage of a diode located in the die. A low-impedance thermal path between the die and the PCB is provided by the pins. Therefore, the sensor effectively monitors the temperature of the PCB. However, the thermal path for the ambient air is not as efficient because the plastic device package functions as a thermal insulator from the die. This limitation applies to plastic-packaged silicon temperature sensors. If the application requires the measurement of ambient air, the TO-92 package should be considered.

The MCP9700/9700A and MCP9701/9701A sensors are designed to source/sink 100 µA (max.). The power dissipation due to the output current is relatively insignificant. The effect of the output current can be described by Equation 4-2.

EQUATION 4-2: EFFECT OF SELF-HEATING

$$T_J - T_A = \theta_{JA}(V_{DD}I_{DD} + (V_{DD} - V_{OUT})I_{OUT})$$

Where:

- T_J = Junction Temperature
- T_A = Ambient Temperature
- θ_{JA} = Package Thermal Resistance (331°C/W)
- V_{OUT} = Sensor Output Voltage
- I_{OUT} = Sensor Output Current
- I_{DD} = Operating Current
- V_{DD} = Operating Voltage

At T_A = +25°C (V_{OUT} = 0.75V) and maximum specification of I_{DD} = 12 µA, V_{DD} = 5.5V and I_{OUT} = +100 µA, the self-heating due to power dissipation ($T_J – T_A$) is 0.179°C.