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### Using the ADT7461 as a Multichannel Temperature Sensor

by Susan Pratt

#### INTRODUCTION

The ADT7461 is digital temperature monitor, with one external and one internal temperature-monitoring channel. It is capable of measuring the temperature of an external sensor accurate to  $\pm 1^{\circ}\text{C}$ , and communicates with a host over the SMBus. This application note describes how to use the ADT7461 in an application where multichannel temperature sensing is required.

In real applications, there is often more than one external temperature of interest. For example, on a PC motherboard, the temperature of the memory card, the graphics processor, and the CPU must all be monitored closely. This application note explains how to adapt the ADT7461 for use as a multichannel temperature sensor, and shows why the ADT7461 is particularly suited for this modification.

#### IMPLEMENTATION

The ADT7461 has one external temperature-monitoring channel and normally measures the temperature of a remote transistor connected between its D+ and D- pins. In order to measure the temperature of more than one remote transistor, the ADT7461 can be used in conjunction with a multiplexer. Figure 1 shows the basic circuit diagram of the application, which uses an ADG729 differ-

ential multiplexer in conjunction with the ADT7461. Both the mux and the ADT7461 are controlled via the SMBus by a host, also shown. There are four external thermal zones monitored in this system, with a diode-connected transistor used as the remote temperature sensor in each zone. The transistors shown in the diagram are PNP type, such as the 2N3906. The emitter of each transistor is connected to one of the switches, while the base and collector are connected to the corresponding switch in the differential switch pair.

The system operates as follows. The ADT7461 is set up by the host to continuously monitor temperature. The host sets the mux via the SMBus to connect one of the remote transistors to the inputs of the ADT7461. The ADT7461 then measures the temperature of the connected remote sensor and stores the result in on-chip registers. The host can now read back the temperature over the SMBus. The host switches the mux to another of the remote sensors, and reads back its temperature in the same manner.

If required, the ADT7461 can be set to trigger its  $\overline{\text{ALERT}}$  output if the measured temperature exceeds limits pre-programmed into on-chip registers. The  $\overline{\text{ALERT}}$  signal can be used to interrupt the host in the event of an over- or undertemperature event, as an SMBALERT, or can be used to drive a fan.

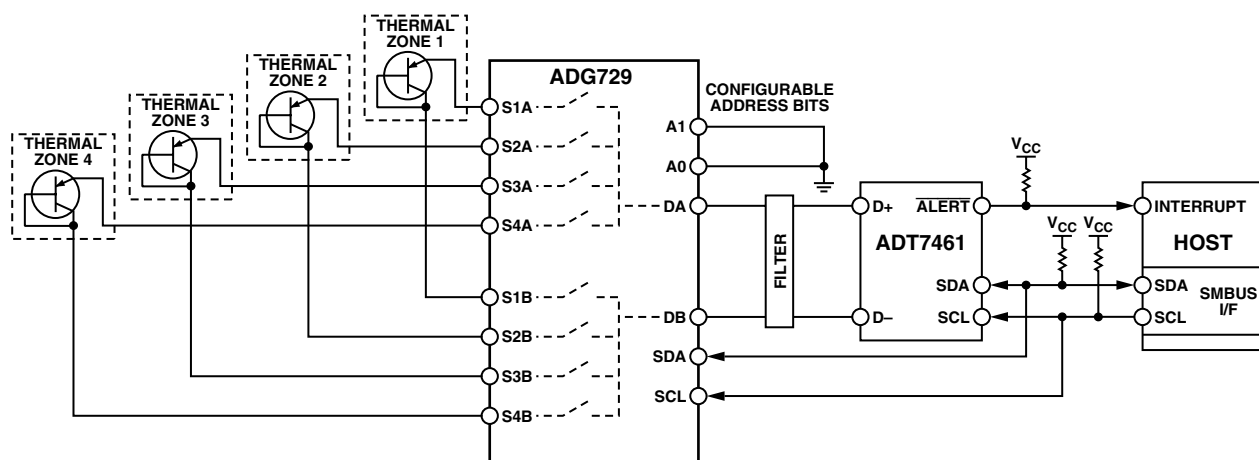


Figure 1. Application Circuit Diagram

## ADG729 GENERAL DESCRIPTION

The ADG729 is a 4-channel differential multiplexer that can be controlled via a 2-wire serial interface. To open and close one of the switch pairs, a control word is written to the ADG729 over the serial interface. Two external address pins allow the user to set the 2 LSBs of the 7-bit slave address. The part has low on-resistance and low leakage currents, with guaranteed break-before-make switching action.

## HARDWARE CONSIDERATIONS

### Series Resistance

The ADT7461 is a dual-channel digital temperature monitor. One feature in particular that allows it to be used in this application is its ability to automatically cancel out the effect of resistances in series with the external temperature sensor. Any resistance in the path between the remote sensor and a standard digital temperature sensor affects the accuracy of the temperature measurement. Typically, there is a 0.5°C offset in the measured temperature value per ohm of parasitic resistance in series with the sensor. The ADT7461, however, automatically cancels the effect of this series resistance. Up to 3 kΩ of series resistance can be cancelled out of the temperature measurement; this is transparent to the user.

This attribute allows the ADT7461 to be transformed into a multichannel temperature monitor. The multiplexer has a resistance associated with it ( $R_{ON}$ ). This resistance is subject to channel matching and flatness issues, which can result in a varying temperature offset. A typical value for the on-resistance of the ADG729 is 2.5 Ω, 4.5 Ω maximum, with channel matching of 0.8 Ω max. Using a standard temperature sensor, these figures result in temperature offsets of 2.25°C, with variations of up to 0.4°C between each temperature zone, due only to the multiplexer. A standard temperature monitor could not claim accuracy of  $\pm 1^\circ\text{C}$  when taking these variables into account.

With the ADT7461, series resistance is automatically cancelled, so the switch on-resistance and channel-to-channel  $R_{ON}$  variations have no effect. No user calibration is required, so the ADT7461 can be immediately hooked directly to the multiplexer. Also, any resistance associated with the PCB tracks or other connectors is cancelled, allowing the remote temperature sensors to be placed at a distance from the ADT7461.

### Noise

Another factor affecting the performance of this system is noise. Any noise coupled into the ADT7461's D+ and D- inputs distorts temperature measurement. A very noisy environment can swamp the temperature measurement completely, rendering any result useless. A number of options are available to the user to help reduce system noise.

Using a differential multiplexer ensures that the D+ and D- signal paths to the ADT7461 are similar. Any noise picked up on the signal path enters the part differentially, where it can be filtered.

Adding a simple R-C-R filter between the D+ and D- inputs of the ADT7461 also reduces system noise. The series resistance feature of the ADT7461 allows sufficiently large resistance values to build an adequate filter.

### Routing

The ADG729 should be placed as close as possible to the ADT7461. All tracks to the remote transistor should be similar in length; this is particularly the case of the D+ and D- tracks to each individual transistor.

## CONTROLLING THE SYSTEM

### Control via the Serial Interface

The host controls both the ADT7461 and the ADG729 over the serial interface. The ADT7461 is at address 0x22. The address of the ADG729 is configurable; its 5 MSB address bits are 10001, while its 2 LSBs are determined by the state of the A0 and A1 input pins.

The ADT7461 is programmed first. Values should be written to the limit and offset registers, and the required conversion rate should be set. More information on how to configure the ADT7461's internal registers can be found in the ADT7461 data sheet.

Finally, Bit 6 in the ADT7461's configuration register should be cleared. This sets the ADT7461 to run mode. The ADT7461 takes one measurement on the external channel, followed by a measurement on the internal channel, at intervals determined by the conversion rate. The results are stored in on-chip registers, and can be read back over the serial interface. If none of the switches on the multiplexer are closed, then the external temperature reading should be disregarded.

The goal of this system is to monitor the temperature of all four thermal zones. To measure the temperature of each zone, the host writes to the ADG729 to close one of the differential switch pairs, connecting the temperature transistor to the ADT7461. To control the mux, each one of the 4 LSBs of serial data written to the ADG729 represents one of the switch pairs. Setting a bit turns on the corresponding switch pair.

The host selects which of the thermal zones to monitor, and sets the mux appropriately. On its next conversion cycle, the ADT7461 measures its internal temperature and the external temperature of the transistor connected to its inputs. The results are stored in the results registers. The host reads back these results over the serial bus. To read the temperature of each thermal zone, the host repeats the procedure of setting the mux, and reads back the temperature in a round-robin fashion. Figure 2 is a flowchart illustrating how the system operates.

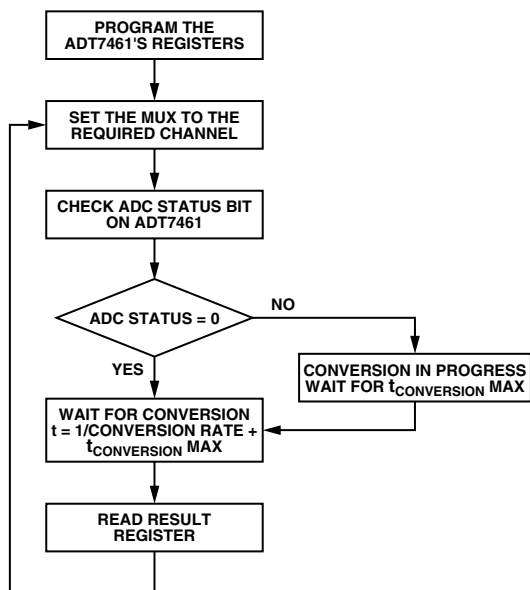


Figure 2. Flow Chart

### Timing Considerations

The host monitors the four thermal zones in a round-robin fashion. If the temperature in one of the zones changes, it could be some time before the host reads back the temperature from that zone. It is therefore important to consider the timing in this system to ensure that the delay between successive temperature readings for each zone is minimized. For each temperature reading, the host needs to set the mux to the required thermal zone, measure the temperature, and then read it back. The time taken to monitor all four temperature zones can be calculated as follows:

(time taken to switch mux + time required to guarantee measurement + time required to read result)  $\times$  4.

If the serial clock is running at 200 kHz, the time taken to write to the mux is  $\sim 90 \mu\text{s}$ . The host must then leave sufficient time for a conversion to complete on the ADT7461's external channel before reading the results register. The time required for a conversion depends on the conversion rate programmed in the ADT7461's register. For example, at a rate of 16 conversions/sec, a conversion sequence begins every 62 ms and takes a maximum of 12.56 ms to complete. In each sequence, a conversion on both the internal and external channel is performed.

The host should wait until at least one conversion has occurred before reading the results register. If the host does not leave sufficient time for a conversion to complete, the result in the register might not correspond to the thermal zone currently being monitored. To ensure that the correct temperature zone measurement is in the result register, the host should check the ADC status bit,

Bit 7 in the ADT7461's status register. If the ADC status bit is 0, no conversion is taking place. To guarantee that a measurement is taken for the current thermal zone, the host should wait for a time equal to

$$(1/\text{conversion rate} + t_{\text{CONVERSION MAX}})$$

With a conversion rate of 16 conversions, this wait time is equal to  $(62.5 \text{ ms} + 12.56 \text{ ms}) = 75.06 \text{ ms}$ . If the ADC status is 1, this means a conversion is in progress and the user should wait for it to finish. This can be guaranteed by waiting for a time equal to the maximum conversion time, given in the data sheet. Figure 2 illustrates this point.

Once the conversion has been completed, the host reads the results register. How long this takes depends on a number of factors:

- Is the host interested in just the external temperature, or does it want to read the internal temperature as well?
- What resolution is required on the temperature measurement? If  $0.25^\circ\text{C}$  resolution is required on the external temperature, the contents of two registers must be read.
- What address is the address pointer in the ADT7461 set to?

If the user is only interested in the external temperature channel, with a resolution of  $1^\circ\text{C}$  and the address pointer already set to the external temperature result register, the time required to read the result is only  $90 \mu\text{s}$  (with  $\text{DCLK} = 200 \text{ kHz}$ ).

However, if the user would like to read both the internal and external temperatures with a resolution of  $0.25^\circ\text{C}$  on the external measurement, and the user needs to set the address pointer, this takes longer. To set the address pointer and read from the internal result register, followed by both the external high byte and low byte results registers, takes  $540 \mu\text{s}$ .

The time available to perform the temperature measurements is application dependant. Some applications tolerate a large time interval between successive measurements of the same thermal zone, while in other applications, this time has to be minimized. It is up to the system designer to decide what tolerances their application has.

### Using the Limit Registers

The ADT7461 has on-chip high and low limit registers for the external and internal measurement channels. If a measurement falls outside the upper and lower limits programmed into these registers, the  $\overline{\text{ALERT}}$  output asserts and a flag is set. The same temperature limits apply to each of the four thermal zones, because the ADT7461 has only one set of limit registers.

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The internal temperature limit registers can be written to at addresses 0x0B (high limit) and 0x0C (low limit). The external temperature limit registers span two registers each. The high limit higher byte can be written to at address 0x0D, with the lower byte at write address 0x13. The external temperature lower limit is at write addresses 0x0E (higher byte) and 0x14 (lower byte). More information on the limit registers can be found in the ADT7461 data sheet.

## ALTERNATIVE CIRCUIT CONFIGURATION

In some applications, it might be preferable to control the multiplexer via address bits rather than via the SMBus. Writing directly to the mux could be achieved by using spare GPIOs in the system. The ADG709 is a 4-channel differential multiplexer. Writing to the address bits, A0 and A1, controls the mux settings. This device can be used instead of the ADG729 if addressable control is required.

## REFERENCES

The following are available on <http://www.analog.com>:

- ADT7461 Data Sheet
- ADG729 Data Sheet
- ADG709 Data Sheet

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