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ADC diagnostic on the ADuC703x series

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INTRODUCTION

The ADuC7030/ADuC7033 integrates two 16-bit sigma delta ADCs to monitor current, voltage and temperature in battery monitoring applications.

It also integrates multiple diagnostic support circuits on-chip:

- internal test voltage,
- internal short mode and
- internal current sources.

These circuits allow the device to test core digital functionality and analog front-end in-circuit. This application note explains how to use these features.

INTERNAL TEST VOLTAGE

The current channel can be configured to convert on an internal fixed test voltage set by the selected reference. Four different references options are available in this mode and are as follow:

a. Internal 1.2V reference divided by 136, which gives a fixed input voltage of 8.8mV. ADC0CON[5,4]=00.
b. External reference divided by 136. ADC0CON[5,4]=01.
c. External reference/2, divided by 68. ADC0CON[5,4]=10.
d. (AVDD, GND)/2 divided by 68, which gives a fixed input voltage of 19.1mV. ADC0CON=11.

Note that for configurations c or d, the divider is lower, therefore maximum gain equals 64. For configuration a and b, the maximum gain can be 128.
The divider is not a precision divider and a margin of at least 3% should be used for diagnostics for any gain range.

INTERNAL SHORT MODE

The current and voltage input channels can also be shorted internally ADC0CON[7,6]=01 and ADC1CON[7,6]=11. Converting on the internal short will allow an assessment of the internal ADC noise to be determined.

INTERNAL CURRENT SOURCES: CURRENT ADC DIAGNOSTICS

The ADuC7030/ADuC7033 features the capability to detect open-circuit conditions and short-circuit conditions on the current channel of the module.

ADC internal configuration

The current ADC has a current source on each input. These two current sources are controlled via ADC0CON[14,13] as shown in Figure 1.

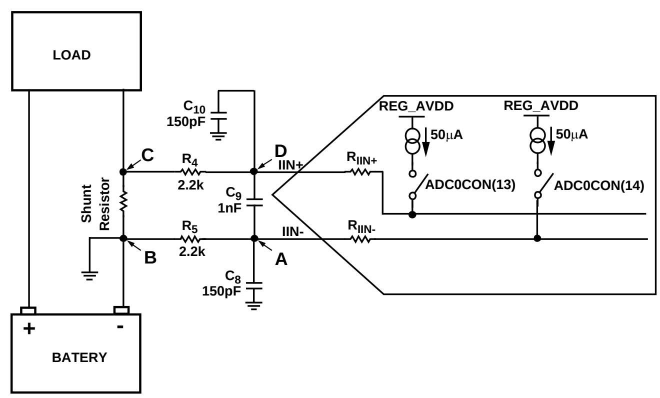

Figure 1. Current ADC diagnostic

When using the current sources, note that resistors R_{IIN+} and R_{IIN-} are present on the current ADC inputs. The expected range of R_{IIN+} and R_{IIN-} values is between 1.2kΩ and 2.2kΩ, accounting for part-to-part variation and temperature. The difference in R_{IIN+} and R_{IIN-} on any given part is expected to be about 2%.

Similarly, there is variation in the diagnostic currents from the nominal 50µA. The range of I_{DIAG} to account for is between 45uA and 60uA, with up to 2% variation between I_{DIAG+} and I_{DIAG-} on any part at a given time.

The variability in value of R_{IIN+}, R_{IIN-} and I_{DIAG+}, I_{DIAG-} places a limit on the minimum external resistance value, which can be reliably detected.

Principle of the diagnostic

For each test, a measurement on the ADC must be performed and recorded in the diagnostic routine. A second measurement with one or two of the sources gives a result that should be compared with the first result to give diagnostic information.

Shorted inputs

The calculation below shows the effect of the internal resistance, on the ADC result if the IIN+ and IIN- inputs are shorted. The reference used for the diagnostics is the internal 1.2V reference, the PGA setting is 1, output coding is 2's complement. This configuration corresponds to an LSB weight of 36.6µV.

Minimum value:

$$ADC0DAT = \frac{45\mu A \cdot 1.2k\Omega}{36.6\mu V} = 1475d = 0x5C3$$

Maximum value:

$$ADC0DAT = \frac{60\mu A \cdot 2.2k\Omega}{36.6\mu V} = 3604d = 0xE14$$

The use of the IIN+ and IIN- currents is shown in Table 1.

Table 1: Current ADC Diagnostics

Fault Condition	Tests
Short between points D and C (R_4 shorted) or between D and A (C_9 shorted) or point D grounded (C_{10} shorted)	1. Turn off both current source, read value1 from ADC0DAT 2. Turn on the current source on IIN+. Read value2 from ADC0DAT. Subtract value 1 from value2. 3. If the result is greater than +maximum value (calculated above), IIN+ input is not shorted.
Short between points A and B (R_5 shorted) or between A and D (C_9 shorted) or point A grounded (C_8 shorted)	1. Turn on current source on input IIN-. Read value3 from ADC0DAT. Subtract value 1 from value3. 2. If the result is less than -Maximum value (calculated above), IIN- input is not shorted.
Miscellaneous , e.g. short at point D to ground or short at point A to ground or R4 <> R5.	1. Turn off both current source, read value1 from ADC0DAT 2. Turn on current source on IIN-. Read value3 from ADC0DAT. Subtract value1 from value3. 3. If the absolute value is greater than $(R_{IIN}+R_{EXT})\times DI + (DR_{IIN}+DR_{EXT})\times I$, there is an open or short circuit. DI is the maximum mismatch in I (2%), DR_{IIN} is mismatch in R_{IIN} (2%), DR_{EXT} is maximum of [|R4-R5)|/R4] and the maximum possible values should be used for I, R_{IIN}, R_{ext}.
Open Circuit between point D and C (R_4 unsoldered, or IIN+ unsoldered)	1. Turn on current source on input IIN+. Read value2 from ADC0DAT. 2. If value2 is equal to Positive Full Scale (0x7FFF in Bi Polar Mode), IIN+ input is Open Circuit
Open Circuit between point A and B (R_5 unsoldered, or IIN- unsoldered)	1. Turn on current source on input IIN-. Read value3 from ADC0DAT. 2. If value3 is Negative Full Scale (0x8000 in Bi Polar Mode) IIN- input is Open Circuit

Limitations

The maximum voltage caused by I_{DIAG} and R_{IIN} equals $I_{DIAG\_MAX} \times R_{IIN\_MAX}$ = 132mV. Therefore, even if the IIN+ input is shorted to ground a delta of up to 132mV between value1 and value2 in Step1 is possible.

This limits the minimum value of external resistor whose presence is detectable via the first two steps of the above table to (Vmax-Vmin)/Imin = 1.75kΩ. If the resistance is less than this then a short-circuit condition cannot be detected under some combinations of I_{diag} and R_{IIN} values.

The third step in the table gives better resolution; a shorted 250 Ohms resistor indicates an error with loose resistor tolerances. However, it does not indicate a failure if both R4 and R5 are both shorted to ground or if the IIN+ and IIN- pins are shorted together.

Figure 2 gives a flowchart of the current ADC diagnostic.

Note: The time required to detect an open circuit might require a delay between turning on the current source and taking a measurement so that any external capacitors on the IIN+ or IIN- pins are charged.

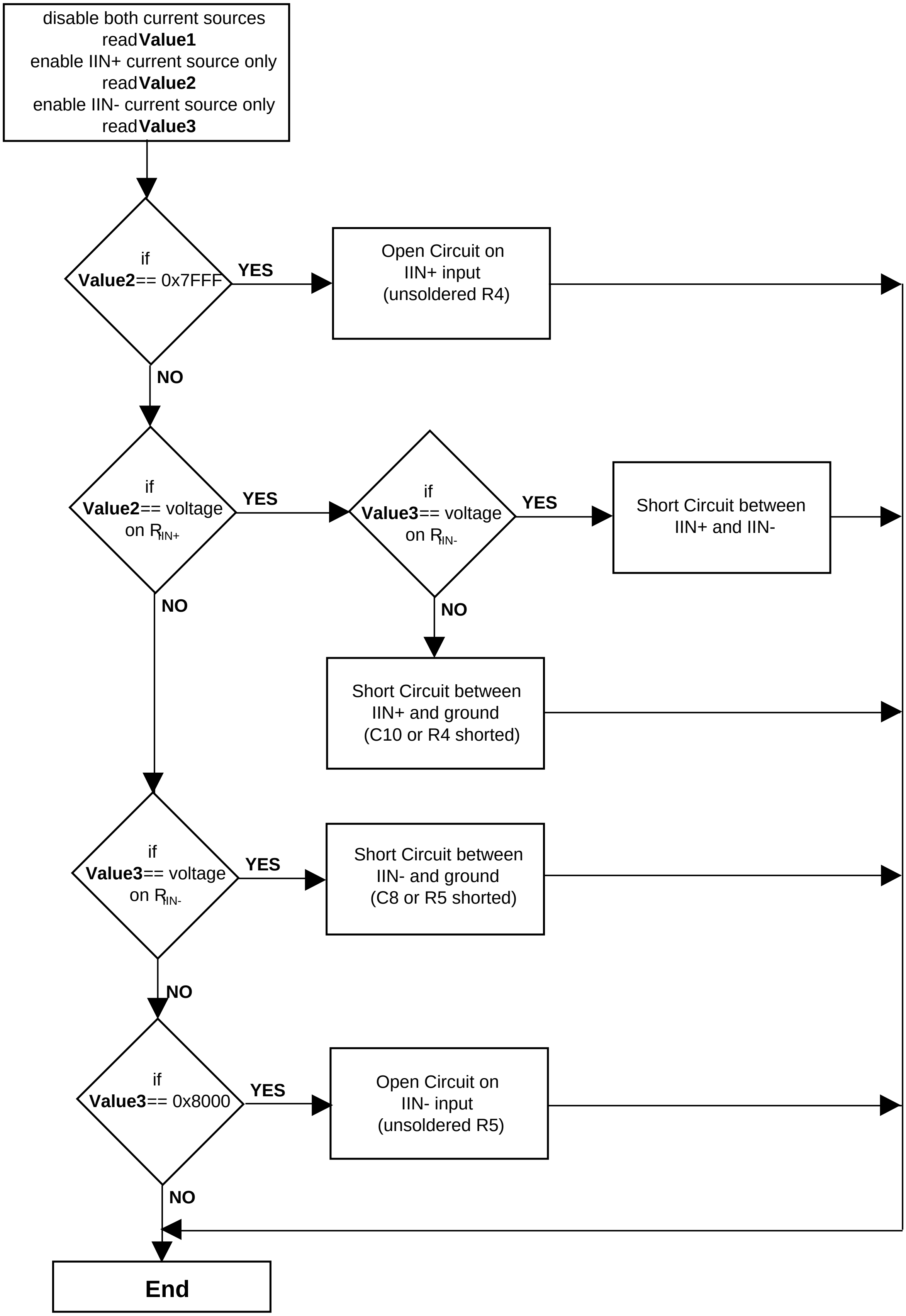

Figure 3 flowchart of current ADC diagnostic

INTERNAL CURRENT SOURCES: TEMPERATURE ADC DIAGNOSTICS

The ADuC7030/ADuC7033 features the capability to detect Open Circuit conditions on the Temperature Channel inputs. This is accomplished using the two current sources on VTEMP+ and GND_SW, which are controlled via ADC1CON[14,13].

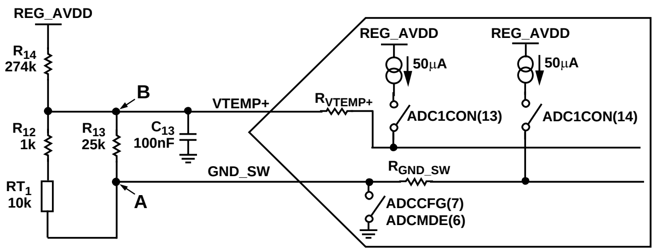

Figure 3 Temperature channel diagnostic

Figure 3 shows a typical configuration for the temperature channel inputs. In this configuration, there is no external connection to AGND.

Resistors R_{VTEMP+} and R_{GND_SW} are on the temperature ADC inputs when the current sources are on. R_{VTEMP+} and R_{GND_SW} values are between 150 and 300 Ω. These values will be used for the diagnostic.

The use of the VTEMP current sources is shown in Table 2.

Table 2. Voltage/Temperature ADC Diagnostics

Fault Condition	Tests
Short circuit between points A and B or point B grounded.	Turn on current source on VTEMP+ input. Read value2 from ADC2DAT. If it is greater than the maximum voltage (calculated below) the inputs are not shorted
Open Circuit on inputs VTEMP+ or GND_SW	Turn on current source on VTEMP+ input. Read value2 from ADC2DAT. If value is positive full scale (0x7FFF in Bi Polar Mode) VTEMP+ or GND_SW is unsoldered
Open Circuit between point B and REG_AVDD (R_{14} is unsoldered)	Turn off current source on VTEMP+ input. Turn on current source on GND_SW input for removing charges in capacitors on input VTEMP+ and charges in external C_{13} capacitor. Turn off both current sources. Read value1 from ADC2DAT. If value1 is near zero, REG_AVDD is not connected to the resistor divider.

The calculation below shows the effect of the internal resistance, on the ADC result if the inputs are shorted. The reference used for the diagnostics is (REG_AVDD, AGND)/2 and the output coding is unipolar, which correspond to an LSB weight of 19.84µV.

Minimum value = 150Ω (R_{IIN} min)

$$ADC2DAT = \frac{45\mu A \cdot 150\Omega}{19.84\mu V} = 340d = 0x154$$

Maximum value = 300Ω (R_{IIN} max)

$$ADC2DAT = \frac{60\mu A \cdot 300\Omega}{19.84\mu V} = 907d = 0x38B$$

Figure 4 gives a flowchart of the temperature channel diagnostic.

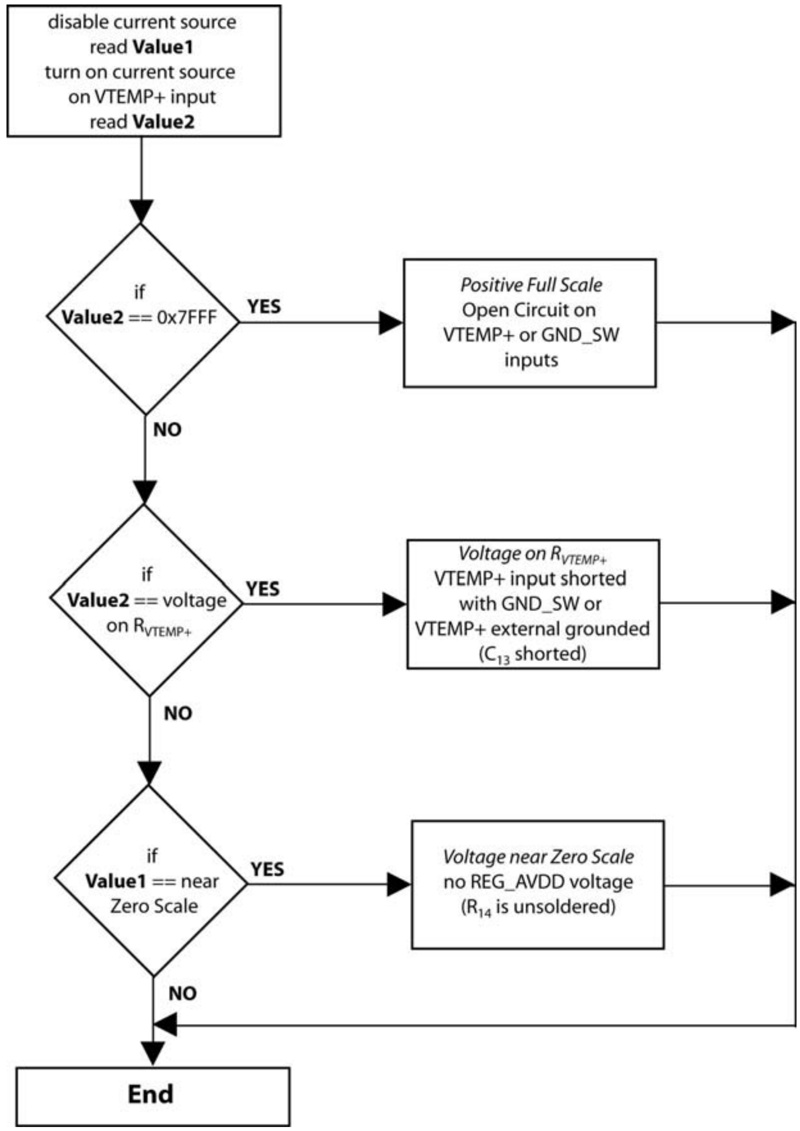

Figure 4 Diagram temperature channel diagnostic

Limitations

If the NTC resistance and I_{DIAG} are both high, Full-Scale can theoretically be generated without an open-circuit being present. However, the I_{DIAG} current has a slight positive Temp-Co so R_{NTC} will be low when I_{DIAG} is highest.