

## Configuring ADuCM350–BIO3Z Board for 50kHz Bio-Impedance Measurement

### INTRODUCTION

This application note details how to setup the [ADuCM350](#) to optimally measure Bio-Impedance using 4-wire, bio-impedance measurement. The [EVAL-ADuCM350EBZ](#) with BIO3Z board is shown in figure 1.

The 4-wire, bio-impedance measurement application using [ADuCM350](#) is detailed on [AN-1302](#). For more details on

ADuCM350, refer to ADuCM350's [Datasheet](#), [User guide](#), and [Engineer Zone](#).

Note: When performing the Bio-Impedance measurement on the body, please ensure the laptop is unplugged from the power source as an additional precaution.

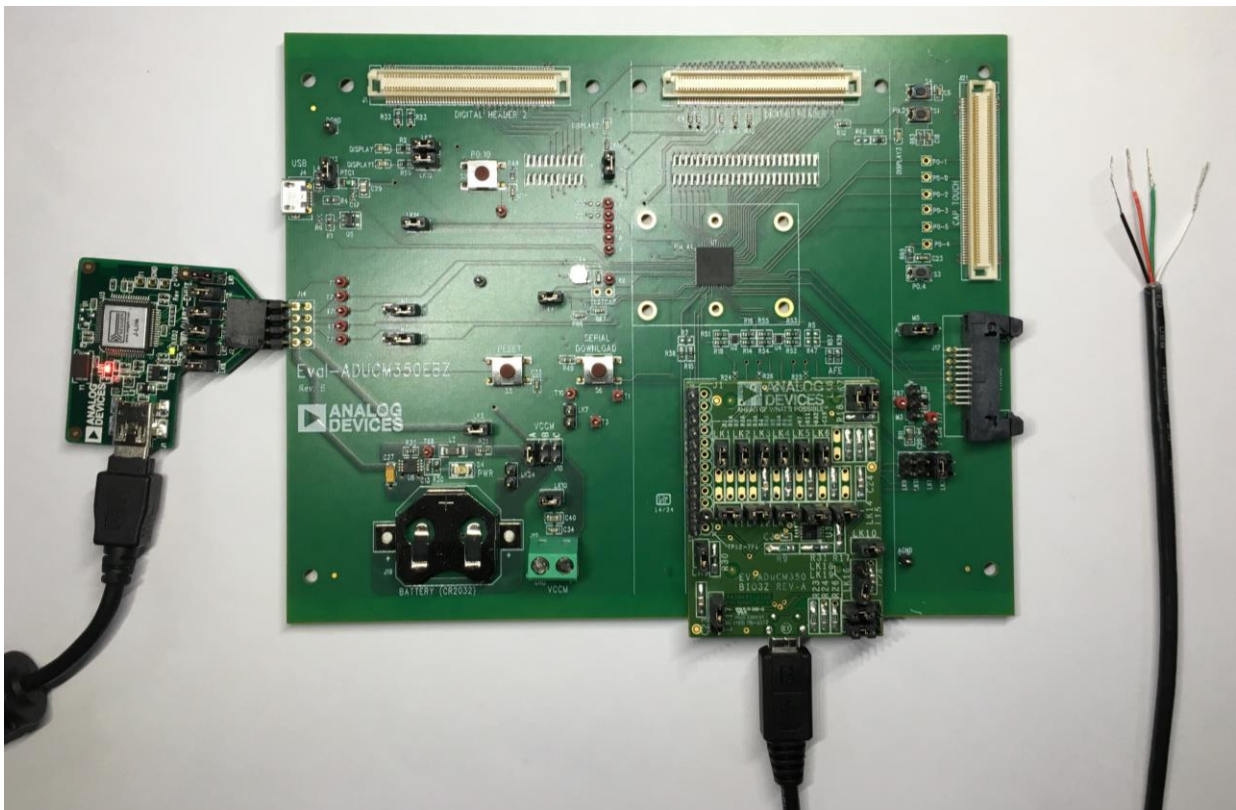


Figure 1. EVAL-ADuCM350EBZ and BIO3Z Board

### 50KHZ BIO-IMPEDANCE CALCULATION

#### Variables

Several variables are considered when calculation the 50kHz Bio-Impedance. These variables are listed below:

- Excitation Frequency
- Excitation Voltage
- Unknown Impedance,  $Z_{UNKNOWN}$

- Calibration Resistor ( $R_{CAL}$ )
- Access Impedance
- TIA Resistor ( $R_{TIA}$ )
- Instrumentation Amplifier Gain Resistor ( $R_G$ )

## Excitation Frequency

For Bio-Impedance measurements, a high excitation frequency is required. Good accuracy is achieved using 50 kHz.

## Excitation Voltage

A large excitation voltage is also used to achieve best signal to noise ratio (SNR). A 600 mV<sub>PEAK</sub> is recommended as excitation voltage.

## Unknown Impedance

In this application note, the user wants measure the bio-impedance of a human body. The impedance range for Bio-Impedance applications is typically 1kΩ - 5 kΩ (from left wrist to right finger). This will serve as the unknown impedance, Z<sub>UNKNOWN</sub>, for the calculation.

## RCAL

To calculate the RCAL value to calibrate the system, the lowest unknown impedance, Z, plus the R<sub>LIMIT</sub> is used. If RCAL is equal to the magnitude of minimum impedance, the signal going into the DFT will be large. This improves repeatability and accuracy.

Therefore, an RCAL of 1kΩ is used for this application.

## Access Impedance

A current limiting resistor (R<sub>LIMIT</sub>) and DC blocking / isolating capacitors (C<sub>ISO1</sub> and C<sub>ISO2</sub>) are required in Bio-Impedance measurement to target the IEC60601 Standard. These components will contribute towards the total access impedance of the excitation leg (Z<sub>ACCESS1</sub>) and measurement leg (Z<sub>ACCESS2</sub>). C<sub>ISO</sub> should be large, but also needs to be cost effective. A 47nF should satisfy both metrics.

$$Z_{ACCESS1} = R_{LIMIT} + C_{ISO1}$$

$$Z_{ACCESS2} = C_{ISO2}$$

The IEC60601 Standard limit for patient leakage at 50 kHz is 500 μA<sub>RMS</sub> (707 μA<sub>PEAK</sub>). To make that the 500 μA<sub>RMS</sub> is achieved, a limiting resistor (R<sub>LIMIT</sub>) is added at the drive led. R<sub>LIMIT</sub> is determined through the calculation below:

$$R_{LIMIT} = \text{Excitation Voltage} / \text{Current Limit}$$

$$R_{LIMIT} = 600\text{mV}_{PEAK} / 707\mu\text{A}_{PEAK}$$

$$R_{LIMIT} = 848 \Omega$$

Use 1 kΩ for additional safety margin

## TIA Resistor (R<sub>TIA</sub>)

The series components now add to this minimum impedance seen by the ADuCM350 TIA. For R<sub>TIA</sub> calculations use the minimum Z<sub>UNKNOWN</sub>. Calculating the impedance of extra circuitry in the network gives

$$Z_{ACCESS1} + Z_{UNKNOWN\_MIN} + Z_{ACCESS2}$$

Using Excitation frequency of 50 kHz, the impedance of C<sub>ISO2</sub> is calculated as:

$$Z_{CISO} = 1/(2 \pi f C_{ISO})$$

$$Z_{CISO} = -i67.73$$

The minimum impedance seen by the TIA, Z<sub>T</sub>:

$$Z_T = 1000 - i67.73 + 100 \Omega - i67.73$$

$$Z_T = 1108.31 \Omega \angle -7.02^\circ$$

The maximum current seen at the TIA is

$$600 \text{ mV}_{PEAK} / 1108.31 \Omega = 541 \mu\text{A}_{PEAK}$$

The maximum ADC range for ADuCM350 is 750mV<sub>PEAK</sub>. To avoid non-linearity at the ends of the range, use 80% of the total range = 600mV<sub>PEAK</sub>.

$$R_{TIA} = 600\text{mV}_{PEAK} / 541\mu\text{A}_{PEAK}$$

$$R_{TIA} = 1108\Omega$$

Use R<sub>TIA</sub> = 1000Ω.

## Instrumentation Amplifier (AD8226) Gain Resistor (R<sub>G</sub>)

The maximum impedance for Bio-Impedance measurement application is Z<sub>UNKNOWN\_MAX</sub> = 5kΩ. The maximum current into TIA is 541μA<sub>PEAK</sub> thus, the maximum voltage drop across R<sub>TIA</sub> is

$$1\text{k}\Omega * 541\mu\text{A}_{PEAK} = 541\text{mV}_{PEAK}$$

The maximum ADC range of ADuCM350 is 750mV<sub>PEAK</sub>. Thus the gain required is

$$750\text{mV}_{PEAK} / 541\text{mV}_{PEAK} = 1.386$$

To calculate AD8226 gain, use

$$G = 1 + (49.9\text{k}\Omega / R_G); \text{ see AD8226 datasheet for details}$$

$$R_G = 127.98 \text{ k}\Omega; \text{ use } 120\text{k}\Omega$$

## HARDWARE SETUP

When setting up the EVAL-ADuCM350EBZ motherboard

- For the voltage measurement, insert LK1 (Auxiliary Channel A).
- Open LK6.
- To send data through UART, insert M1 and M2 on position B.

For the ADuCM350 BIO3Z board

- Insert LK7, LK8, LK9, and LK10.
- To perform Bio-Impedance measurement, insert LK16, LK17, LK18 and LK19 on position A.
- Mount the EV-ADuCM50-BIO3Z into EVAL-ADuCM350EBZ through AFE connect.

- Connect the USB cable into BIO3Z board
- Connect  $Z_{UNKNOWN}$  on the stripped end of the USB cable as detailed in Figure 2.

By default, the ADuCM350 BIO3Z board is configured to measure the  $1.5k\Omega$  on-board resistor to check the board functionality. Links LK16, LK17, LK18 and LK19 are on position B.

To power up the board, connect the USB-SWD/UART-EMUZ through J14 of EVAL-ADuCM350EBZ and into a USB port of a PC. For more power options, refer to EVAL-ADuCM350EBZ user guide.

The USB-SWD/UART-EMUZ is also used to download firmware into the ADuCM350 or read back results through UART.

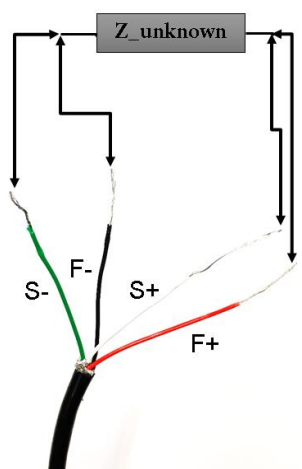


Figure 2. USB Cable to  $Z_{UNKNOWN}$  Connection

## MEASUREMENT RESULTS

Load the “*ImpedanceMeasurement\_4WireBioIsolated\_BodyComp*” firmware to EVAL-ADuCM350EBZ board to run the functionality described on this application note.

The  $1.5k\Omega$  on-board resistor is measured to check the board functionality described in this application note. Links LK16, LK17, LK18 and LK19 are inserted on position B. The absolute and relative measurement results of this configuration is displayed in Figure 3.

To read back the result,

1. Power up the EVAL-ADuCM350EBZ board using USB-SWD/UART-EMUZ through a USB port.
2. Open a UART Terminal, use application like Putty or Tera-term, select the correct COM port and set baud rate to 460800.
3. Correct COM port can be identified through “Control Panel>Hardware and Sound>Devices and Printers>Device Manager”

### Impedance Magnitude

The measured impedance using the 4-wire, Bio-impedance Measurement is  $\sim 1493\Omega$ .

The measured impedance using 2-wire measurement is  $\sim 2504\Omega$ . This measured value includes the  $Z_{ACCESS}$  impedance added into  $Z_{UNKNOWN}$ .

### Impedance Phase

The current 4-wire bio-impedance configuration is not capable of measuring accurate phase measurements.

## Measurement Count

	4wire, Bio-isolated Measurement Magnitude	4wire, Bio-isolated Measurement Phase	2wire Measurement Magnitude	2wire Measurement Phase
1207,	1493.3125,	-171.5000,	2504.4375,	-3.0625,
1208,	1493.3125,	-171.5000,	2504.4375,	-3.0625,
1209,	1493.3125,	-171.5000,	2504.4375,	-3.0625,
1210,	1493.3125,	-171.5000,	2504.2500,	-3.0625,
1211,	1493.3125,	-171.5000,	2504.4375,	-3.0625,
1212,	1492.7500,	-171.5000,	2504.2500,	-3.0625,
1213,	1492.5625,	-171.5000,	2503.0625,	-3.0625,
1214,	1492.7500,	-171.5000,	2504.2500,	-3.0625,
1215,	1493.5625,	-171.5000,	2504.7500,	-3.0000,
1216,	1493.3125,	-171.5000,	2504.2500,	-3.0625,
1217,	1493.3125,	-171.5000,	2504.4375,	-3.0625,
1218,	1493.3125,	-171.5000,	2504.4375,	-3.0625,
1219,	1493.3125,	-171.5000,	2504.2500,	-3.0625,
1220,	1492.5625,	-171.5000,	2503.0625,	-3.0625,
1221,	1492.8750,	-171.5000,	2503.5625,	-3.0000,
1222,	1493.5625,	-171.5000,	2504.5625,	-3.0625,
1223,	1492.8750,	-171.5000,	2503.5625,	-3.0000,
1224,	1492.7500,	-171.5000,	2504.2500,	-3.0625,

Figure 3. Results Displayed in UART Terminal

## SOFTWARE SETUP

### Firmware Example

A code used for ADuCM350-BI03Z to validate the solution discussed in this application note is provided on **ImpedanceMeasurement\_4WireBioIsolated\_BodyComp.zip** file.

1. After downloading the software development kit, unzip the **ImpedanceMeasurement\_4WireBioIsolated\_BodyComp.zip** into C:\Analog Devices\ADuCM350BBCZ\EVALADUCM350EBZ\examples.
2. Click the **ImpedanceMeasurement\_4WireBioIsolated\_BodyComp** folder.
3. Open the .eww file in IAR.

4. Click Project>Download>Download Active Application
5. Open a UART Terminal, use application like Putty or Tera-term, select the correct COM port and set baud rate to 460800.
6. Hit “RESET” on **ADuCM350** board. The UART terminal should now reflect the results from Bio-Impedance measurement.

The code has easy programmability for excitation frequency, excitation voltage, and RCAL value. It is possible to code other changes to the measurement into the measurement sequence. Figure 4 shows a snapshot of the code when opened in IAR.

Details on how to setup IAR can be find through this link: <https://ez.analog.com/docs/DOC-11062>.

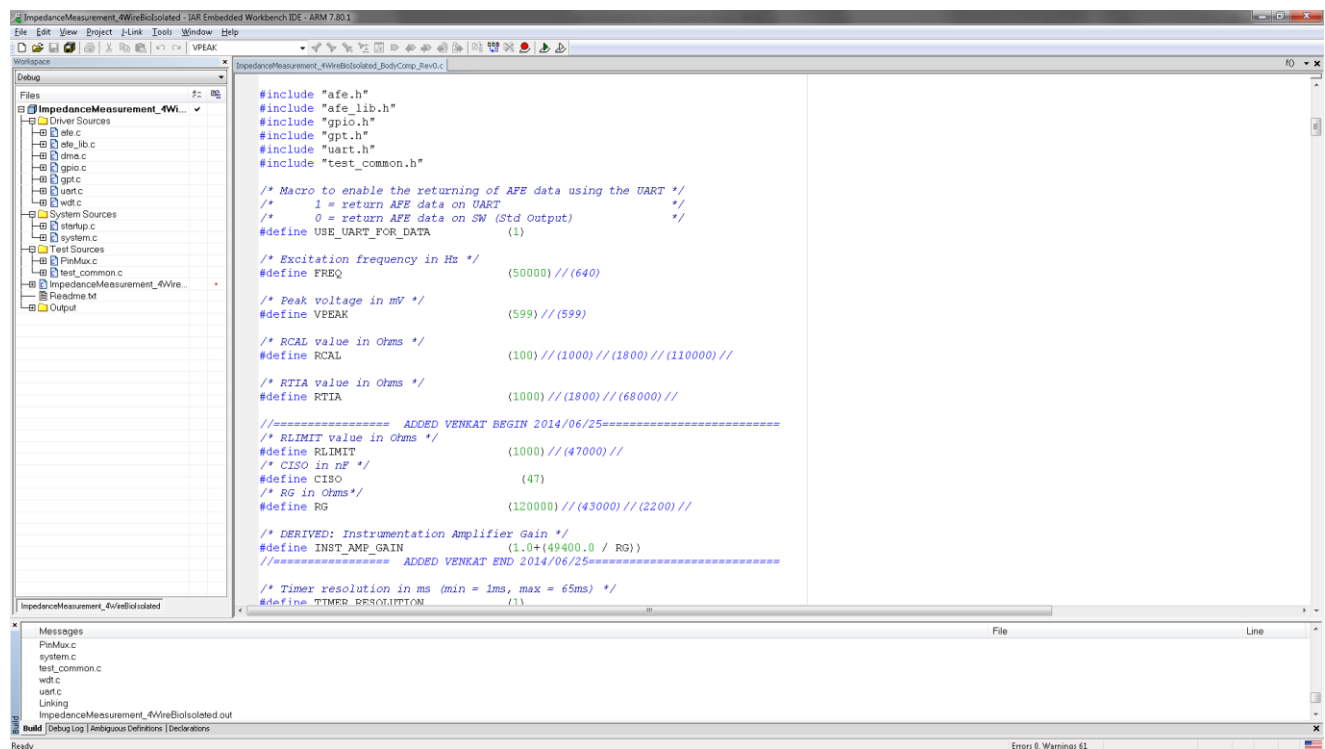


Figure 4. Code Snapshot on IAR

**NOTES**