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AD5940 Evaluation Kit User Guide

FEATURES

Debug and programming capability for AD5940
Evaluation capabilities for bioelectric and electrochemical measurements
SensorPal GUI user guide for electrochemical and bioelectric measurements

EVALUATION KIT CONTENTS

EVAL-AD5940BIOZ evaluation kit
- **EVAL-ADICUP3029**
- **EVAL-AD5940ARDZ**
- **AD5940-BioElectric**
- **ECG snap connector to micro USB cable**
- **Micro USB to USB cable**

EVAL-AD5940ELCZ evaluation kit
- **EVAL-ADICUP3029**
- **EVAL-AD5940ARDZ**
- **AD5940Sens2**
- **MicroUSB to USB cable**

GENERAL DESCRIPTION

This user guide refers to the AD5940 evaluation kit. The boards included allow the evaluation of the AD5940 and all its features.

The ADICUP3029 board is an Arduino form factor motherboard containing the ADuCM3029 microcontroller that runs sample firmware and communicates with the AD5940.

The EVAL-AD5940ARDZ board is designed to be versatile and enable different measurements, such as bioelectric, electrochemical, and potentiostat measurements. This is made possible by the expander board headers. The AD5940 kit contains two expander boards. The AD5940-BioElectric for bioimpedance and biopotential measurements, and the AD5940Sens2 for amperometric and impedance measurements.

The evaluation kit also includes custom USB to ECG cables to connect the kit to the human body for bioelectric and biopotential measurements.

LIMITATIONS ON USE AND LIABILITY

The application described in this application note is specific to the AD5940 and the AD8233 for use with the EVAL-ADICUP3029 evaluation board. In addition to the terms of use contained in the evaluation board user guides, it is understood and agreed to that the evaluation board or design must not be used for diagnostic purposes and must not be connected to a human being or animal. This evaluation board is provided for evaluation and development purposes only. It is not intended for use or as part of an end product. Any use of the evaluation board or design in such applications is at your own risk and you shall fully indemnify Analog Devices, Inc., its subsidiaries, employees, directors, officers, servants and agents for all liability and expenses arising from such unauthorized usage. You are solely responsible for compliance with all legal and regulatory requirements connected to such use.

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REVISION HISTORY

7/2018—Revision 0: Initial Version

EVALUATION HARDWARE

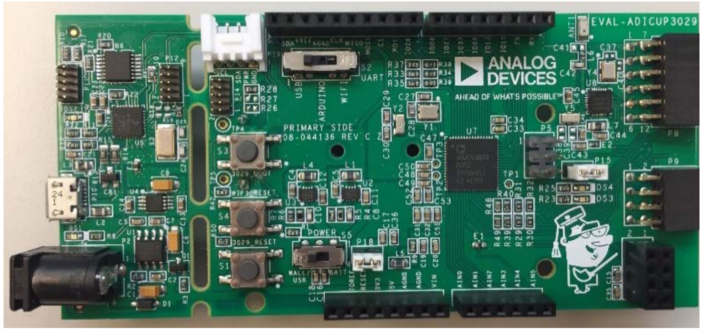


Figure 1. EVAL-ADICUP3029

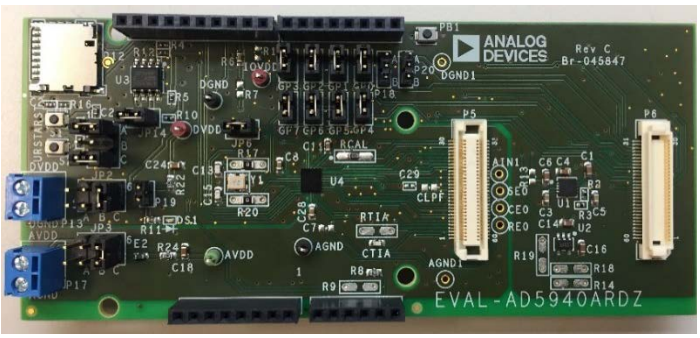


Figure 2. EVAL-AD5940ARDZ

Figure 3. AD5940-BioElectric Evaluation Daughter Card

Figure 4. AD5940Sens2 Daughter Card

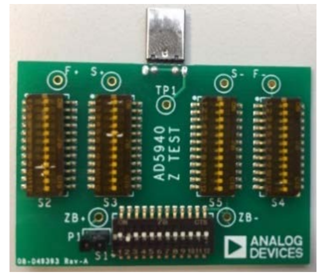


Figure 5. AD5940 Impedence Test Board

Figure 6. USB to Micro-USB Cable

Figure 7. Custom ECG Cables

EVAL-ADICUP3029

The EVAL-ADICUP3029 interfaces between the PC and the AD5940. It features an on-board debugger and can be powered from either the USB cable or by batteries. The power supply option is selected by Switch 5.

Board Setup

Unpack the board and ensure S2 is switched to USB position. Ensure S5 is switched to wall/USB (see Figure 8).

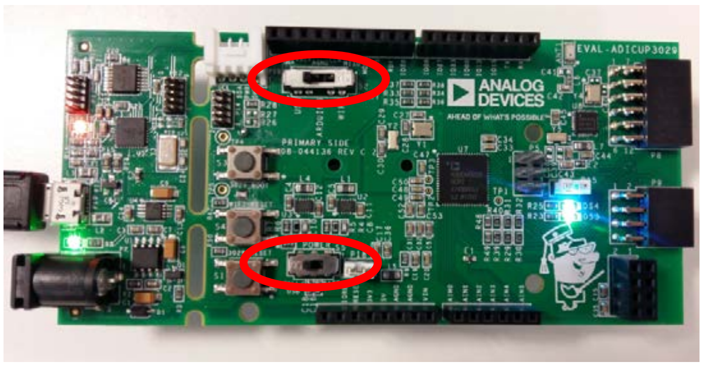


Figure 8. EVAL-ADICUP3029

Connect the board to the PC via the USB cable. It automatically installs the required software drivers. Click on the pop up for details on the driver installation (see Figure 9).

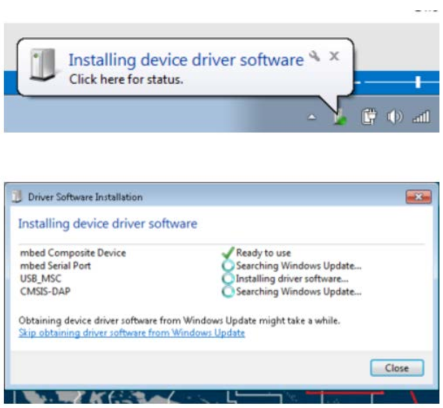


Figure 9. ADICUP3029 Drivers

Ensure the four drivers shown in Figure 9 are installed correctly before proceeding.

If the mbed serial port fails, install the drivers manually from the mbed website.

To check if the drivers installed, correctly navigate to the device manager. Navigate to **Portable Devices** > **DAPLINK** and **Ports** > **mbed Serial Port** (see Figure 10). The COM port number is required for connecting to serial capture program such as RealTerm and SensorPal graphical user interface (GUI).

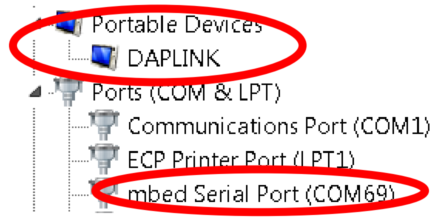


Figure 10. Device Manager

For further information about the EVAL-ADICUP3029, visit the EVAL-ADICUP3029 product page.

Downloading Firmware

The ADICUP3029 provides an interface to download firmware to the part without any IDE or software. When the board is connected to the PC, the DAPLINK(D:) appears in Windows® Explorer (see Figure 11). Drag and drop a .hex file into this drive, and the firmware automatically downloads to the ADuCM3029 microcontroller. Reset the microcontroller to begin executing the firmware.

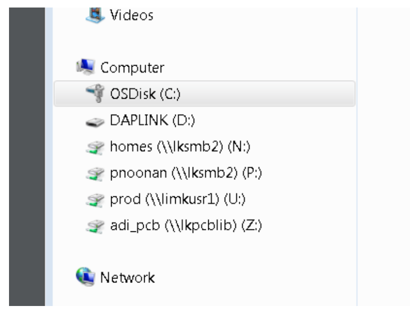


Figure 11. DAPLINK Drive

EVAL-AD5940ARDZ

Power Supply

The evaluation board is laid out to minimize coupling between the analog and digital sections of the board. To this end, the ground plane is split with the analog section on the bottom half and a digital section on the top half of the board.

AVDD and DVDD can be powered either from the same supply or separately with the following options:

- 3.3 V directly from the Arduino connector
  - DVDD: JP2 jumper in Position A
  - AVDD: JP3 jumper in Position A
- 3.3V connected to P13 (DVDD) and P17 (AVDD)
  - DVDD: JP2 jumper in Position C
  - AVDD: JP3 jumper in Position C
- ADM7155ACPZ LDO
  - DVDD: JP2 jumper in Position B
  - AVDD: JP2 jumper in Position B
  - JP4 between Pin 2 and Pin 3 to enable LDO
- ADP160AUJZ LDO
  - DVDD: JP2 jumper in Position B
  - AVDD: JP2 jumper in Position B
  - JP5 between Pin 2 and Pin 3 to enable auxiliary LDO
  - Remove R13 and add 0 Ω resistor to R14.

- Add R18 and R19. Calculate R18 and R19 using the following equation:

  $V_{OUT} = 1.0\ \text{V}\ (1 + R18/R19) + R18$

For further clarity, refer to EVAL-AD5940ARDZ.pdf, located in the **AD5940Firmware&Documentation** folder.

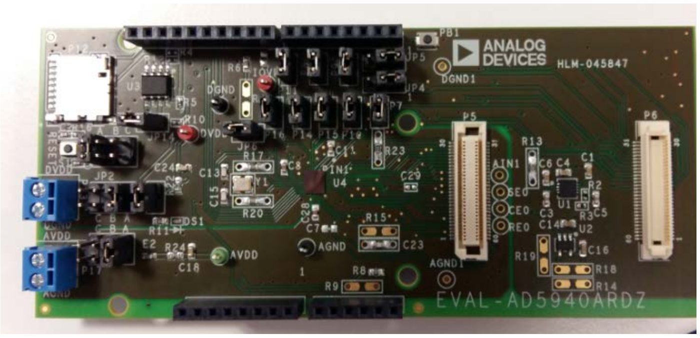


Figure 12. EVAL-AD5940ARDZ

Default Jumpers

The default jumper settings are shown in Figure 12. Both DVDD and AVDD are powered by 3.3 V from the Arduino shield (JP2 and JP3 in Position C).

JP1 controls the reset signal and has two jumpers in Position A and Position C, respectively. Position A connects the AD5940 reset pin to the reset button. Position C connects the AD5940 reset pin to a general purpose input/output (GPIO) on the ADuCM3029 microcontroller.

Table 1. Default Jumper Descriptions

Jumper	Description
JP4, JP5	Enable the low dropouts (LDOs); By default, the LDOs are disabled
JP14	Enable I^2C electrically erasable programmable read-only memory (EEPROM)
JP10	Powers LED
JP6	Power IOVDD
P7, P8, P9, P10, P11, P14, P15, and P16	Connect AD5940 GPIOs to Arduino header and to the ADuCM3029

AD5940-BIOELECTRIC

The AD5940-BioElectric board is designed specifically for bioimpedance and biopotential measurements. The board contains the AD8233 heart rate monitor, isolation capacitors and limit resistors necessary for bioelectric measurements. For further details, refer to AN-1557 in the Application Notes folder.

AD5940SENS2

AD5940Sens2 is designed specifically for 2- and 3-wire impedance, amperometric, and potentiostat measurements. The board contains two resistor capacitor (RC) networks (Test 1 and Test 2) to verify measurement sequences. There is also a USB connector that provides an option to connect custom cable to the board. By default the board is configured to measure Test 1. Details on the supported measurements can be found in AN-1563.

SENSORPAL USER GUIDE

INSTALLATION

SensorPal is a light weight, easy to use desktop tool to rapidly configure the AD5940 carry out measurements.

The **AD5940_Firmware&Documentation** directory contains a GUI folder. SensorPal installer is located in this folder. To install SensorPal, take the following steps:

1. Run the **SensorPal Installer_vXXXX.exe** installer and follow on-screen instructions to install the program.
2. An **Analog Devices** folder is automatically created in the C drive on your PC. Navigate to **C:\Analog Devices\SensorPal\Firmware Files** (the default install path for the SensorPal GUI).
3. Connect the ADICUP3029 and AD5940 to the PC and navigate to **C:\Analog Devices\SensorPal\Firmware Files** (the default install path for GUI).
4. Drag and drop the **SensorPal-Firmware.hex** file onto the DAPLINK (D:) drive. This installs the required firmware onto the ADICUP3029 so it will work with the GUI.
5. Power cycle the ADICUP3029 board by pressing the **URST** button on the EVAL-AD5940ARDZ board.
6. After SensorPal is installed on the PC, open the SensorPal GUI. A window similar to Figure 14 is displayed. Upon the first time opening the GUI, the graph and tool belt are blank.
7. Select the COM port that the ADICUP3029 is connected to. It should read: If unsure of the COM port number refer to the Board Setup section. If the correct COM port does not appear in the dropdown menu right away, click the arrows to the right of the dropdown to refresh the list of ports (see Figure 13). If the port still does not appear, close the SensorPal GUI, power cycle the board, then reopen SensorPal and try again.

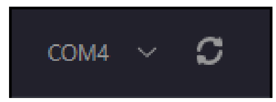


Figure 13. COM Port Dropdown Menu and Refresh Button

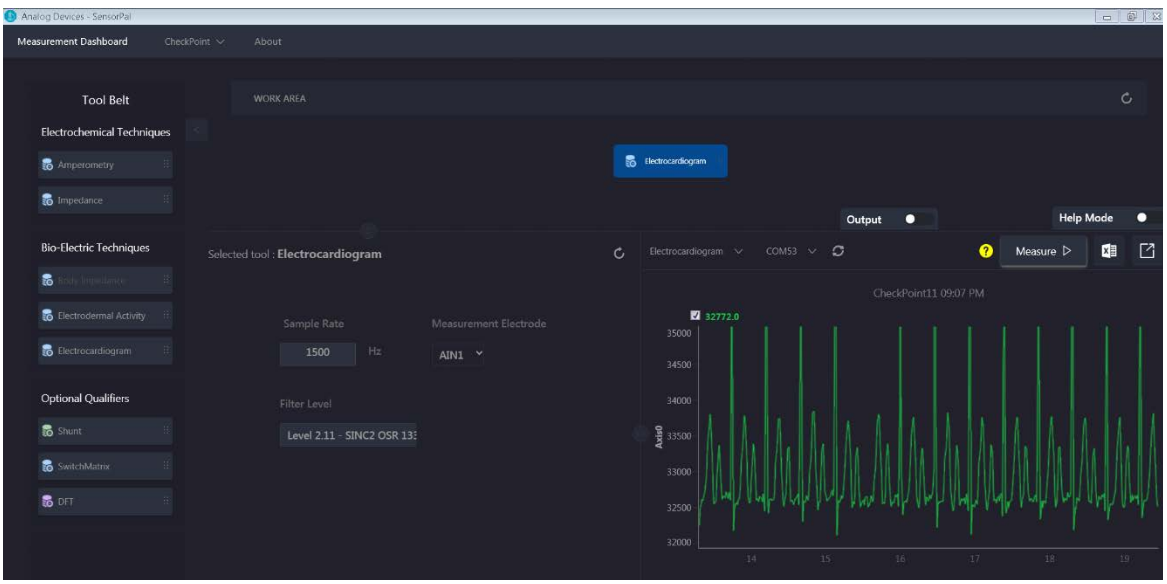


Figure 14. SensorPal

QUICK TEST

After the AD5940 evaluation kit is set up and the SensorPal software is installed, perform a quick out-of-the-box test to ensure the board is set up and working properly. As an example, quickly test the body impedance measurements by taking the following steps:

1. Plug the AD5940ARDZ into the ADICUP3029 via the Arduino connectors.
2. Plug the ADICUP3029 into the PC via the microUSB port on the board.
3. Plug the AD5940-BioElectric evaluation daughter card into the AD5940ARDZ board.
4. Plug the AD5940 impedance test board into the microUSB port on the AD5940-BioElectric evaluation daughter card as in Figure 15.

Figure 15. Body Impedance Hardware Test Setup

5. On the bottommost bank on the impedance test board (labeled **S1** and the only horizontal bank on the board), press switch number 1 (the leftmost switch) downwards using a paperclip or pencil to activate a 100 Ω resistance value.
6. Open the SensorPal GUI and ensure the correct COM port is connected.
7. Under the **Bio-Electric Techniques** section in the tool belt, drag the **Body Impedance** measurement into the work area. Delete any other existing measurements in the work area by hovering over the measurement and pressing the trash bin icon in the bottom right corner.
8. Click the **Body Impedance** measurement to highlight it and view the configurable parameters beneath (keep all default parameter values).
9. Press the green **Measure** button to begin collecting data until the measurement is complete.
10. The resulting graph looks similar to the one in Figure 16, with the impedance measurements very close to 100 Ω.

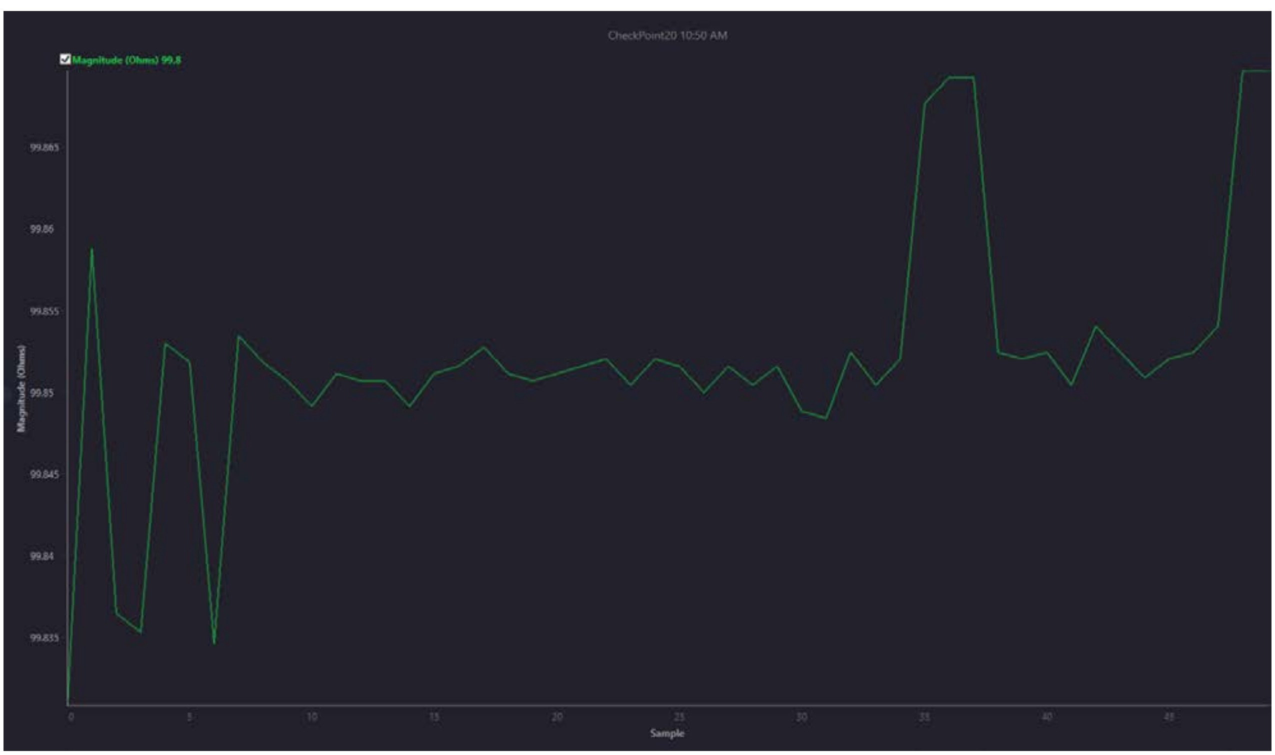


Figure 16. Quick Test Body Impedance Result

MEASUREMENT VALIDATION AND TESTING

Body Impedance

The 4-wire bioimpedance analysis (BIA) approach uses a high precision excitation voltage source to excite the sensor with a known high frequency voltage, V_{AC}. The response current (I) is measured and the impedance (Z) is calculated by the following equation: $Z = V_{AC}/I$.

The AD5940 impedance test board is used to validate the accuracy of the AD5940 measurements. The impedance test board features an array of standard valued resistors and capacitors, which are separated into banks labeled S1, S2, S3, S4, and S5. Any of the resistor values can be used for body impedance tests. The S1 bank on the board is highlighted in Figure 17 for reference.

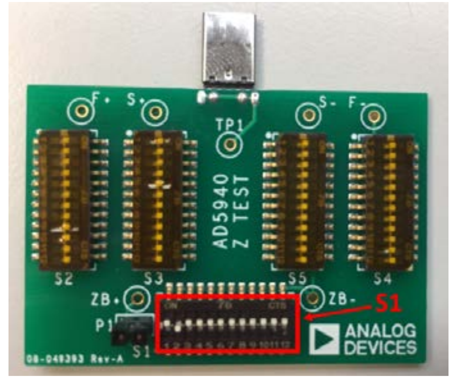


Figure 17. AD5940 Impedance Test Board with S1_2 Activated

A schematic of the S1 bank is shown in Figure 18, with units in ohms (Ω). R1 in the schematic corresponds to Switch 1 on the S1 bank (S1_1). The full schematic of the impedance test board can be found here. The S2, S3, S4, and S5 banks on the board can additionally be used to simulate contact impedance on the electrodes.

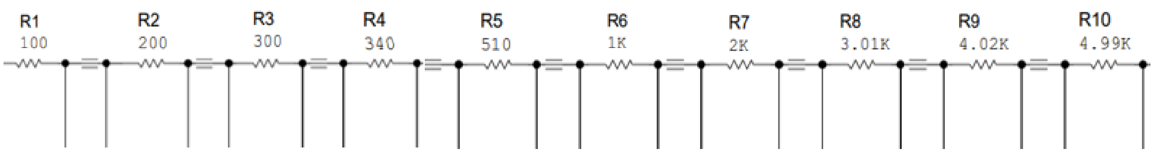


Figure 18. AD5940 Impedance Test Board S1 Bank Schematic

Select the desired resistor value to test by pushing the switch downwards toward the row of numbers (1 to 12) on the S1 (or S2, S3, S4, or S5) bank. Use a paperclip (or another thin, pointed object) to change the switches by moving the switches back and forth. Multiple resistors can be selected simultaneously to put the resistors in series and increase the total equivalent resistance.

To perform a body impedance validation test using the AD5940 evaluation board, take the following steps:

1. Plug the AD5940ARDZ into the ADICUP3029 via the Arduino connectors.
2. Plug the ADICUP3029 into the PC via the microUSB port on the board.
3. Plug the AD5940-BioElectric evaluation daughter card into the AD5940ARDZ board as in Figure 19.
4. Plug the AD5940 impedance test board into the microUSB port on the AD5940-BioElectric evaluation daughter card as in Figure 19.

Figure 19. Body Impedance Hardware Setup

5. Select the desired resistor value on the Z Test Board using the S1 bank switches. The resistor selected for this test was the S1_2 resistor, which has a value of 200Ω.
6. Ensure the ADICUP3029 is connected to the PC via the micro-USB port.
7. Open the SensorPal GUI and ensure the correct COM port is selected.
8. Under the **Bio-Electric Technique**s section in the tool belt, drag the **Body Impedance** measurement into the work area. Delete any other existing measurements in the work area by hovering over the measurement and pressing the trash bin icon in the bottom right corner.

9. Click the **Body Impedance** measurement to highlight it and view the configurable parameters beneath. The body impedance parameters that can be set are shown in Table 2
10. Once the desired parameters are set, press the green Measure button to begin collecting data.
11. The results are the absolute impedance value and force/sense out the isolation components in the paths on F+ and F−

Table 2. Body Impedance Measurement Parameters

Parameter	Description	Value for Test
Internal R_{TIA} Selection	Resistor value in the feedback loop of the transimpedance amplifier.	1 kΩ
Transimpedance Amplifier Capacitance	Capacitor value in the transimpedance amplifier (depends on the maximum current range)[1].	16 pF
Calibration Resistor	Known impedance value voltage is applied to for system calibration.	10000 Ω
Start	Initial frequency of the voltage applied.	10000 Hz
Stop	Highest frequency of the voltage applied.	10000 Hz
Points	Number of different frequencies (sampling points) between start and stop.	50
Logarithmic	When a frequency sweep is performed, defines whether the frequency increments are logarithmic or not.	Yes
Power Mode	Power level of the board.	Automatic
Filter Level	Level of the SINC filter applied to data coming from the analog-to-digital converter (ADC).	Level 1.1—SINC3 OSR2
Hanning Window	Selects whether the data is filtered through a Hanning window or not.	Yes
DFT Number	Level of the discrete Fourier transform applied to the data.	16384
Amplitude	Magnitude of the voltage applied.	800 mV-pp
PGA Gain Select	Programmable gain amplifier.	GNPGA_1_5
Resistor on Impedance Test Board	Resistance being measured.	200 Ω

[1] For more information on Body Impedance measurements on the AD5940, refer to the AN-1557.

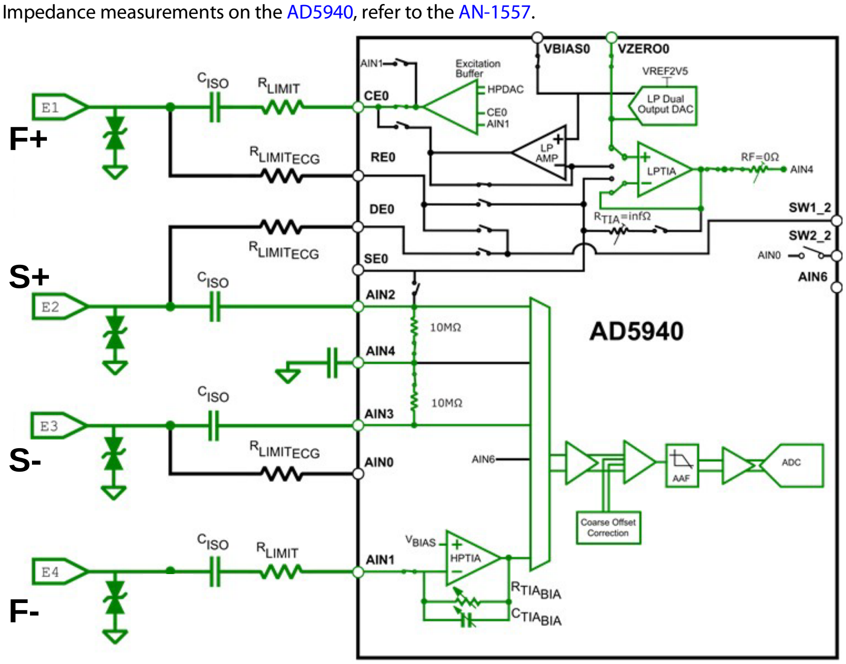


Figure 20. Measurement Block Diagram

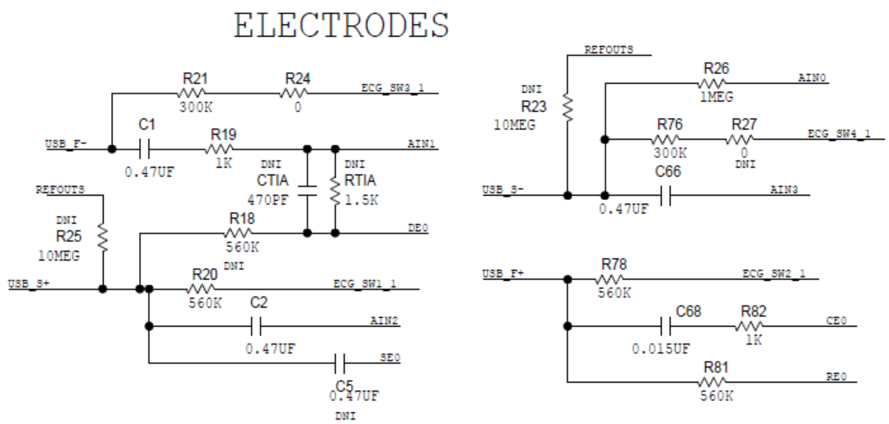


Figure 21. Bioelectric Board Electrode Schematic

12. When the software has finished collecting data, the resulting graph looks similar to the one in Figure 22 (sampled at one frequency). As in the Figure 22, the impedance value, whether sampled at one frequency or over a range of frequency, should be nearly equal to the total equivalent resistive value selected on the Z test board (in this case 200 Ω).

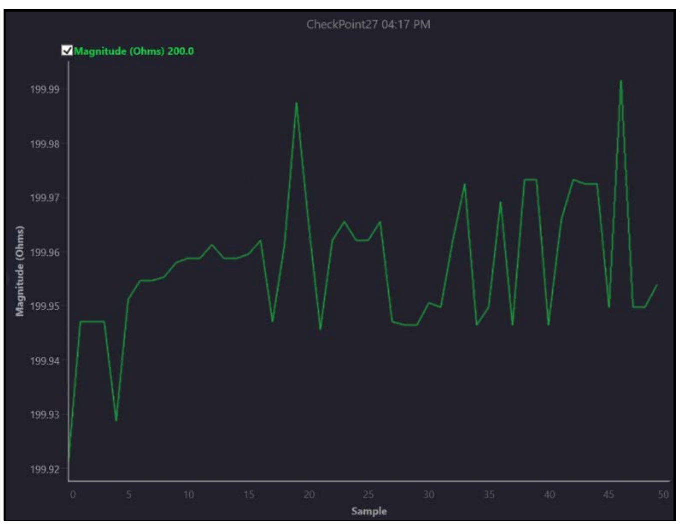


Figure 22. BIA Validation Test Result—200 Ω on Impedance Test Board

If using electrodes to measure body impedance on an equivalent sensor, or body simulator, the leads on the custom ECG cable provided are as in Figure 23. Connect the F+ and S+ electrodes to positive side and connect F− and S− to the negative side.

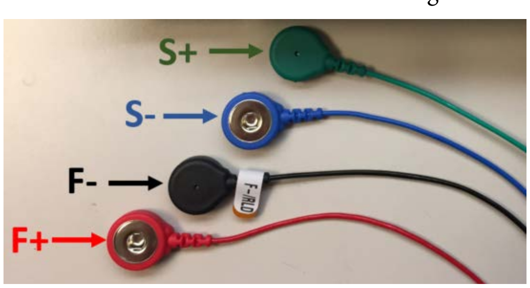


Figure 23. Custom Cables

Electrodermal Activity

Electrodermal activity (EDA) refers to the continuous changes in the electrical conductivity of the skin that occur as a result of sweat secretion by the body. For example, during high stress, the sweat glands in the body are activated, causing the surface of the skin to become wet and thus more conductive. Such a change reduces the skin's overall impedance.

The AD5940 impedance test board is used to validate the accuracy of the EDA measurements and is shown in Figure 24. The impedance test board features an array of standard valued resistors and capacitors, which are separated into banks labeled S1, S2, S3, S4, and S5. A full schematic of the impedance test board can be found in the schematics folder. High-value resistors in the range of 10 kΩ to 10 MΩ can be used for EDA tests. These resistance values are located from S2 switch 5 (R25) to S2 switch 10 (R30) on the S2 bank and from S3 switch 6 (R36) to S3 switch 10 (R40).

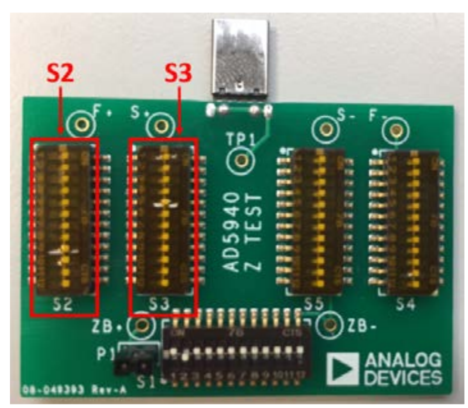


Figure 24. AD5940 Impedance Test Board with S2 and S3 Highlighted

Select the desired resistor value to test by pushing the switch downwards toward the row of numbers (1 to 12) on the desired bank. The switches can be easily changed using a paperclip (or other thin, pointed object) to move the switches back and forth. Multiple resistors can be selected simultaneously to put the resistors in series and increase the total equivalent resistance.

To perform an EDA validation test using the AD5940 evaluation board, follow the instructions below:

1. Plug the AD5940ARDZ into the ADICUP3029 via the Arduino connectors.
2. Plug the AD5940-BioElectric evaluation daughter card into the AD5940ARDZ board.
3. Plug the AD5940 impedance test board into the microUSB port on the AD5940-BioElectric evaluation daughter card as in Figure 25.

Figure 25. EDA Hardware Setup

4. Select the desired resistor value on the impedance test board using the switches on the S2 and S3 banks.
5. Ensure the ADICUP3029 is connected to the PC via the board's microUSB port.
6. Open the SensorPal GUI and ensure the correct COM port is selected.
7. Under the B**io-Electric Techniques** section in the tool belt, drag the **Electrodermal Activity** measurement into the work area. Delete any other existing measurements in the work area by hovering over the measurement and pressing the trash bin icon in the bottom right corner.
8. Click the **Electrodermal Activity** measurement to highlight it and view the configurable parameters beneath. The electrodermal activity parameters are shown in Table 3.

Table 3. EDA Measurement Parameters

Parameter	Description	Value for Test
Measurement Frequency	Frequency at which voltage is applied and measurement is taken.	100 Hz
Measurement Electrode	Electrode where current is applied.	CE0
Sensor Board	Daughter card that is attached to the AD5940ARDZ and that is used to take measurements.	AD5940-BioElectric
SINC3 Oversampling Rate	Oversampling rate of the SINC filter applied to the response current data.	2
Transimpedance Amplifier Resistance	Resistor value in the feedback loop of the transimpedance amplifier (depends on the maximum current range)[1].	100 kΩ
Calibration Resistor	External resistor used for calibration of internal R_{TIA}.	10 kΩ
DFT Number	Level of the discrete Fourier transform applied to the data.	16
Hanning Window	Selects whether the data is filtered through a Hanning window or not.	No
Resistor on Impedance Test Board	Resistance that is being measured.	4.22 MΩ (R25)

[1] For more information on EDA measurements on the AD5940, refer to the AN-1557.

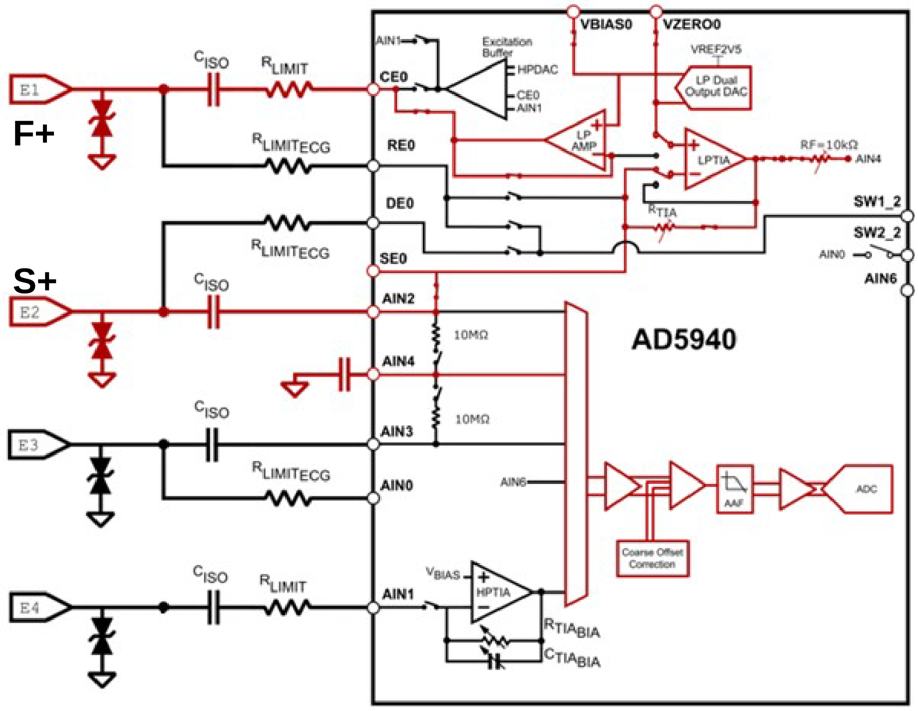


Figure 26. EDA Measurement Block Diagram

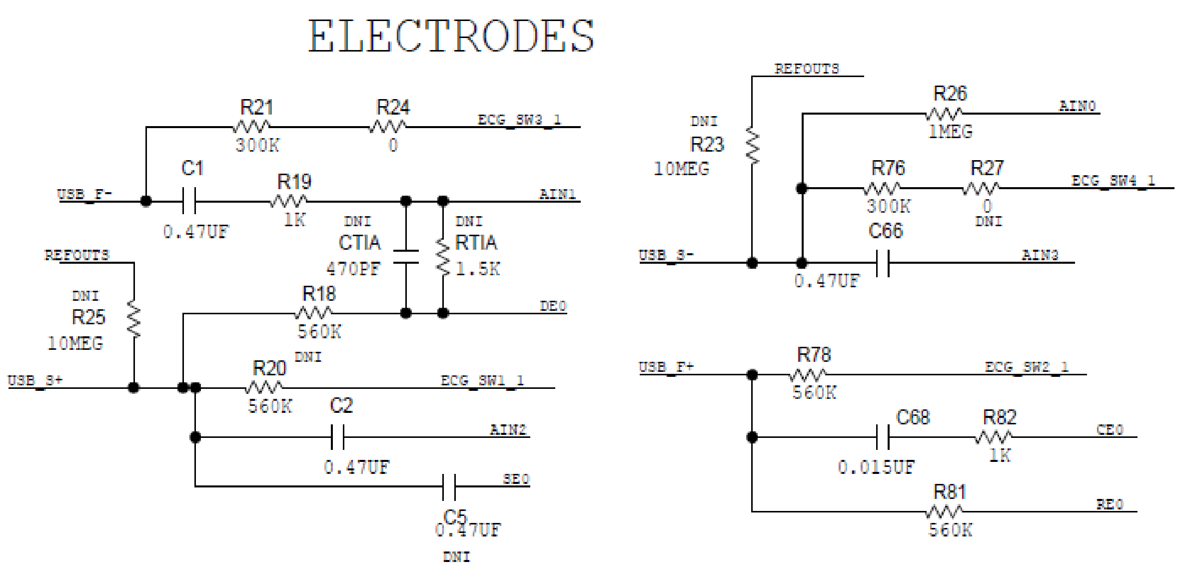


Figure 27. Bioelectric Electrodes Schematic

9. After the desired parameters are set, press the green **Measure** button to begin collecting data. Press the red **Abort Measurement** button at any time to finish collecting data.
10. The measurement is a relative impedance measurement that takes into account isolation components:
    - CE0 to F+ = R_{LIMIT} = R82 = 1 kΩ and C_{ISO} = C68 = 0.015 µF
    - S + to AIN2 = C_{ISO} = C2 = 0.47 µF
    - At 100 Hz these components have a very small impact (equivalent Z = ~1 kΩ)on overall impedance of 4.22 MΩ
11. When the software has finished collecting data, the resulting graph should look similar to the one in Figure 28

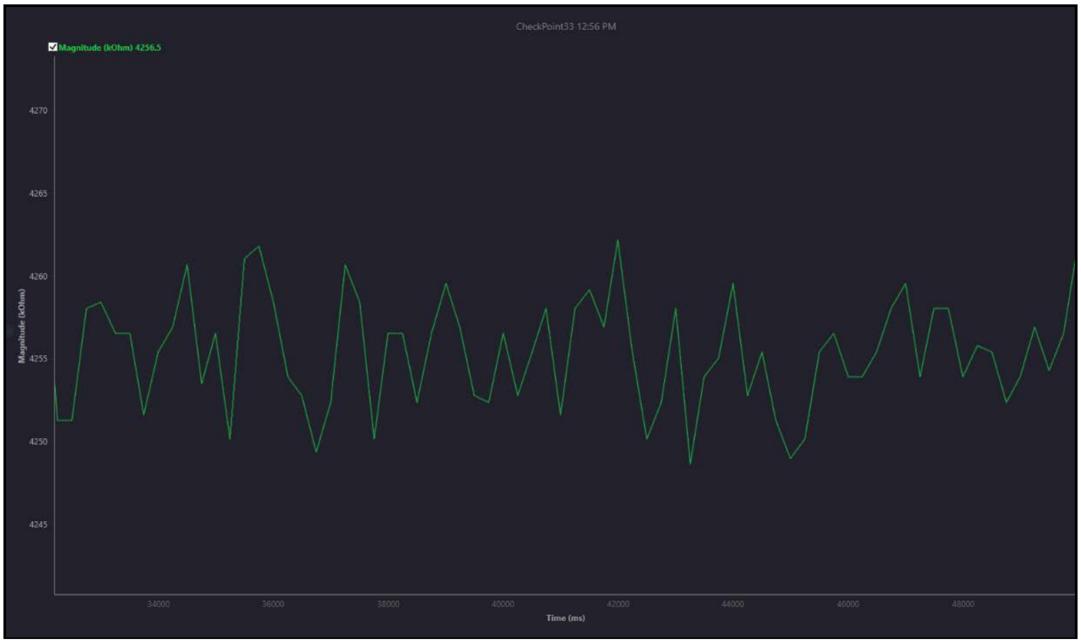


Figure 28. EDA Validation Test Result—4.22 MΩ on Impedance Test Board

If using electrodes to measure EDA on an equivalent sensor, the leads on the custom ECG cable provided are as in Figure 29.

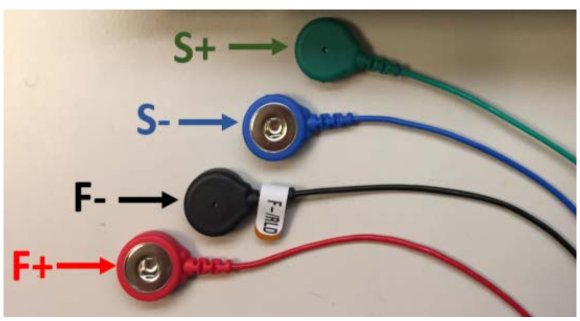


Figure 29. Leads on Custom Cable

Electrocardiogram

An electrocardiogram (ECG) is a measure of how the electrical activity of the heart changes over time as action potentials propagate throughout the heart during each cardiac cycle. Typically, the ECG is measured from the surface of the skin, which can be done by placing electrodes directly on the skin and reading the potential difference between them.

The AD5940 evaluation kit comes equipped with custom ECG cables. These can be used with four wearable electrodes to measure ECG rate on a sensor/ECG simulator. The ECG cables are labeled in Figure 30.

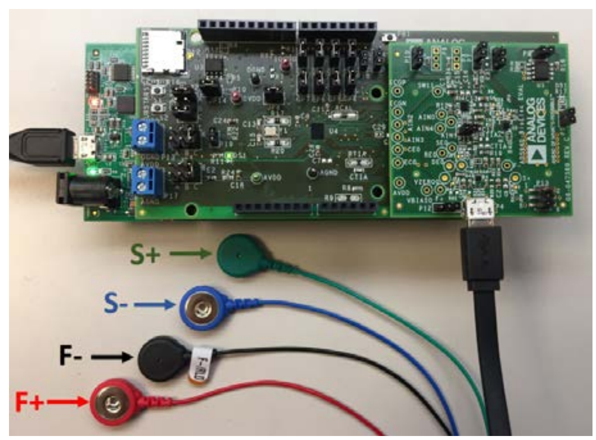


Figure 30. Full Hardware Setup with ECG Cables Labelled

The ECG cables are marked on block diagrams as E1, E2, E3, and E4. The cable connections are as follows:

- E1 = F+ = red
- E2 = S+ = green
- E3 = S− = blue
- E4 = F− = black

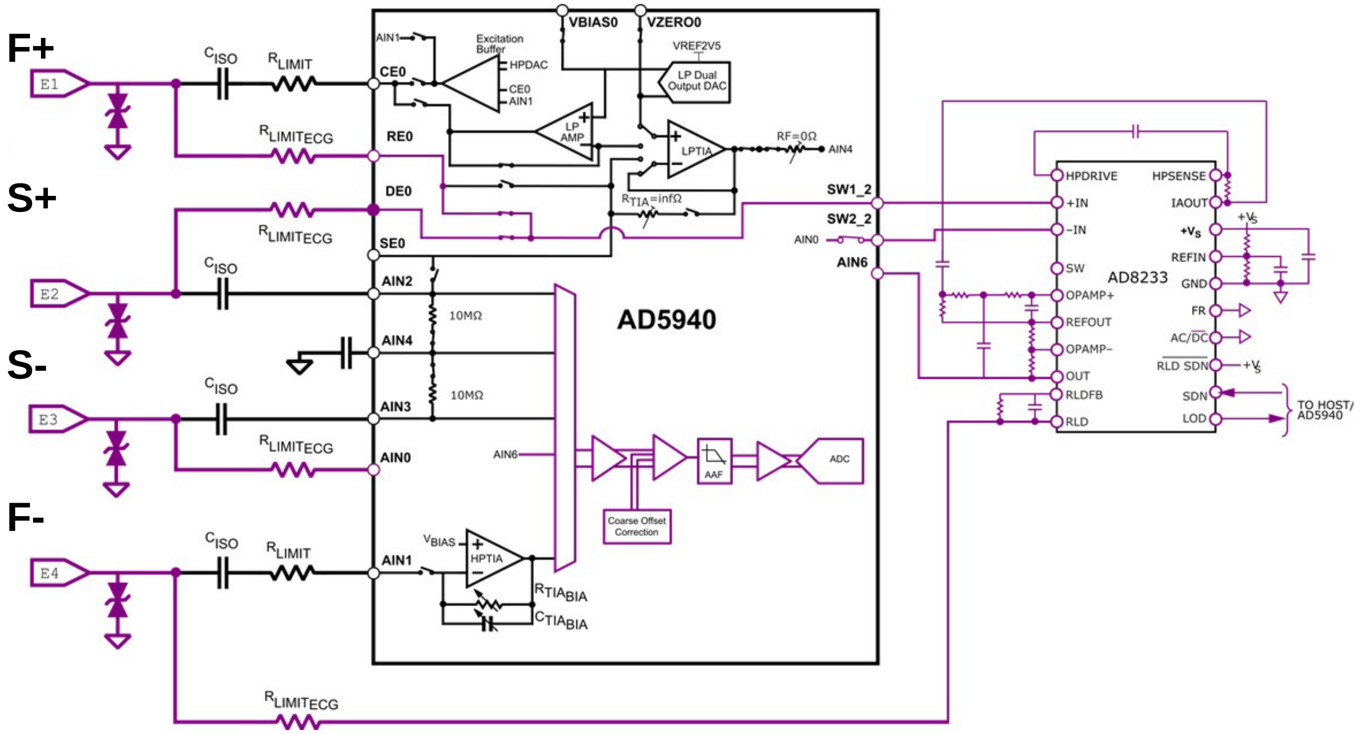


Figure 31. ECG Measurement Block Diagram

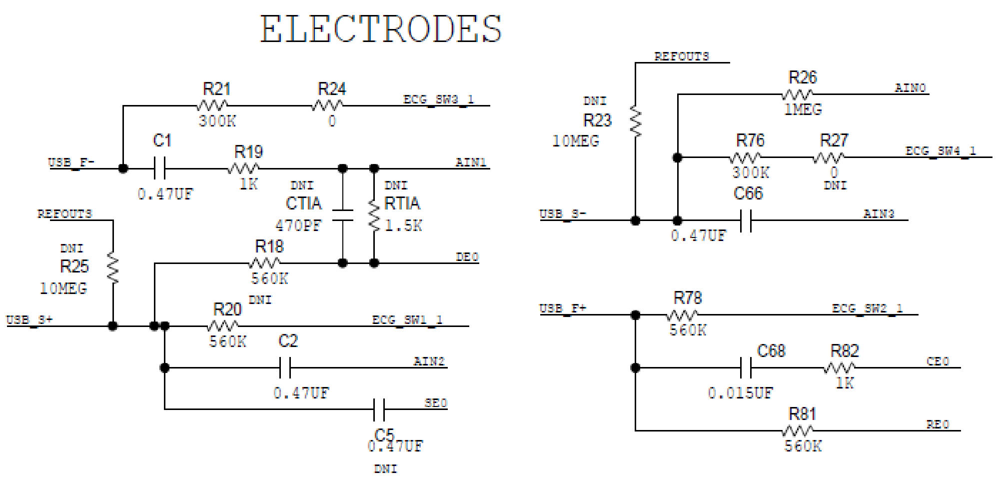


Figure 32. Bioelectric Board Electrode Schematic

The ECG sensor can be tested using an ECG simulator and following the instructions below:

1. Plug the AD5940ARDZ into the ADICUP3029 via the Arduino connectors.
2. Plug the AD5940-BioElectric evaluation daughter card into the AD5940ARDZ board.
3. Plug the microUSB end of the custom ECG cable into the USB port on the AD5940-BioElectric evaluation daughter card.
4. Ensure the ADICUP3029 is connected to the PC via the microUSB to USB cable. Refer to the full hardware setup in Figure 30.
5. Connect the colored ECG leads to the ECG simulator as follows:
   - Red (F+) to LA (left arm)
   - Blue (S–) to RA (right arm)
   - Green (S+) to LL (left leg)
   - Black (F–) to RLD (right leg drive)
6. Turn on the ECG simulator and set the ECG rate to the desired value (80 bpm in this case).
7. Open the SensorPal GUI and ensure the correct COM port is connected.
8. Under the **Bio-Electric Techniques** section in the tool belt, drag the **Electrocardiogram** measurement into the work area. Delete any other existing measurements in the work area by hovering over the measurement and pressing the trash bin icon in the bottom right corner.

9. Click the **Electrocardiogram** measurement to highlight it and view the configurable parameters beneath. The ECG parameters that can be set are shown in Table 5.

Table 4. ECG Parameters[1]

Parameter	Description	Value for Test
Sample Rate	Rate at which the board takes measurements	1500 Hz
Sensor Board	Daughter card that is attached to the AD5940ARDZ and that is used to take measurements	AD5940-BioElectric
Filter Level	Level of the SINC filter applied to data coming from the ADC	Level 1.2—SINC3 OSR 4

[1] For more information on ECG measurements on the AD5940, refer to the AN-1557.

10. Once the desired parameters are set, press the green Measure button to begin collecting data. The device will continue collecting data until you press the red **Abort Measurement** button.
11. When you have finished collecting data, the resulting graph should look similar to the one in Figure 33. Due to coupling from the power cable connected to the PC, some noise at around 60 Hz may be present in the reading.

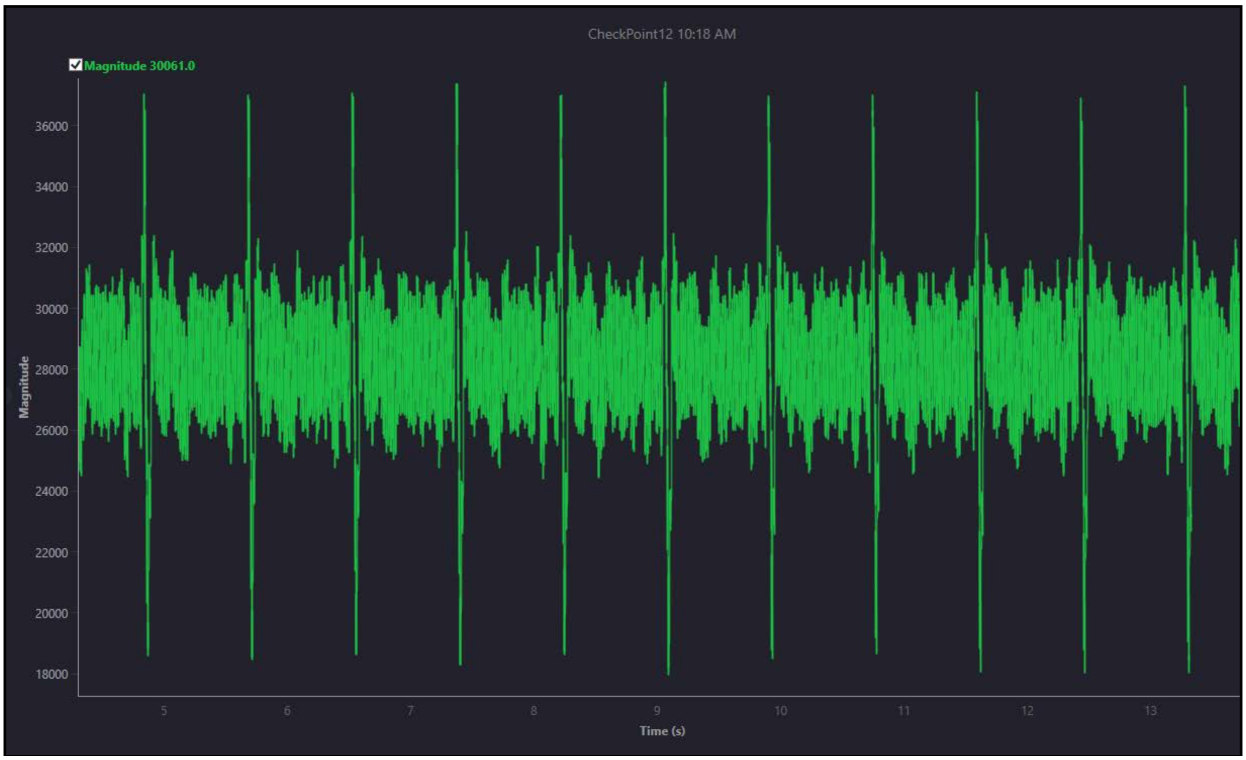


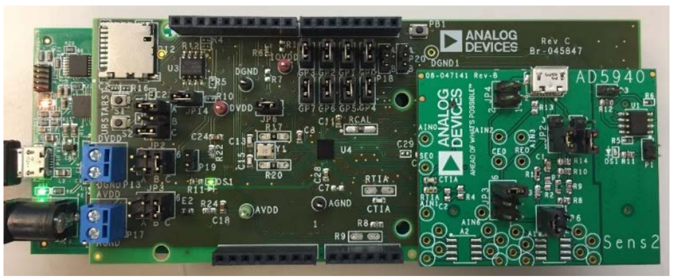
Figure 33. ECG Validation Test Result—ECG Simulator at 80 bpm

Linear Sweep Voltammetry

Linear Sweep Voltammetry is an electrochemical measurement in which the voltage applied to an electrochemical cell is incremented linear to a point then decremented linear, in the shape of triangle (a ramp signal up and then back down). The response current on the working electrode is measured.

To perform a linear sweep voltammetry validation test using the AD5940 evaluation board, follow the instructions below:

1. Plug the AD5940 evaluation board (EVAL-AD5940ARDZ) into the Arduino connectors on the ADICUP3029.
2. Plug the AD5940Sens2 daughter card into



the AD5940ARDZ board as in Figure 34.

Figure 34. Hardware Setup for Linear Sweep Voltammetry Validation TestOn the AD5940Sens2 board, place a jumper on JP6 between PIN1 and PIN2 (the right-hand column) as in Figure 35. This connects a 750 Ω resistor network to the AD5940.

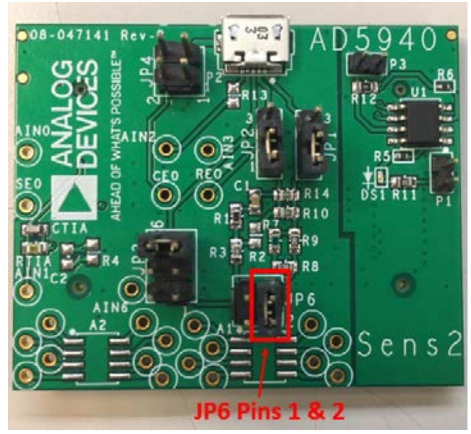


Figure 35. JP6 Jumper Configuration for Voltammetry Test on Sens2 Board

3. Connect the ADICUP3029 to the PC via the USB-to-microUSB cable.
4. Open the SensorPal GUI and ensure the correct COM port is connected.
5. Under the **Electrochemical Techniques** section in the tool belt, drag the **Linear Sweep Volt** measurement into the work area. Delete any other existing measurements in the work area by hovering over the measurement and pressing the trash bin icon in the bottom right corner.
6. Click the **Linear Sweep Volt** measurement to highlight it and view the configurable parameters beneath. The parameters that can be set are shown in Table 5.

Table 5. Linear Sweep Voltammetry Parameters

Parameter	Description	Value for Test
Ramp Start	Starting voltage of the ramp signal	−1000 mV
Ramp Peak	Peak voltage of the ramp signal	1000 mV
Points	The voltage ramps from Ramp Start to Ramp Peak in Points equal increments	866
Sample Delay	Time for signal to settling before sampling again	20 ms
Ramp Duration	The voltage ramps from Ramp Start to Ramp Peak for this amount of time	30000 ms
Transimpedance Amplifier Resistance	Resistor value in the feedback loop of the transimpedance amplifier (depends on the maximum current range)[1]	200 Ω

[1] For more information on voltammetry measurements on the AD5940, refer to the AN-1563.

7. Once the desired parameters are set, press the green **Measure** button to begin collecting data. The device will

continue collecting data until all of the samples have been taken.

8. When you have finished collecting data, the resulting graph should look similar to the one in Figure 36. As in the Figure 36, the response current (green) increases as the input voltage (blue) increases with time, which is expected.

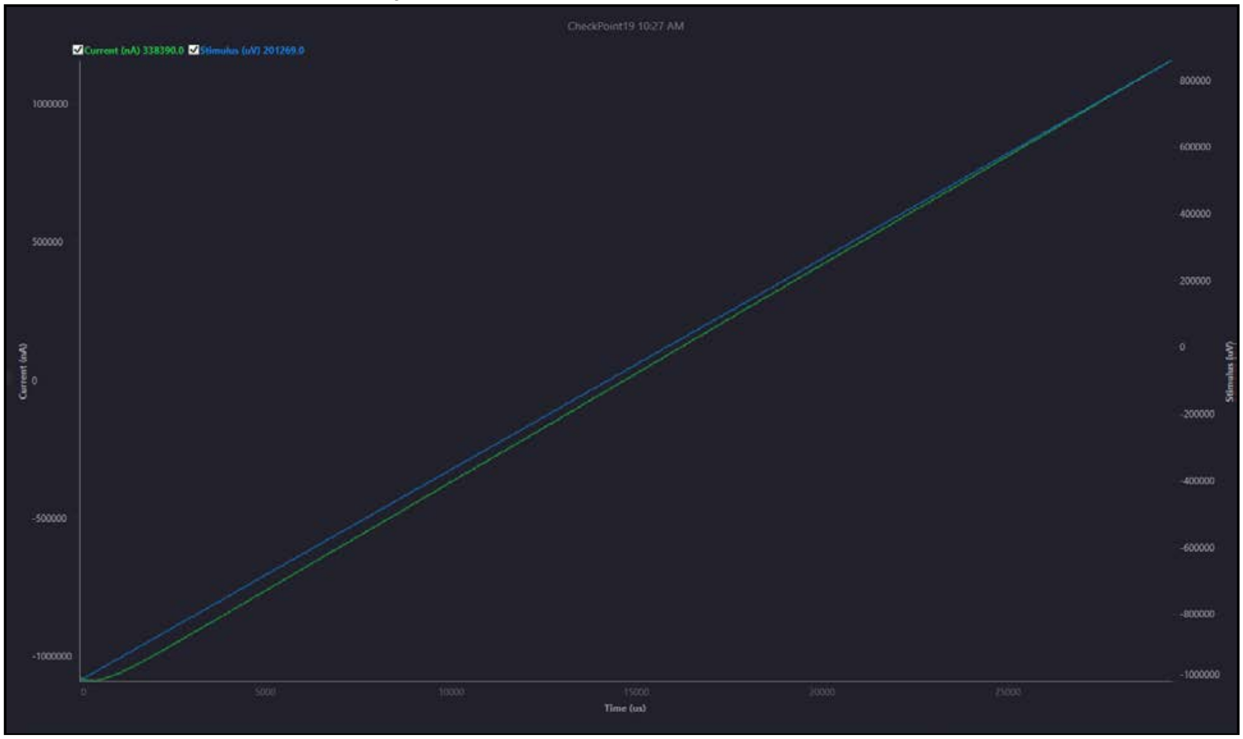


Figure 36. Linear Sweep Voltammetry Validation Test Results

Chronoamperometry

Amperometry measures the response current through an electrode as the voltage is varied. To validate this measurement, the evaluation board features a built-in RC circuit. The board applies a step voltage to the circuit and measures the response current, which ideally is a decaying exponential.

To perform an amperometry validation test using the AD5940 evaluation board, follow the instructions below:

1. Plug the AD5940 evaluation board (AD5940ARDZ) into the Arduino connectors on the ADICUP3029
2. Plug the AD5940Sens2 daughter card into the AD5940ARDZ board as in Figure 37.

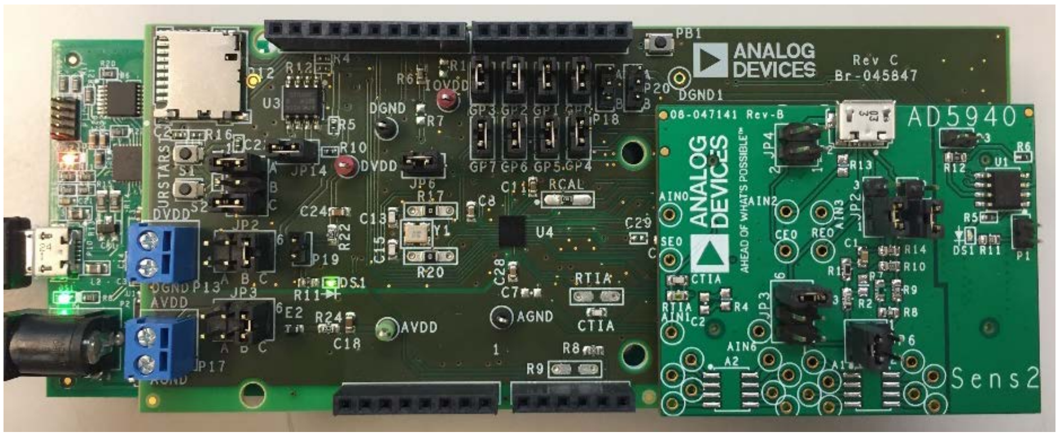


Figure 37. Hardware Setup for Amperometry Validation Test

3. On the AD5940Sens2, ensure the jumper on JP6 is connected to PIN3 and PIN4 (the left-hand column) as in Figure 38. This will ensure that the board is configured to perform TEST 1.

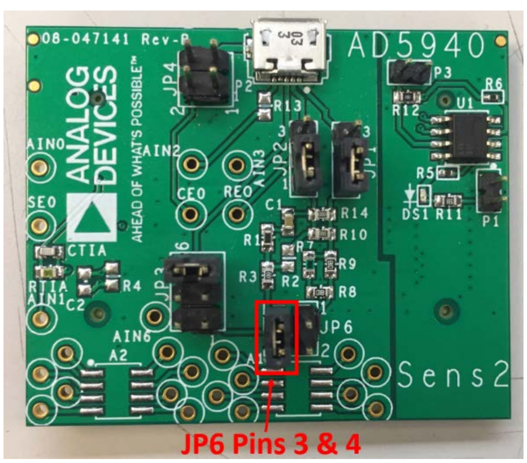


Figure 38. JP6 Jumper Configuration for TEST1 on Sens2 Board

4. Connect the ADICUP3029 to the PC via the USB-to-microUSB cable.
5. Open the SensorPal GUI. Ensure the software is connected to the correct COM port.
6. Under the **Electrochemical Techniques** section in the tool belt, drag the **Amperometry** measurement into the work area. Delete any other existing measurements in the work area by hovering over the measurement and pressing the trash bin icon in the bottom right corner.

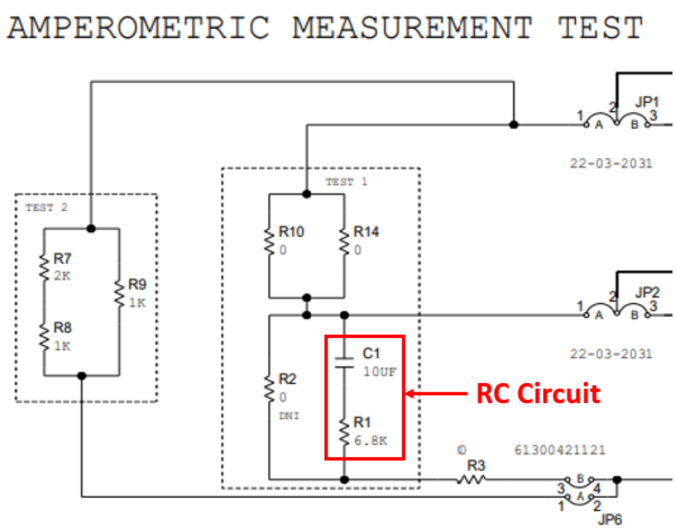


Figure 39. Board Configuration for Two Amperometric Measurement Tests

Click the Amperometry measurement to highlight it and view the configurable parameters beneath. Ensure the parameters are set to the values shown in

7. Table 6.

Table 6. Chrono-Amperometric Parameters[1]

Parameter	Description	Value for Test
E0	Initial voltage of the step input applied to the counter electrode.	0 mV
E1	Final voltage of the step input applied to the counter electrode.	500 mV
T0	Time at which data collection starts.	500000
T1	Time at which peak current is measured, immediately after step voltage is applied.	500000
Excitation Electrode	Electrode where the excitation voltage is applied.	CE0 (Counter Electrode)
Sense Electrode	Electrode where the current response is measured on.	SE0LOAD (Sense Electrode)[2]
Data Source	N/A[3]	LPF_SINC2
SINC2 Oversampling Rate	Oversampling rate of the SINC filter applied to the response current data. Can obtain data at frequencies up to half this value.	44
Transimpedance Amplifier Resistance	Resistance value in the feedback loop of the transimpedance amplifier (RTIA).	10 K[2]

[1] For more information on amperometry measurements on the AD5940, refer to the AN-1563.
[2] Value is different from the default parameter values
[3] N/A means not applicable

8. After the parameters are set, press the green **Measure** button to begin collecting data. The device will continue collecting data until you press the red **Abort Measurement** button.
9. When you have finished collecting data for TEST 1, the resulting graph should look similar to the one in Figure 40. As expected, the response current behaves as it would in a typical RC circuit.

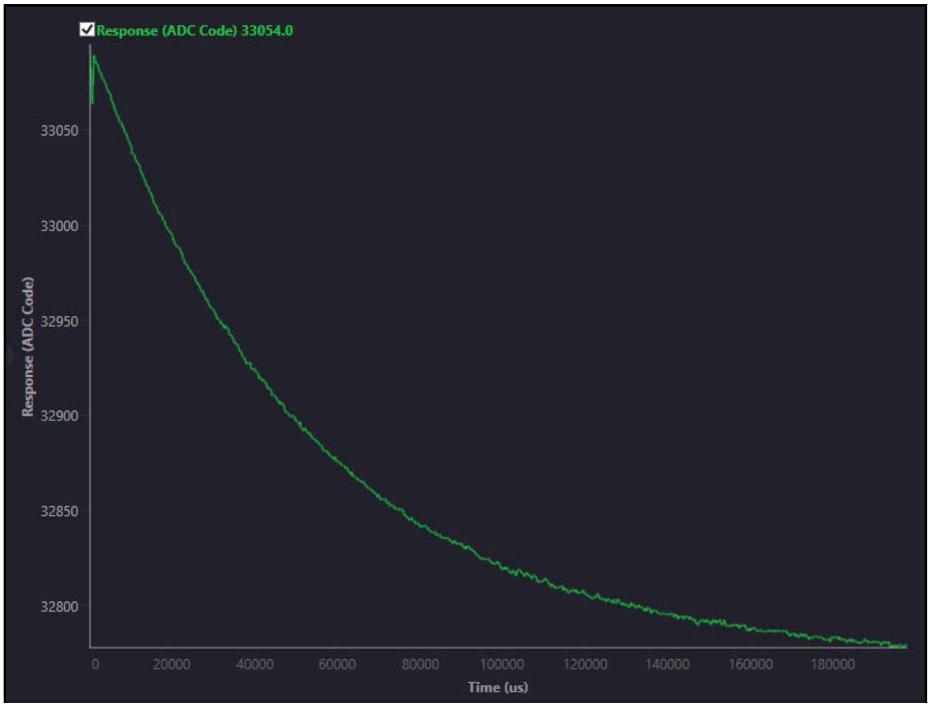


Figure 40. Amperometry Validation Test—TEST 1 Results

Electrochemical Impedance Spectroscopy

To perform an electrochemical impedance validation test using the AD5940 evaluation board, follow the instructions below:

1. Plug the AD5940 evaluation board (AD5940ARDZ) into the Arduino connectors on the ADICUP3029.
2. Plug the AD5940Sens2 daughter card into the AD5940ARDZ board as in Figure 41.
3. Connect the ADICUP3029 to the PC via the USB-to-microUSB cable.
4. Open the SensorPal GUI. Ensure the software is connected to the correct COM port.
5. Under the **Electrochemical Techniques** section in the tool belt, drag the **Impedance** measurement into the work area. Delete any other existing measurements in the work area by hovering over the measurement and pressing the trash bin icon in the bottom right corner.
6. Click the **Impedance** measurement to highlight it and view the configurable parameters beneath. The impedance parameters that can be adjusted are shown in Table 7.

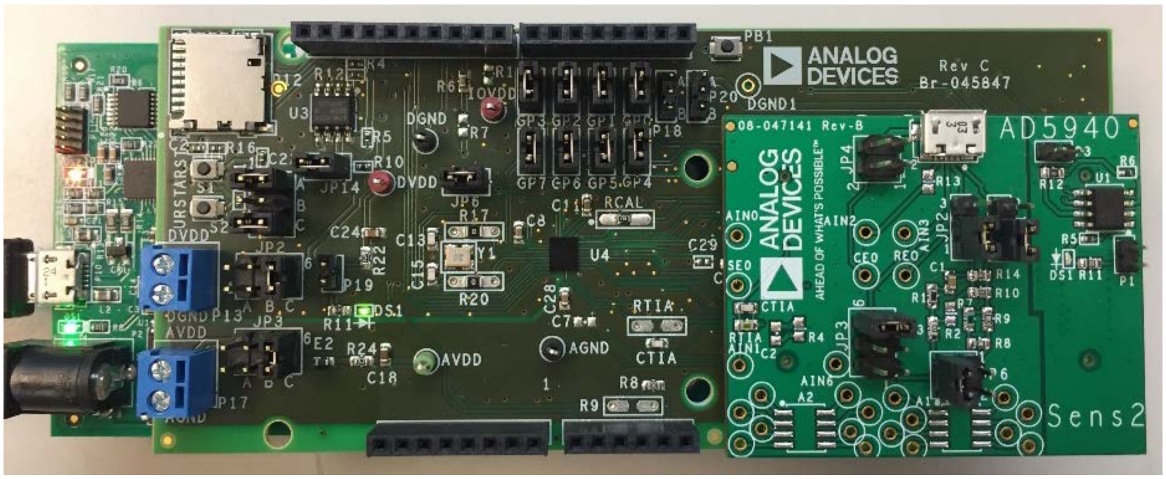


Figure 41. Hardware Setup for Electrochemical Impedance Validation Test

Table 7. EIS Measurement Parameters[1]

Parameter	Description	Value for Test
Amplitude	Magnitude of the applied voltage.	800 mV
Start	Initial frequency of the applied voltage in frequency sweep.	1000 Hz[2]
Stop	Final frequency of the applied voltage in frequency sweep.	100000 Hz[2]
Increment/Samples	Number of sample frequencies between start and stop.	101[2]
Power Mode	Power level of the board	Low Power
Calibration Resistor	Known impedance value voltage is applied to for system calibration	10000 Ω
SINC3 Oversampling Rate	Oversampling rate of the SINC3 filter applied to the response current data. Can obtain data at frequencies up to half this value.	2
SINC2 Oversampling Rate	Oversampling rate of the SINC2 filter applied to the response current data. Can obtain data at frequencies up to half this value.	22

[1] For more information on impedance measurements on the AD5940, refer to the AN-1563.
[2] Value is different from the default parameter values

7. After the parameters are set, press the green Measure button to begin collecting data. The measurement should stop once all of the samples have been acquired.
8. When all data is collected, the resulting graph looks similar to the one in Figure 42. As expected, the impedance of the system decreases exponentially with an increase in frequency.

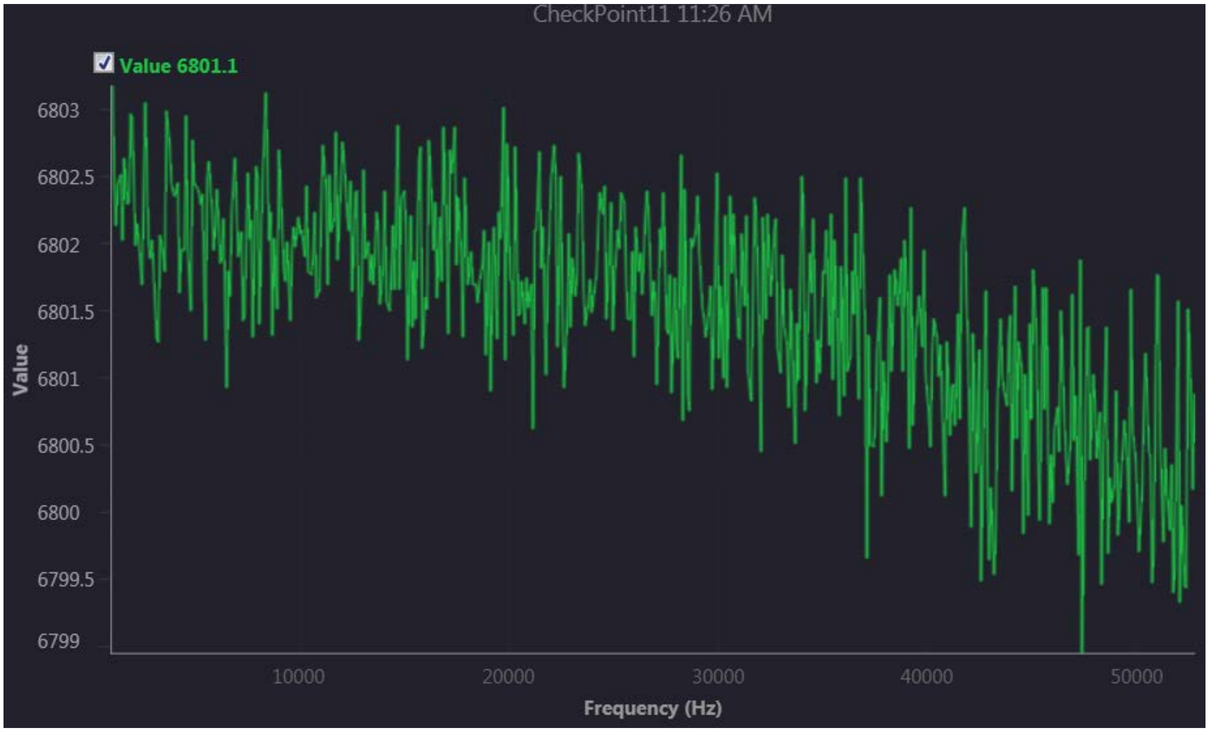


Figure 42. Electrochemical Impedance Validation Test

TIPS AND TRICKS

1. Enable help mode to get information about specific parameters, measurement techniques, and measurement theories. Hover the mouse over a certain parameter or measurement on the screen to view the relevant information.

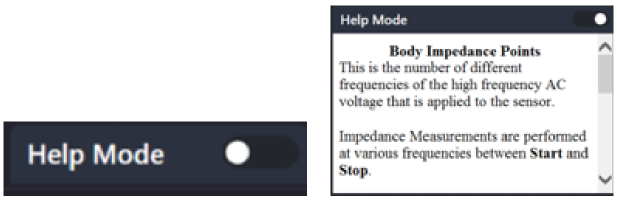


Figure 43. Help Mode

2. Export the generated graph data to a Microsoft® Excel file by clicking the Excel icon above the graph area. The file explorer opens for the user to name and save the file.

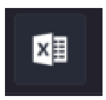


Figure 44. Export to Excel

3. Click the **expand** button to toggle the graph full screen or restore it to its original size.

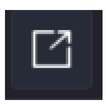


Figure 45. Toggle Full Screen

4. Use the scroll wheel on the mouse to zoom in and out on certain sections of the graph.

5. Hover over a point on the graph to view the point's x-value. Click on the point to view the point's y-value.

Figure 46. Graph Data Points

6. After data collection has finished, double-click the graph area to fit the graph to the screen.

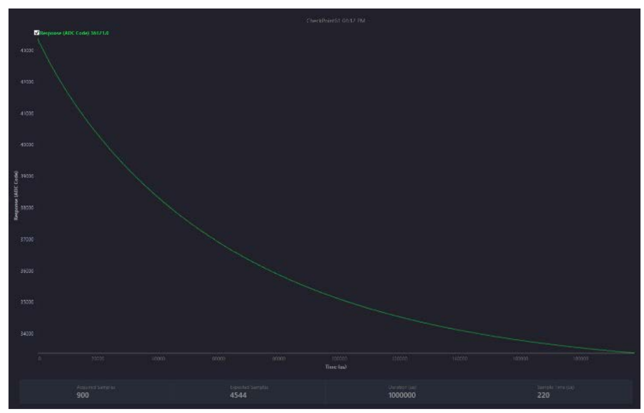


Figure 47. Graph Fit

TROUBLESHOOTING

If a user experiences errors with any of the validation tests or the resulting graphs do not look similar to the ones displayed in the previous sections, refer to the troubleshooting help below to ensure that each board is configured properly with its default settings:

EVAL-AD5940ARDZ

Ensure the jumpers on the EVAL-AD5940ARDZ are in their default positions as described in Table 8.

Table 8. EVAL-AD5940ARDZ Default Jumper Positions

Jumper	Default Position
JP1	One jumper in Position A, one jumper in Position C
JP2	Position C
JP3	Position C
JP4, JP5	Disabled (no jumper inserted)
JP14	Inserted
JP10	Inserted
JP6	Inserted

Refer to the board schematic, EVAL-AD5940ARDZ-REVC.pdf for more details.

AD5940-BioElectric Daughter Card

Ensure the jumpers on the AD5940-BioElectric daughter card are in their default positions as described in Table 9.

Table 9. AD5940-BioElectric Default Jumper Positions

Jumper	Default Position
P1	Inserted
P2	Connected to PIN1 and PIN2
P7	Connected to PIN2 and PIN3
P9	Inserted
P10	Connected to PIN1 and PIN2
P12	Connected to PIN2 and PIN3
P13	Connected to PIN3 and PIN5

AD5940Sens2 Daughter Card

Ensure the jumpers on the AD5940Sens2 daughter card are in their default positions as described in Table 10.

Table 10. AD5940Sens2 Default Jumper Positions

Jumper	Default Position
JP1, JP2	Connected to PIN1 and PIN2
JP3	Connected to PIN5 and PIN6
JP6	Connected to PIN1 and PIN2 (except for amperometry tests, in which case it is connected to PIN3 and PIN4)

INSTALLING AND USING IAR WORKBENCH

IAR Workbench is the IDE of choice for developing firmware for the AD5940. IAR provides an evaluation licence that is free but limits the code size to 32 kB. Currently, none of the evaluation examples in the AD5940 development pack exceed this.

HOW TO DOWNLOAD IAR

To download IAR Workbench, go to the IAR website. Click on the **Download Software** link to download latest version. The download is a large file (roughly 1.3 GB), so the internet download speed affects download time.

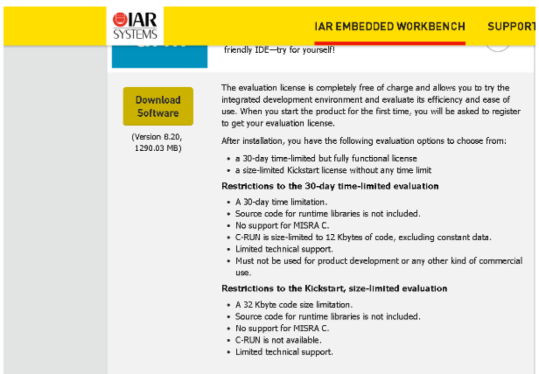


Figure 48. IAR Download

After downloaded, run the executable. When the pop up in Figure 49 appears, click **Install IAR Embedded Workbench® for ARM**.

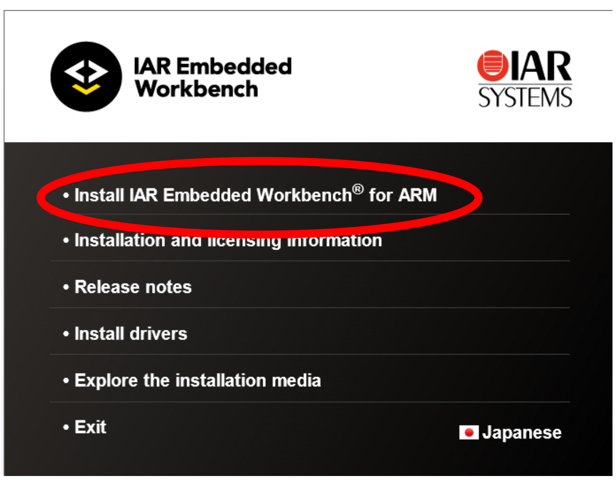


Figure 49. IAR Installation

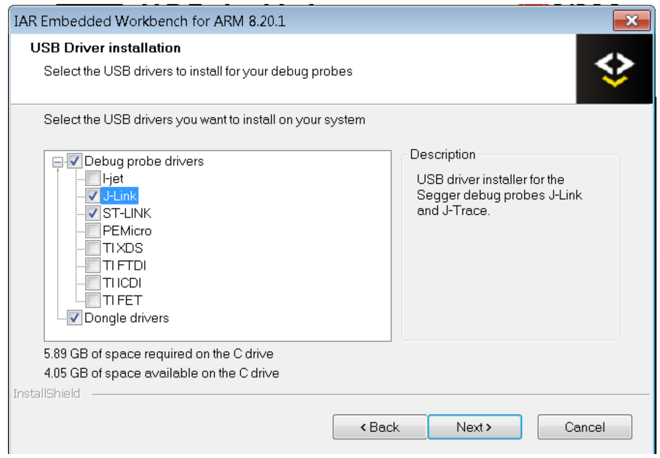


Figure 50. IAR Drivers

Once the installation has completed, open IAR. Go to **Help->License Manager** to open the license manager dialog box.

Navigate to **Licence** > **Get Evaluation Licence** (see Figure 51).

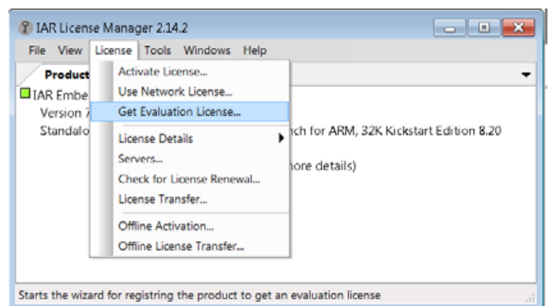


Figure 51. Evaluation Licence

The user must register with IAR to get the evaluation licence. Follow online registration instructions. Select **size limited licence** as opposed to **time limited licence**. An email is sent with a link. Click this link to reveal the license number.

After the license number is entered, the window shown in Figure 52 is displayed.

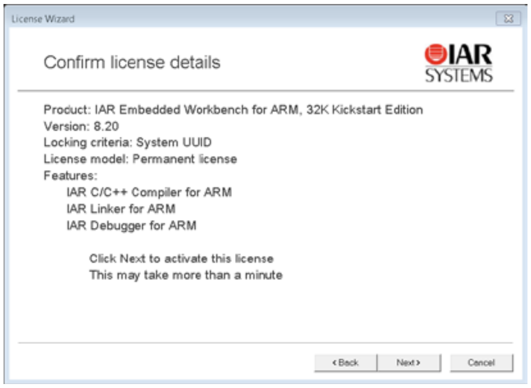


Figure 52. License Confirmation

RUNNING EXAMPLE FIRMWARE IN IAR

To open a sample project, run IAR Workbench. Go to **File** > **Open Workspace.**

Navigate to the AD5940 development package and open one of the example projects. The path for the IAR project file is the following:

…\AD594x_Firmware&Documentation\Firmware\examples\AD5940_BIA\ADICUP3029\ADICUP3029.eww

After the project has opened, go to **Project** > **Rebuild All** to compile and build the project.

To run the firmware on the evaluation hardware, ensure the hardware is connected to the PC. Press the **Download and Debug** button on the toolbar (see Figure 53).

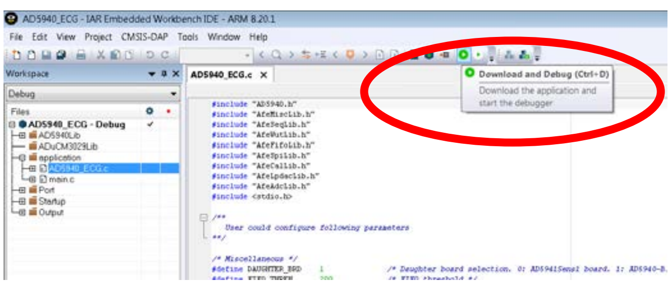


Figure 53. Launching Debugger

After the debugger has opened, press the green "**Play**" button in the toolbar (or press F5 on the keyboard) to begin execution

If required, IAR support for the ADuCM3029 must be installed. To install it, download the executable from the link and run the executable.

VIEWING MEASUREMENT RESULTS

The AD5940 firmware is configured to send measurement results to the PC via the UART interface. To view results open a terminal program such as RealTerm. Set the baud rate to 230400 and set the COM port to the port that ADICUP3029 is connected (see Figure 54). If unsure which port the ADICUP3029 is connected to, go to **device manager** > **mbed serial port**. The COM port number is in brackets beside it (see Figure 10).

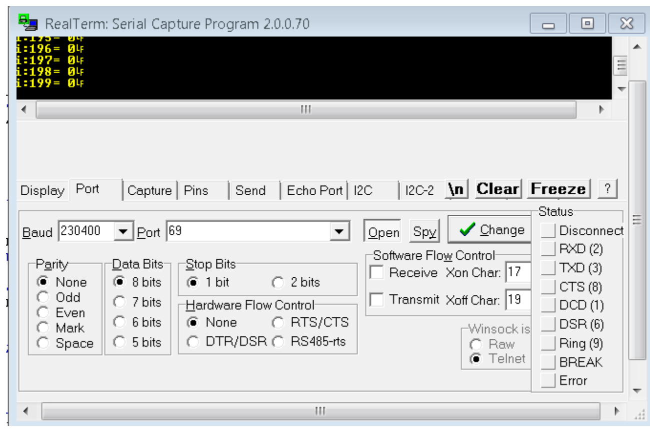


Figure 54. AD5940 Results in RealTerm

NOTES

ESD Caution

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

Legal Terms and Conditions

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NONINFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS ($100.00). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.

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