

## Evaluating the **ADuCM355** Precision Analog Microcontroller

### FEATURES

Debug/programming capability of **ADuCM355**  
 Evaluation capability with electrochemical gas sensors  
 ADT7420 0.5 C accurate temperature sensor via I<sup>2</sup>C  
 USB power option and connection to PC

### EQUIPMENT NEEDED

PC  
 Electrochemical gas sensor (not provided)

### DOCUMENTS NEEDED

[ADuCM355 data sheet](#)

### SOFTWARE NEEDED

IAR Embedded Workbench

### GENERAL DESCRIPTION

The **ADuCM355** system on a chip provides the features needed to bias and measure a range of different electrochemical sensors. The EVAL-ADuCM355QSPZ allows users to evaluate the performance of the **ADuCM355** when implementing a range of different electrochemical techniques, including chronoamperometry, voltammetry, and electrochemical impedance spectroscopy (EIS).

### EVALUATION BOARD PHOTOGRAPH

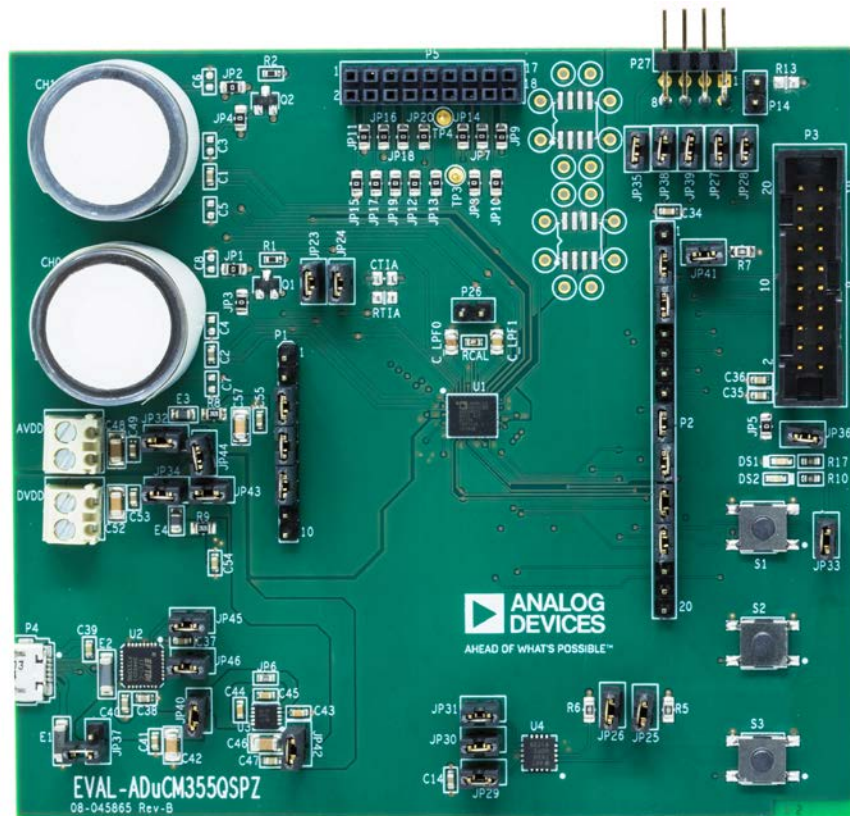


Figure 1. **ADuCM355** Evaluation Board

## TABLE OF CONTENTS

Features .....	1	Installing the ADuCM355 Support Package .....	7
Equipment Needed.....	1	Running GPIO Example.....	7
Documents Needed.....	1	Application Examples .....	10
Software Needed.....	1	Cyclic Voltammetry Example.....	10
General Description .....	1	Electrochemical Impedance Spectroscopy Example .....	11
Evaluation Board Photograph.....	1	Chronoamperometry Example.....	11
Power Configurations .....	3	DC Current Example .....	12
USB Direct via P4.....	3	HSTIA Gain Resistor Calibration .....	12
3.3 V Direct via AVDD and DVDD Connectors .....	5	Low Power TIA0/TIA1 Gain Resistor Calibration .....	15
Power via USB from 8-Pin Connector (P27).....	5	Connecting an External Gain Resistor Across the High Speed	
Power via External 5 V Supply to 2-Pin Connector (P37).....	5	TIA .....	16
Connecting an Electrochemical Sensor.....	6	Mass Erase a Part That Is Not Responding to SWD	
Getting Started with the IAR Embedded Workbench Tool .....	7	Commands.....	17
Downloading IAR .....	7		

## POWER CONFIGURATIONS

This section lists and describes the four different options to power the evaluation board. The different power options are as follows:

1. Power via a micro USB connector, P4. This is the default power option.
2. Connect 3.3 V to AVDD and DVDD connectors. This setup is useful for measuring current consumption of the board via current meter.
3. Power via the debug header P27 (ultimately a different USB connection option to the PC). This setup is useful if using the older serial wire debug and universal asynchronous receiver transmitter board (UART), the EVAL-SWD/UART-EMUZ setup.
4. Power via the [ADP7158](#) low dropout (LDO). The USB connector sources 5 V for LDO.

### USB DIRECT VIA P4

#### Micro-USB Connector, P4 Setup

To power the board via the micro-USB connector, take the following steps:

1. Close JP40, JP42, JP43, JP44, JP45, and JP46.
  - JP45 and JP46 connect the UART pins from the [ADuCM355](#) to the UART-USB transceiver chip (U2) (see Figure 1 and Figure 2).
  - JP40 connects the 5 V USB supply to the input of the LDO (U3) (see Figure 1, Figure 3, and Figure 4).
  - JP42 connects the LDO output (3.3 V) to the board power supply filters (see Figure 1, Figure 3, and Figure 4).
  - JP43 and JP44 connect the DVDD rail to filters for the AVDD\_DD and AVDD analog supplies to the [ADuCM355](#) (see Figure 1, Figure 3, and Figure 4).
2. Open JP37.



Figure 2. Power via Micro-USB Cable Directly

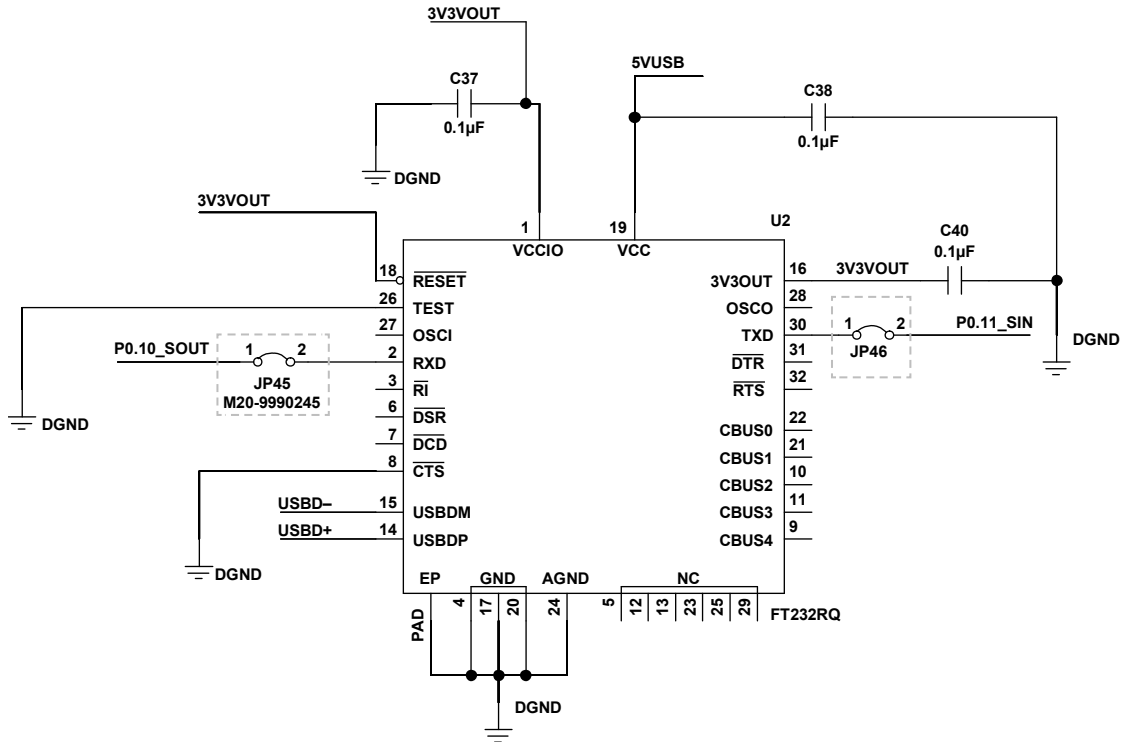


Figure 3. JP45 and JP46 to Connect ADuCM355 UART Pins to USB Transceiver

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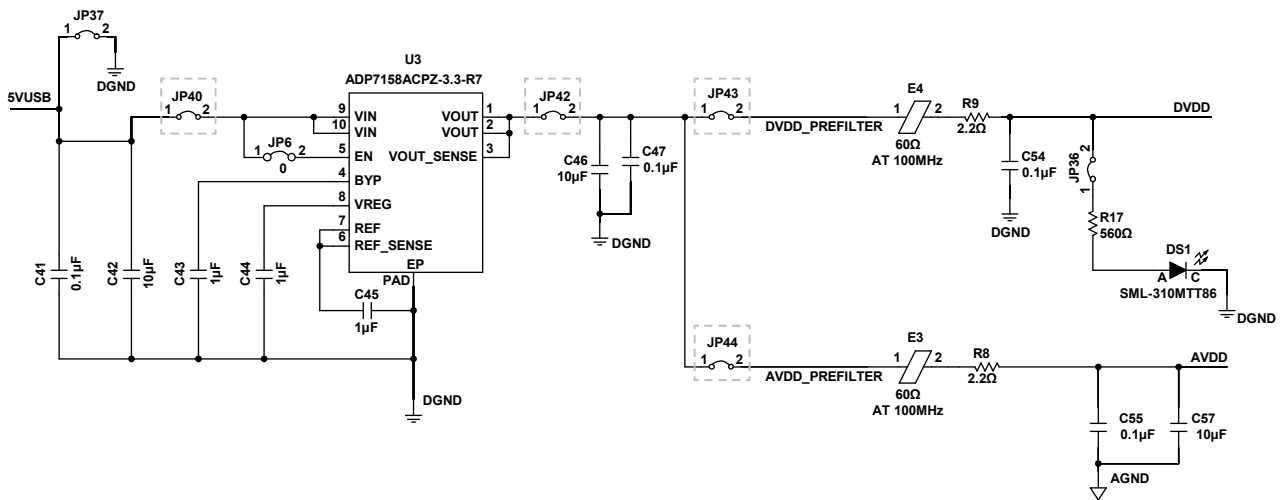


Figure 4. Schematic Section Showing Key Jumpers Around LDO and Power Supply

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**3.3 V DIRECT VIA AVDD AND DVDD CONNECTORS**

This set up is useful for measuring the current consumption (IDD) of just the ADuCM355 itself.

To power the evaluation board, apply 3.3 V supply directly to Pin 1 on AVDD and DVDD.

**Jumper Setup**

To set up the jumper, take the following steps:

1. Close JP32, JP34, JP43, and JP44.
2. Open JP37 and JP42.

**POWER VIA USB FROM 8-PIN CONNECTOR (P27)**

If using the older USB-serial wire debug (SWD)/UART connector and debug interface, the ADuCM355 can also be powered from the USB. The UART-USB interface is handled by the USB-SWD/UART board.

**Jumper Setup**

To set up the jumper, close JP35, JP40, JP42, JP43, and JP44.

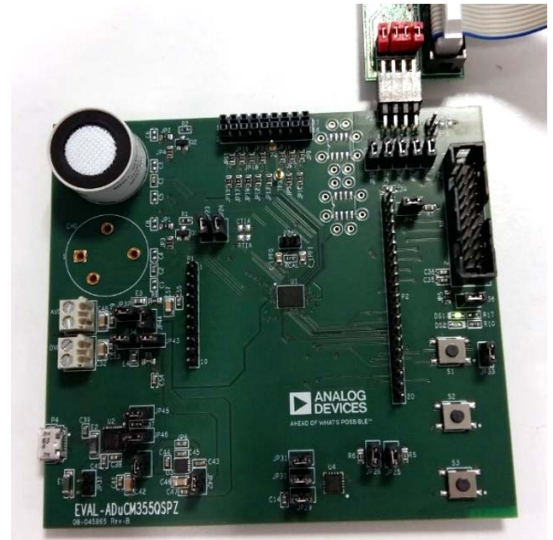


Figure 5. Power via 8-Pin Connector P27

**POWER VIA EXTERNAL 5 V SUPPLY TO 2-PIN CONNECTOR (P37)**

The last option is to connect 5 V to the 2-pin header (P37). This 5 V is the input to the ADP7158 low dropout (LDO) which has a 3.3 V output voltage. The micro-USB cable must not be connected to P4. This option is a debug/test option only.

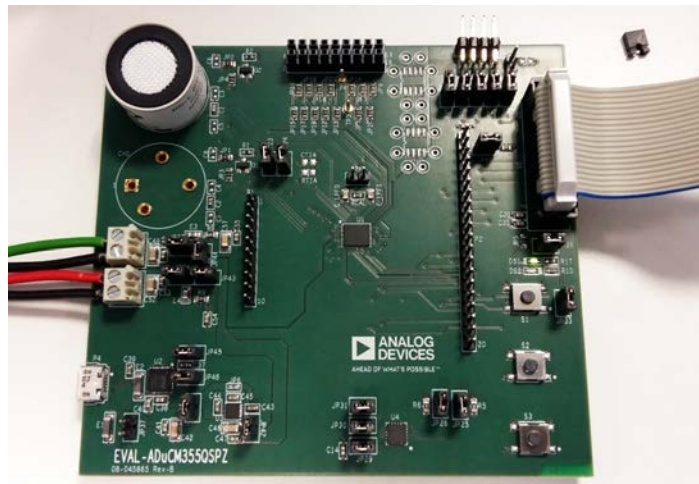


Figure 6. Power DVDD and AVDD Directly via Power Header Blocks

## CONNECTING AN ELECTROCHEMICAL SENSOR

The ADuCM355 has two measurement channels for electrochemical sensors. A 2-lead, 3-lead, or 4-lead sensor can be connected to either CH0 or CH1. Figure 7 shows an electrochemical sensor connected to CH1.



Figure 7. Sensor Connector

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# GETTING STARTED WITH THE IAR EMBEDDED WORKBENCH TOOL

## DOWNLOADING IAR

The ADuCM355 evaluation firmware has been tested using IAR7.4. An evaluation version of the Embedded Workbench is provided with the ADuCM355 evaluation software. Further details on the Embedded Workbench can be found on the IAR website.

## INSTALLING THE ADuCM355 SUPPORT PACKAGE

Download the ADuCM355 support package and extract the contents. Run the executable, and follow installation instructions. This installation installs all required drivers and patches for ADuCM355 in IAR.

By default, the sample firmware is installed in C:\Analog Devices\ADuCM355V2.0.1.30.

The sample firmware contains the following folders:

- The **Common** folder contains all library files common to every application.
- The **Examples** folder contains specific example projects (see the Running GPIO Example section).
- The **Inc** folder contains some include files for the microprocessor.

## RUNNING GPIO EXAMPLE

To run the general purpose input/output (GPIO) example, open the ADuCM355V2.0.1.3.0 directory and go to **examples > M355\_GPIO.iar**. Double click on **M355\_GPIO.eww** to open the project in the IAR workbench.

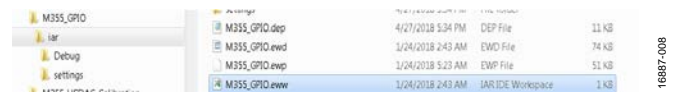


Figure 8. M355\_GPIO.eww File Location

## IAR Folder Structure

The IAR project folder structure is shown to the left of the IAR window as in Figure 9. The **app** folder contains files specific to the open application. In Figure 9, **M355\_GPIO.c** is the example shown. The **common** folder contains the required library files for the open application. For the GPIO example, the library files are **AfeWdtLib.c**, **ClkLib.c**, **DioLib.c**, and **UrtLib.c**. The start-up folder contains start-up files for the microprocessor, and the output folder contains the **M355\_GPIO.out** file. All subsequent firmware examples follow this folder structure in IAR.

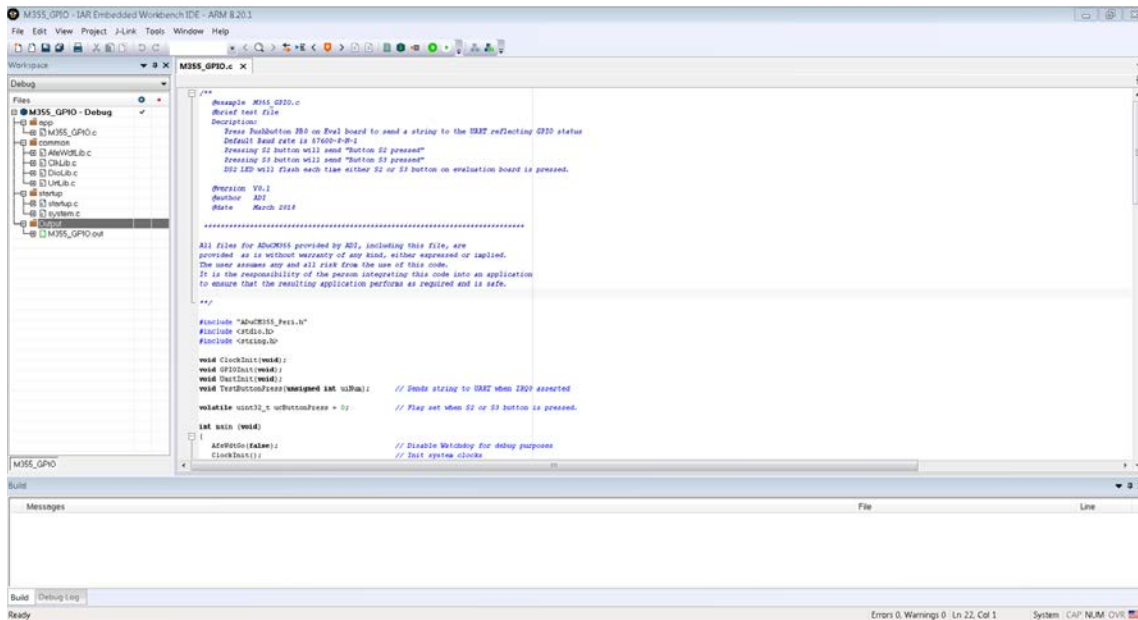


Figure 9. IAR Workbench

**Compiling and Running Firmware**

To compile and build the firmware, take the following steps:

1. Go to **Project > Rebuild All** (see Figure 10).

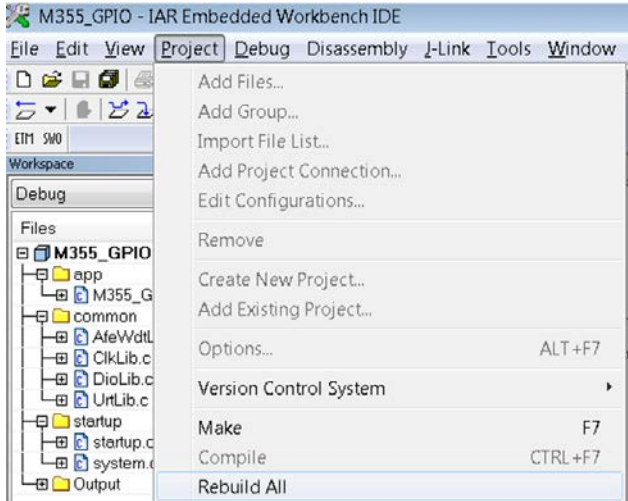


Figure 10. Project > Rebuild All

2. The message shown in Figure 11 appears in the build window.

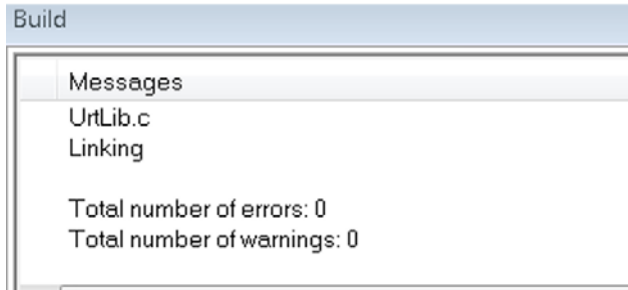


Figure 11. Project > Build

3. To run the firmware on the ADuCM355, ensure the evaluation board is powered on and the J-Link debugger is connected. Press the **Download and Debug** button to load the firmware to the ADuCM355 and launch the debugger (see Figure 12). It usually takes a few seconds to launch and download, but the delay can be longer.

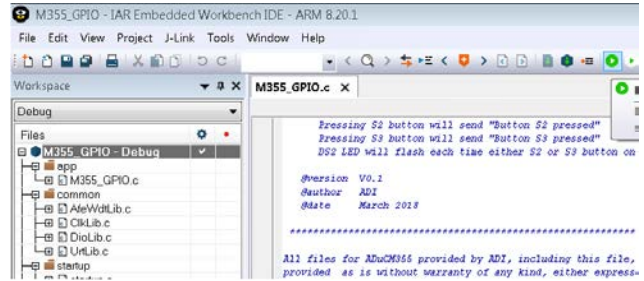


Figure 12. Launching the Debugger

4. Open a terminal program such as RealTerm to view UART data from the ADuCM355 (see Figure 13). The baud rate is 57600 bits/second.

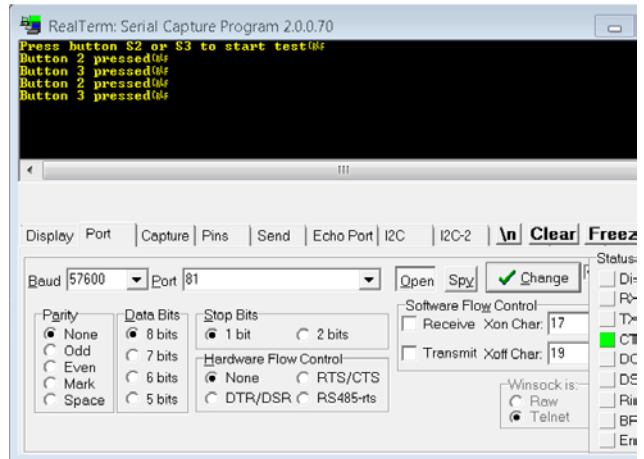


Figure 13. UART Data in RealTerm



5. Figure 14 shows the debug interface. Click on the blue arrow to begin code execution. UART prompts the user to press either S2 or S3. The LED (DS2) toggles on and off with each button press.

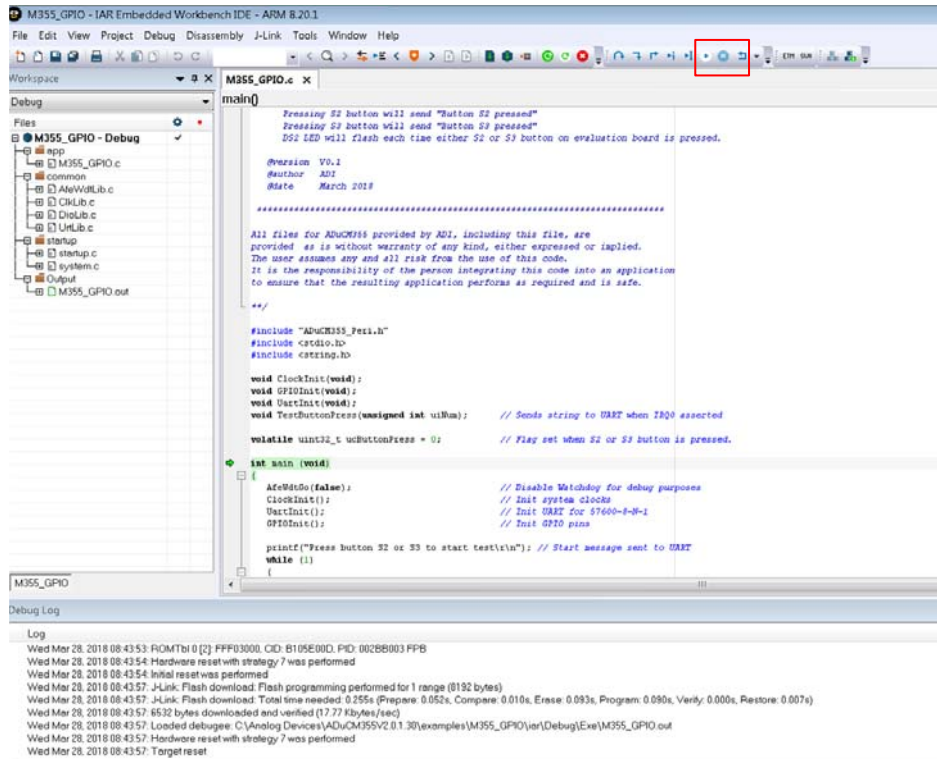


Figure 14. Debug Interface

## APPLICATION EXAMPLES

### CYCLIC VOLTAMMETRY EXAMPLE

Cyclic voltammetry is a common electrochemical measurement in which the current on the sense electrode is measured in response to a ramp like voltage applied on the counter electrode.

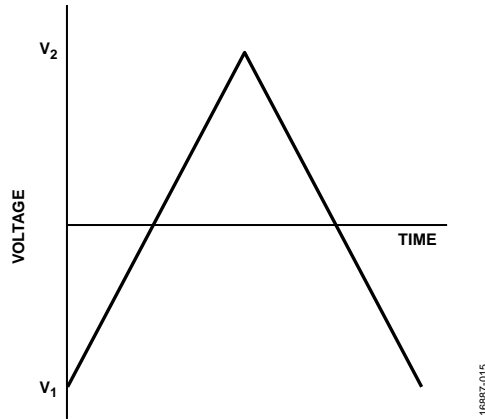


Figure 15. Typical Cyclic Voltammetry Waveform

In the [ADuCM355](#) firmware package, the M355\_CycloVoltammetry project demonstrates how to implement a cyclic voltammetry measurement on the [ADuCM355](#). In the `M355_Ramp.c` file, there is a description of the measurement. There are also a number of macro definitions that define the measurement.

For this example project, the selected options are as follows:

- `#define SENSOR_DUAL_CHANNEL_ENABLE 0`  
//Only run test on Channel 0
- `#define SENSOR_RAMP_SE 1`  
//Select SE0 electrode for measurement
- `#define REC_OPTION`  
`REC_ADCDAT //Record ADC Data`
- `#define OPT_RAMP_MEAS. 1`  
//Measure current and pin voltages
- `#define SNS_DC_VBIAS_DEFAULT0` sets the Channel 0 VBIAS default voltage
- `#define SNS_DC_VZERO_DEFAULT0` sets the Channel 0 VZERO default voltage
- `#define SNS_DC_RLOAD_DEFAULT0` sets the Channel 0 Low Power TIA (LPTIA) RLOAD default value
- `#define SNS_DC_RGAIN_DEFAULT0` sets the Channel 0 LPTIA's gain resistor (RTIA) gain default value

To test the firmware, constructing a dummy electrochemical cell using 1 kΩ resistors in a star network is recommended (see Figure 16). Connect each pin of the resistor network to CE0, RE0, SE0, and DE0 on P5.



Figure 16. Resistor Star

To begin measuring and gathering data, open a terminal program such as RealTerm. Configure the baud rate for 115200. Compile and build the project in IAR and launch the debugger. Run the measurement, and save the data to a .csv file for processing. If `OPT_RAMP_MEAS` is set to 1, there are six measurements for each channel, as follows:

- Current on Channel 1
- Voltage on DE0
- Voltage on RE0
- VZERO voltage
- VBIAS0 voltage
- Current

To plot the current response of the ramp test, open the saved .csv file in Microsoft® Excel. The first set of data points under `RAMP_DATA` is the current measurements. Figure 17 shows the `RAMP_DATA` data points after being plotted.

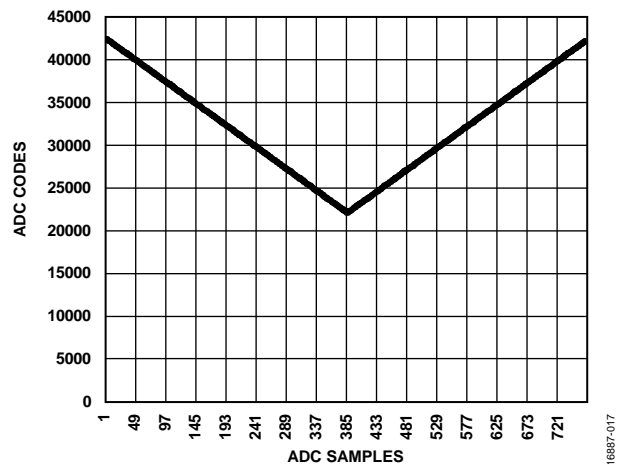


Figure 17. Example SE0 Channel Current Measurement—ADC Codes on the Y-Axis, ADC Sample Number on X-Axis

**ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY EXAMPLE**

EIS is a common electrochemical measurement in which an ac excitation signal is applied to an electrochemical cell. The response current is measured, and the impedance is calculated.

On the ADuCM355, EIS measurement is a three step process. The response current in each step is measured using a high speed transimpedance amplifier (HSTIA).

The EIS measurement process is as follows:

1. Signal is applied across R<sub>CAL</sub>.
2. Signal is applied across R<sub>LOAD</sub>.
3. Signal is applied across Z<sub>SENSOR</sub> + R<sub>LOAD</sub>.

R<sub>CAL</sub> is a precision resistor connected to the RCAL0 pin and the RCAL1 pin.

R<sub>LOAD</sub> is the internal load resistor on the SE0 path

Z<sub>SENSOR</sub> is the impedance under test.

The actual impedance is calculated by the following equation:

$$Z_{SENSOR} = Z_{SENSOR + R_{LOAD}} - Z_{R_{LOAD}}$$

For the purpose of this initial test, a dummy electrochemical cell can be used. Connect three 1 kΩ resistors in a star network and connect to CE0, RE0, and SE0 on P5 (see Figure 18).

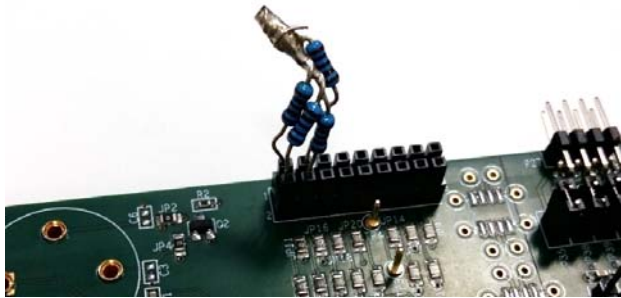


Figure 18. 1 kΩ Resistor Star Connected on P5

The two user options in the M355\_ECSns\_EIS.c file, are as follows:

- #define EIS\_DCBIAS\_EN. This macro defines whether there is a dc bias applied across the sensor as is required for O<sub>2</sub> sensors.
- Select the frequency of sine wave excitation signal. This is defined in ImpResult [] array. By default, there are twelve frequencies already populated. These frequencies can be modified as required.

To run the impedance measurement, launch the debugger in IAR, and open a terminal program with 57600 baud rate. Start executing the code. A prompt to press S2 is sent over UART and displayed in the terminal. By pressing S2, the impedance test begins. It takes up to 20 seconds because there are twelve frequency points to measure. When the measurement is complete, the results are sent to the UART (see Figure 19). Optionally, save the results in a Microsoft Excel file for further analysis.

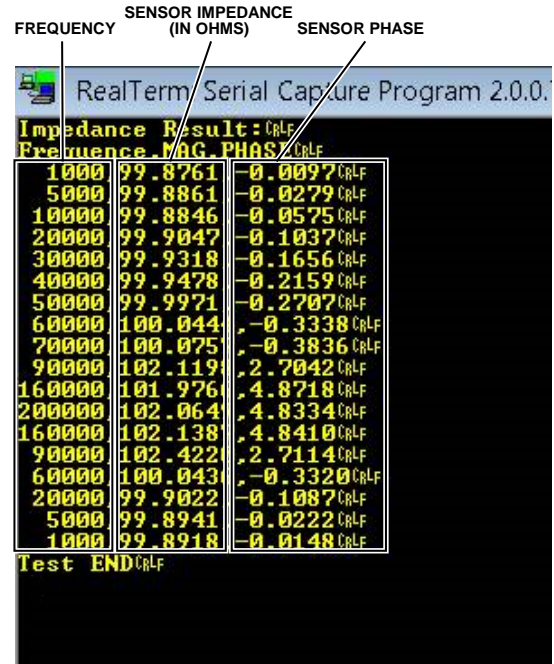


Figure 19. Impedance Results

**CHRONOAMPEROMETRY EXAMPLE**

Chronoamperometry is an electrochemical technique in which the voltage applied to an electrochemical cell is stepped. The response current on the sense electrode is measured. Figure 20 shows a typical chronoamperometric measurement and sensor response.

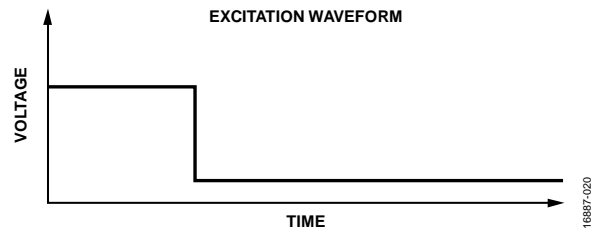


Figure 20. Typical Chronoamperometric Excitation Waveform

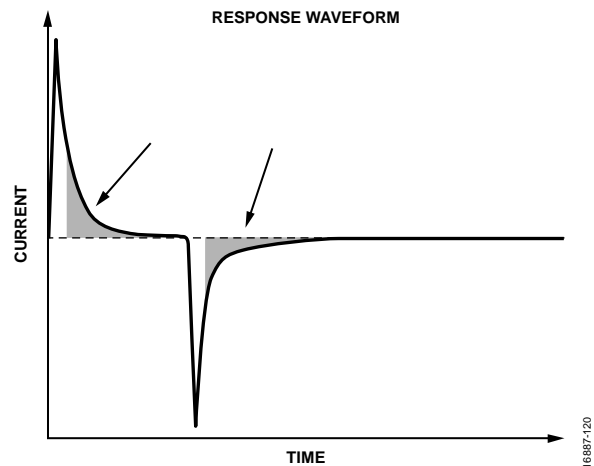


Figure 21. Typical Chronoamperometric Response Waveform

In the [ADuCM355](#) firmware development package, the `M355_ECSns_CapaTest` project implements a chronoamperometric measurement.

The `M355_ECSns_CapaTest.c` file contains a data structure defined to select measurement options. The user can change these measurement options to modify measurement.

There is also a structure (`SNS_CFG_Type`) that sets up a data structure to configure each sensor channel. For this demo, only sensor Channel 0 is used.

All default values are used. The resistor star model is connected to P5 as was the case in the examples described in the Cyclic Voltammetry Example section and the Electrochemical Impedance Spectroscopy Example section.

Load the project in IAR, and open a terminal program. Compile and build the project, and launch the debugger interface. Start code execution, and save the UART data to a .csv file for processing.

## DC CURRENT EXAMPLE

The dc current is a standard electrochemical measurement. Depending on the sensor type, a bias voltage is applied between the reference and sense electrodes. The current output on the sense electrode is measured.

In the [ADuCM355](#) firmware package, the project `M355_ECSns_DCTest` implements a dc current measurement on two electrochemical cells connected to CH0 and CH1. Channel 0 is configured for a zero biased sensor,  $V_{BIAS} - V_{ZERO} = 0$ . A carbon monoxide (CO) sensor is an example of a zero biased sensor. Channel 1 is configured for a biased sensor,  $V_{BIAS} - V_{ZERO} = 600$  mV. An oxygen ( $O_2$ ) sensor is an example of a biased sensor.

For the purpose of testing, connect the 1 k resistor star network to CH0 and CH1. Ensure the [ADuCM355](#) board is powered, and

the debugger is connected to the computer. Open the project in IAR, build, and run the debugger. Open a terminal program to view the results. The output is the raw analog-to-digital converter (ADC) codes (see Figure 22).

## HSTIA GAIN RESISTOR CALIBRATION

HSTIA has three different programmable gain resistor options (see Figure 23).

The user adjusts the gain resistors shown in Figure 23 to convert the current from the SE0/SE1/DE0 input or the DE1 input to a differential voltage across the RTIA2 resistor, RTIA2\_03 resistor, or RTIA2\_05 resistor.

The RTIA2, RTIA2\_03, and RTIA2\_05 resistors have an initial accuracy range as specified in the [ADuCM355](#) data sheet. The resistors also vary with temperature as specified in the [ADuCM355](#) data sheet.

If the HSTIA is uncalibrated for the selected gain resistor and ADC PGA setting, an error is present if trying to measure an absolute input current.

By using the high speed DAC (HSDAC) to create a differential voltage across an external precision RCAL resistor that is connected to the [ADuCM355](#) RCAL0 pin and RCAL1 pin, a precision calibration current can be generated and this is routed through any of the three HSTIA gain resistors.

Because the calibration current value is known, and the ADC can measure the voltage drop across the RTIA2 resistor, RTIA2\_03 resistor, and RTIA2\_05 resistor, the exact RTIA2/RTIA2\_03/RTIA2\_05 value can be determined.

Figure 24 shows the setup and switch settings that connect the HSDAC output to the external RCAL resistor and the current flow into the HSTIA and RTIA2 gain resistor.

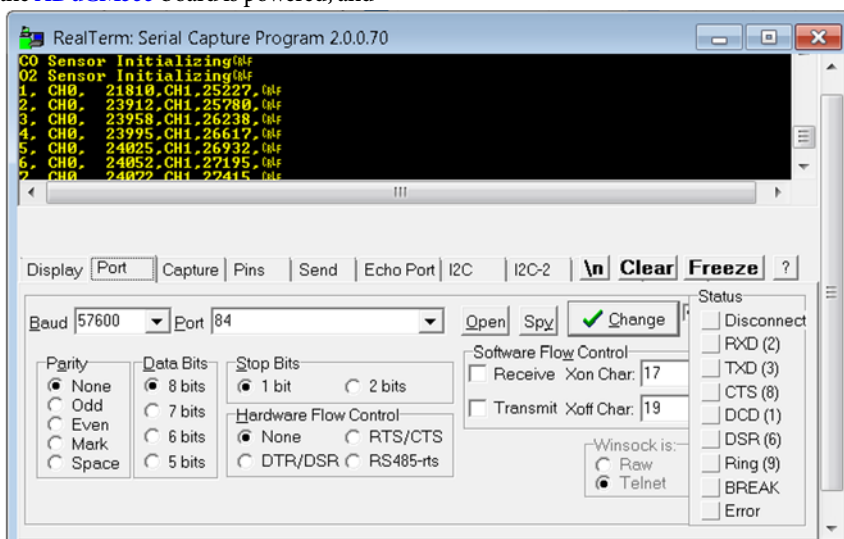


Figure 22. CO Sensor on Channel 0 Output, Channel 1 Floating

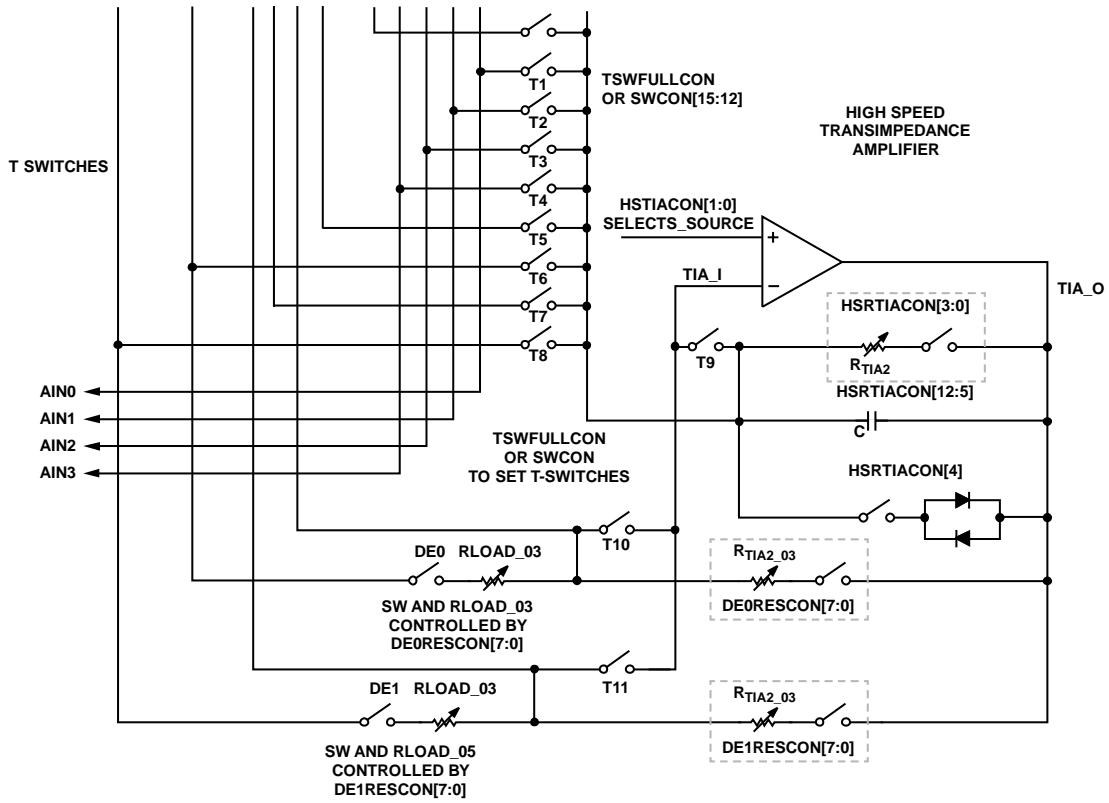


Figure 23. HSTIA Programmable Gain Resistors

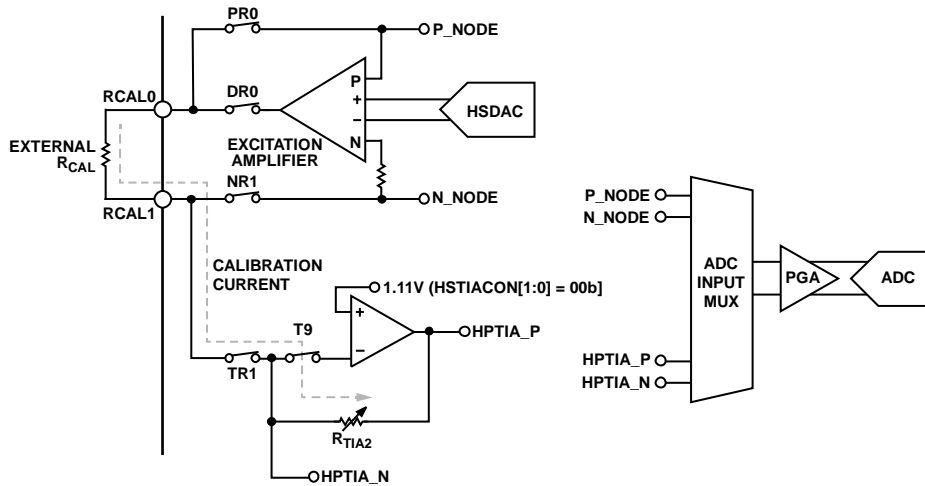


Figure 24. HSDAC, HSTIA, and Switch Matrix Settings for RTIA2 Calibration

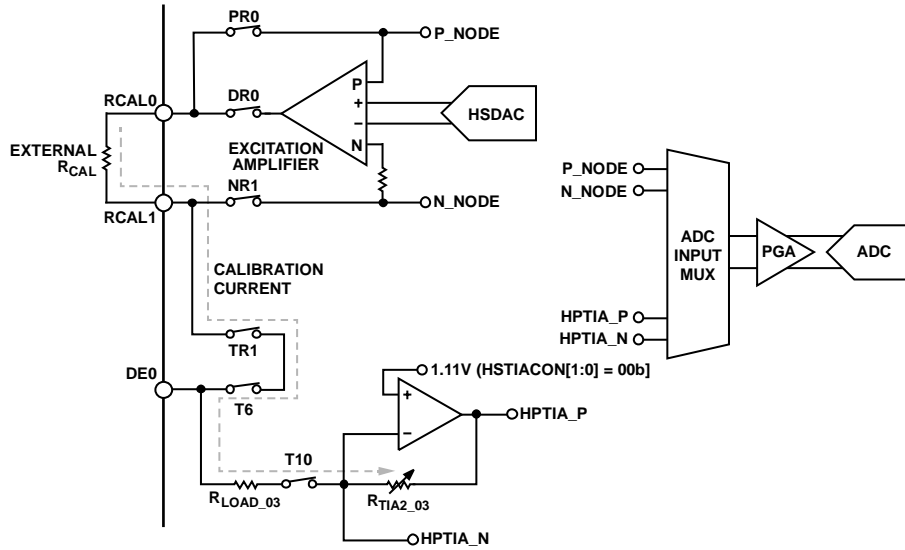


Figure 25. HSDAC, HSTIA, and Switch Matrix Settings for RTIA2\_03 Calibration

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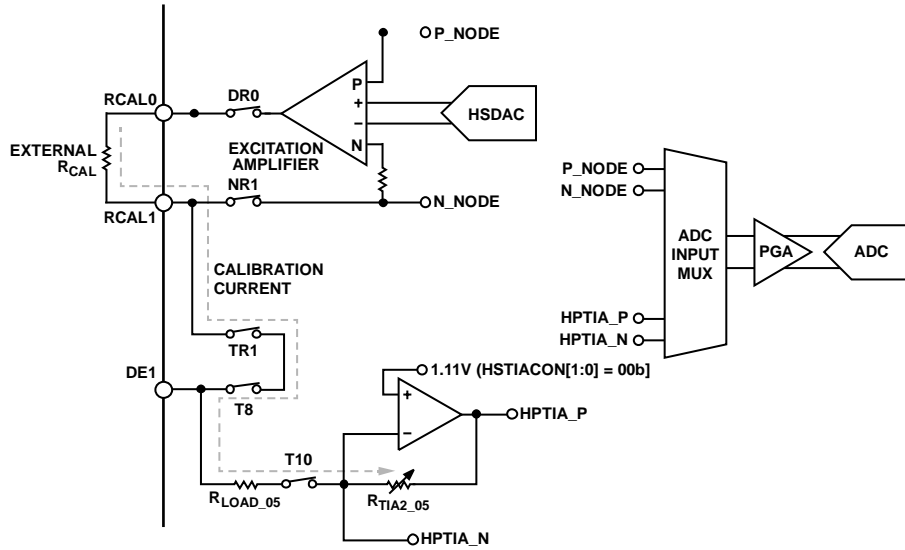


Figure 26. HSDAC, HSTIA, and Switch Matrix Settings for RTIA2\_05 Calibration

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The code example project **M355\_HSRTIA\_Calibration** in the **examples** folder demonstrates how to configure the part to calibrate the 5 kΩ setting for RTIA2, RTIA2\_03, and RTIA2\_05.

The example code sends text to the UART similar to that shown in the Figure 27. The baud rate used is 57600-8-N-1. The text can be viewed by a viewing terminal such as RealTerm or HyperTerminal.

To use the M355\_HSRTIA\_Calibration example code, take the following steps:

1. Press the **S3** button on the evaluation board to start the calibration sequence.
  - The program calibrates the ADC offset and gain errors for LP mode with a PGA gain setting of 1.5.
  - The HSDAC offset error is calibrated out.
  - The required HSDAC differential voltage is generated across the external RCAL resistor
  - The voltage across RCAL is measured via the ADC P\_NODE and N\_NODE input channels, which allows determines the calibration current **i**.

- The calibration current is switched into each of RTIA2, RTIA2\_03, and RTIA2\_05 and the voltage drop across each measured in turn.
- The ADC HPTIA\_P input channel and HPTIA\_N input channel are measured for each of the three switch configurations shown in Figure 24, Figure 25, and Figure 26.

2. After calibration, apply a current source to any of the SE0, DE0, or DE1 inputs. Press the **S2** button to trigger a measurement of the input currents to the SE0 pin, DE0 pin, and DE1 pin. **S2** may also be pressed before calibration to allow the user compare the precalibration and postcalibration results.

**LOW POWER TIA0/TIA1 GAIN RESISTOR CALIBRATION**

The ADuCM355 contains two independent, low power TIA channels.

Each TIA has an independent, programmable gain resistor to scale the input current from the SE0 pin and the SE1 pin to a voltage that the ADC can measure.

Calibration details to follow shortly.

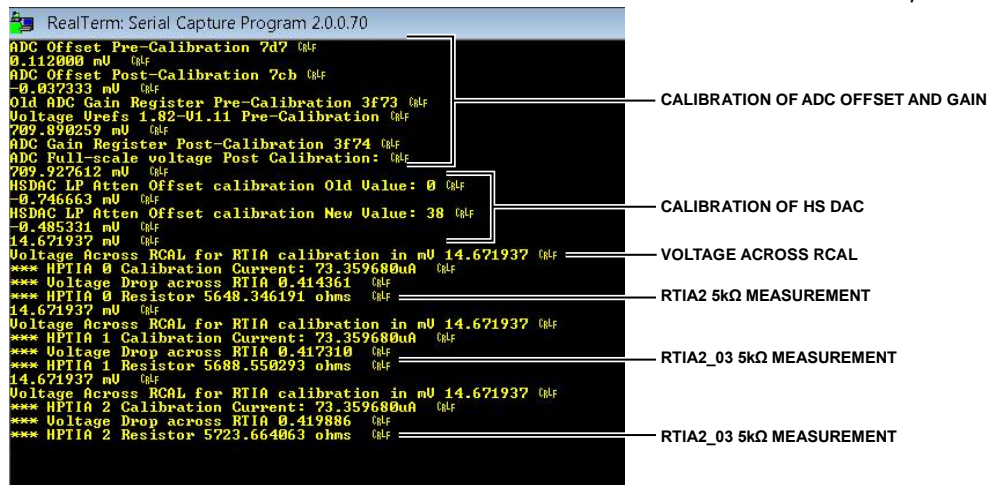


Figure 27. M355\_HSTIA\_Calibration Output Text to UART Port

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## CONNECTING AN EXTERNAL GAIN RESISTOR ACROSS THE HIGH SPEED TIA

The internal high speed TIA has a programmable gain resistor to allow a user configure high speed current measurement channel for different input current ranges. But there is an option to connect an external gain resistor instead.

The EVAL-ADuCM355QSPZ supports the connection of an external RTIA resistor across the AIN0 pin and DE0 pin, which are labelled RTIA on the top side of the printed circuit board (PCB).

The current into the HSTIA will flow from AIN0 into the HSTIA inverting input with the HSTIA connected to DE0.

The ADC measures the voltage drop across the external RTIA by selecting the input channels HPTIA\_P and HPTIA\_N (see Figure 28).

When the external gain resistor is populated by the customer, this gain resistor can be used instead of the internal RTIA2 resistor, RTIA2\_03 resistor, and RTIA2\_05 resistor.

The code example project **M355\_ExternalRTIA** in the **examples** folder shows how to setup the HSTIA for an external gain resistor.

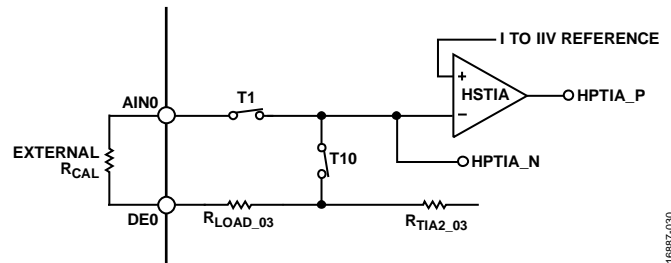


Figure 28. ADuCM355 External RTIA Connection to the HSTIA



## MASS ERASE A PART THAT IS NOT RESPONDING TO SWD COMMANDS

The SWD debug tools can only communicate with the microcontroller when the device is in fully active mode.

Similarly, watchdog or software resets when a debug session is starting result in the debug session ending with errors.

To recover a part that is locked like this, mass erase the user flash.

To mass erase the user flash, take the following steps:

1. Put the device into boot mode by holding the S3 button down.
2. While holding S3 down, press and release the reset button, (S1).
3. The device is now locked in a while loop in the kernel space and does not execute user code.
4. In IAR, navigate to **Project > Download > Erase memory** (see Figure 29).
5. The window shown in Figure 30 appears. Press **OK**.

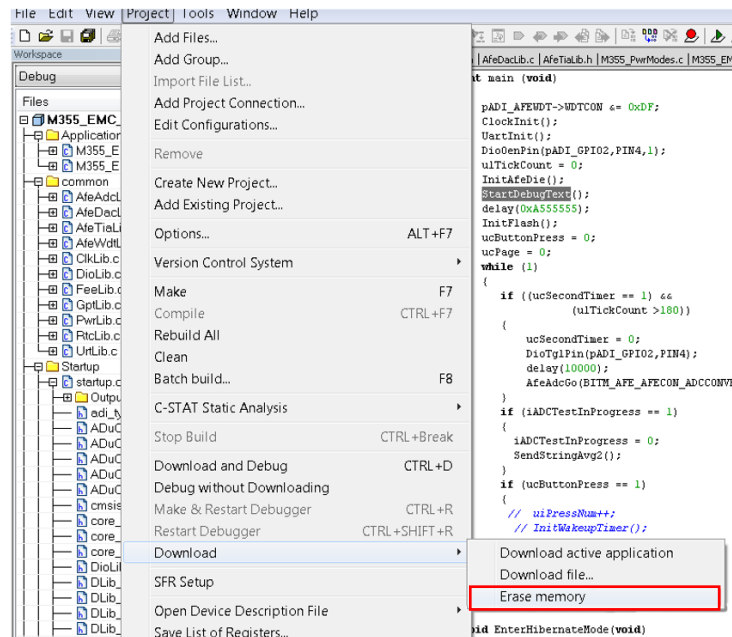


Figure 29. Embedded Workbench Erase Flash Memory Option

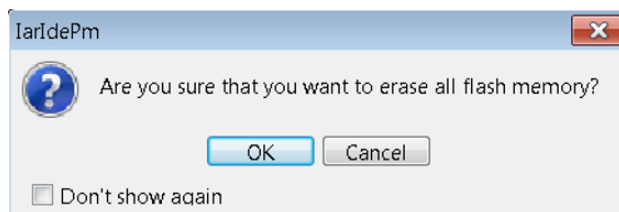


Figure 30. Erase All Flash Memory

## 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 NON-INFRINGEMENT 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.