EVAL-ADuCM355QSPZ Evaluation Board

UG-1308

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Evaluating the ADuCM355 Precision Analog Microcontroller with Chemical Sensor Interface

FEATURES

Debug and programming capability of the ADuCM355
Evaluation capability with electrochemical gas sensors
ADT7420 ±0.25°C accurate temperature sensor via I²C
MicroUSB power option and connection to PC

EQUIPMENT NEEDED

PC running Windows® 7 or later
Electrochemical gas sensor or resistor star network

DOCUMENTS NEEDED

ADuCM355 hardware reference manual
ADuCM355 data sheet

SOFTWARE NEEDED

IAR Embedded Workbench or Keil µVision
ADuCM355 GitHub Repository
Terminal program such as RealTerm

GENERAL DESCRIPTION

The ADuCM355 on-chip system provides the features needed to bias and to 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).

Complete specifications for the ADuCM355 are available in the ADuCM355 data sheet, which must be consulted in conjunction with this user guide when using the EVAL-ADuCM355QSPZ.

EVALUATION BOARD PHOTOGRAPH

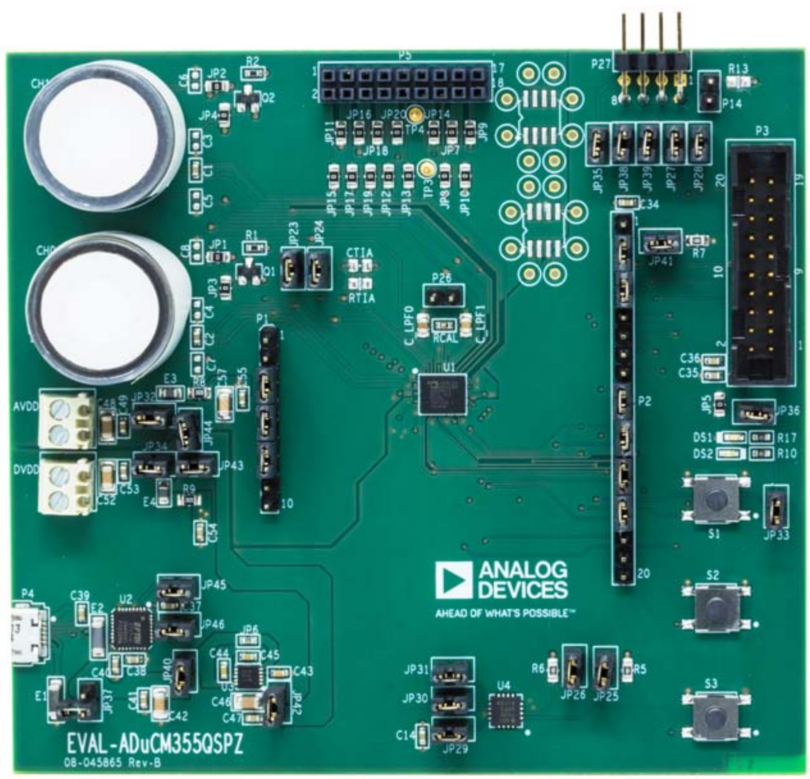

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Figure 1.

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REVISION HISTORY

4/2021—Rev. 0 to Rev. A

Changes to Features Section, Equipment Needed Section, Software Needed Section, and General Description Section ... 1
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Changes to Connecting an Electrochemical Sensor Section ... 7
Deleted Figure 8; Renumbered Sequentially ... 7
Changed Getting Started with the Tool Chain Section to Getting Started with the Tool Chain Section ... 8
Changes to Downloading the Integrated Development Environment (IDE) Section, Installing the ADuCM355 Support Package Section, Running a GPIO Example in IAR Embedded Workbench Section, and Project Folder Structure Section ... 8
Replaced Figure 9 ... 9
Changes to Compiling and Running Firmware Section and Figure 11 Caption ... 10
Replaced Figure 10 and Figure 12 ... 10
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Changes to Low Power TIA0/TIA1 Gain Resistor
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2/2019—Revision 0: Initial Version

POWER CONFIGURATIONS

This section describes the four different options to power the EVAL-ADuCM355QSPZ. The different power options include the following:

- Power via a microUSB connector, P4, and the on-board ADP7158 low dropout (LDO) regulator, which is the default power option.
- Connect 3.3 V to the AVDD and DVDD connectors. This setup is useful for measuring the current consumption of the EVAL-ADuCM355QSPZ via the current meter.
- Power via the 8-pin P27 debug header (a different USB connection option to the PC).
- Power via an external 5 V supply to the 2-pin JP37 connector. Optionally, an external 5 V supply can power the ADP7158 instead of the USB using this setup.

MicroUSB DIRECT POWER VIA P4 AND ADP7158 LDO REGULATOR

To power the EVAL-ADuCM355QSPZ via the P4 microUSB connector, take the following steps:

1. Ensure that the JP40 and JP42 to JP46 jumpers are inserted. These jumpers control the features shown in Table 1.
2. Remove the JP37 jumper.

Table 1. Jumper Connections

Jumper	Description
JP45 and JP46	Connect the UART pins from the ADuCM355 to the UART to USB transceiver chip (U2) (see Figure 3).
JP40	Connects the 5 V USB supply to the LDO input (U3) (see Figure 4).
JP42	Connects the 3.3 V LDO output to the EVAL-ADuCM355QSPZ power supply filters (see Figure 4).
JP43 and JP44	Connect the DVDD and AVDD rails to filters for the DVDD and AVDD analog supplies to the ADuCM355 (see Figure 4).

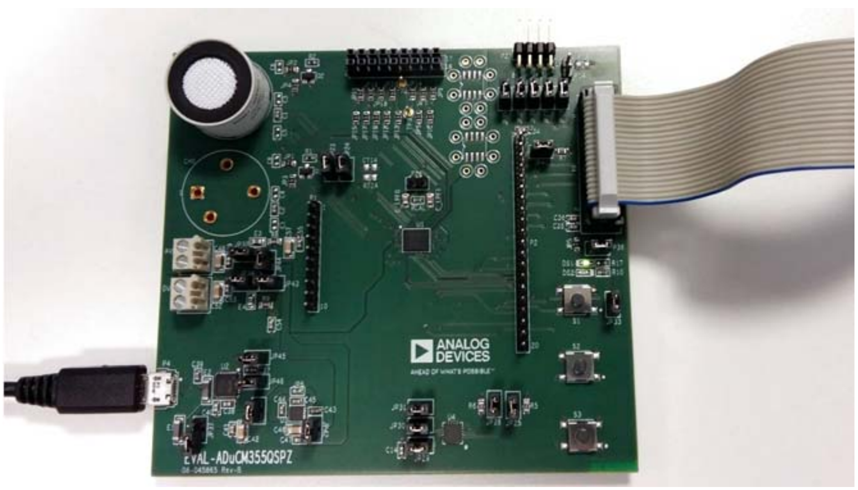

Figure 2. Direct Power via MicroUSB Cable

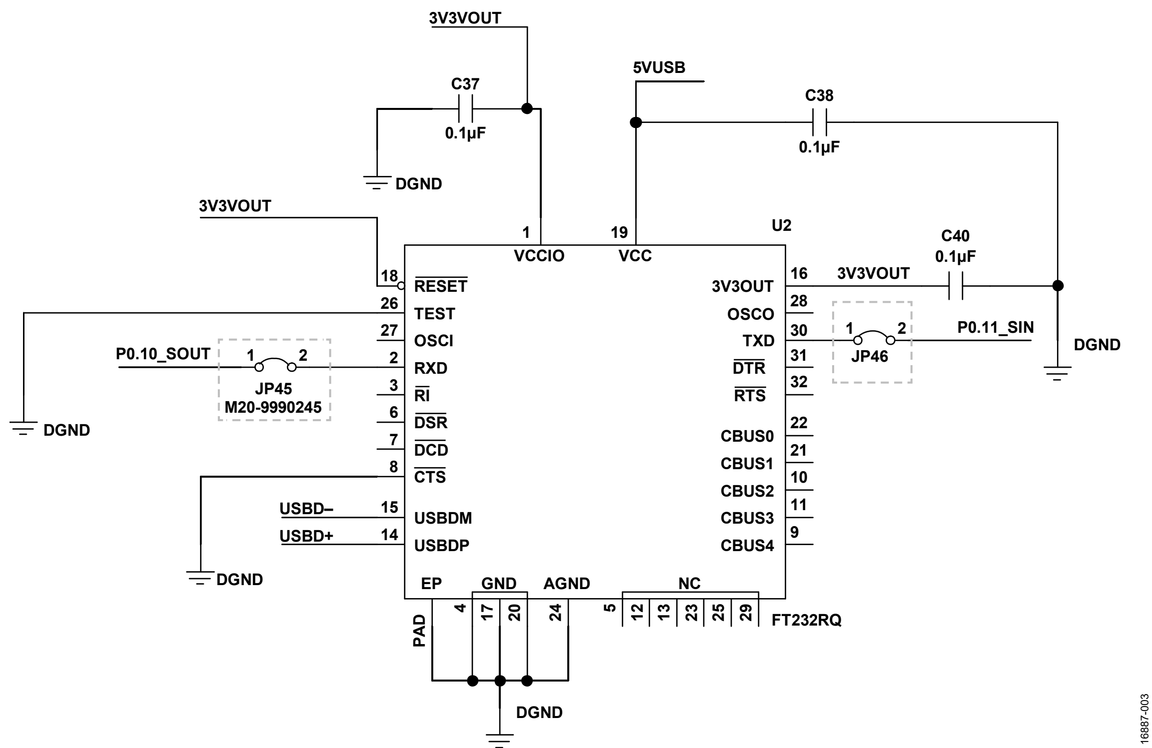

Figure 3. JP45 and JP46 Connect the ADuCM355 UART Pins to the USB Transceiver

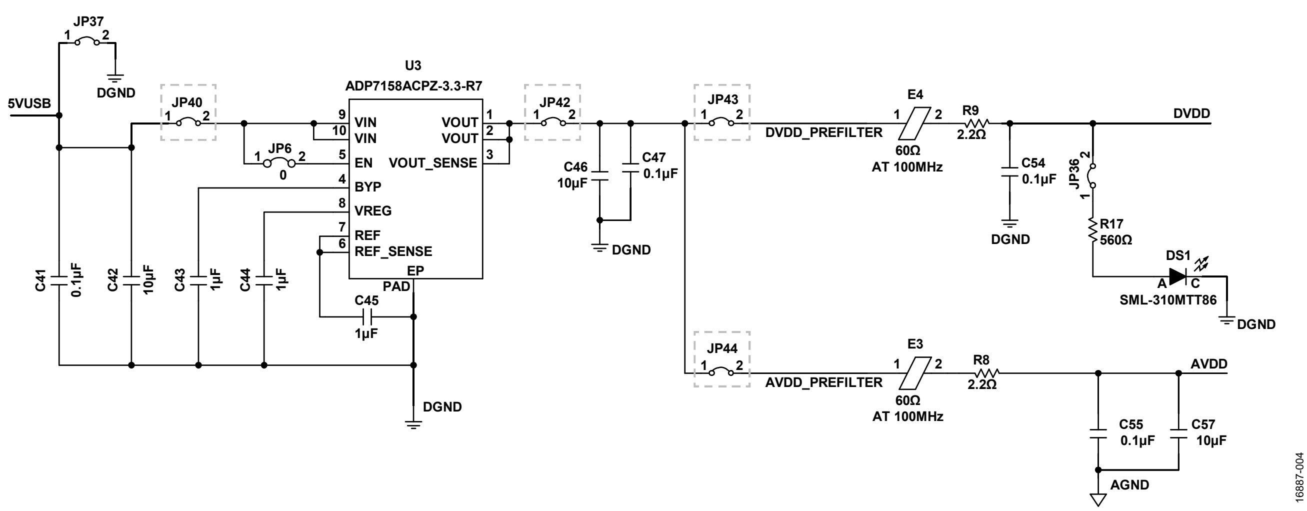

Figure 4. Schematic Section with Key Jumpers Around LDO and Power Supply

DIRECT 3.3 V POWER VIA THE AVDD AND DVDD CONNECTORS

To measure the ADuCM355 current consumption (I_{DD}), connect 3.3 V directly to the AVDD and DVDD connectors.

To power the EVAL-ADuCM355QSPZ in this case, apply a 3.3 V supply directly to Pin 1 on the AVDD connector and to Pin 1 on the DVDD connector.

Jumper Setup with Direct 3.3 V Connection

The jumper settings required when using a 3.3 V connection are as follows:

1. Insert JP32, JP34, JP43, and JP44.
2. Remove JP42.

For additional information, see Figure 6.

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

If using the older USB-SWD/UART and debug interface, the ADuCM355 can also be powered from the USB. The UART to USB interface is handled by the USB-SWD/UART-EMUZ board.

Jumper Setup with Power via USB

Close JP35, JP40, JP42, JP43, and JP44 when using power via the USB (see Figure 5).

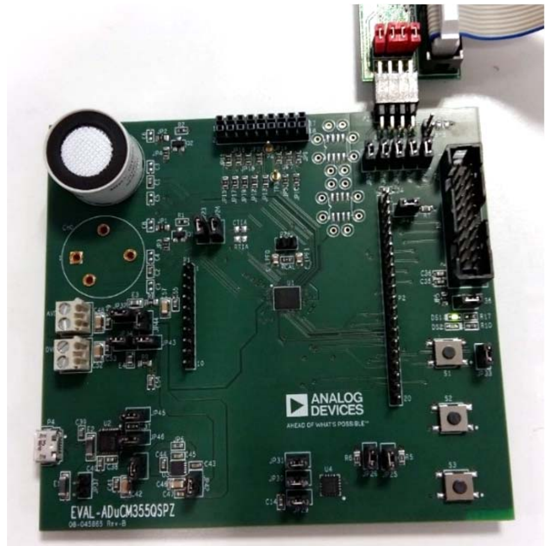

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Figure 5. Power via 8-Pin P27 Debug Connector

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

The last power supply option is to connect an external 5 V supply to the 2-pin P37 connector. This 5 V supply is the input to the ADP7158 LDO regulator that has a 3.3 V output voltage. Do not connect the microUSB cable to P4. This option is a debug or test option only.

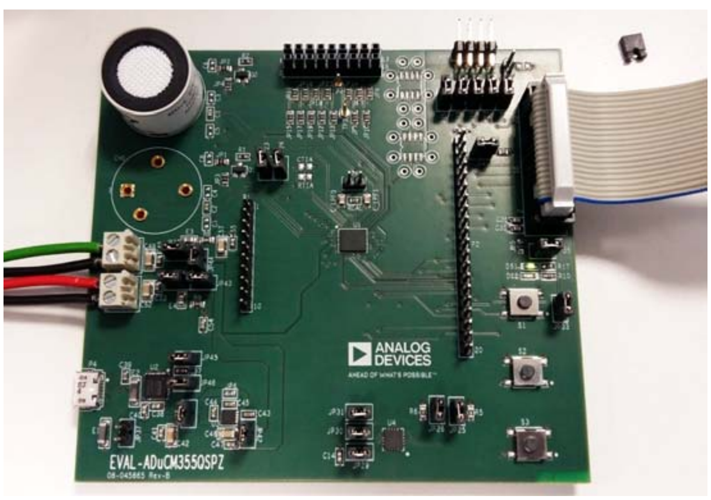

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Figure 6. Power DVDD and AVDD Directly via Power Header Blocks

CONNECTING AN ELECTROCHEMICAL SENSOR

The ADuCM355 has two measurement channels (CH0 and CH1) 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.

16887-007

Figure 7. Sensor Connector

GETTING STARTED WITH THE TOOL CHAIN

DOWNLOADING THE INTEGRATED DEVELOPMENT ENVIRONMENT (IDE)

The ADUCM355 firmware examples use either the IAR Embedded Workbench® or Keil µVision® IDEs to run the firmware. Ensure that a full or evaluation version of either software is downloaded and installed to run the example applications. IAR Embedded Workbench supports the ADUCM355 with Version 8.32.1 and later for ARM. Keil µVision supports Version 5.28 and later.

INSTALLING THE ADuCM355 SUPPORT PACKAGE

The ADUCM355 firmware examples are source controlled on www.GitHub.com. To clone the repository, execute the following command of the Git command line:

```
git clone --
recursive https://github.com/analogdevicesin
c/aducm355-examples.git
```

This command downloads the main repository and the submodules. If the code from the web browser downloads, the **examples/ad5940lib** folder does not download automatically and compilation errors occur. Download the code manually from GitHub in the shared library file that contains the ADUCM355 examples and the AD5940 example. Both devices have the same analog front end.

When using Keil µVision, the ADUCM355 device family pack can be downloaded as part of a Cortex® microcontroller software interface standard (CMSIS) pack. Download the pack from GitHub.

The sample firmware contains the following folders:

- The **common** folder contains all library files common to all applications.
- The **examples** folder contains specific example projects. This folder is divided into the following three subfolders:
- The **AnalogDie** folder contains example projects that demonstrate how to use specific blocks on the analog die.
- The **DigitalDie** folder contains examples that demonstrate how to use the digital die and peripherals such as SPI or I²C.
- The **ApplicationExamples** folder contains application level examples such as **M355_ECSns_DualWE**, which demonstrates how to configure a dual working electrode sensor and calculate gas parts per million (PPM) readings.
- The **inc** folder contains files included for the microprocessor.

RUNNING A GPIO EXAMPLE IN IAR EMBEDDED WORKBENCH

The ADUCM355 CMSIS pack is not supported for IAR Embedded Workbench. To use IAR Embedded Workbench, clone the repository from the GitHub directory, as described in the Installing the ADuCM355 Support Package section. To run the general-purpose input/output (GPIO) example, navigate to **examples** > **DigitalDie** > **M355_GPIO** > **iar**. Double click the **M355_GPIO.eww** file to open the project in the IAR Embedded Workbench (see Figure 8).

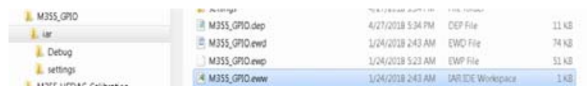

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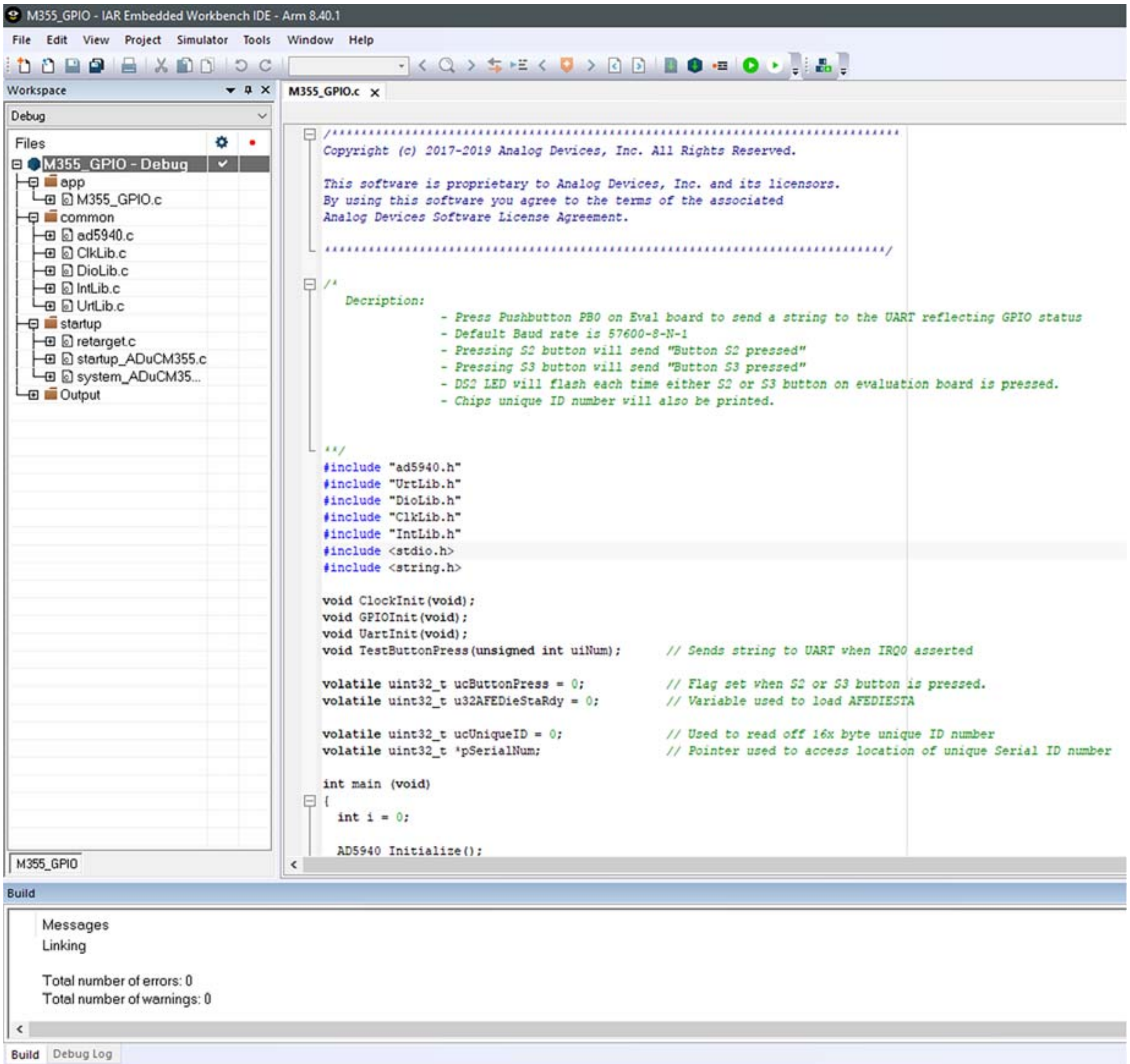
*Figure 8. **M355_GPIO.eww** File Location*

Project Folder Structure

The IAR Embedded Workbench project folder structure is shown to the left of the IAR Embedded Workbench window (see 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 **ad5940.c**, **ClkLib.c**, **DioLib.c**, **IntLib.c**, and **UrtLib.c**. The **startup** folder contains start-up files for the microprocessor, and the **Output** folder contains the files that are autogenerated by the IDE. All subsequent firmware examples follow this folder structure in the IAR Embedded Workbench.



16887-009

Figure 9. IAR Embedded Workbench

Compiling and Running Firmware

To compile and run the ADuCM355 firmware, take the following steps:

1. In the IAR Embedded Workbench window, navigate to **Project** > **Rebuild All** (see Figure 10).

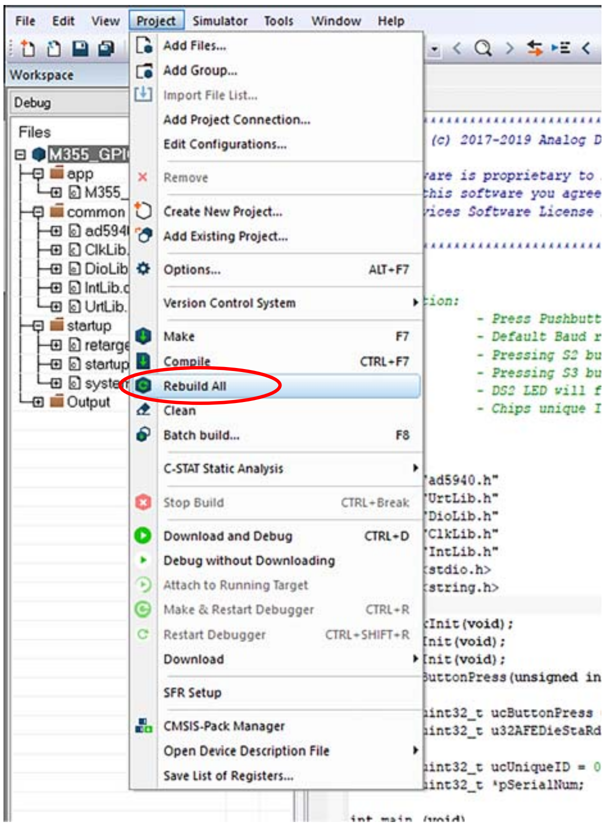


Figure 10. ***Project*** *>* ***Rebuild All***

2. Click **Rebuild All**. The IDE begins building the executable from the source files, which may take a couple of seconds. The message shown in Figure 11 appears in the **Build** window when the build is complete.

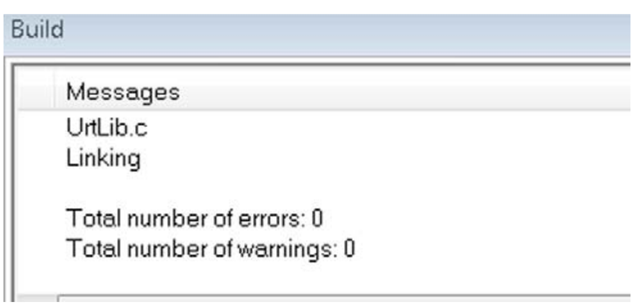


Figure 11. ***Build*** *Output Window*

3. To run the firmware on the ADuCM355, ensure that the EVAL-ADuCM355QSPZ is powered on and the J-Link debugger is connected to P3 on the EVAL-ADuCM355QSPZ, then click **Download and Debug** to load the firmware to the ADuCM355 and launch the debugger (see Figure 12). Launching and downloading the debugger can take a few seconds or more.

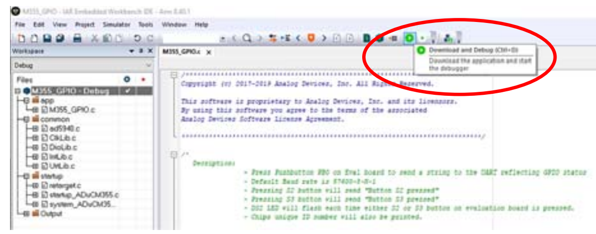


Figure 12. Launching the Debugger

4. Open a terminal program such as RealTerm to view the UART data from the ADuCM355 (see Figure 13). The baud rate is 230,400 bps.

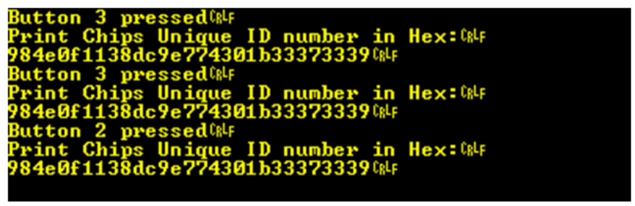


Figure 13. UART Data in RealTerm

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

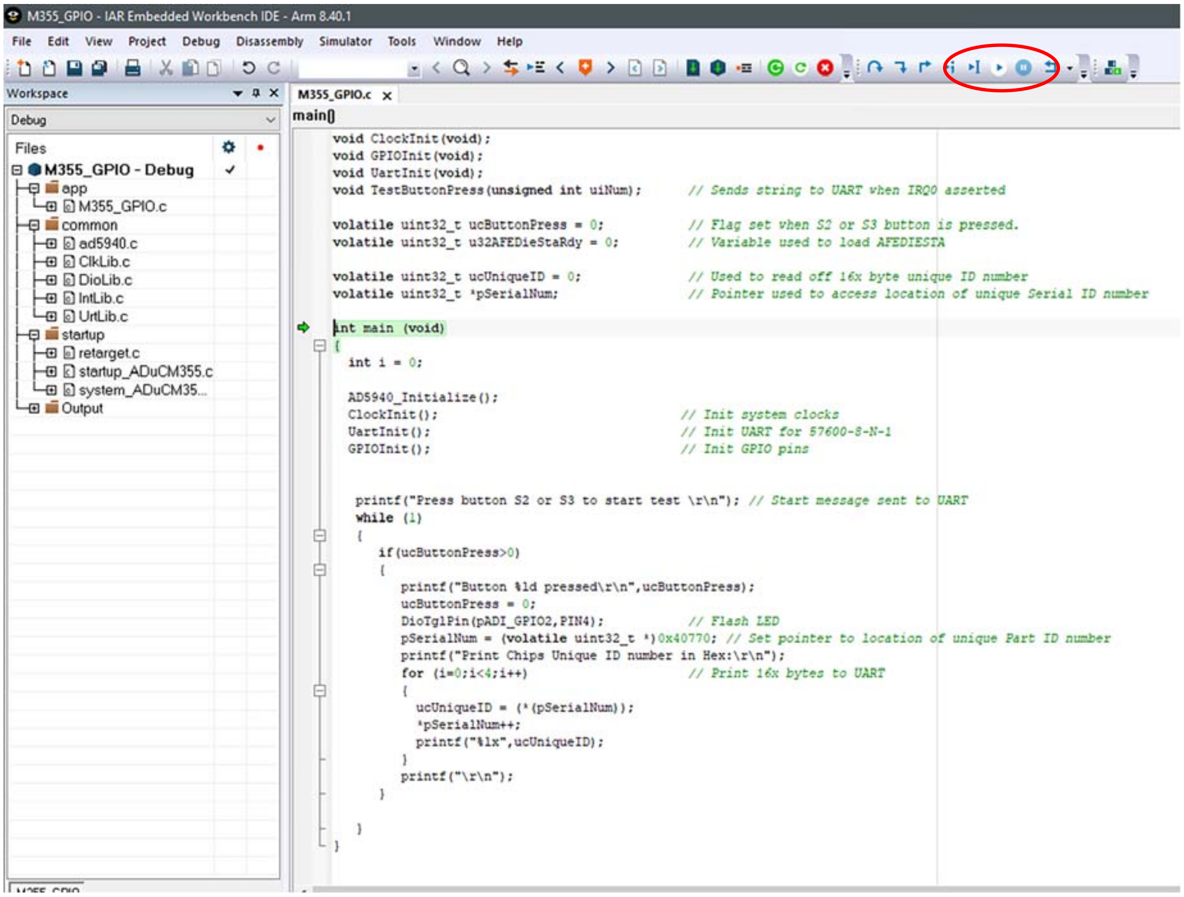


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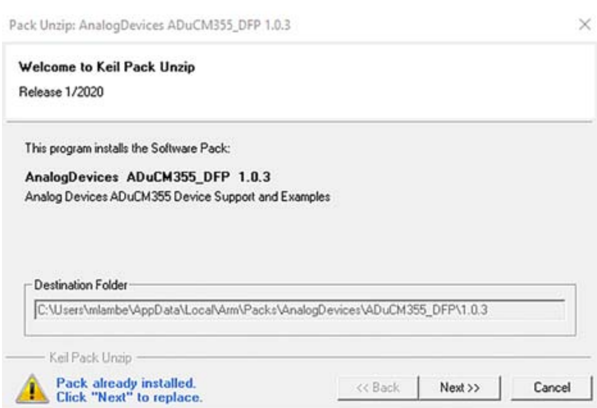
Figure 14. Debug Interface

RUNNING A GPIO EXAMPLE IN KEIL µVISION

To download the ADuCM355 device family pack for Keil µVision, visit the Keil website and search for MDK5 software packs. Save the **.pack** file to a directory on the PC. Double click the file to install the pack.



16887-215

Figure 15. ADuCM355 Pack Installer

Follow the on screen instructions to unzip the contents from the **.pack** file, and click **Finish** when complete. Open Keil µVision, and open the pack installer, as shown in Figure 16.

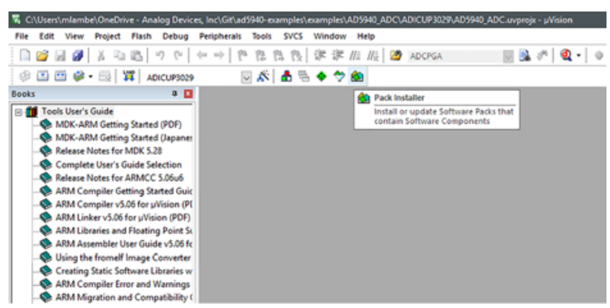


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Figure 16. Opening Pack Installer in Keil µVision

On the left side of the pack installer window, click the **Devices** tab and select the **ADuCM355**, as shown in Figure 17. On the right side of the pack installer window, click the **Examples** tab (see Figure 18). All supported example projects for the ADuCM355 display as shown in Figure 18.

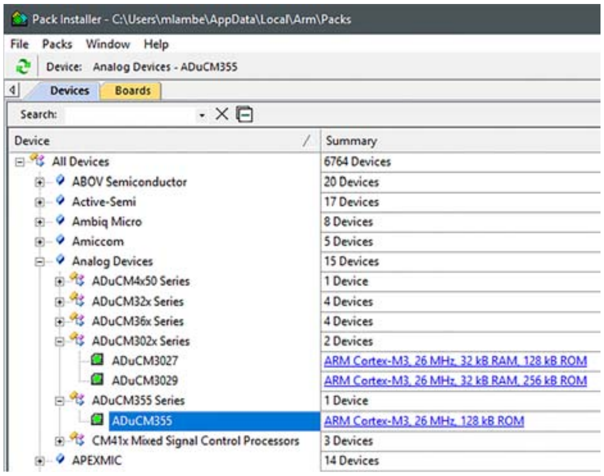

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Figure 17. Pack Installer Devices

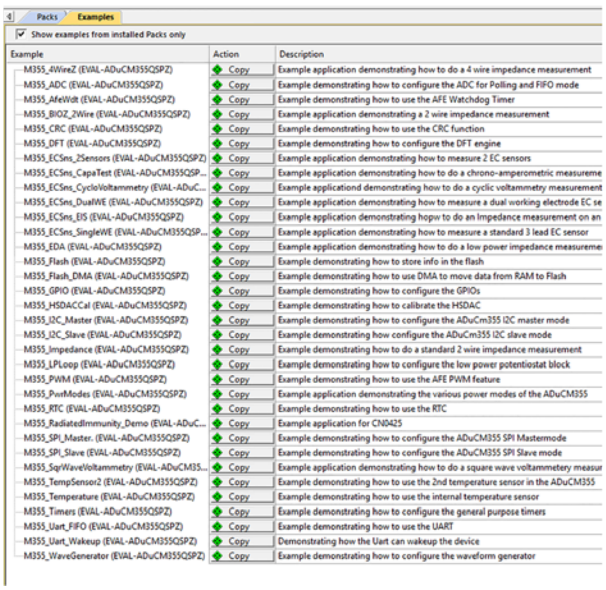
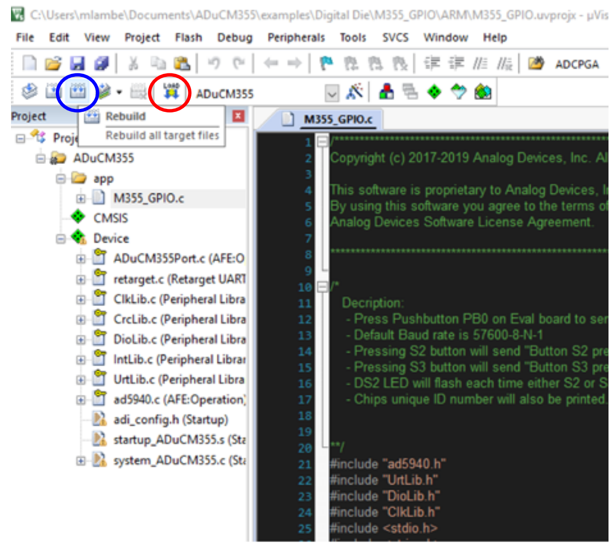

16887-218

Figure 18. ADuCM355 Examples

Find the **M355_GPIO (EVAL-ADuCM355QSPZ)** example, and then click the **Copy** button next to the example to copy the example project into a local directory and launch the project in Keil µVision. To compile and build the project, click the **Rebuild** icon shown in the blue circle in Figure 19. To load the code onto the ADuCM355, ensure that the EVAL-ADuCM355QSPZ is powered on and the mIDAS-Link debugger is connected, and then click the load icon shown in the red circle in Figure 19.



16887-219

Figure 19. Build and Load Project

APPLICATION EXAMPLES

This section describes how to use the ADuCM355 application examples that are part of the ADuCM355 software development kit (SDK). The ADuCM355 is a dual-die device that has a Cortex-M3 digital die and an analog front-end (AFE) die. The AFE die and the AD5940 are the same except for some differences in which pins are bonded out, and both devices share a common library interface to simplify firmware development. The main library files in the SDK are **AD5940.c** and **AD5940.h**. All functions in this library are compatible with the ADuCM355, AD5940, and AD5941. All AFE related function names begin with **AD5940_**. Some projects in the SDK have files labeled **AD5940Main.c**, which contain the upper controllers that control the AFE die and are mostly common between the ADuCM355, AD5940, and AD5941.

The Cyclic Voltammetry Example section outlines how to use the following example projects:

- M355_ECSns_CycloVoltammetry
- M355_ECSns_EIS
- M355_ECSns_CappaTest
- M355_ECSns_SingleWE
- M355_ECSns_DualWE
- M355_AfeWdt

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 reference electrode. Figure 20 shows a typical, stepped differential voltage between the reference and working electrodes of the sensor where V1 is the initial voltage on the reference electrode and V2 is the peak voltage on the reference electrode.

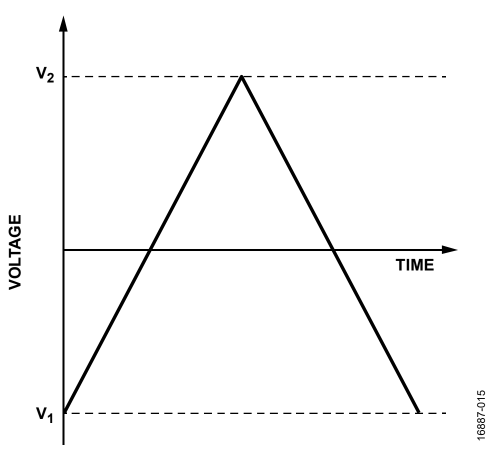


Figure 20. Typical Cyclic Voltammetry Waveform

In the ADuCM355 firmware package, the **M355_ECSns_CycloVoltammetry** project demonstrates how to implement a cyclic voltammetry measurement on the ADuCM355. There are two main files within the project, **AD5940Main.c** and **Ramp.c**. The **AD5940Main.c** file contains the upper controllers that control the high level application parameters. The **Ramp.c file** contains the low level device configuration for the cyclic voltammetry measurement.

Figure 21 shows the **AD5940RampStructInit (void)** function defined in the **AD5940Main.c** file. Modify the main parameters for the signal such as ramp start voltage, ramp peak voltage, and ramp duration for this function within this file.

```
void AD5940RampStructInit(void)
{
  AppRAMPCfg_Type *pRampCfg;

  AppRAMPGetCfg(&pRampCfg);

  pRampCfg->bParaChanged = bTRUE;
  /* Step1: configure general parmaters */
  pRampCfg->SeqStartAddr = 0x10;
  pRampCfg->MaxSeqLen = 1024-0x10;
  pRampCfg->RcalVal = 200.0;
  pRampCfg->ADCRefVolt = 1820.0f;
  pRampCfg->FifoThresh = 800;
  pRampCfg->SysClkFreq = 16000000.0f;
  pRampCfg->LFOSCClkFreq = LFOSCFreq;

/* Configure Current measurement channel */
  pRampCfg->LPTIARtiaSel = LPTIARTIA_200R;
  pRampCfg->LPTIARloadSel = LPTIARLOAD_SHORT;

  /* Configure ramp signal parameters */
  pRampCfg->RampStartVolt = -500.0f;
  pRampCfg->RampPeakVolt = +500.0f;
  pRampCfg->VzeroStart = 1300.0f;
  pRampCfg->VzeroPeak = 1300.0f;
  pRampCfg->StepNumber = 400;
  pRampCfg->RampDuration = 10*1000;
  pRampCfg->SampleDelay = 2.0f;
}
```

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Figure 21. Cyclic Voltammetry Parameters

To test the firmware, construct a dummy electrochemical cell using 1 kΩ resistors in a star network (see Figure 22). Connect each resistor network pin to the CE0, RE0, SE0, and DE0 pins on the P5 header. Ensure that the configurations are constructed as shown in Figure 22.

Figure 22. Resistor Star Network Connected to P5 Header

To begin measuring and gathering data, open a terminal program such as RealTerm. Configure the baud rate for 230,400 bps. Compile and build the project in the preferred IDE and load the code onto the ADuCM355. Run the measurement, and save the data to a **.csv** file for processing. If the definition of OPT_RAMP_MEAS (parameter defined in the **Ramp.h** file) is set to 1,the following four measurements are performed:

- Current through SE0.
- Voltage on SE0.
- Voltage on RE0.
- Current through SE0 measured a second time.

To plot the current response of the test, open the saved **.csv** file in Microsoft® Excel. Figure 23 shows the plotted response current.

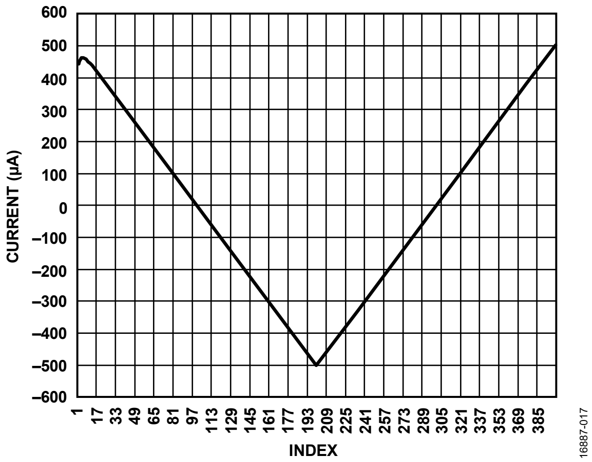

Figure 23. Example SE0 Channel Current Measurement

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

The EIS measurement process is as follows:

1. A signal is applied across R_{CAL}.
2. A signal is applied across R_{LOAD}.
3. A signal is applied across $Z_{SENSOR} + R_{LOAD}$.

In each step of the measurement processes, the measured current is input to the discrete Fourier transform (DFT) hardware accelerator that calculates the complex number of the current measurement and provides the real and imaginary parts. R_{CAL} is a precision resistor connected to the ADuCM355 RCAL0 and RCAL1 pins, R_{LOAD} is the internal load resistor on the SE0 path, and Z_{SENSOR} is the impedance under test.

Use the following equation to calculate the actual impedance:

$$Z_{SENSOR} = (Z_{SENSOR} + R_{LOAD}) - Z_{RLOAD}$$

where:
$Z_{SENSOR} + R_{LOAD}$ is the impedance of R_{SENSOR} and R_{LOAD} measured together as a single impedance.
Z_{RLOAD} is the impedance of R_{LOAD}.

Open the **M355_ECSns_EIS** example project in the preferred IDE. For the purpose of this initial test, a dummy electrochemical cell is used. Connect three 1 kΩ resistors in a star network, and connect the star network to the CE0, RE0, and SE0 pins on P5 of the EVAL-ADuCM355QSPZ (see Figure 22).

In the **AD5940Main.c** file, there are several configurable parameters that are shown in Figure 24. To couple the ac excitation signal on top of a dc bias, set the SensorCH0.SensorBias parameter. To apply a frequency sweep, modify the SweepCfg parameters.

```
/* Configure EC Sensor Parameters */
/*Sensor is connected to CH0 on EVAL-ADuCM355QSPZ */
pImpedanceCfg->SensorCh0.LpTiaRf = LPTIARF_1M;
pImpedanceCfg->SensorCh0.LpTiaRl = LPTIARLOAD_10R;
pImpedanceCfg->SensorCh0.LptiaRtiaSel = LPTIARTIA_200R;
pImpedanceCfg->SensorCh0.Vzero = 1100;
pImpedanceCfg->SensorCh0.SensorBias = 00;

/* Set switch matrix to connect to sensor in Ch0 for im
pImpedanceCfg->DswitchSel = SWD_CE0;
pImpedanceCfg->PswitchSel = SWP_RE0;
pImpedanceCfg->NswitchSel = SWN_SE0LOAD;
pImpedanceCfg->TswitchSel = SWT_SE0LOAD;

/* The dummy sensor is as low as 5kOhm. We need to make s
   small enough that HSTIA won't be saturated. */
pImpedanceCfg->HstiaRtiaSel = HSTIARTIA_200;

/* Configure the sweep function. */
pImpedanceCfg->SweepCfg.SweepEn = bFALSE;
pImpedanceCfg->SweepCfg.SweepStart = 1.0f;    /* Start :
pImpedanceCfg->SweepCfg.SweepStop = 100e3f;
pImpedanceCfg->SweepCfg.SweepPoints = 10;
pImpedanceCfg->SweepCfg.SweepLog = bTRUE;
/* Configure Power Mode. Use HP mode if frequency is hi
pImpedanceCfg->PwrMod = AFEPWR_LP;
/* Configure filters if necessary */
pImpedanceCfg->ADCSinc3Osr = ADCSINC3OSR_4;
pImpedanceCfg->DftNum = DFTNUM_16384;
pImpedanceCfg->DftSrc = DFTSRC_SINC3;
```

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Figure 24. EIS Parameters

To run the impedance measurement, take the following steps:

1. Launch the debugger in the IAR Embedded Workbench.
2. Open a terminal program with a 230,400 bps baud rate.
3. Execute the code.
4. A prompt to press the S2 switch is sent over the UART and displays in the terminal. Press S2 to begin the impedance test.
5. When the impedance measurement completes, the results are sent to the UART (see Figure 25). Save the results in a Microsoft Excel file for further analysis, if necessary.

```
This ADuCM355!
Note: Current Silicon is S2
AD5940LIB Version:v0.2.1
Freq:1000.00 RzMag: 994.150330 Ohm , RzPhase: 0.019261
Freq:2000.00 RzMag: 993.996521 Ohm , RzPhase: 0.084209
Freq:3000.00 RzMag: 994.096558 Ohm , RzPhase: 0.090480
Freq:4000.00 RzMag: 994.020447 Ohm , RzPhase: 0.136317
Freq:5000.00 RzMag: 993.997925 Ohm , RzPhase: 0.165386
Freq:6000.00 RzMag: 993.408569 Ohm , RzPhase: 0.193936
Freq:7000.00 RzMag: 994.222412 Ohm , RzPhase: 0.219638
Freq:8000.00 RzMag: 993.592529 Ohm , RzPhase: 0.240163
Freq:9000.00 RzMag: 994.125366 Ohm , RzPhase: 0.289740
Freq:10000.00 RzMag: 993.953674 Ohm , RzPhase: 0.324506
```

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Figure 25. 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 26 and Figure 27 show typical chronoamperometric measurement and sensor responses.

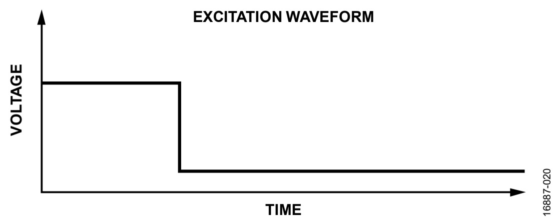

Figure 26. Typical Chronoamperometric Voltage Stimulus Waveform

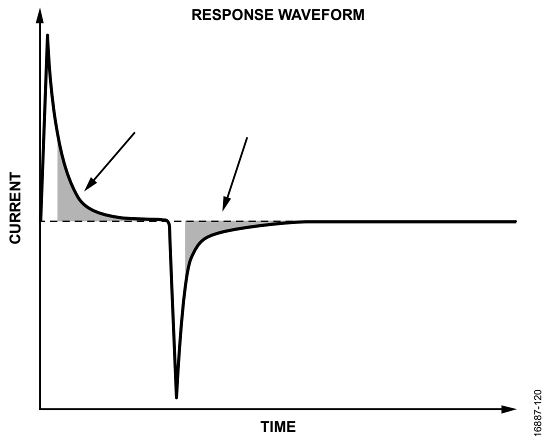

Figure 27. Typical Chronoamperometric Current Response Waveform

In the ADuCM355 firmware development package, the **M355_ ECSns_CapaTest** project implements a chronoamperometric measurement.

The **AD5940Main.c** file contains an **AD5940AMPStructInit**()function that modifies the main measurement parameters.

For the following example, only CH0 is used and all default values are used. The resistor star model is connected to P5, as per the examples described in the Cyclic Voltammetry Example section and the EIS Example section.

Load the project in the preferred IDE and open a terminal program. Compile and build the project and load the code onto the ADuCM355. Start the code execution and save the UART data to a **.csv** file for processing.

The example code sends the following three arrays of results to the UART at a 230,400 bps baud rate:

- The first set of values includes the current measurement results for the SE0 channel in µA.
- The next set of values includes the voltage measurement results for the SE0 channel in V.
- The final set of values includes the voltage measurement results for the RE0 channel in V.

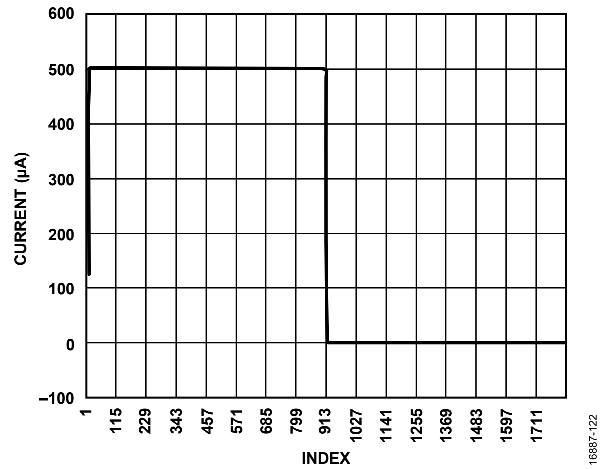

*Figure 28. Output Data Using the **M355_ECSns_Capatest** Example with Three 1 kΩ Resistors*

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 **M355_ECSns_ SingleWE** project implements a dc current measurement on an electrochemical cell connected to CH0. The measurement parameters can be configured in the **AD5940AMPStructInit()** function in the **AD5940Main.c** file. For testing purposes, connect the 1 kΩ resistor star network to P5. Set the **Vzero** firmware parameter to 1100 mV, and set the **SensorBias** firmware parameter to 500 mV to apply a 500 mV bias across the 1 kΩ resistor network. Ensure that the EVAL-ADuCM355QSPZ is powered on and that the debugger is connected to the PC. Then open the project in the preferred IDE, and compile and run the example application. Open a terminal program to view the results. The output is the current measured through the SE0 pin on P5 of the EVAL-ADuCM355QSPZ (see Figure 29).

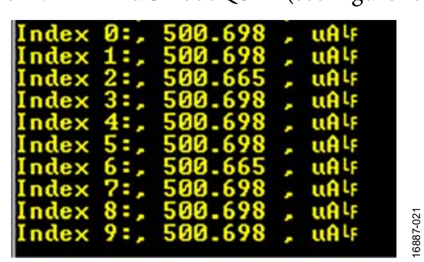

Figure 29. CH0 Output

4-LEAD ELECTROCHEMICAL SENSOR EXAMPLE

Many electrochemical sensors come in 4-lead packages that have a counter, a reference, and two sensing electrodes. The ADuCM355 supports biasing and measuring of these sensor types.

The **M355_ECSns_DualWE** example project configures the low power, potentiostat CH0 channel to bias the sensor. The current flowing to and from the SE0 pin is measured via the low power TIA Channel 0 (TIA0). The current flowing from the SE1 electrode is measured via the low power TIA Channel 1 (TIA1).

The TIA amplifiers convert the current to a voltage that is measured via the analog-to-digital converter (ADC), and the source code calculates the current flowing in each electrode.

The **M355_ECSns_DualWE** code example project is located in the **examples** folder.

Figure 30 shows the configurable parameters located in the **AD5940Main.c** file. Modify the value of the correct LpTiaRtiaSel parameter for each channel based on the maximum expected current.

Figure 31 shows the connection details between the 4-lead sensor and the ADuCM355.

```
/* Configure CH0 Parameters */
pAmpCfg->SensorCh0.LpTiaRf = LPTIARF_1M;
pAmpCfg->SensorCh0.LpTiaRl = LPTIARLOAD_10R;
pAmpCfg->SensorCh0.LptiaRtiaSel = LPTIARTIA_10K;
pAmpCfg->SensorCh0.Vzero = 1110;
pAmpCfg->SensorCh0.SensorBias = 0;

/* Configure CH1 measurement parameters */
pAmpCfg->SensorCh1.LpTiaRf = LPTIARF_1M;
pAmpCfg->SensorCh1.LpTiaRl = LPTIARLOAD_10R;
pAmpCfg->SensorCh1.LptiaRtiaSel = LPTIARTIA_96K;
```

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Figure 30. Dual Working Electrode Configuration

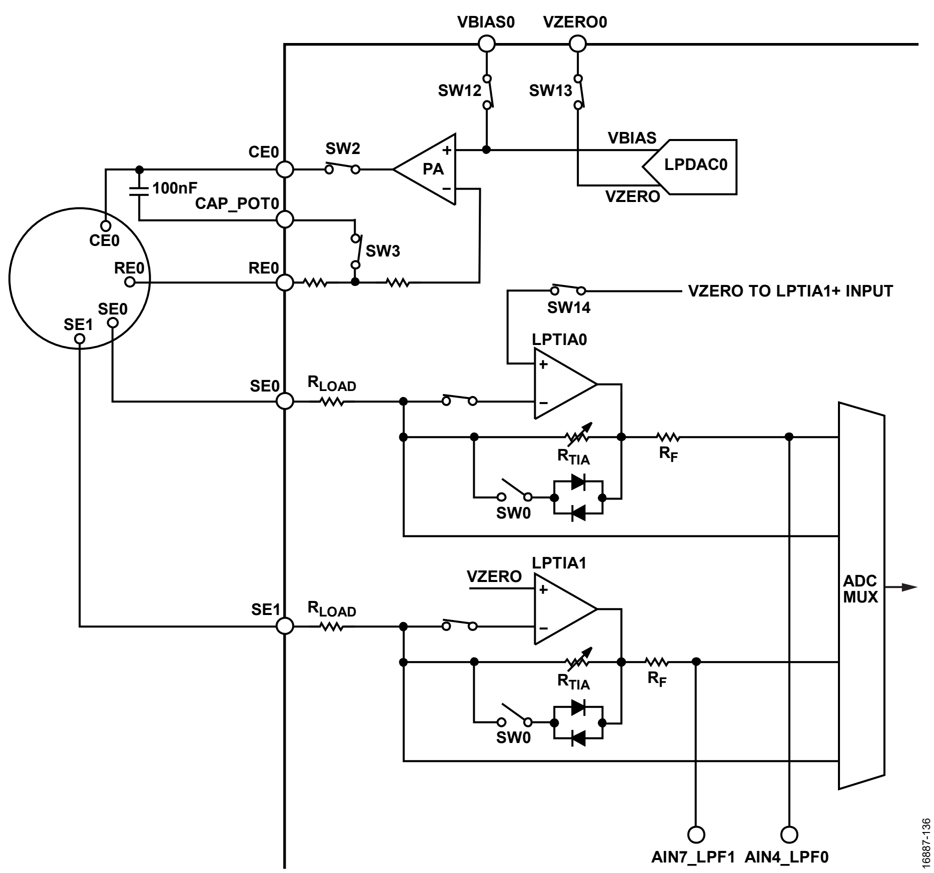

Figure 31. Circuit Setup for 4-Lead, Dual Gas Detection Sensor

CONNECTING AN EXTERNAL GAIN RESISTOR ACROSS THE HIGH SPEED TIA

The internal high speed TIA has a programmable gain resistor that allows the user to either configure a high speed current measurement channel for different input current ranges, or to connect an external gain resistor instead.

The EVAL-ADuCM355QSPZ supports the connection of an external transimpedance amplifier resistor (R_{TIA}) across the AIN0 pin and DE0 pin, which is labeled RTIA on the top side of the printed circuit board (PCB).

The current flows from the AIN0 pin into the high speed TIA inverting input with the HSTIA connected to the DE0 pin.

The ADC selects the HPTIA_P and HPTIA_N input channels to measure the voltage drop across the external R_{TIA} resistor (see Figure 32).

When the user populates the external gain resistor, the gain resistor can be used instead of the internal gain resistor. Figure 32 shows the external resistor connected to AIN0 and DE0. Note that R_{LOAD_03} and R_{TIA2_03} are set to 0 Ω so as not to effect the measurement.

The **M355_ExternalRTIA** code example project in the **examples** folder demonstrates how to set up the high speed TIA for an external gain resistor.

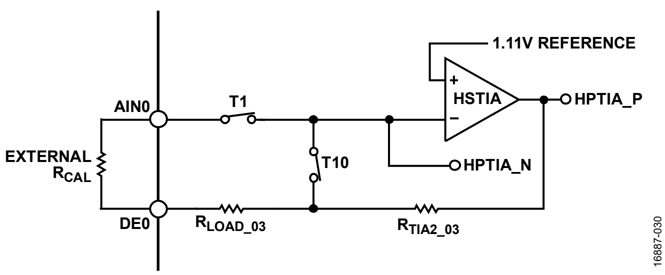

Figure 32. ADuCM355 External R_{TIA} Connection to the High Speed TIA

AFE DIE WATCHDOG TIMER EXAMPLE

The ADuCM355 supports a watchdog timer on the AFE die. The watchdog timer clocks via an oscillator that is completely independent of the clocks in the Cortex-M3 core. Therefore, the watchdog timer meets the IEC 61508 requirement of an independent watchdog timer for a microcontroller and eliminates the need for an external watchdog timer chip.

The **M355_AfeWdt** code example project in the **examples** folder shows how to configure the windowed watchdog mode.

The WDT_INTERRUPT_EN #define parameter configures the project to generate either a reset or an interrupt.

The project uses a default timeout period of 16 sec. A minimum waiting period of 4 sec is required before a watchdog refresh is allowed. Refreshing the watchdog within 4 sec causes a reset or interrupt to occur depending on the setting of Bit 1 of the WDTCON register. If the timeout period elapses, a reset or interrupt also occurs. To avoid a reset or interrupt generation, refresh the watchdog timer within the minimum period of 4 sec and the timeout period of 16 sec.

The watchdog timer refresh is triggered when the ASCII Character 1 is sent from the PC.

ADUCM355 SYSTEM CALIBRATION

Because of the complexity of the ADuCM355 and the large number of voltage and current measurement channels on the device, many calibration routines are implemented to ensure a high level of measurement accuracy. This section describes the main calibration functions with links to further online information.

HIGH SPEED TIA GAIN RESISTOR CALIBRATION

The high speed TIA has three different programmable gain resistor options.

Adjust the gain resistors to convert the current from the SE0, SE1, and DE0 inputs or from the DE1 input to a differential voltage across the R_{TIA2} resistor, R_{TIA2_03} resistor, or R_{TIA2_05} resistor.

The R_{TIA2}, R_{TIA2_03}, and R_{TIA2_05} resistors have an initial accuracy range and vary with temperature, as specified in the ADuCM355 data sheet where R_{TIA2} is the HPTIA R_{TIA} gain resistor on the SE0 and SE1 inputs, and R_{TIA_02} and R_{TIA_05} correspond to the HPTIA R_{TIA} gain on the DE0 and DE1 inputs.

If the high speed TIA is uncalibrated for the selected gain resistor and the ADC programmable gain amplifier (PGA) setting, an error is present when measuring an absolute input current.

To generate a precision calibration current, use the high speed DAC to create a differential voltage across an external precision R_{CAL} resistor that is connected to the ADuCM355 RCAL0 pin and RCAL1 pin. The precision calibration current can be routed through any of the three high speed TIA gain resistors.

Because the calibration current value is known and the ADC can measure the voltage drop across the R_{TIA2}, R_{TIA2_03}, and R_{TIA2_05} resistors, the exact R_{TIA} resistor value can be determined.

Figure 33 to Figure 35 show the setup and switch settings that connect the high speed DAC output to the external R_{CAL} resistor so that the current flows into the high speed TIA and R_{TIA2}, R_{TIA2_03}, and R_{TIA2_05} gain resistors, respectively.

The **AD5940.c** file has a function that calibrates each gain resistor for the HSTIA. For further details on how to use this function, visit https://wiki.analog.com/resources/eval/user-guides/eval-ad5940/calibration_routines/hstia_cal?doc=EVAL-ADuCM355QSPZ-UG-1308.PDF.

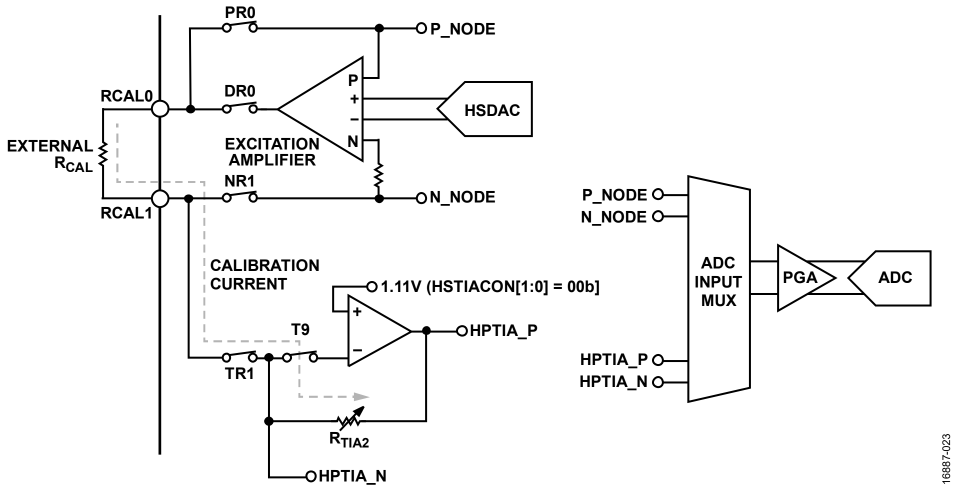

Figure 33. High Speed DAC, High Speed TIA, and Switch Matrix Settings for R_{TIA2} Calibration

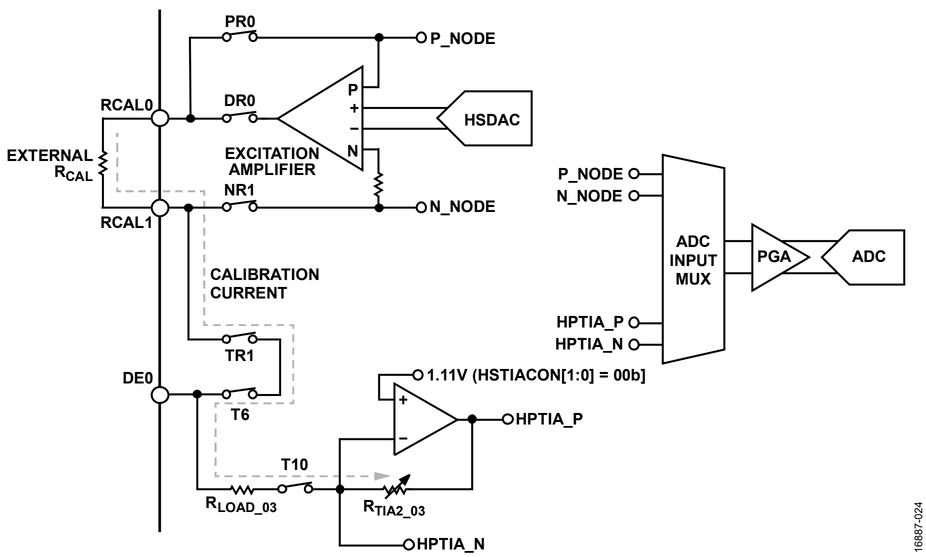

Figure 34. High Speed DAC, High Speed TIA, and Switch Matrix Settings for R_{TIA2_03} Calibration

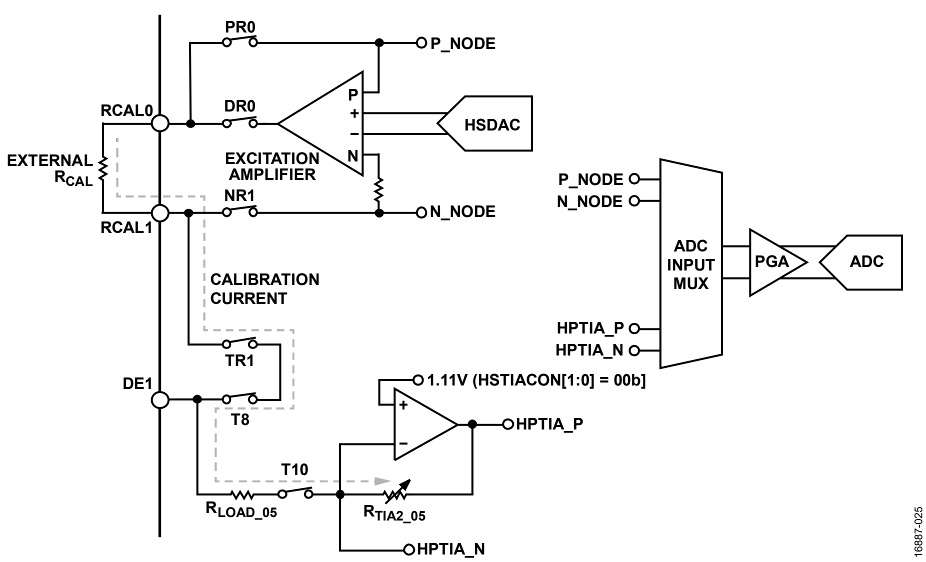

Figure 35. High Speed DAC, High Speed TIA, and Switch Matrix Settings for R_{TIA2_05} Calibration

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.

Figure 36 shows the gain resistor for the low power TIA0. A similar diagram is valid to use for the low power TIA1.

Similar to the example described in the High Speed TIA Gain Resistor Calibration section, adjust the gain resistor to convert the current from the SE0 input pin and the SE1 input pin to a differential voltage across the R_{TIA} resistors.

These resistors have an initial accuracy range and vary with temperature, as specified in the ADuCM355 data sheet.

When these resistors are uncalibrated, an error is present when measuring an absolute input current.

To generate a precision calibration current, use the low power DAC to create a differential voltage across an external precision R_{CAL} resistor that is connected to the ADuCM355 RCAL0 pin and RCAL1 pin. The precision calibration current is routed through either the low power TIA0 gain resistor or the low power TIA1 gain resistor.

Because the calibration current value is known and the ADC can measure the voltage drop across each R_{TIA} resistor, the exact R_{TIA} resistor value can be determined.

Figure 37 and Figure 38 show the setup and switch settings used to connect the low power DAC outputs to the external R_{CAL} resistor so that the current flows into the LPTIAx gain resistors, LPRTIAx.

Several example projects in the ADuCM355 SDK implement a function to calibrate the gain resistor. For further details on how to use this function, visit https://wiki.analog.com/resources/eval/user-guides/eval-ad5940/calibration_routines/lptia_cal?doc=EVAL-ADuCM355QSPZ-UG-1308.PDF.

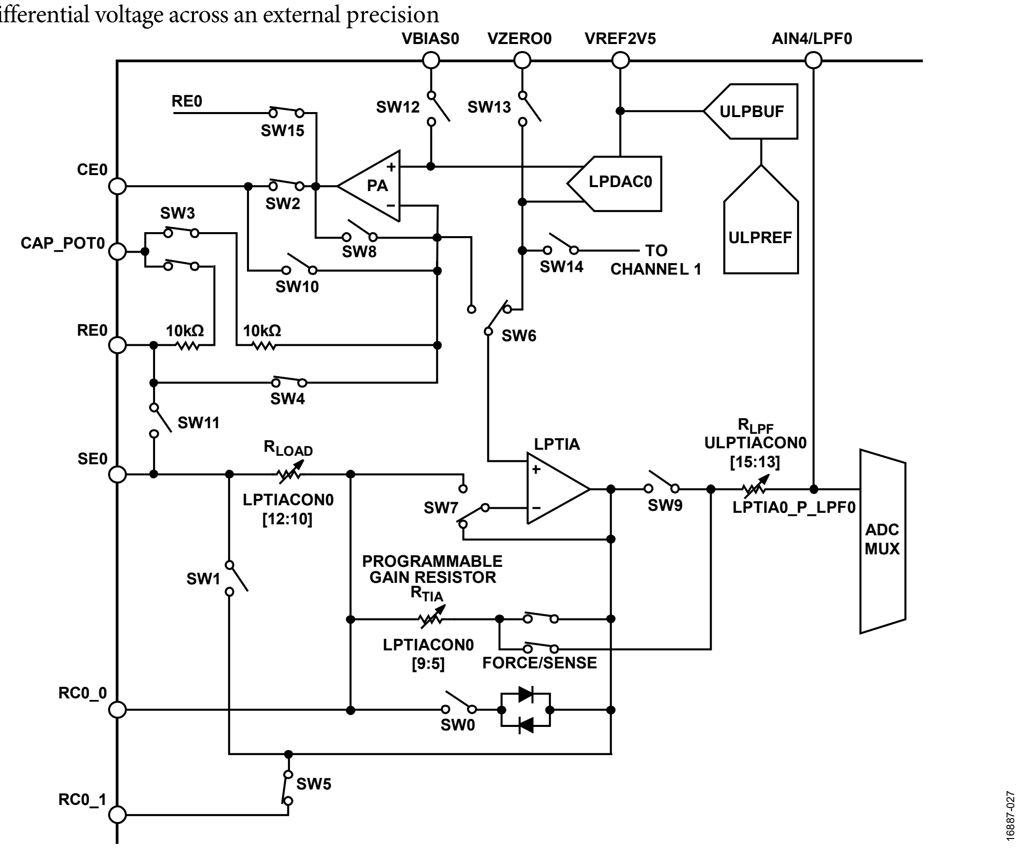

Figure 36. LPTIA0 Gain Calibration Resistor

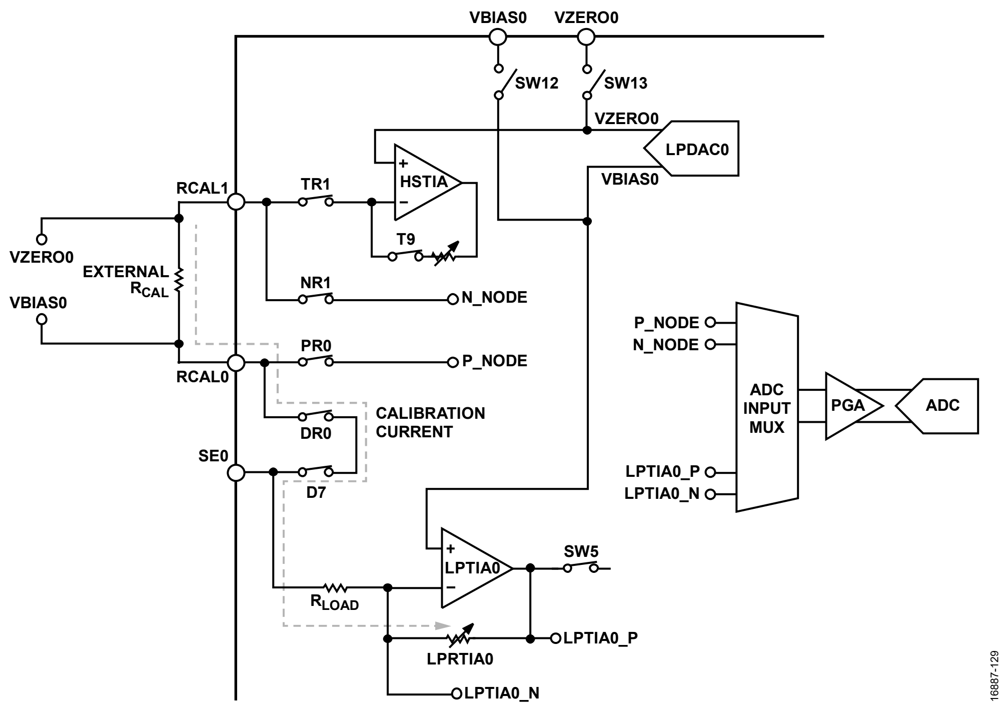

Figure 37. High Speed TIA, Low Power TIA0, and Switch Matrix Settings for LPRTIA0 Resistor Calibration

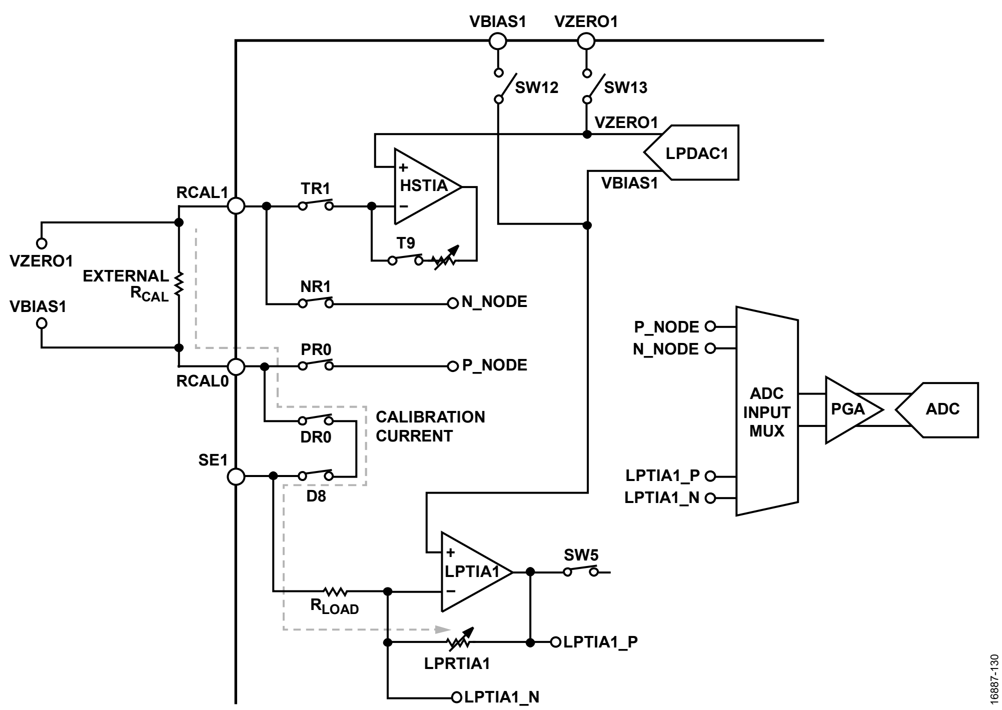

Figure 38. High Speed TIA, Low Power TIA0, and Switch Matrix Settings for LPRTIA1 Resistor Calibration

MASS ERASING A DEVICE NOT RESPONDING TO SWD COMMANDS

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

Similarly, watchdog or software resets that occur when a debug session starts cause the debug session to end with errors.

To recover a device that is locked in this way, mass erase the user flash.

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

1. Hold the S3 button down to place the device in boot mode.
2. While holding the S3 button down, press and release the reset button (S1) to lock the device in a loop in the kernel space so that the device does not execute user code.
3. In the IAR Embedded Workbench, navigate to **Project** > **Download** > **Erase memory** (see Figure 39).
4. The window shown in Figure 40 opens. Click **OK**.

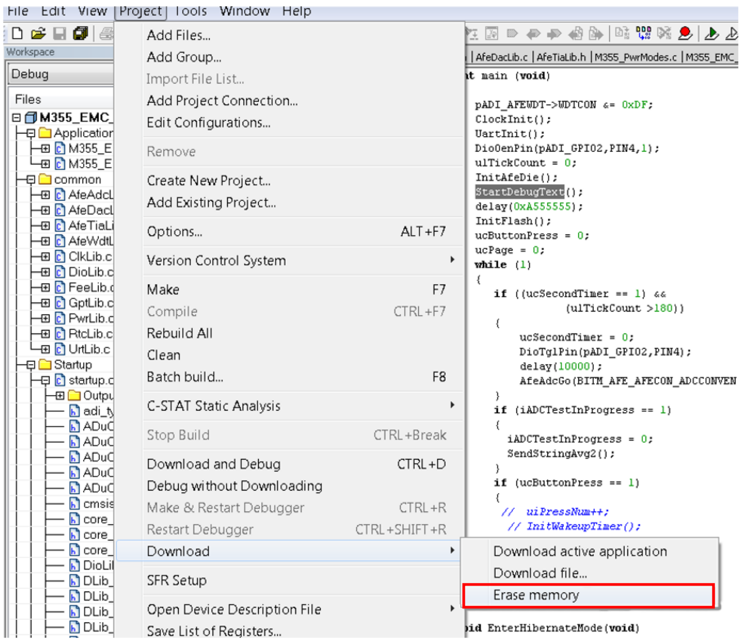

Figure 39. IAR Embedded Workbench Erase Flash Memory Option

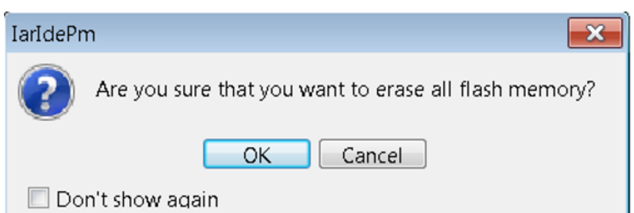

Figure 40. Erase All Flash Memory

ORDERING INFORMATION

To view the complete EVAL-ADuCM355QSPZ schematic, visit https://www.analog.com/media/en/technical-documentation/evaluation-documentation/EVAL-ADuCM355-RevBSchematic.pdf.

To view the PCB layout, visit https://www.analog.com/media/en/technical-documentation/evaluation-documentation/EVAL-ADuCM355-EvalBrd_Layout.pdf.

BILL OF MATERIALS

Table 2.

Name	Value	Part Description	Manufacturer	Part No.
AVDD, DVDD	25.195.0253.0	Connector PCB terminal block 3.5 mm	Wieland Electric GMBH	25.195.0253.0
C1, C2, C14, C34, C35, C36	0.1 µF	Ceramic capacitor, X7R	Wurth Elektronik	8.85012E+11
C9 to C12, C17 to C21, C28, C29	0.1 µF	Ceramic capacitor, X5R, ultrabroadband	American Technical Ceramics	545L104KT10C
C13	220 pF	Ceramic capacitor, X7R	Kemet	C0402C221J5RACTU
C23, C25 to C27, C30, C31	0.47 µF	Ceramic capacitor, X5R, 0402	Taiyo Yuden	LMK105BJ474KV-F
C24	4.7 µF	Ceramic capacitor, X6S, general-purpose	Murata	GRM185C81A475KE11D
C32, C33	7 pF	Ceramic capacitor NP0 (C0G), high frequency, high-Q	Murata	GJM1555C1H7R0CB01D
C37 to C41, C47, C49, C53 to C55	0.1 µF	Ceramic chip capacitor, X8R	TDK	C1608X8R1E104K080AA
C42, C46, C48, C52, C57	10 µF	Tanceram® chip capacitor, X5R, low equivalent series resistance (ESR)	Johanson Dielectrics	250R18X106KV4E
C43 to C45	1 µF	Ceramic capacitor, Y5V	Yageo	CC0603ZRY5V6BB105
CH0, CH1	CO-A4	4-lead electrochemical sensor socket	Alphasense	CO-A4
C_LPF0, C_LPF1	4.7 µF	Ceramic capacitor, 0805, X5R	Taiyo Yuden	EMK212BJ475KG-T
DS1	SML-310MTT86	LED, green surface mount	ROHM	SML-310MTT86
DS2	LNJ926W8CRA	LED, blue surface mount	Panasonic	LNJ926W8CRA
E1, E2	80 Ω at 100 MHz	Ferrite bead, 0.1 Ω maximum dc resistance, 1 A	Murata Manufacturing	BLM41PF800SN1L
E3, E4	60 Ω at 100 MHz	Inductor chip ferrite, 0.02 Ω dc resistance, 3.5 A	Murata	BLM21PG600SN1D
JP4, JP5, JP7 to JP20	0	Resistance jumper	Panasonic	ERJ-6GEY0R00V
JP25 to JP36, JP38 to JP46	M20-9990245	Connector PCB, straight male jumper, 2-position, M020779	Harwin	M20-9990245
JP6	0	Use existing E004447	Panasonic	ERJ-3GSYJ0.0
P1	TSW-110-08-G-S	Connector PCB, straight header 10-position	Samtec	TSW-110-08-G-S
P14, P26	TSW-101-07-G-D	Connector PCB, dual straight header, 2-position	Samtec	TSW-101-07-G-D
P2	TSW-120-07-S-S	Connector PCB, 20-position, unshrouded male header, 0.64 mm square post, 2.5 4 mm pitch, 5.84 mm post height, 2.54 mm solder tail	Samtec	TSW-120-07-S-S
P27	TSW-104-25-F-D-RA	Connector PCB header, 2.54 mm square post, dual row, right angle	Samtec	TSW-104-25-F-D-RA
P3	2520-6002-UB	Connector PCB header, straight male, 20-position	3M	2520-6002UB
P4	47346-0001	Connector PCB microUSB receptacle	Molex	47346-0001
P5	IPS1-109-01-L-D	Connector PCB, 18-position, female header, shrouded dual row, straight, 2.54 mm solder tail, 2.54 mm pitch	Samtec	IPS1-109-01-L-D
Q1, Q2	MMBFJ177	Precision channel junction field effect transistor (JFET) switch	Fairchild Semiconductor	MMBFJ177
R1, R2	150 kΩ	Precision thick film chip resistor, R0603	Panasonic	ERJ-3EKF1503V
R10, R17	560 Ω	Thick film chip resistor	Multicomp (SPC)	MC0063W06031560R
R14	0 Ω	Thick film chip resistor	Multicomp (SPC)	MC00625W040210R

Name	Value	Part Description	Manufacturer	Part No.
R15, R16	100 kΩ	General-purpose chip resistor	Yageo	RC0603JR-07100KL
R3, R4	100 kΩ	Precision thick film chip resistor	Panasonic	ERJ-6ENF1003V
R5, R6, R7	1 kΩ	Precision thick film chip resistor	Panasonic	ERJ-6ENF1001V
R8, R9	2.2 Ω	Thick film chip resistor	Vishay	CRCW08052R20FKEAHP
RCAL	200 Ω	Precision, ultrathin film chip resistor	Susumu Co, LTD	RG1608N-201-W-T1
S1, S2, S3	B3S-1000	Surface-mount mechanical key switch	OMRON	B3S1000
TP3, TP4	31022-00-21-00-00-08-0	Connector PCB pin receptacle	Mill-Max	3102-2-00-21-00-00-08-0
U1	ADUCM355BCCZ	IC precision, analog and electrochemical sensor microcontroller	Analog Devices, Inc.	ADuCM355BCCZ
U2	FT232RQ	IC USB serial UART	FTDI Chip	FT232RQ
U3	ADP7158ACPZ-3.3-R7	IC, 2 A, ultralow noise, high power supply rejection ratio (PSRR), RF linear regulator, 3.3 V V_{OUT}	Analog Devices	ADP7158ACPZ-3.3-R7
U4	ADT7420UCPZ-RL7	IC, 16-bit, digital I^2C temperature sensor	Analog Devices	ADT7420UCPZ-RL7
Y1	32 MHz	IC, crystal, ultramini size, low profile, 8 pF	Epson Toyocom	FA-128, 32MHZ, 10PPM, 8PF

I^2C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

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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