UM11565

NAFExx388 evaluation board

Rev. 3 — 9 August 2023 User manual

Document information

Information	Content
Keywords	NAFE11388, NAFE71388, NAFE13388, NAFE73388, analog front-end, ADC, RTD, thermocouple, universal analog input AFE, PLC, industrial process control systems, 4 mA - 20 mA current loop, 0 V - 10 V input
Abstract	The NAFExx388 evaluation board is easy to test and design for the NAFE11388, NAFE71388, NAFE13388, and NAFE73388, which is a highly configurable, industrial-grade multichannel analog input analog front-end (AFE) that meets high-precision measurement requirements. The device is composed of a low-leakage, high-voltage multiplexer, low-offset drift buffers, a low noise and drift PGA, a precision 24-bit sigma-delta analog-to-digital converter (ADC), low-drift voltage reference. This evaluation board, along with the LPC54628 MCU board, provide an easy-to-use evaluation platform.

Revision history

Rev	Date	Description
v.3	20230809	• Updated grammar and style • Updated Legal information • Added text "The schematic (in pdf) can be launched from the GUI as described in Section 7.4.1." to Section 6 • Added Section 7.4.1, Section 7.6, Section 7.6.1, Section 7.6.2, and Section 7.6.3
v.2	20230614	• Updated Keywords on Page 1 • Minor update to first and second full paragraphs of Section 1 • Section 3.1: Updated list • Section 4.2: Updated list • Table 3: Jumper settings for external power supply (+3.75 V, +15.4 V, -15.4 V): Updated all "Jumper" entries. – From "J78A pin 1 – J78B pin 1" to "J78A pin 1 – J78A pin 2" – From "J78A pin 2 – J78B pin 2" to "J78B pin 1 – J78B pin 2" – From "J78A pin 3 – J78B pin 3" to "J78C pin 3 – J78C pin 2" • Table 4: Jumper settings for AC-DC adapter/transformer power supply (+3.75 V, +15.4 V, -15.4 V): Added second footnote beginning "NXP strongly advises against …"; updated all "Jumper" entries – From "J78B pin 1 – J78C pin 1" to "J78B pin 2 – J78C pin 3" – From "J78B pin 2 – J78C pin 2" to "J78B pin 2 – J78C pin 3" – From "J78B pin 3 – J78C pin 3" to "J78B pin 2 – J78C pin 3" • Added Section 7.4.5; Section 7.4.6; Section 7.4.7; Section 7.4.8; Section 7.5.8 • Updated Figure 1, Figure 4, Section 7.5.8.1 (modified figure aaa-051687, aaa-051688), Section 7.5.8.2 (modified figure aaa-051684)
v.1	20230329	Initial release

IMPORTANT NOTICE

For engineering development or evaluation purposes only

NXP provides the product under the following conditions:

This evaluation kit is for use of ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY. It is provided as a sample IC pre-soldered to a printed-circuit board to make it easier to access inputs, outputs and supply terminals. This evaluation board may be used with any development system or other source of I/O signals by connecting it to the host MCU computer board via off-the-shelf cables. This evaluation board is not a Reference Design and is not intended to represent a final design recommendation for any particular application. Final device in an application heavily depends on proper printed-circuit board layout and heat sinking design as well as attention to supply filtering, transient suppression, and I/O signal quality.

The product provided may not be complete in terms of required design, marketing, and or manufacturing related protective considerations, including product safety measures typically found in the end device incorporating the product. Due to the open construction of the product, it is the responsibility of the user to take all appropriate precautions for electric discharge. In order to minimize risks associated with the customers' applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards. For any safety concerns, contact NXP sales and technical support services.

1 Introduction

The NAFExx388 evaluation board features a highly configurable, industrial-grade, multichannel analog input AFE (AI-AFE) family of parts (11388, 13388, etc. …) that meets high-precision measurement requirements. The device is composed of a low-leakage, high-voltage multiplexer, low-offset drift buffers, a low noise and drift PGA, a precision 24-bit sigma-delta analog-to-digital converter (ADC), and low-drift voltage reference.

The AI-AFE family integrates:

- Input protection circuit for electromagnetic compatibility (EMC) and misuse wire scenarios
- Diagnostic circuits for input, open, and short circuit and impedance detection

An advanced diagnostic circuit is implemented for channel loopback reading, and output voltage or current bias circuits. The two precise reference voltage sources enable end-to-end system self-calibration and advanced anomaly detection for predictive maintenance.

A graphical interface allows the user to easily explore the different functions of the driver. The IC communicates to the host via the industry standard SPI-bus port. The evaluation software runs under the Microsoft Windows 7, 8, and 10 PC platforms.

2 Finding kit resources and information on the NXP website

NXP Semiconductors provides online resources for evaluation board and its supported device(s) on http://www.nxp.com.

The information page for NAFExx388-EVB evaluation board is at http://www.nxp.com/NAFExx388-EVB. The information page provides overview information, documentation, software and tools, parametrics, ordering information and a **Getting Started** tab. The Getting Started tab provides quick-reference information applicable to using the NAFExx388-EVB evaluation board, including the downloadable assets referenced in this document.

3 Getting ready

Working with the NAFExx388-EVB requires the kit contents, additional hardware, and a Windows PC workstation with installed software.

3.1 Kit contents

- Assembled and tested evaluation board NAFExx388-EVB in an antistatic bag
- USB 2.0 cable
- Spare jumpers
- OM13098 (LPC54628) MCU evaluation board

3.2 Assumptions

Familiarity with the SPI-bus is helpful, but not required.

3.3 Static handling requirements

CAUTION

This device is sensitive to ElectroStatic Discharge (ESD). Therefore care should be taken during transport and handling. You must use a ground strap or touch the PC case or other grounded source before unpacking or handling the hardware.

3.4 Minimum system requirements

- PC Pentium processor (or equivalent)
- One USB port (either 3.0 or 2.0 compatible)
- Windows 7, 8, 10
- OM13098 (LPC54628) MCU evaluation board (from www.nxp.com)

3.5 Power requirements

For NAFExx388 setup, connect the PC to the USB port J2 (out of the three USB ports J1, J2, and J3) to power up the OM13098 MCU evaluation board.

Note: *NXP strongly advises against using 24 V input for the NAFE11388-EVB, as this will result in non-compliance of the board to FCC and EU Radiated Emissions requirements. The end user accepts full responsibility if 24 V input is used for the NAFE11388-EVB board.”*

4 Getting to know the hardware

4.1 Board features

Table 1. NAFExx388 evaluation board main components

Device	Description	Location
NAFExx388	Eight-input SW configurable AI-AFE	U1
MAX13256ATB	Transformer driver	U4
TGMR-511V6LF	Transformer	U5
Si8641BC-B-IS1	Quad-channel digital isolators	U7
Si8642BC-B-IS1	Quad-channel digital isolators	U8
MAX14761ETB	Analog switches	U14
CMXDM7002A	N-channel MOSFET	U16
LP2950ACDT-3P3RG	+3.3 V LDO	U17

4.2 Kit featured components

- A complete evaluation platform for the NAFExx388
- Eight input SW configurable AI-AFE
- Easy-to-use GUI-based software demonstrates the capabilities of the NAFE11388 and NAFE13388, which are representative of the AI-AFE family, depending on the part installed on the board.
- An external power supply can be used to power the NAFExx388 evaluation board
- Alternatively, an onboard transformer can be used to provide DC-DC power supply (+3.3 V, ±15 V) to NAFExx388 for potability and demo purpose.
- Convenient test points for easy scope measurements and signal access
- USB interface to the host PC

4.2.1 Jumpers

Table 2. Jumper settings for external power supply (+3.75 V, +15.4 V, -15.4 V)

Setting	Jumper	Comment
EXT_3V3	J78A pin 1 – J78A pin 2	External +3.3 V power selection
EXT_-15V0	J78B pin 1 – J78B pin 2	External -15 V power selection
EXT_15V0	J78C pin 3 – J78C pin 2	External +15 V power selection

Table 3. Jumper settings for AC-DC adapter/transformer power supply (+3.75 V, +15.4 V, -15.4 V)[1]

Setting	Jumper	Comment
3V3_LDO	J78B pin 2 – J78C pin 3	AC-DC adapter/transformer +3.3 V power selection
TX_-15V0	J78B pin 2 – J78C pin 3	AC-DC adapter/transformer -15 V power selection
TX_15V0	J78B pin 2 – J78C pin 3	AC-DC adapter/transformer +15 V power selection

[1] Warning: Make sure J88 = OPEN before connecting AC-DC adapter.

5 Configuring the hardware

The NAFExx388 evaluation kit includes the NAFExx388 evaluation board, an OM13098 (LPC54628) evaluation board, and a USB cable.

To set up the hardware, do the following:

1. Firmly connect the NAFExx388 (AFE) evaluation board to the LPC54628 (microcontroller) evaluation board using the Arduino connectors.
2. To connect both boards, slide J15, J18, J19, and J22 male connectors at the bottom side of the NAFExx388 (AFE) evaluation board into the appropriate female connectors on the LPC54628 (microcontroller) evaluation board as shown in Figure 1.
3. Apply AVDD/DVDD = 3.75 V on J9, HVDD = +15.4 V on J10, and HVSS = -15.4 V on J11 banana jack connectors and turn on the power supply. An approximately 0.4 V additional supply on J9, J10, and J11 accounts for the voltage drop across the Schottky diode for reverse polarity protection and voltage drop across 5 Ω resistor because of the supply current flowing into the pin of the device.
4. Use a USB to uUSB to connect the PC (USB) to the LPC54628EVAL (uUSB).

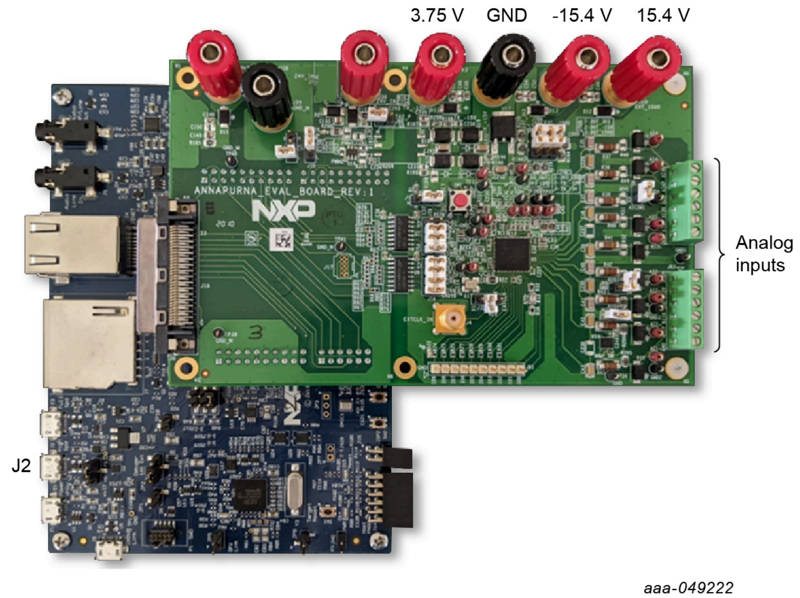

Figure 1. NAFExx388 evaluation board paired with OM13098 (LPC54628) evaluation board

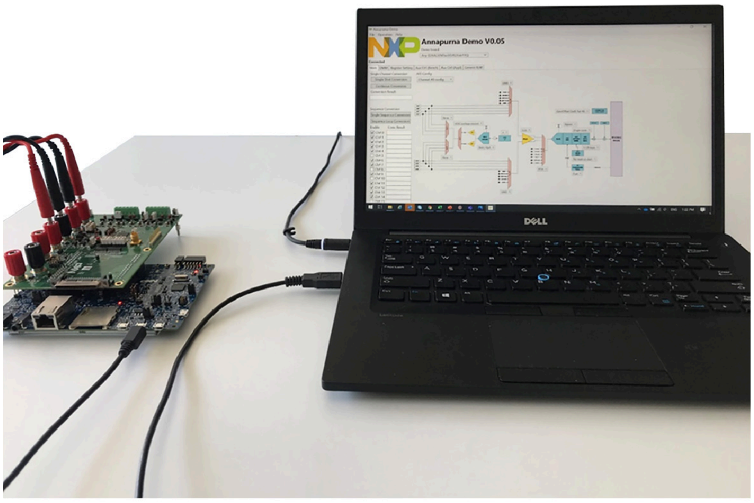

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Figure 2. Test setup showing connectivity between computer and evaluation system

6 Schematic, board layout, bill of materials

The schematic (in pdf) can be launched from the GUI as described in Section 7.4.1.

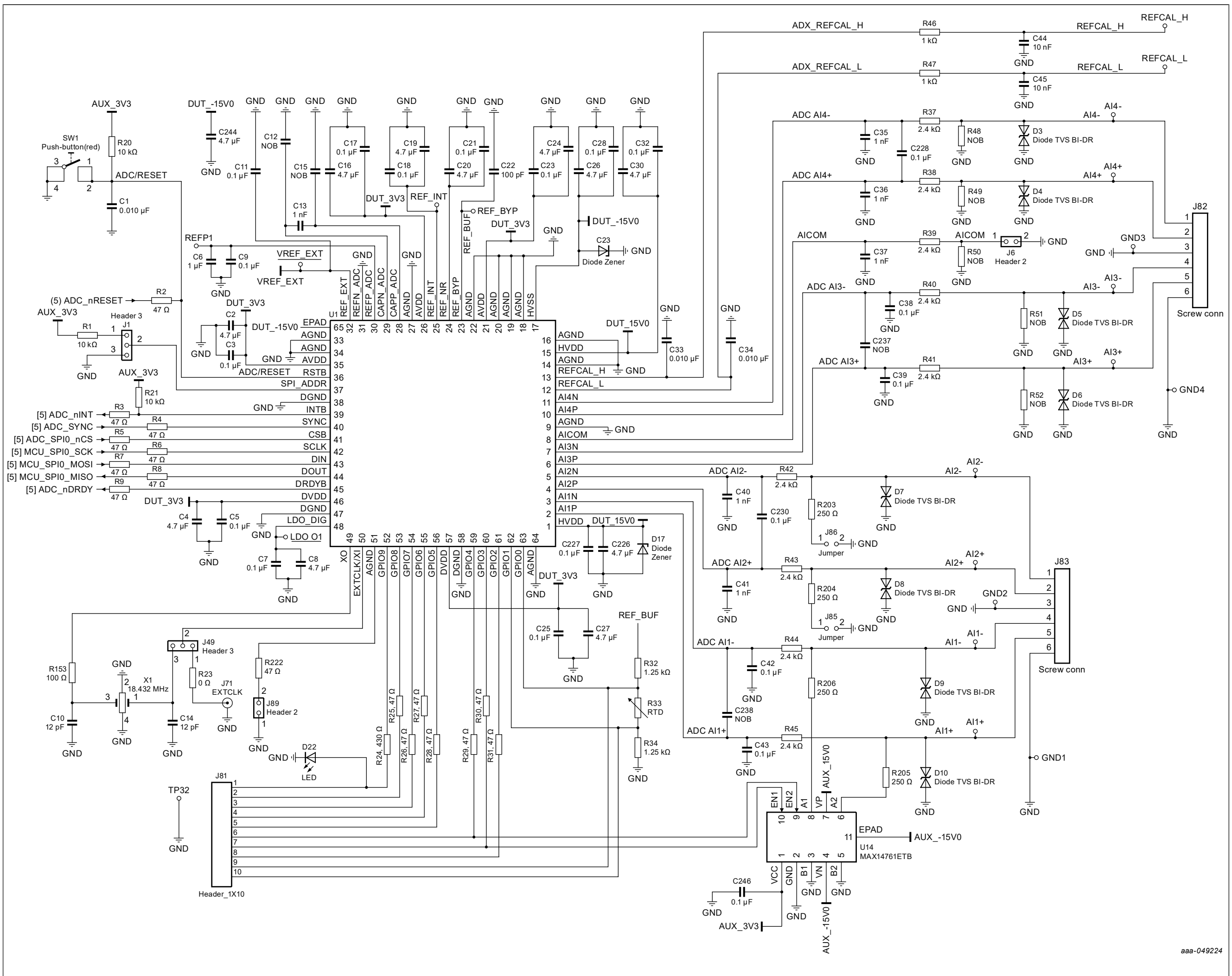


Figure 3. NAFExx388 portion schematic

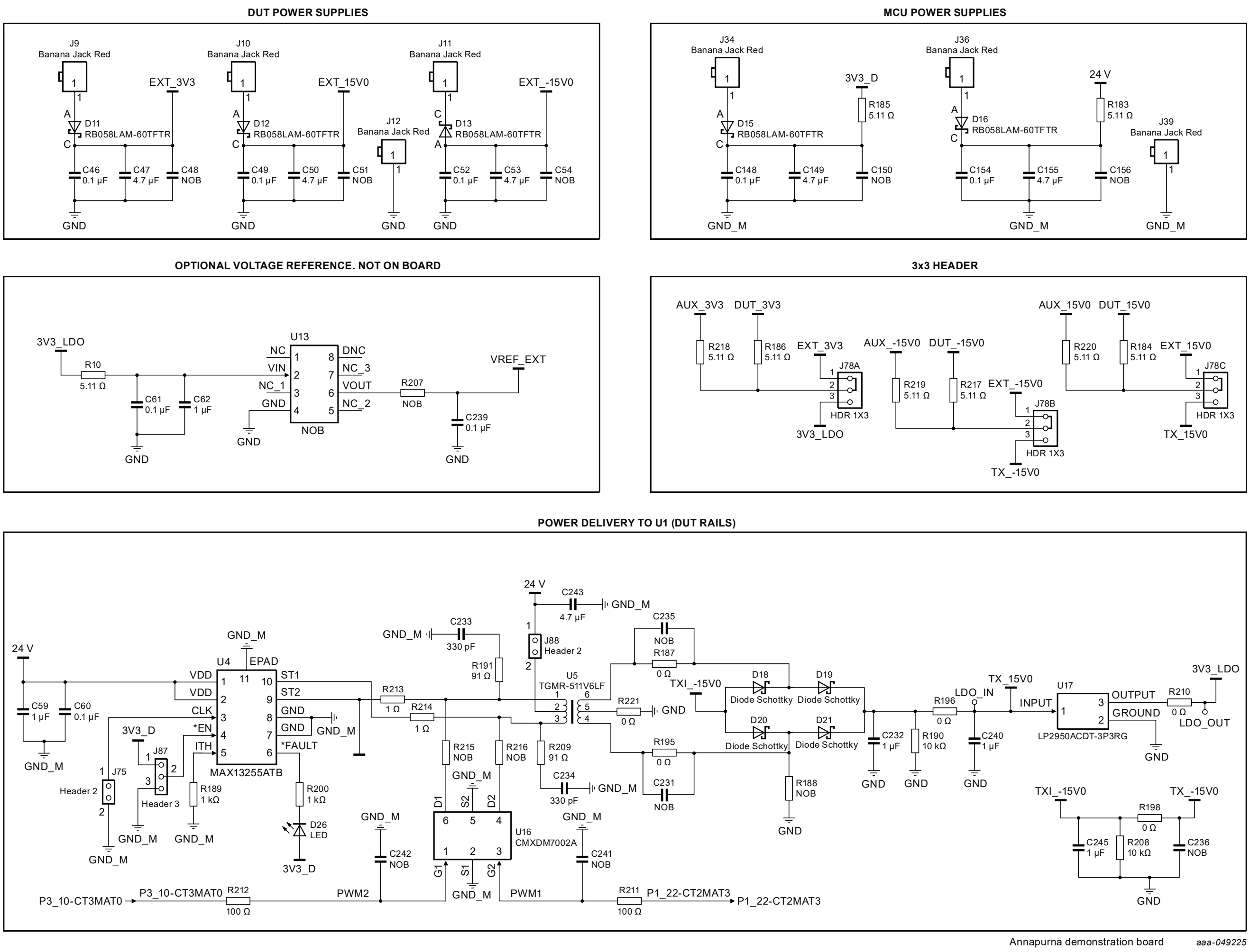


Figure 4. Power supplies portion schematic

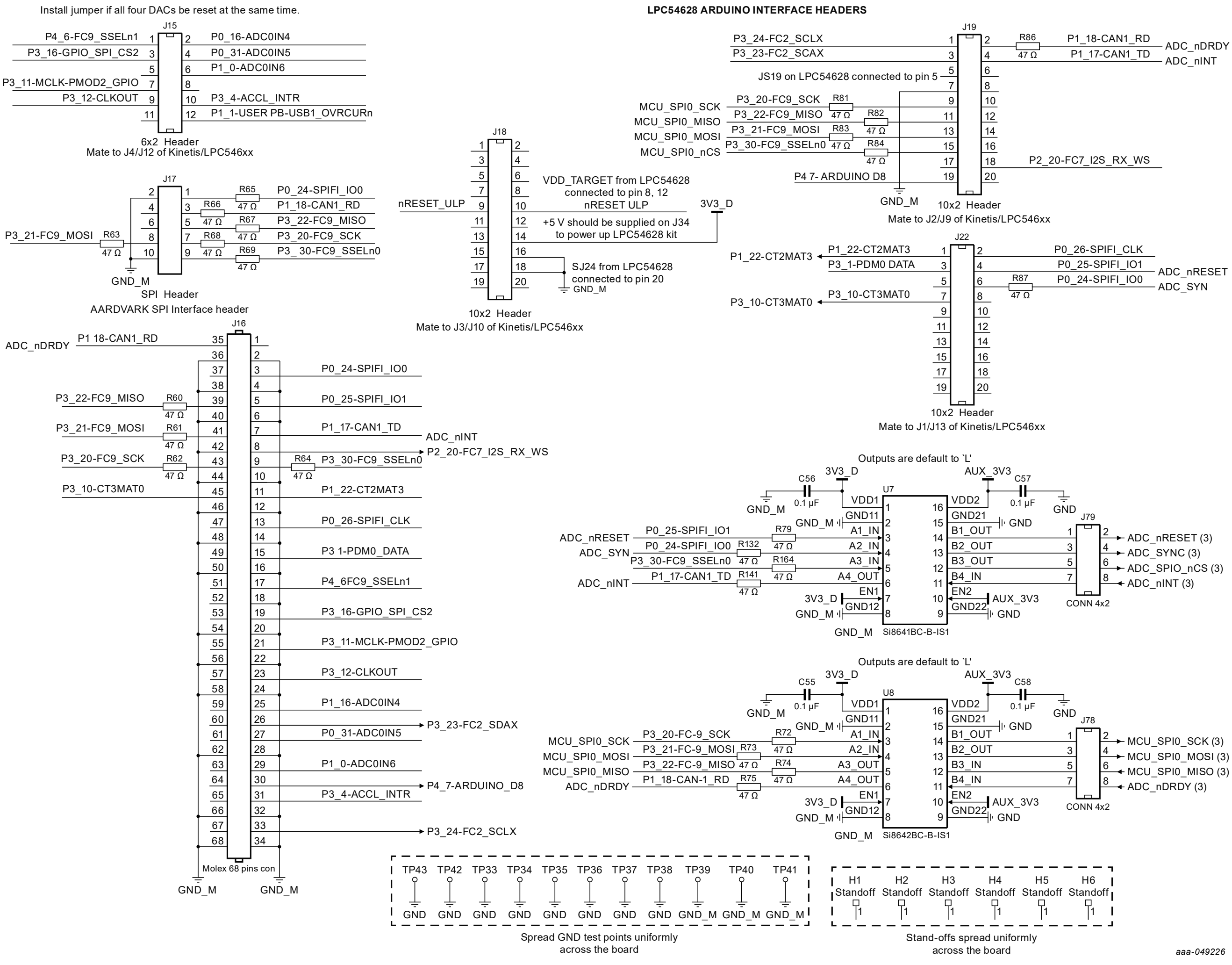


Figure 5. Connectors and isolators portion schematic

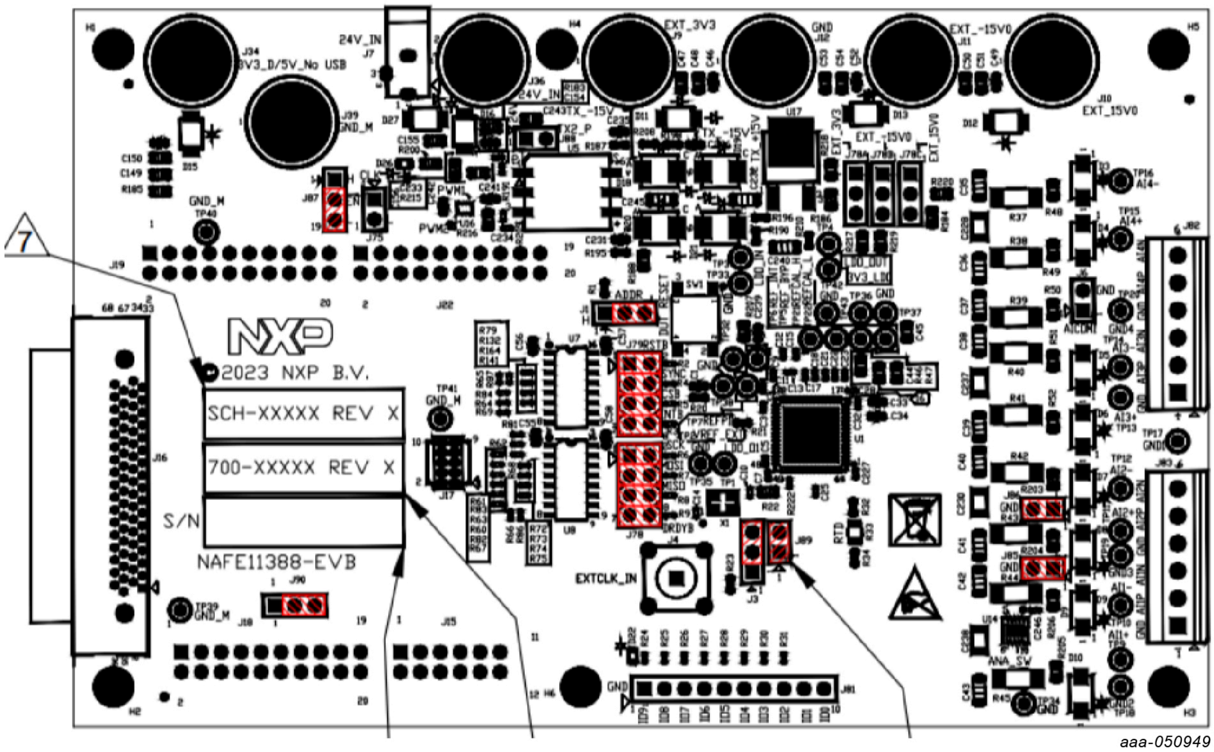


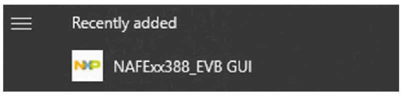
Figure 6. Component and jumpers locations

The schematic, board layout, and bill of materials for the NAFExx388 evaluation board are available at http://www.nxp.com/NAFExx388-EVB.

7 Tool interface

7.1 GUI installation

- Right click on the executable (SetupNAFExx388_x.x.x), run as administrator, and follow the prompts to install the application.
- Click the **Windows Start** button on bottom left and find the *NAFExx388_EVB GUI* application.



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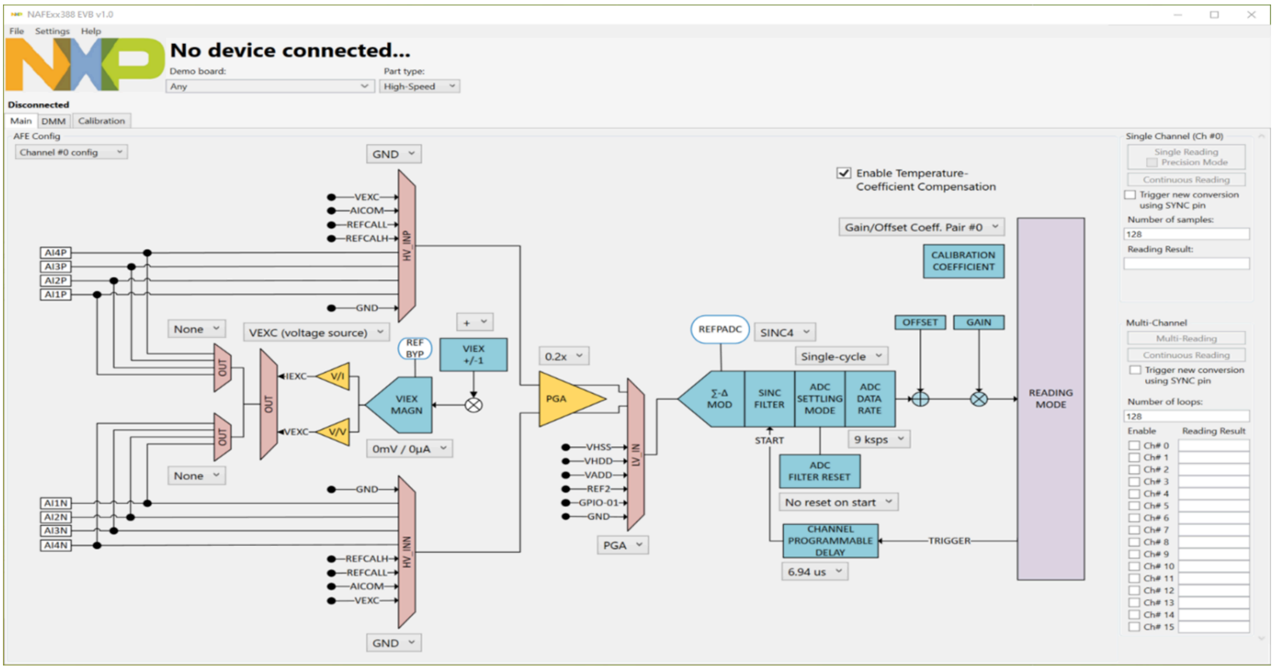

Figure 7. GUI screenshot

7.2 MCU (OM13098) board firmware update

1. The GUI shows an MCU Firmware Update Required message if an older firmware in the MCU board is detected as shown in Figure 8.
2. Click **OK** to update the firmware in the MCU board.
3. Press SW1 (reset button) to reset the MCU board.

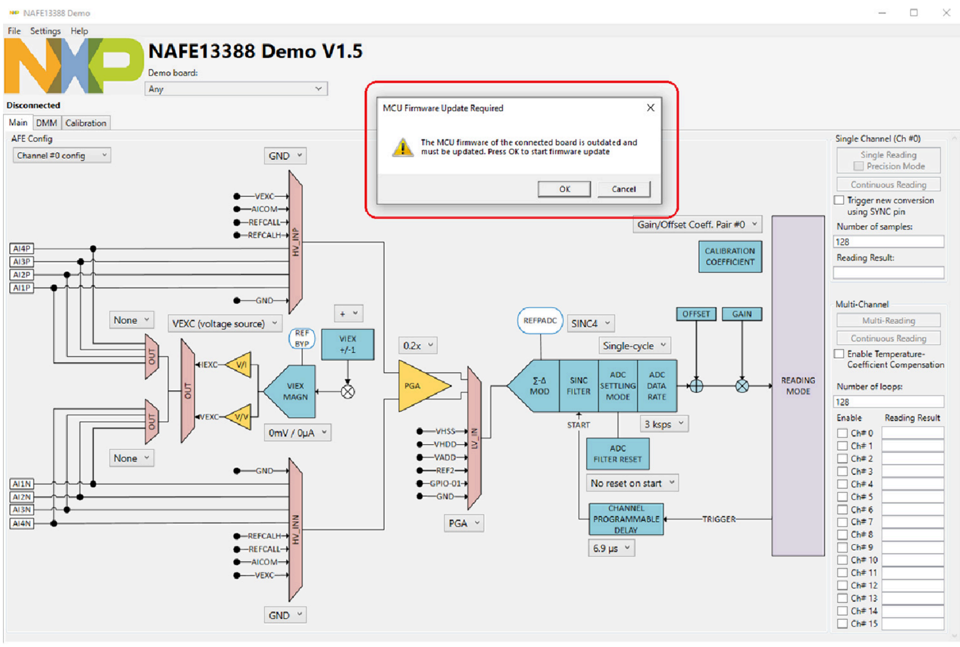

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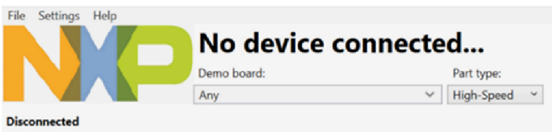
Figure 8. MCU board firmware update

7.3 Connectivity check

1. Click the *NAFExx388_EVB GUI* application to open the GUI. If there isn't connection with the MCU or the evaluation board, the message on the left top of GUI will be the following:



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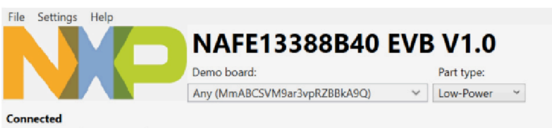
2. The label "Disconnected" indicates if the connection is established between the MCU board and the PC. Upon USB connection, the part read command is issued by the MCU, which updates the part label and type (low power or high speed) accordingly. Upon successful connection with the MCU board, the GUI will be updated with the label "Connected". Furthermore, the GUI will recognize the part number and update itself accordingly.



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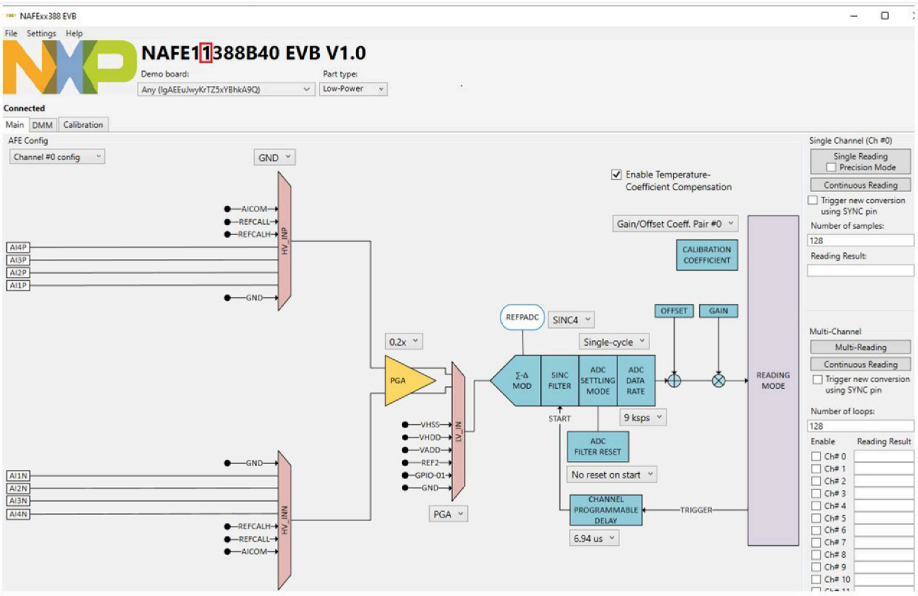
3. a. The part number will follow the data sheet nomenclature:
   i. NAFE11388B40 → No VIEX, low power, factory calibration.

ii. NAFE71388B40 → No VIEX, high speed, factory calibration.
iii. NAFE13388B40 → VIEX, low power, factory calibration.
iv. NAFE73388B40 → VIEX, high speed, factory calibration.
v. NAFE13188B40 → VIEX, low power, no factory calibration.

4. The NAFExx388 GUI is a smart GUI that caters to the full part family. The block diagram is updated based on the part read back, that is, the VIEX block shows up for NAFEx3388 devices only.



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7.4 Using the tool

7.4.1 Schematic shortcut

It is possible to open the EVKit Schematic directy from the GUI using the menu bar.

Help → EVKit Schematic.

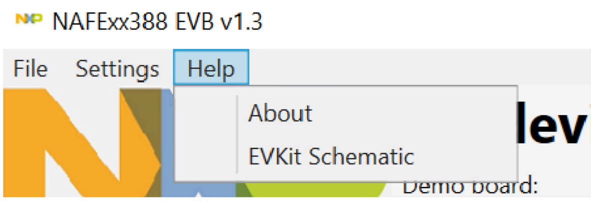

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Figure 9. EVKit Schematic

7.4.2 Channel configuration

1. Select the channel gain using the dropdown menu of the programmable gain amplifier (PGA).
2. Configure the data rate, SINC filter order, and Settling mode via the corresponding dropdown menu of the ADC

7.4.3 Conversion modes

Five types of reading (conversion) modes are possible from the device:

- Single-Channel Single-Reading (CMD_SS)
- Single-Channel Continuous Reading (CMD_SC)
- Multi-Channel Single-Reading (CMD_MS) (available in future revision)
- Multi-Channel Multi-Reading (CMD_MM)
- Multi-Channel Continuous Reading (CMD_MC)

Refer to the data sheet for more about these conversion modes.

1. Single-Channel Single-Reading
   a. Click the **Single Reading** button after picking Inputs under test from the MUX drop-down menu.
   b. Read the input voltage on Reading Result box.
2. Single-Channel Continuous Reading
   a. Enter the number of samples required in the box and click the **Continuous Reading** button. Once the **Continuous Reading** button is clicked, a dialog box will open to pick a folder to create a .csv conversion results file on the hard drive with the number of samples requested.
3. Multi-Channel Multi-Reading
   a. Preconfigure appropriate channels to be sequenced using the AFE configuration dropdown menu and enable those channel numbers accordingly under the Multi-Channel section at the bottom right of the GUI.
   b. Click the **Multi-Reading** button.
   c. Read the input voltages in Reading Result multibox.
4. Multi-Channel Continuous Reading
   a. Preconfigure the appropriate channels to be sequenced using the AFE configuration dropdown menu and enable those channel numbers under the Multi-Channel section at the bottom right of the GUI.
   b. Click the **Continuous Reading** button and wait for the dialog box to pick the folder to create a .csv conversion results file on the hard drive with the number of samples requested.

7.4.4 Data-rate selection

The AI-AFE provides a flexible ADC configuration that enables the user to configure Settling mode, digital SINC filter, and data rate. As reported in the data-rate table, the data-rate output is a function of the combination of Settling mode, digital SINC filter, and data rate.

The easier way to configure the AI-AFE is:

1. Select the Settling mode (normal or single cycle)
2. Select the digital SINC filter
3. Select the data rate

For example, to select 9000 sps in Single-Cycle Settling mode and SINC4:

1. Select normal settling in the Settling mode dropdown menu.
2. Select SINC 4 in the filter dropdown menu.
3. Select 9000 sps in the data-rate dropdown menu.

Table 4. Data rate dropdown menu

		Normal settling					Single-cycle settling				
DRO code	OSR	SINC4	SINC4+ SINC1	SINC4+ SINC2	SINC4+ SINC2	SINC4+ SINC4	SINC4	SINC4+ SINC1	SINC4+ SINC2	SINC4+ SINC2	SINC4+ SINC4
0	8	288000					72000				
1	12	192000					48000				
2	16	144000					36000				
3	24	96000					24000				
4	32	72000					18000				
5	48	48000					12000				
6	64	36000					9000				
7	96	24000					6000				
8	128	18000					4500				
9	192	12000					3000				
10	256	9000					2250				
11	384	6000					1500				
12	512		4500.00	4500.00	4500.00	4500.00		2250.00	1500.00	1125.00	900.00
13	768		3000.00	3000.00	3000.00	3000.00		1500.00	1000.00	750.00	600.00
14	1024		2250.00	2250.00	2250.00	2250.00		1125.00	750.00	562.50	450.00
15	2048		1125.00	1125.00	1125.00	1125.00		562.50	375.00	281.25	225.00
16	4096		562.50	562.50	562.50	562.50		281.25	187.50	140.63	112.50
17	5760		400.00	400.00	400.00	400.00		200.00	133.33	100.00	80.00
18	7680		300.00	300.00	300.00	300.00		150.00	100.00	75.00	60.00
19	11520		200.00	200.00	200.00	200.00		100.00	66.67	50.00	40.00
20	23040		100.00	100.00	100.00	100.00		50.00	33.33	25.00	20.00
21	38400		60.00	60.00	60.00	60.00		30.00	20.00	15.00	12.00
22	46080		50.00	50.00	50.00	50.00		25.00	16.67	12.50	10.00
23	76800		30.00	30.00	30.00	30.00		15.00	10.00	7.50	6.00
24	92160		25.00	25.00	25.00	25.00		12.50	8.33	6.25	5.00
25	115200		20.00	20.00	20.00	20.00		10.00	6.67	5.00	4.00
26	153600		15.00	15.00	15.00	15.00		7.50	5.00	3.75	3.00
27	230400		10.00	10.00	10.00	10.00		5.00	3.33	2.50	2.00
28	307200		7.50	7.50	7.50	7.50		3.75	2.50	1.88	1.50

Table 5. Calibration coefficients table

CHANNEL POINTER/ GAIN OFFSET POINTER	PGA SETTING	OFFSET COEFF	GAIN COEFF
0	PGA0: Channel gain = 0.2 V/V SINGLE ENDED AIxP	0x0000FD	0x7EC2EA
1	PGA1: Channel gain = 0.4 V/V SINGLE ENDED AIxP	0x0000FA	0x7EC43D
2	PGA2: Channel gain = 0.8 V/V SINGLE ENDED AIxP	0x0000FA	0x7EC0BB
3	PGA3: Channel gain = 1.0 V/V SINGLE ENDED AIxP	0x000000	0x800000
4	PGA5: Channel gain = 2.0 V/V SINGLE ENDED AIxP	0x000000	0x800000
5	PGA7: Channel gain = 4.0 V/V SINGLE ENDED AIxP	0x000000	0x800000
6	PGA8: Channel gain = 8.0 V/V SINGLE ENDED AIXP	0x000000	0x800000
7	PGA9: Channel gain = 16 V/V SINGLE ENDED AIxP	0x000000	0x800000
8	PGA0: Channel gain = 0.2 V/V SINGLE ENDED AIxN	0x0000FC	0x7EC25C
9	PGA1: Channel gain = 0.4 V/V SINGLE ENDED AIxN	0x0000FF	0x7EC3F2
10	PGA2: Channel gain = 0.8 V/V SINGLE ENDED AIxN	0x0000FF	0x7EC089
11	PGA3: Channel gain = 1.0 V/V SINGLE ENDED AIxN	0x000000	0x800000
12	PGA5: Channel gain = 2.0 V/V SINGLE ENDED AIxN	0x000000	0x800000
13	PGA7: Channel gain = 4.0 V/V SINGLE ENDED AIxN	0x000000	0x800000
14	PGA8: Channel gain = 8.0 V/V SINGLE ENDED AIXN	0x000000	0x800000
15	PGA9: Channel gain = 16 V/V SINGLE ENDED AIxN	0x000000	0x800000

7.4.5 System and GPIOs configuration

It is possible to manage some settings of the ADC system through the System/GPIO view.

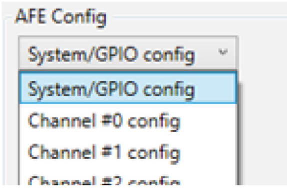

Figure 10. System/GPIO view

The settings that are possible to change are:

- Reference selection for REF_BYP and REFPADC
- ADC Data BIT, 24 or 16 bits
- Clock selection: Internal, External, or Crystal
- Data ready signal behavior

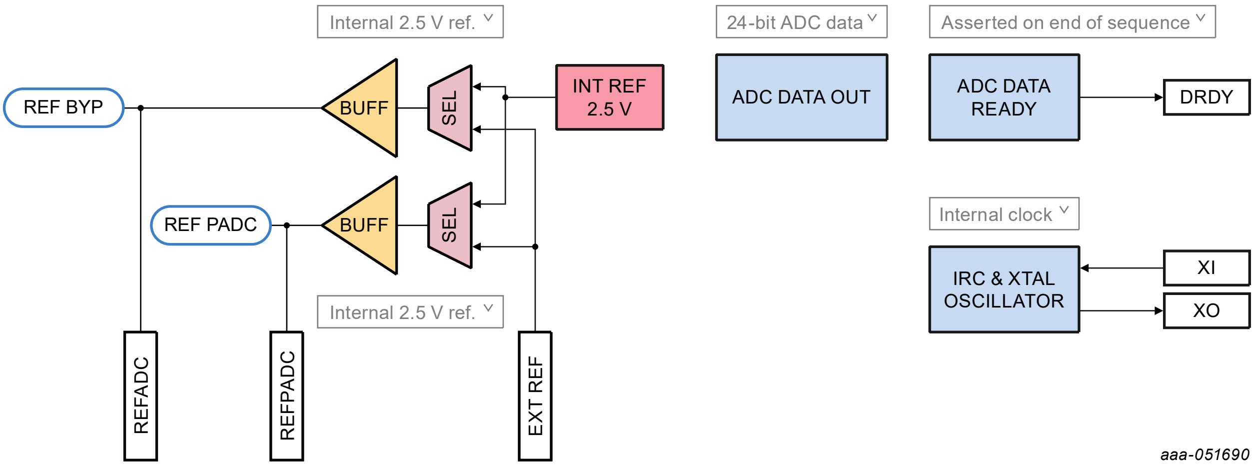

Figure 11. Settings

The NAFE has ten GPIOs, manageable from the GUI, in Output and Input modes.

The GPIOs are schematized on the GUI as an array of settings.

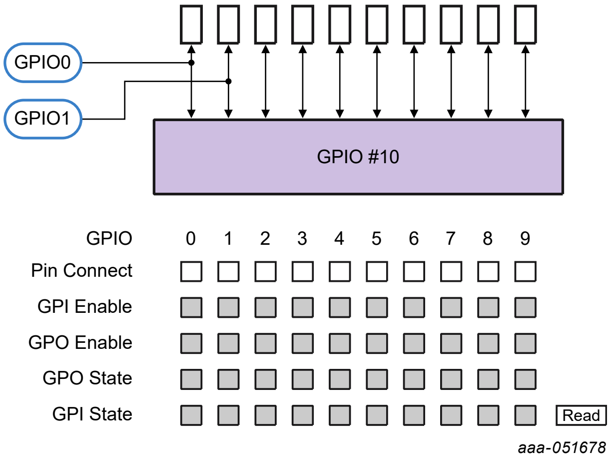

Figure 12. GPIO settings

The bits that can be accessed from this matrix are:

- Pin Connect: Should be enabled to use the connected pins as GPIOs.
- GPI/GPO Enable: Depending on the desired functionality, GPI/GPO must be enabled.
- GPO State: Enable or disable this cell to put 1 or 0 on the selected GPIOs.
- GPI State: Click the Read button to update the cell states of the GPIOs set as Input.

7.4.6 DMM view

The DMM tab is a simple interface used to view the data acquired (Continuous mode) as a function of time.

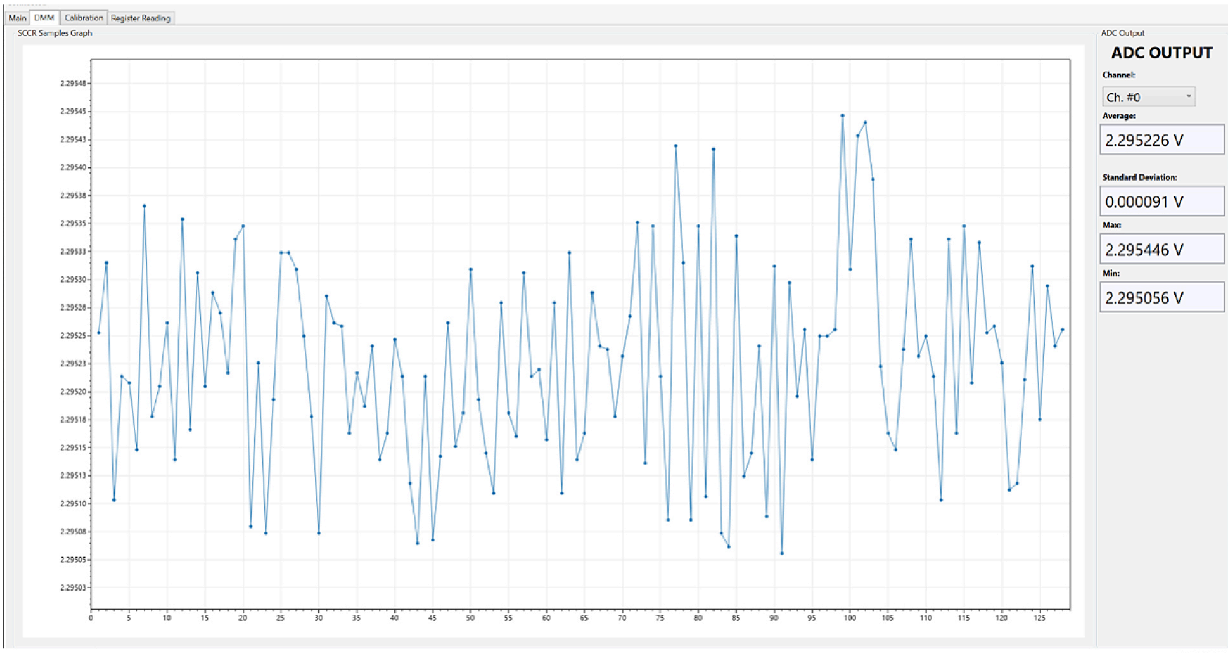

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Figure 13. DMM tab

7.4.7 Register Reading tab

In the Register Reading tab, it is possible to read some registers of the device, system registers, and channel-based registers, in case a channel-based register is needed to select the register requested in the channel's selector.

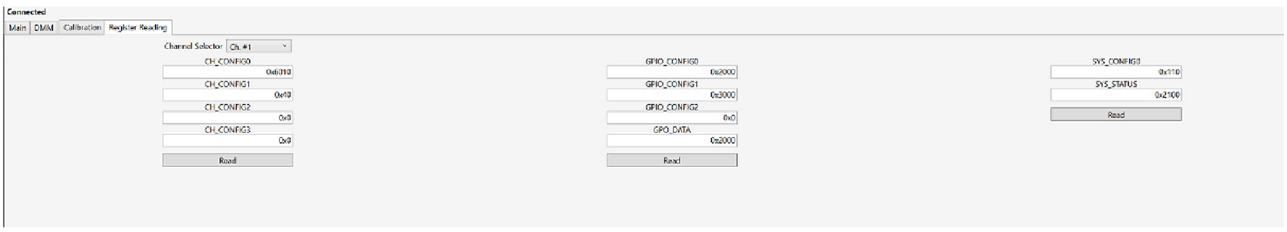

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Figure 14. Register Reading

7.4.8 Calibration tab

Follow the instructions present in the Calibration tab to perform a calibration of the device. The selected Gain/ Offset registers will be written and updated according to the procedure.

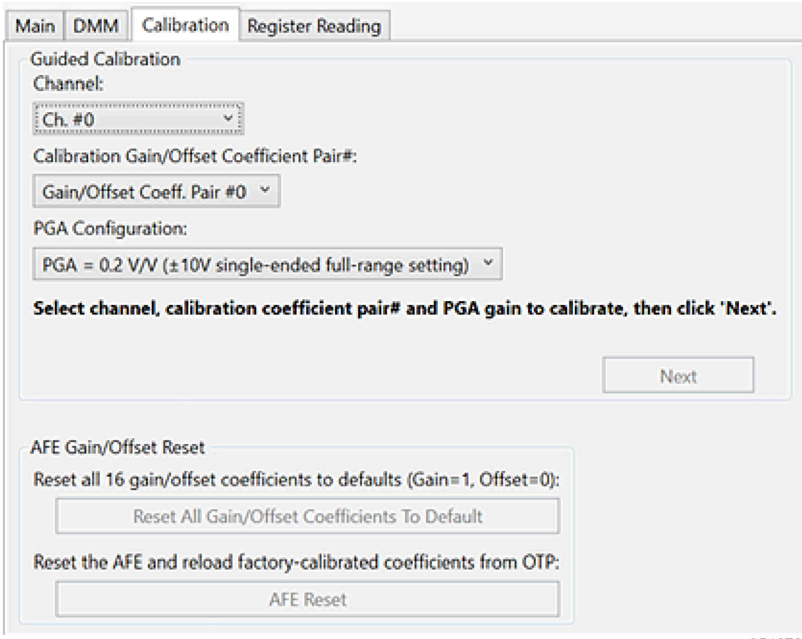
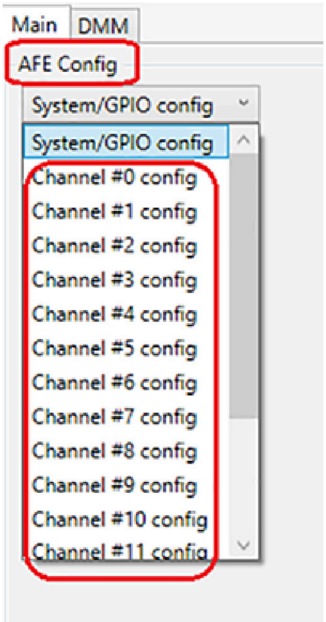


Figure 15. Calibration tab

7.5 Application test cases

7.5.1 Single-Channel Reading (SCR) example

1. Select which channel configuration (channel #0 - #16 config) will be used to read the voltage in the AFE Config dropdown menu.



aaa-049231

Figure 16. AFE Config

2. Select input channels from the MUX dropdown menu (HV_INP, HV_INV).

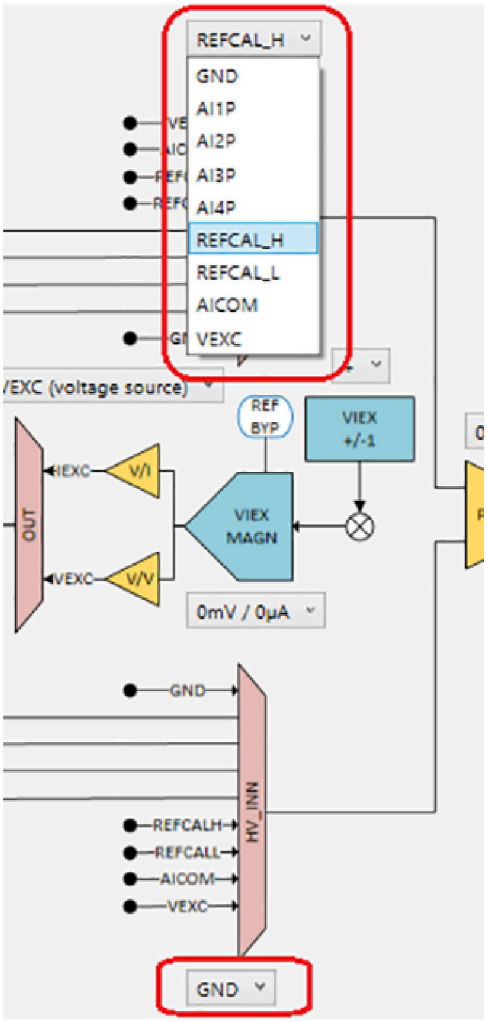
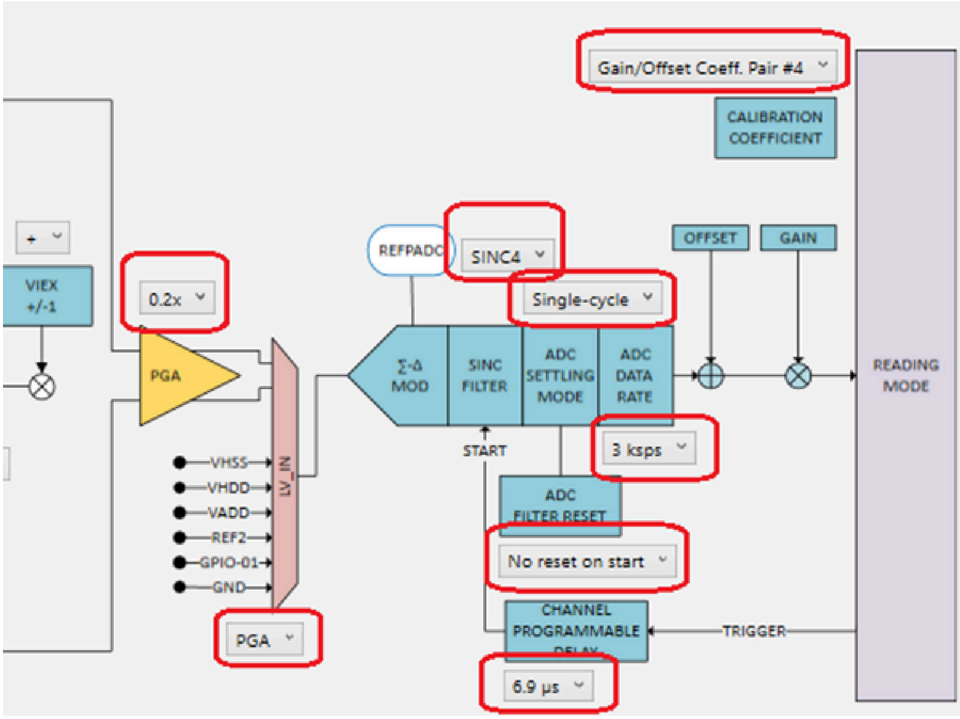


Figure 17. Input channels

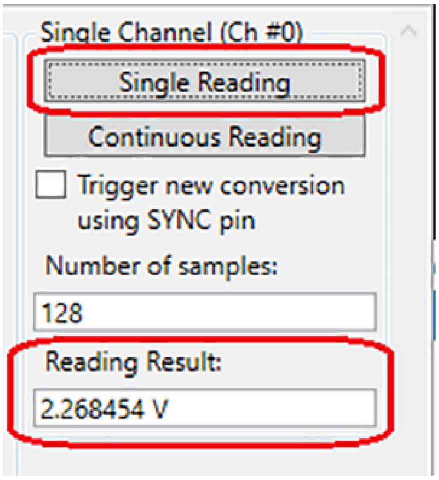
3. Select PGA, SINC FILTER, ADC SETTING MODE, ADC DATA RATE, CHANNEL PROGRAM DELAY, and CALIBRATION COEFFICIENT settings in the dropdown menus.



aaa-049233

Figure 18. Dropdown menus

4. Click the **Single Reading** button to read a single-channel voltage value in the Reading Result box.



aaa-049234

Figure 19. Single Reading button

7.5.2 Single-Channel Continuous Reading (SCCR) example

1. Follow steps 1 through 3 described in Section 7.5.1.
2. Key in the number in the Number of samples box.

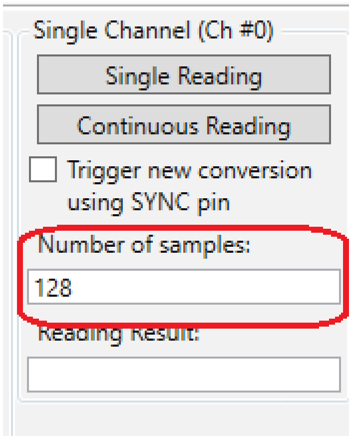


Figure 20. Number of samples

3. Click the **Continuous Reading** button to read in Single Channel multiple-voltage values, and export data in the .csv file.

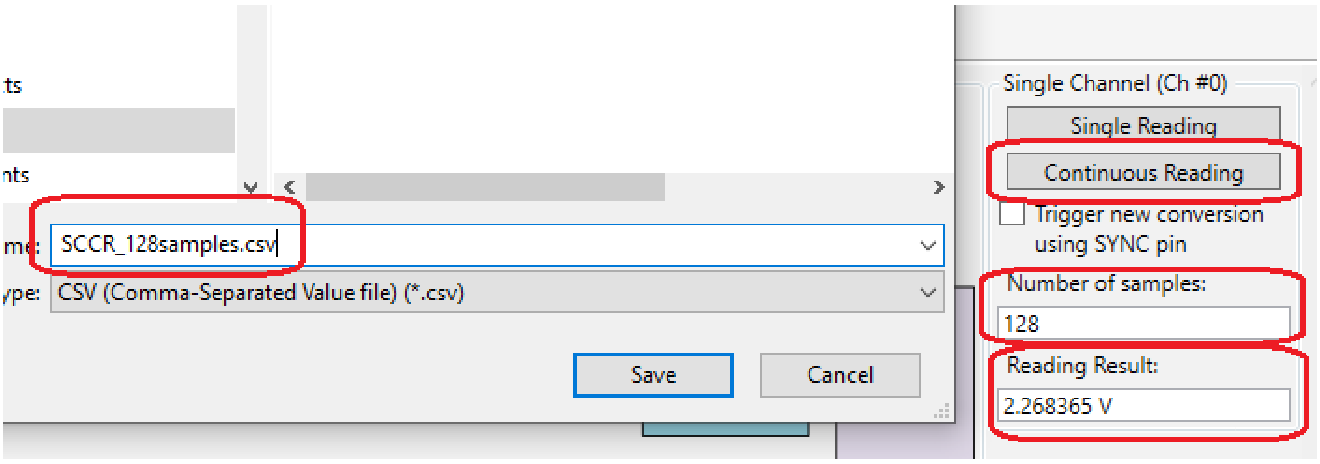


Figure 21. Continuous Reading button

4. Open the .csv file to see number of voltage values.

	A	B	C	D	E	F
1	Sample #	Ch #	Value (hex)	Value (decimal)	Voltage (V)	
2	0	0	0B9D3C	761148	2.268398	
3	1	0	0B9D2A	761130	2.268344	
4	2	0	0B9D2C	761132	2.268350	
5	3	0	0B9D3F	761151	2.268407	
6	4	0	0B9D3D	761149	2.268401	
7	5	0	0B9D2C	761132	2.268350	
8	6	0	0B9D3C	761148	2.268398	
9	7	0	0B9D1E	761118	2.268308	
10	8	0	0B9D29	761129	2.268341	
11	9	0	0B9D40	761152	2.268410	
12	10	0	0B9D3C	761148	2.268398	
13	11	0	0B9D22	761122	2.268320	
14	12	0	0B9D3F	761151	2.268407	
15	13	0	0B9D34	761140	2.268374	
16	14	0	0B9D48	761160	2.268434	
17	15	0	0B9D42	761154	2.268416	
18	16	0	0B9D2C	761132	2.268350	

Figure 22. Voltage values

7.5.3 Multi-Channel Reading (MCR) example

1. Select multiple channels by clicking in the Enable checkboxes.

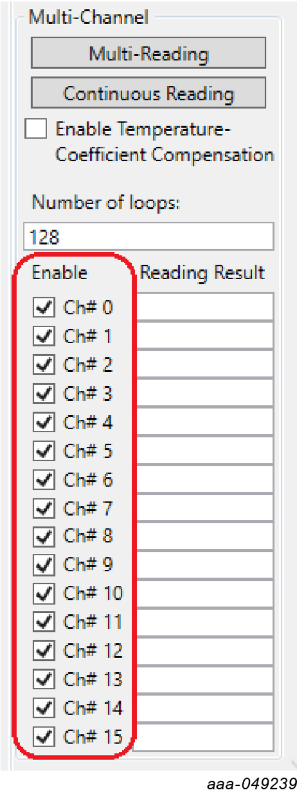


Figure 23. Select channels

2. Select the enabled channel configuration (channel #0 - #16 config) one by one in the AFE Config dropdown menu.

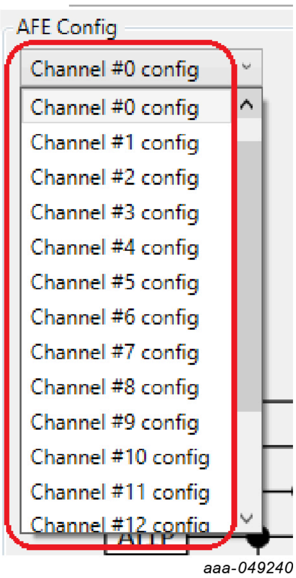
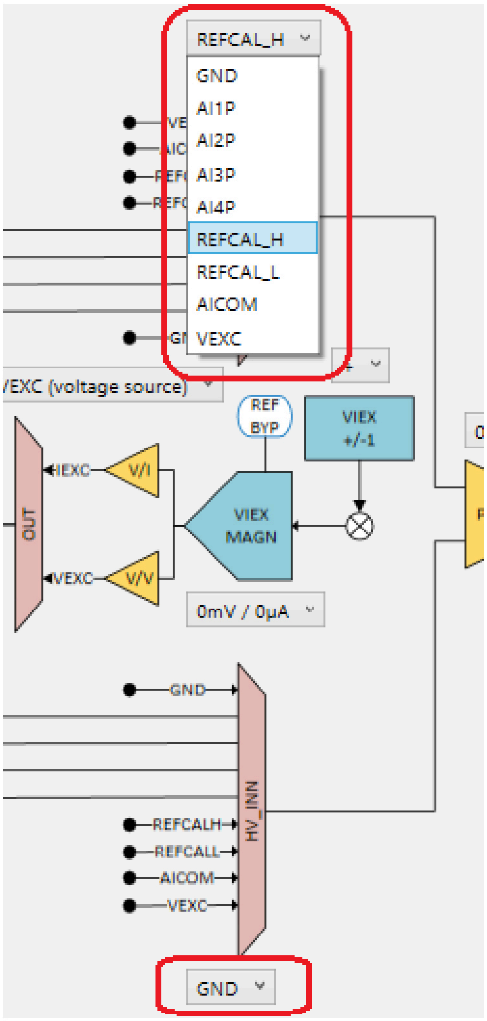


Figure 24. Channel configuration

3. Select input channels from the MUX dropdown menu (HV_INP, HV_INV).



aaa-049241

Figure 25. MUX dropdown menu

4. Select PGA, SINC FILTER, ADC SETTING MODE, ADC DATA RATE, CHANNEL PROGRAM DELAY and CALIBRATION COEFFICIENT settings for each channel configuration in the dropdown menus.

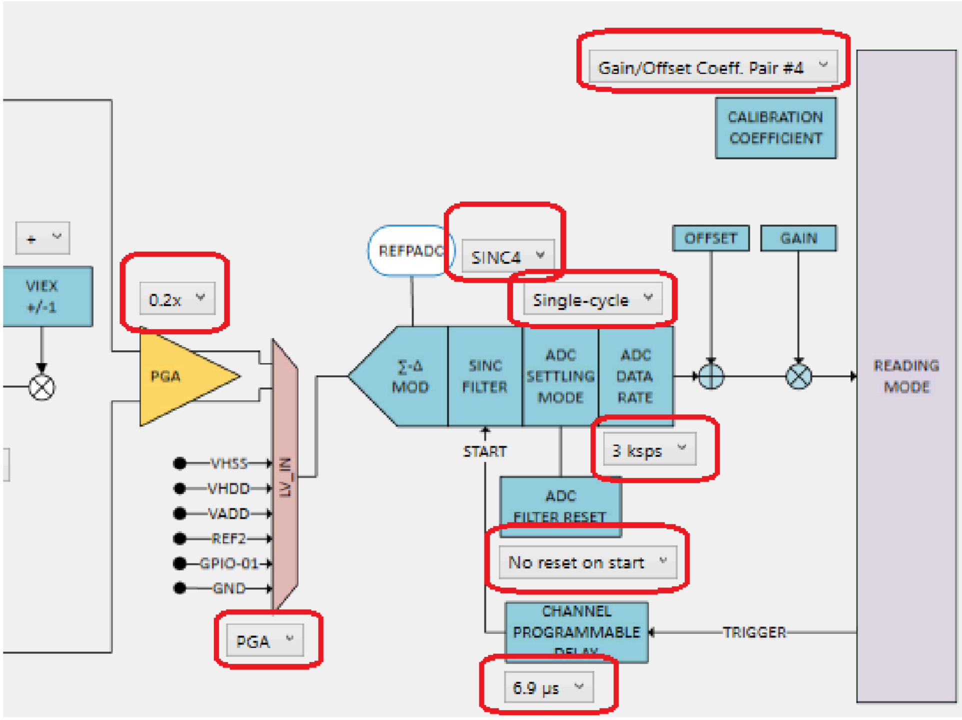


Figure 26. Select settings

5. Click the **Multi-Reading** button to read the voltage value in multiple channels in the Reading Result boxes.

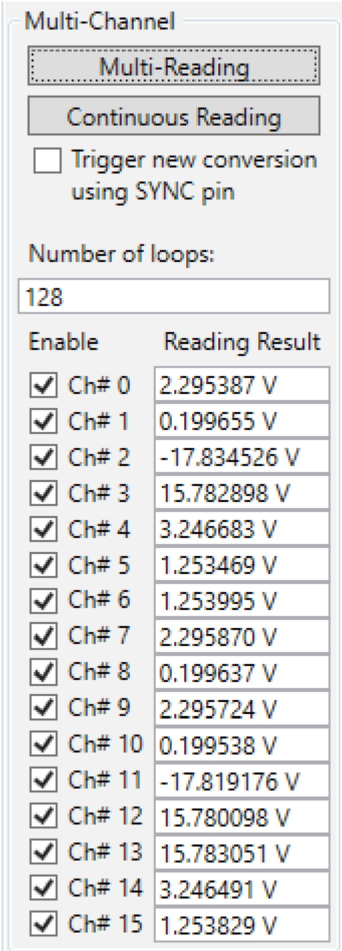
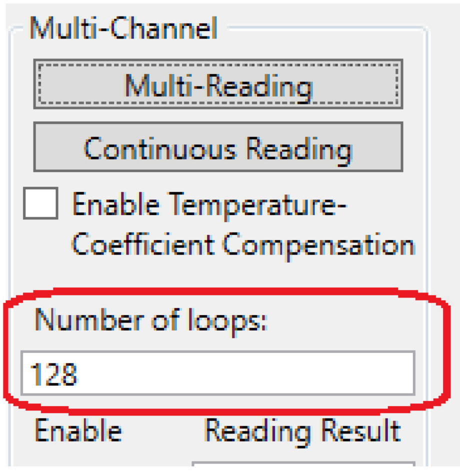


Figure 27. Multi-Reading button

7.5.4 Multi-Channel Continuous Reading (MCCR) example

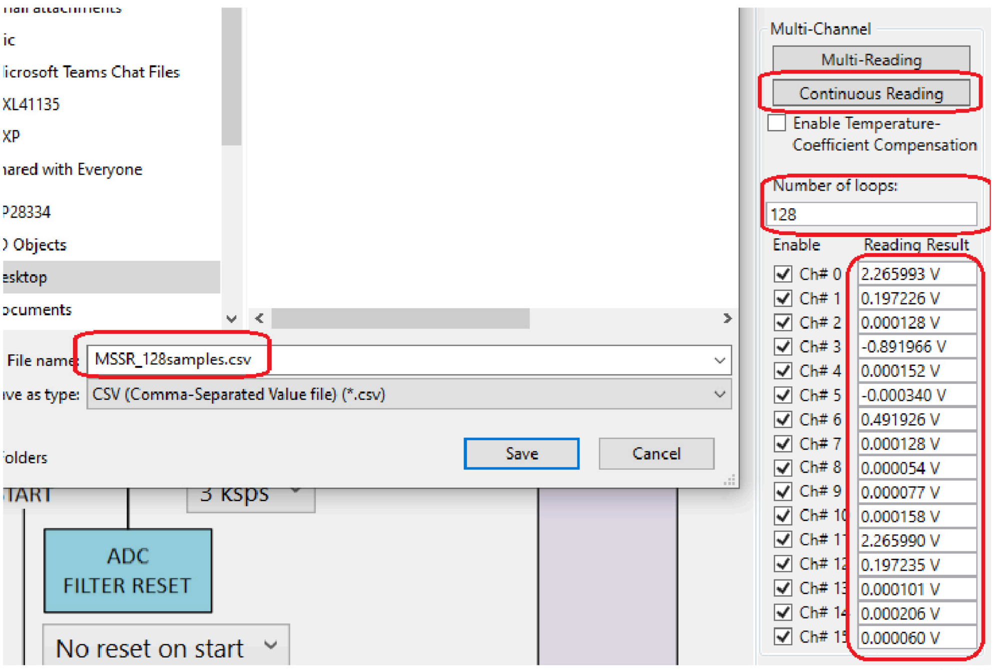
1. Follow steps 1 through 3 as described in Section 7.5.3.
2. Key in the number in the Number of loops box.



aaa-049244

Figure 28. Number of loops

3. Click the **Continuous Reading** button to read the voltage values of multiple channels and export data in the .csv file.



aaa-049245

Figure 29. Continuous Reading

4. Open the .csv file to see the number of voltage values.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Sample #	Ch #	Value (hex)	Value (decimal)	Voltage (V)	Ch #	Value (hex)	Value (decimal)	Voltage (V)	Ch #	Value (hex)	Value (decimal)	Voltage (V)
2	0	0	0B99EA	760298	2.265865	1	00001A	26	0.000077	2	45	69	0.000206
3	1	0	0B9A02	760322	2.265936	1	28	40	0.000119	2	00000F	15	0.000045
4	2	0	0B99FF	760319	2.265927	1	12	18	0.000054	2	22	34	0.000101
5	3	0	0B9A23	760355	2.266034	1	20	32	0.000095	2	00000F	15	0.000045
6	4	0	0B9A0F	760335	2.265975	1	00002F	47	0.00014	2	00001D	29	0.000086
7	5	0	0B9A26	760358	2.266043	1	14	20	0.00006	2	00002D	45	0.000134
8	6	0	0B9A17	760343	2.265999	1	35	53	0.000158	2	32	50	0.000149
9	7	0	0B9A10	760336	2.265978	1	30	48	0.000143	2	00001C	28	0.000083
10	8	0	0B99FD	760317	2.265921	1	00001C	28	0.000083	2	00002F	47	0.00014
11	9	0	0B9A22	760354	2.266032	1	00002D	45	0.000134	2	28	40	0.000119
12	10	0	0B9A0A	760330	2.26596	1	00002D	45	0.000134	2	33	51	0.000152
13	11	0	0B9A2A	760362	2.266055	1	28	40	0.000119	2	22	34	0.000101
14	12	0	0B9A01	760321	2.265933	1	38	56	0.000167	2	32	50	0.000149
15	13	0	0B9A0F	760335	2.265975	1	14	20	0.00006	2	20	32	0.000095
16	14	0	0B9A2A	760362	2.266055	1	28	40	0.000119	2	22	34	0.000101
17	15	0	0B9A2A	760362	2.266055	1	38	56	0.000167	2	20	32	0.000095

aaa-049246

Figure 30. Voltage values

7.5.5 Save and load configuration file

The NAFExx388 GUI provides user-friendly save-and-load configuration file function, which allows the user to save current AFE channel #0-16 configurations, GPIO configuration, SCCR number of samples, MCCR-enabled channel, and MCCR number of loops in an .acs (AFE configuration settings) file. The user can load a previously saved .acs configuration file to load in all configuration settings into the GUI without the need to manually change every setting one by one in the GUI.

7.5.5.1 Save configuration file

1. Launch the NAFExx388 GUI, select all configuration settings (AFE channel #0-16 configuration settings, SCR/SCCR/MCR/MCCR settings), and proceed to the particular measurement or calibration. If the test result is as expected, the user can select Save AFE configuration in the File tab in the NAFExx388 GUI as shown in Figure 31.

aaa-049247

Figure 31. Save AFE configuration

2. Key in a file name (such as test1_save.acs) to save the particular measurement configuration settings in an .acs file to be used for future measurement.

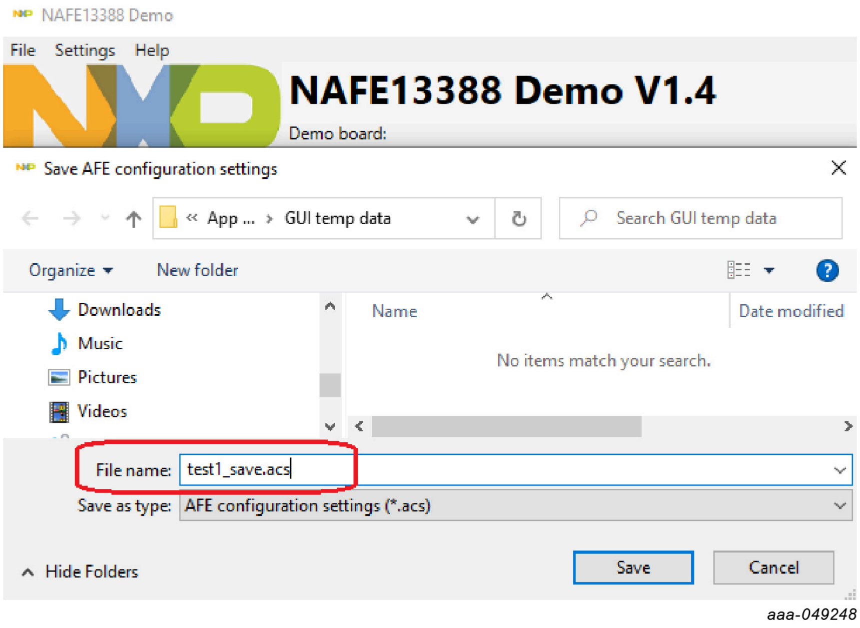


Figure 32. Example save file

7.5.5.2 Load configuration file

1. To launch the NAFExx388 GUI, select Open AFE configuration in the File tab.

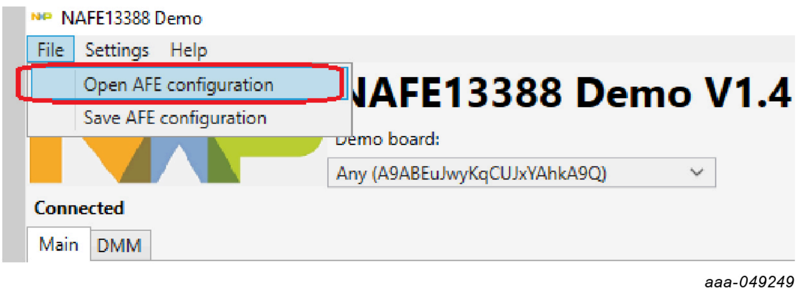


Figure 33. Launch the GUI

2. Open the saved .acs file to load all configuration settings and proceed, repeating the previous measurement or modifying some settings for a new measurement.

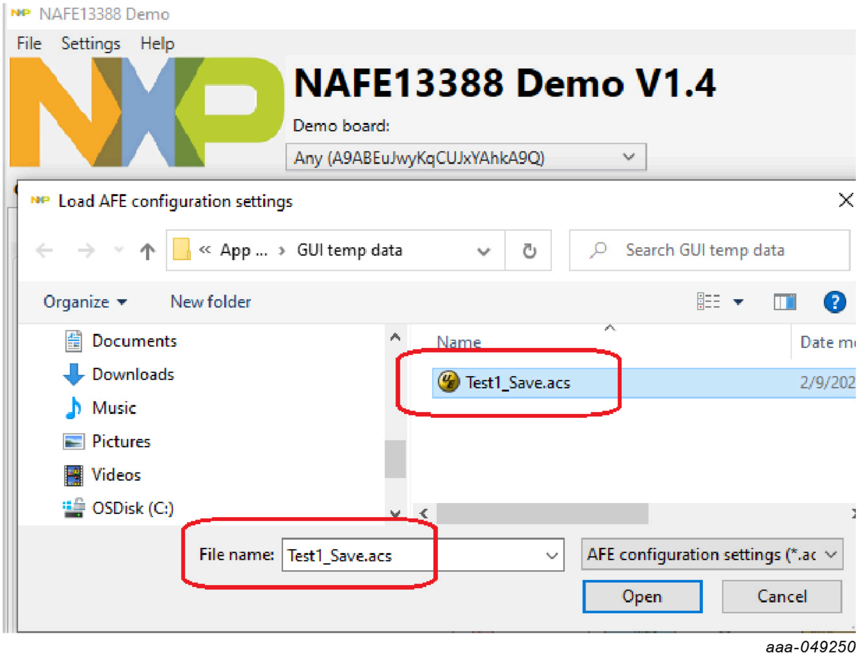


Figure 34. Open example save file

7.5.6 Fast Fourier transform (FFT) spectrum analysis

It is important the frequency of the source generator and the AI-AFE clock are coherent to perform an accurate spectrum analysis. Two conditions should be satisfied to have a coherent measurement:

1. The source generator and AI-AFE clock should be synchronized.
2. The input frequency, data-rate output, and sample counts should be selected to produce an integer of sinewave cycles.

If the conditions above are not satisfied, FFT spectral leakage could occur and produce an inaccurate measurement.

A high-quality source is required to characterize the AC performance. Otherwise, the performance could be limited to the source performance.

7.5.6.1 Simple test setup

In order to synchronize the AI-AFE and the source generator, use a two-output arbitrary waveform generator (AWG).

The output 1 provides the sinewave input to the AI-AFE, while the output 2 provides the external clock at 18.432 MHz for the AI-AFE.

Reset or power cycle the AFE, so the AFE selects the external clock automatically.

Note: *The external clock source should be already ON.*

aaa-049251

Figure 35. Simple test setup

7.5.6.2 Test conditions for coherent measurement

Sample Number = 8192.

Master clock (MCLK) = 18.432 MHz (provided by AWG, CH-2)

Input Frequency = 1001.953125 Hz (provided by AWG, CH-1)

MCLK	18.4320
MCLK/4	9.2160
Sample Number	8192
Sampling Rate	144000
Number of Cycle	57
Input Frequency	1001.953125000

aaa-049252

Figure 36. Input frequency

Note: *If the ADC is set in Normal Settling mode, it is recommended to capture five more samples, (for example, 4096 + 5 = 4101, instead of 4096) and discard the first five samples before calculating the FFT (for example, 4101 - 5 = 4096).*

The reason for this recommendation is that in Normal Settling mode, the first four or five samples are not settled if the ADC is in Normal Settling mode. This doesn’t apply if the ADC is set in Single-Cycle Settling mode.

7.5.6.3 Measurement results

In this simple setup, the performance is limited by the source generator that has limited AC performance.

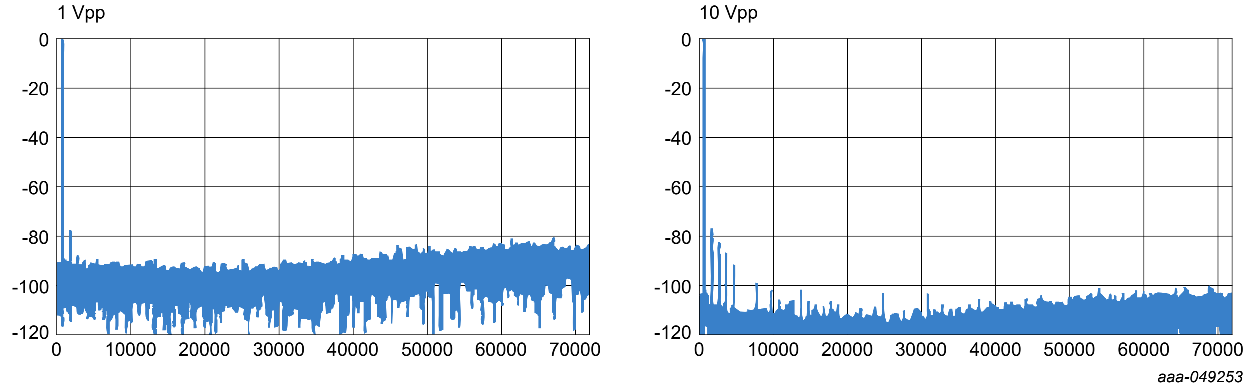


Figure 37. 1 kHz sinewave digitized at 144 ksps

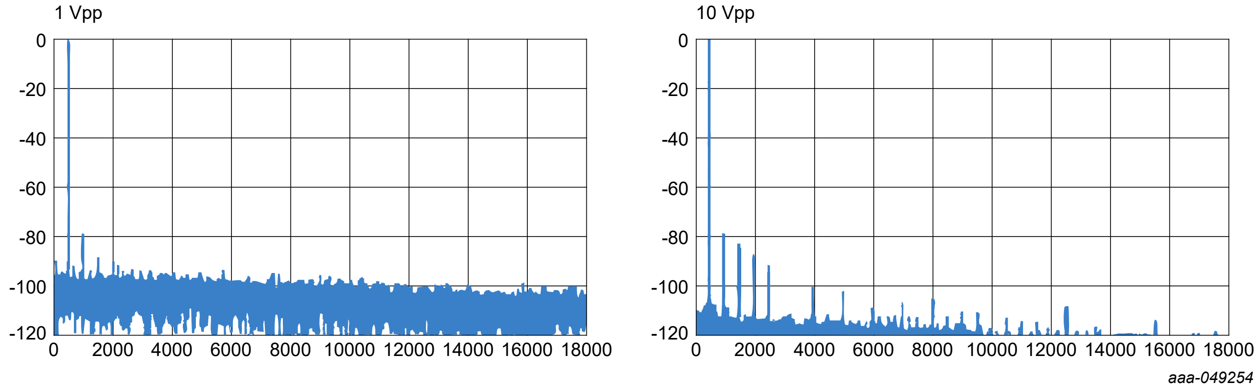


Figure 38. 1 kHz sinewave digitized at 36 ksps

7.5.7 Single-Channel Continuous Reading (SCCR) using SPI command vs SYNC pin

7.5.7.1 Using SPI command

1. GUI setting: Select Single-Cycle mode, ADC data rate = 12 ksps, PD = 6.9 µs and clock on Continuous Reading button.

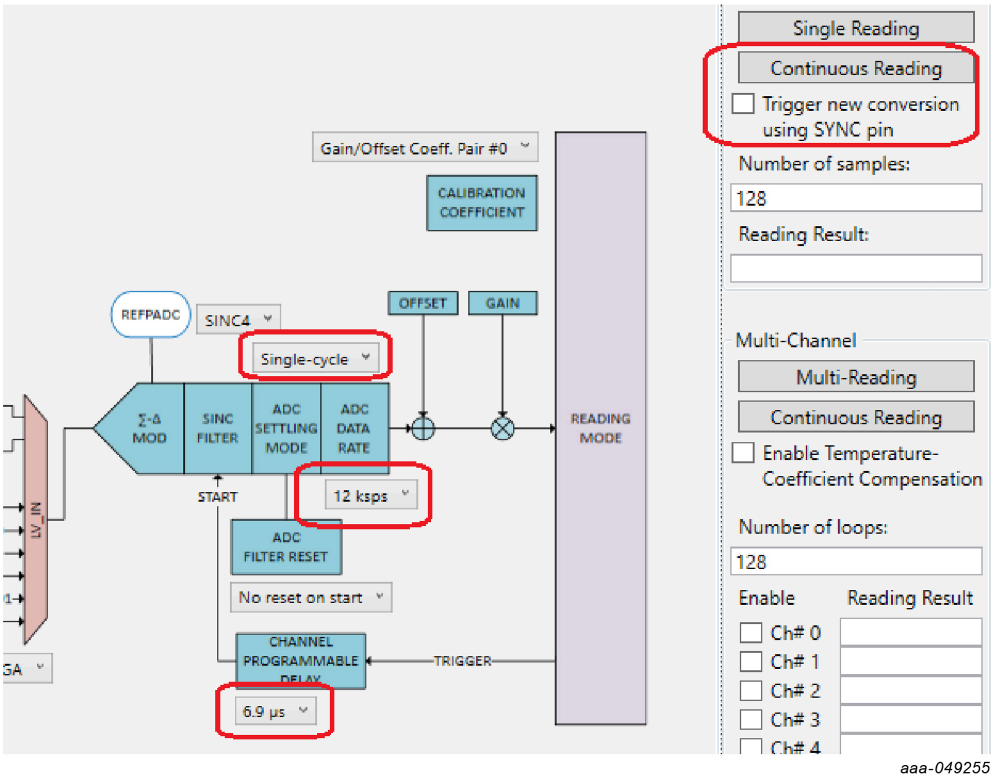
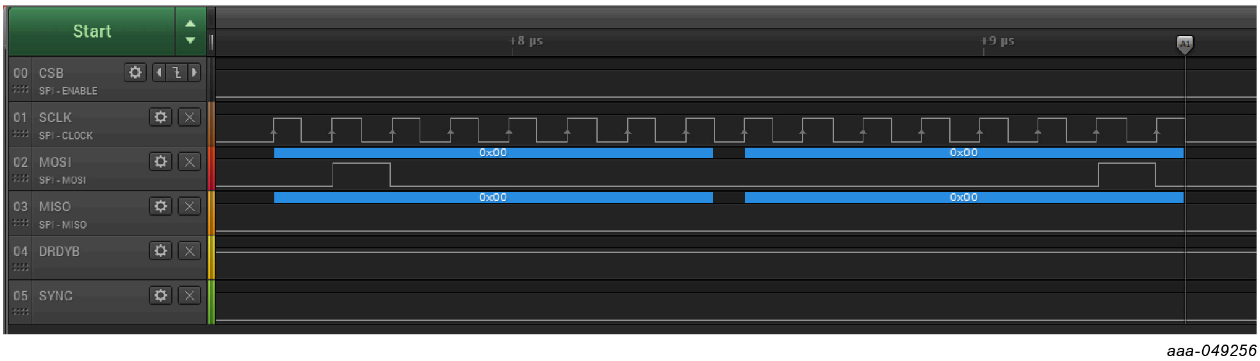
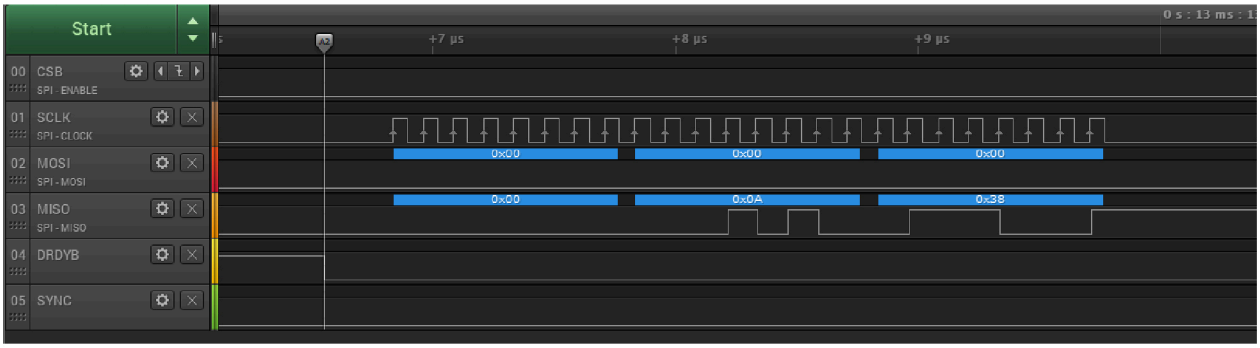


Figure 39. Single-Channel Continuous Reading using SPI command

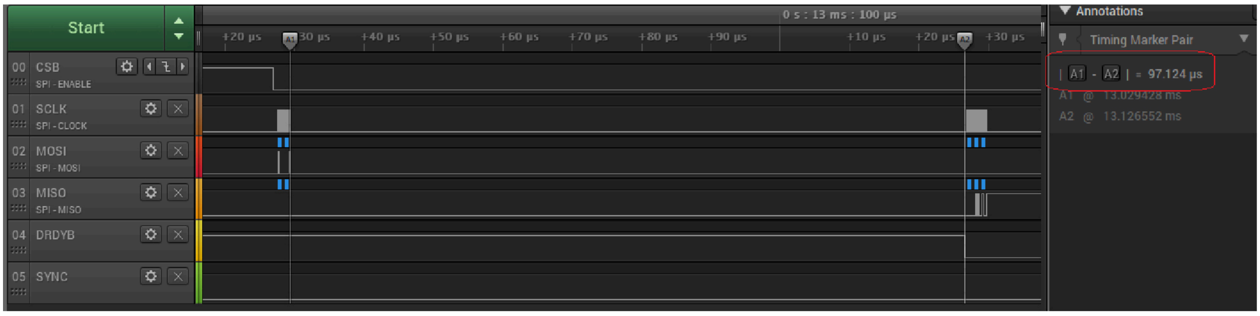
2. Logic analyzer waveform: The captured waveforms show the last falling edge of the clock using SPI command with respect to the falling edge of the DRDYB signal, which is the ADC reading time.





aaa-049257

Figure 40. A1 is measured at last falling edge of SPI clock, A2 is measured at falling edge of DRDYB pin

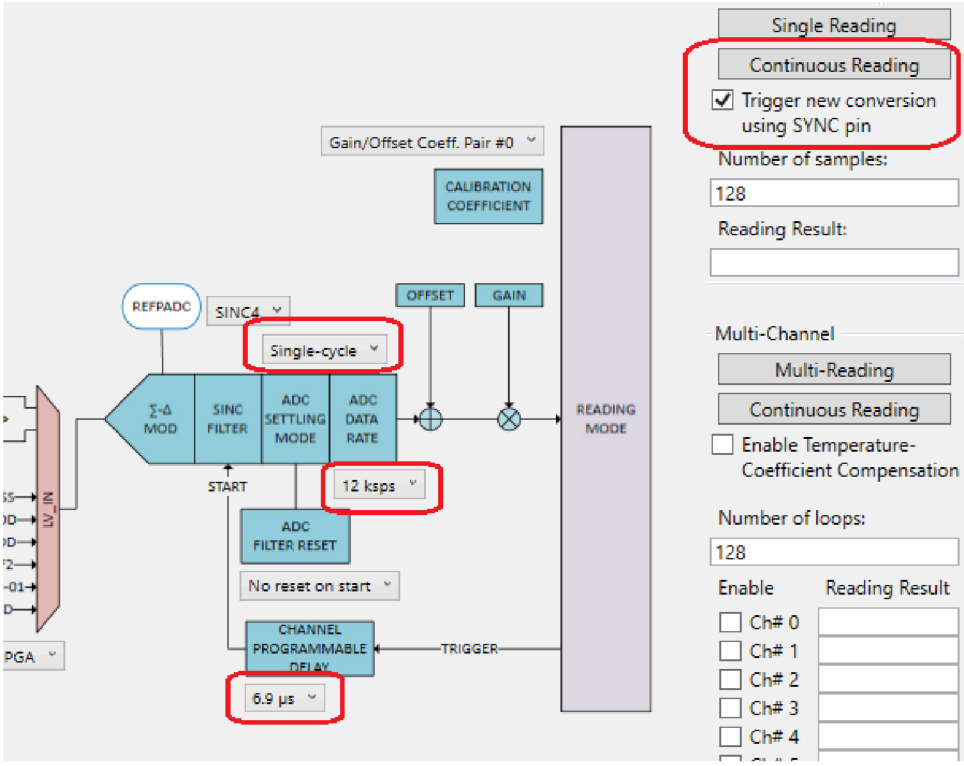


aaa-049258

Figure 41. SPI command to DRDYB signal waveform (A1 to A2 = 97.12 µS)

7.5.7.2 Using SYNC pin

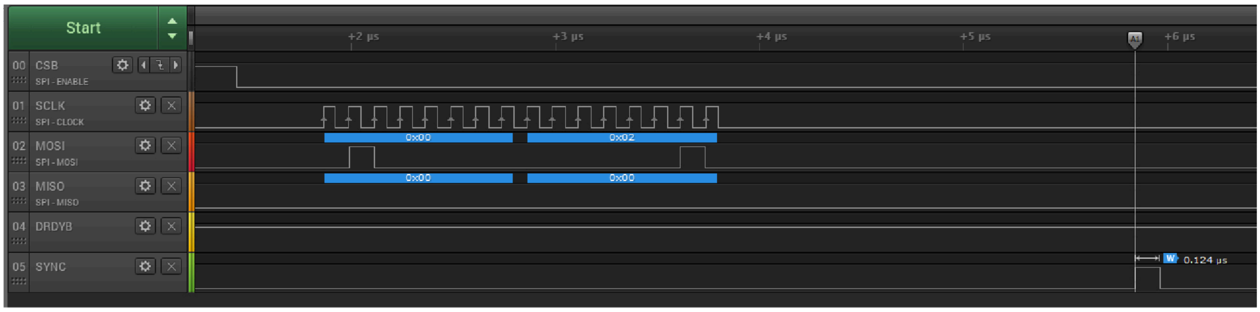
1. GUI setting: Select Single-Cycle mode, ADC data rate = 12 ksps, PD = 6.9 µs, select the Trigger new conversion using SYNC pin checkbox and click the Continuous Reading button.



aaa-049259

Figure 42. Single Channel Continuous Reading using SYNC pin

2. Logic analyzer waveform: The captured waveforms show the rising edge of the SYNC pulse with respect to the falling edge of DRDYB signal, which is ADC reading period time.



aaa-049260

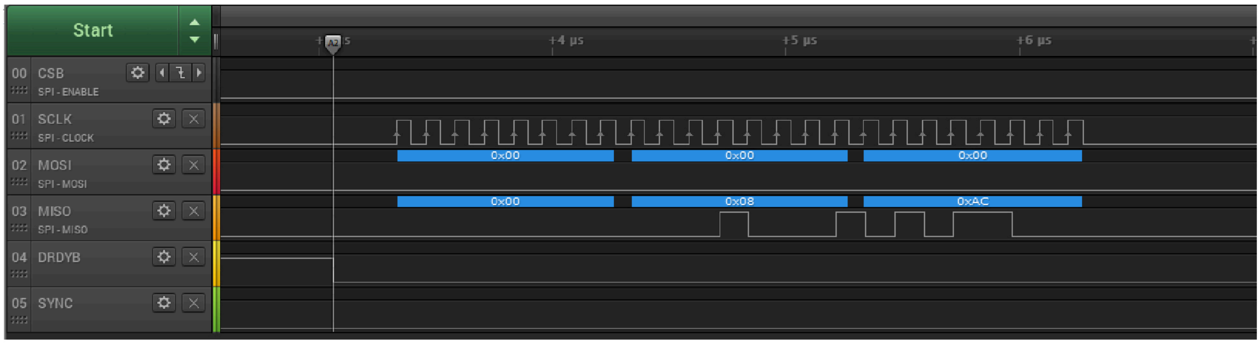


Figure 43. A1 is measured at rising edge of SYNC pulse, A2 is measured at falling edge of DRDYB pin

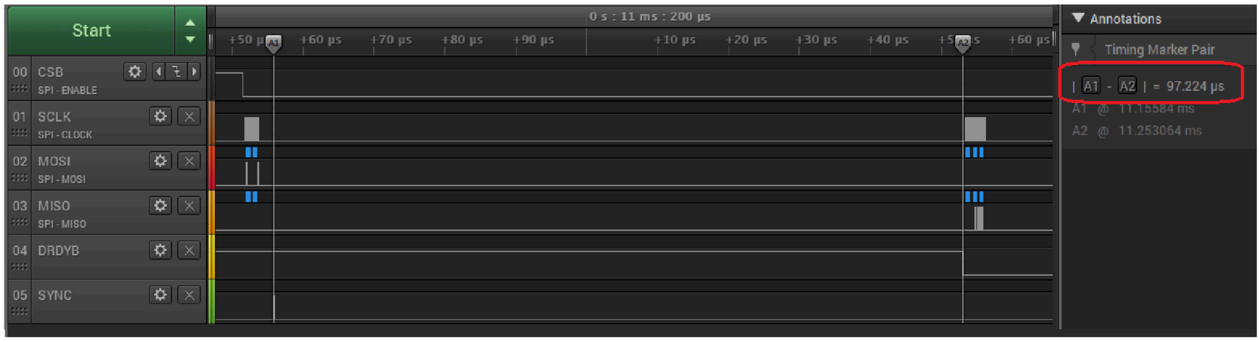


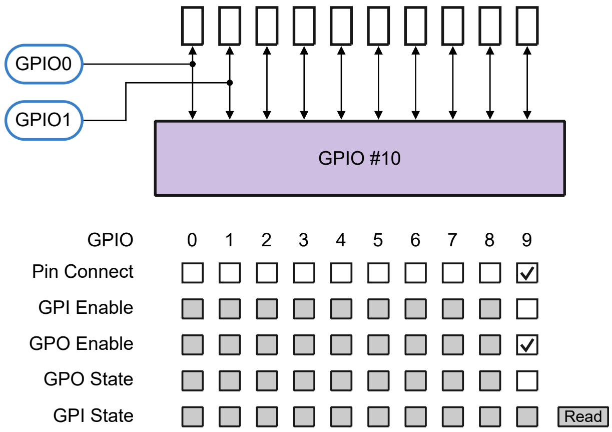
Figure 44. SYNC pulse to DRDYB signal waveform (A1 to A2 = 97.224 uS)

7.5.8 GPIO management

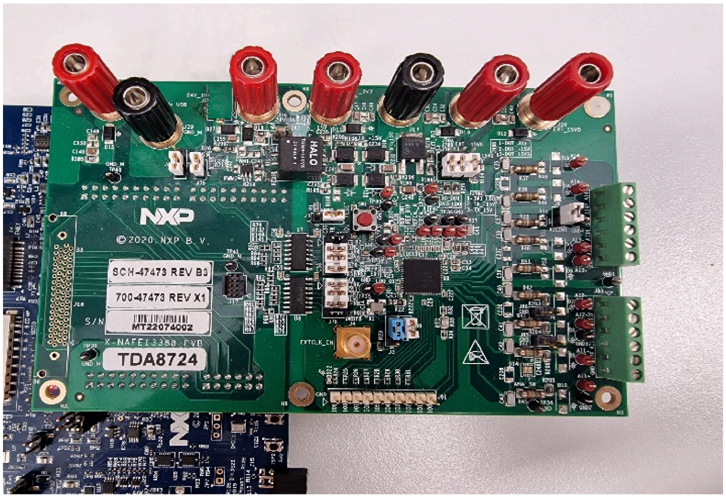
7.5.8.1 Output

An onboard LED is connected to GPIO9. The onboard LED makes GPIO9 the best GPIO to test the output behavior.

1. Configure GPIO9 as output.

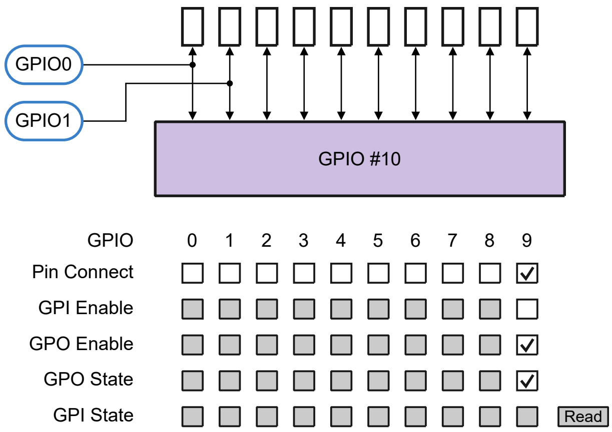


aaa-051685

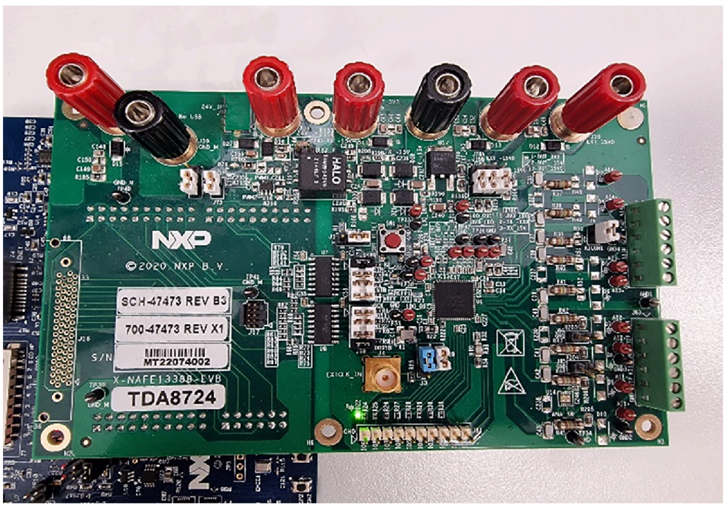


aaa-051687

2. Set the GPO state cell, then observe the LED status change accordingly.



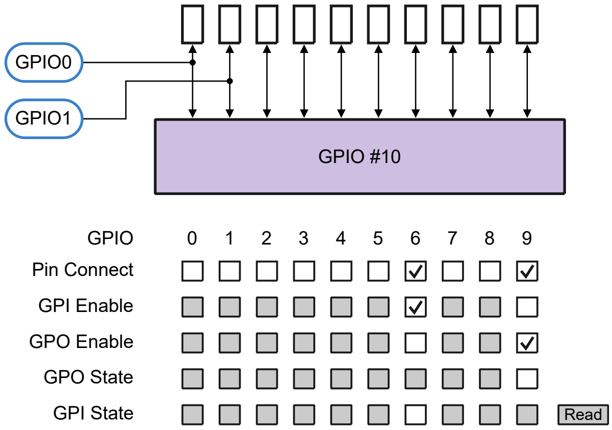
aaa-051686



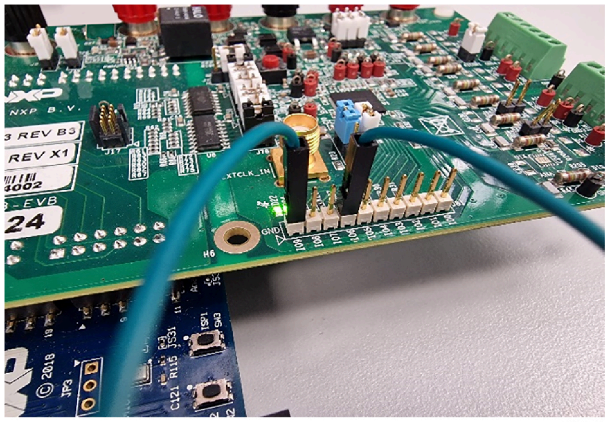
aaa-051688

7.5.8.2 Input

1. Short GPIO9 to GPIO6, set GPIO6 as INPUT and GPIO9 as OUTPUT.

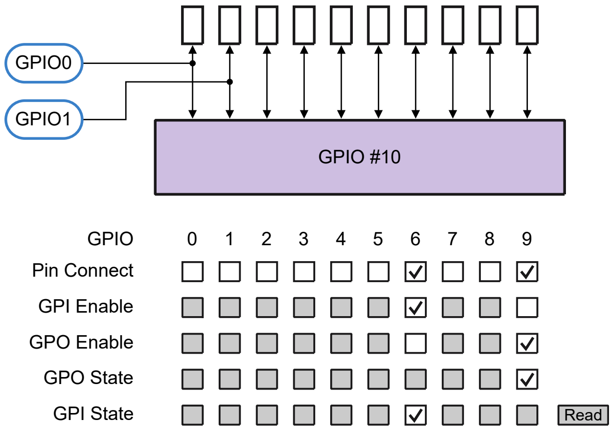


aaa-051683



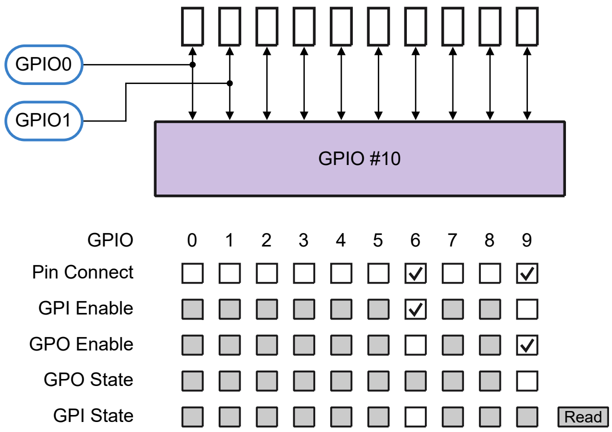
aaa-051684

2. Set High GPIO9 and click the **Read** button.



aaa-051681

3. Set Low GPIO9 and click the **Read** button.



aaa-051682

7.6 Applications demo

In the GUI, it is possible to try three typical applications of the NAFE:

- On-board RTD temperature measurement.
- Four wires PT100 temperature measurement.
- Load cell, weight measurement.

Under the Application tab are three sub tabs, one for each of the above stated applications.

7.6.1 Onboard RTD

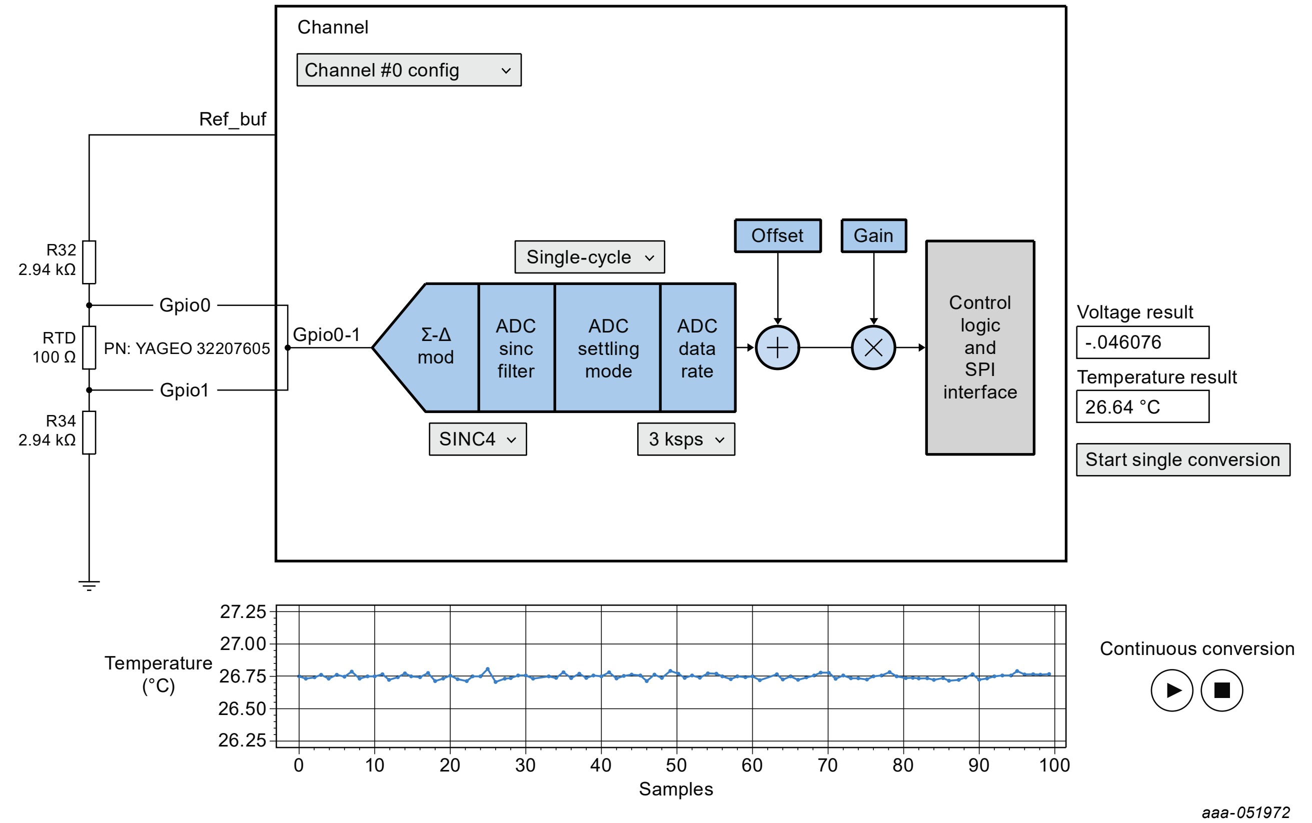


Figure 45. Voltage divider power

The EVKit features a voltage divider composed of two resistors and one thermistor. The voltage divider is powered by ref_buf output, as shown in the left portion of Figure 45.

In this section, it is possible to configure only:

- SINC filter
- Single/Normal-cycle
- Data rate

Pressing ► (Play) below “Start single conversion” will execute a single conversion. Two results will be shown: the voltage raw result and the temperature conversion.

In the bottom side of the tab, there is a chart and two buttons: ► (Play) and ■ (Stop). By pressing **Play**, a continuous conversion will be performed until the **Stop** button is pressed. The continuous conversion is configured to make 100 samples at a time. These samples will be plotted on the chart.

Figure 46. Continuous conversion warning

It is not possible to set slow rates too slow if Continuous mode is used. A warning message will appear below the Continuous conversion buttons as shown in Figure 46.

7.6.2 External 4 W PT100

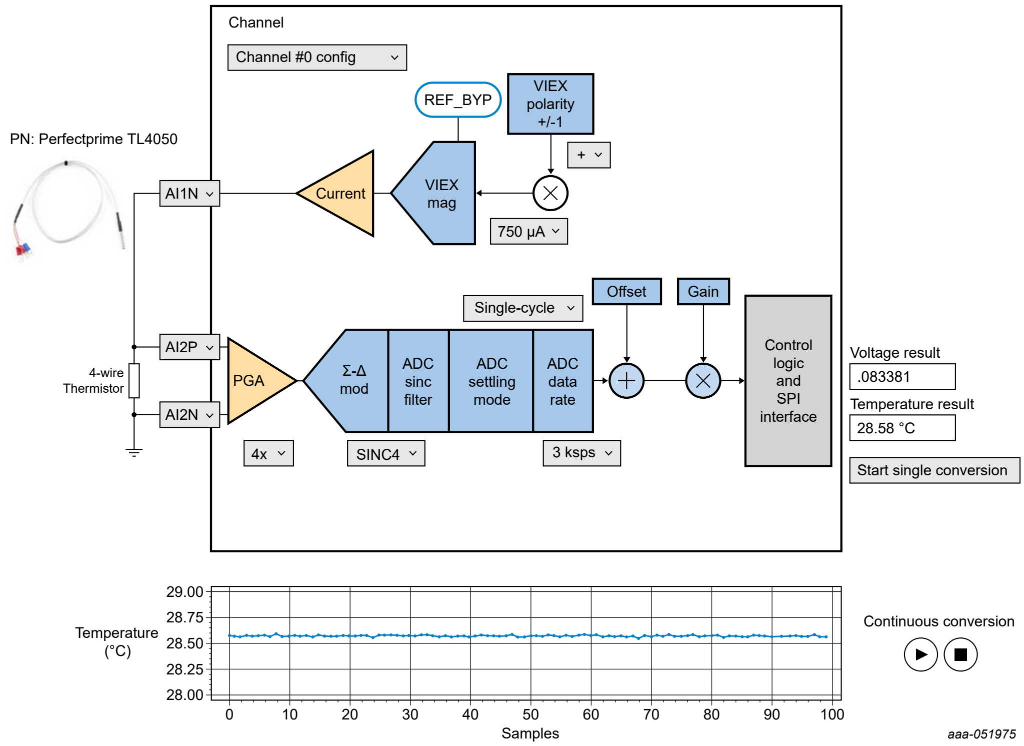


Figure 47. External 4 W PT100 tab

PT 100 temperature sensors are the most common type of platinum resistance thermometer. PT indicates the sensor is made from Platinum (Pt), 100 means, at 0 °C, the sensor has a resistance of 100 ohms (Ω). The four-wire configuration makes it possible to force a current through two wires and read the voltage on the other two wires. This allows the reading of voltage, eliminating the voltage drop because of the current.

In this section is possible to configure:

- Sinc filter
- Single/Normal-cycle
- Data rate
- Input pin (Sense)
- Output current pin (Force)
- Current magnitude
- Current sign

Pressing ► (Play) below "Start single conversion" will execute a single conversion. Two results will be shown: the voltage raw result and the temperature conversion.

At the bottom of the tab, there are a chart and two buttons: ▶ (Play) and ■ (Stop). By pressing ▶ (Play), a continuous conversion will be performed until the ■ (Stop) is pressed. The continuous conversion is configured to make 100 samples at a time. These sample will be plotted inside the chart.

Figure 48. Continuous conversion warning

It is not possible to set slow rates too slow if Continuous mode is used. A warning message will appear below the Continuous conversion buttons as shown in Figure 48.

7.6.3 Load Cell

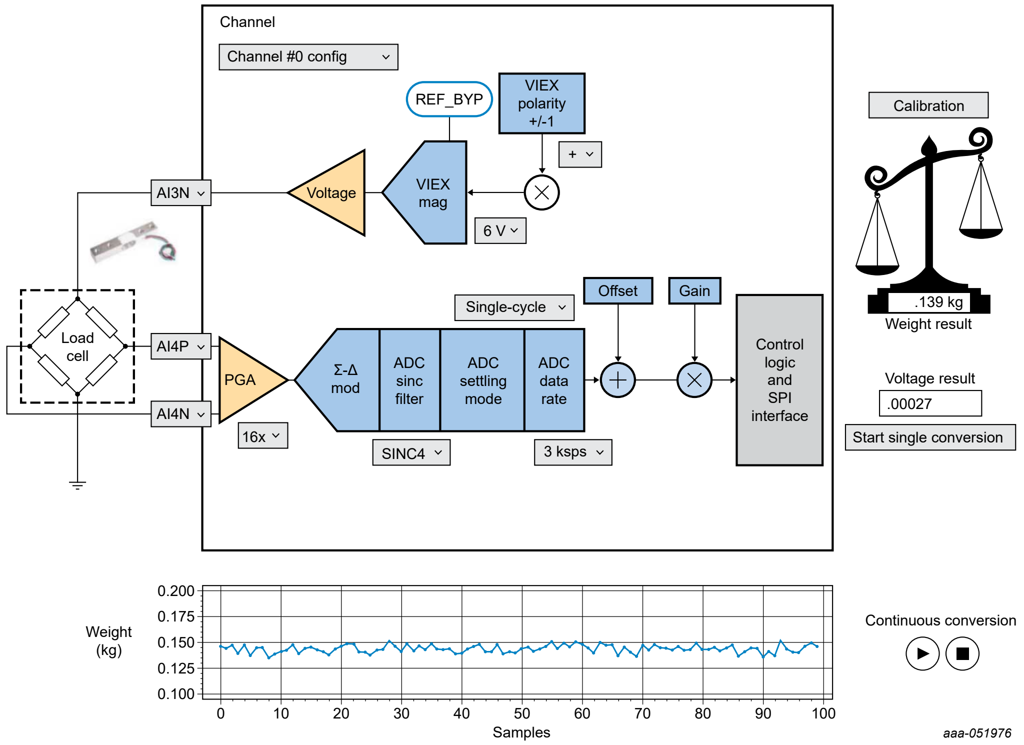


Figure 49. Strain gauge load cell

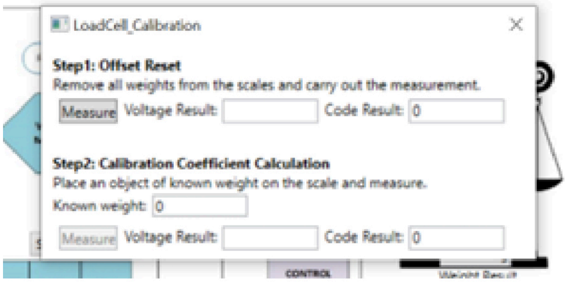
The internal functioning of a load cell differs according to the load cell chosen. There are, for example, hydraulic load cells, pneumatic load cells, and strain gauge load cells. For this example, shown in Figure 49, a strain gauge load cell was chosen.

In this section is possible to configure:

- Sinc filter
- Single/Normal-cycle
- Data rate
- Input pin (Sense)
- Output voltage pin (Force)
- Voltage magnitude
- Voltage sign

The voltage proportional to the force is very small (a few mVolts), which is why it is recommended to use 16x PGA.

For this kind of conversion, a calibration is needed before starting. This is because the load cell structure transfer function depends on the structure where the load cell is mounted. The calibration button will be bold and red each time a calibration is needed. When this button is pushed, a dialog appears.



aaa-051977

Figure 50.

The calibration process consists of two steps (as shown in the pop up dialogue window)::

1. **Offset Reset:** Remove all weight from the scale, and take one measurement. This value will be the value at 0 load, therefore the system offset.
2. **Calibration Coefficient Calculation:** Place an object of known weight on the weight scale, write the known weight (unit kg) in the input box, and take a measurement.

These two measurements take about 4 to 5 seconds.

Pressing ▶ (Play) below “Start single conversion” will execute a single conversion. Two results will be shown: the voltage raw result and the temperature conversion.

At the bottom of the tab, there are a chart and two buttons: ▶ (Play) and ■ (Stop). By pressing ▶ (Play), a continuous conversion will be performed until the ■ (Stop) is pressed. The continuous conversion is configured to make 100 samples at a time. These sample will be plotted inside the chart.

aaa-051973

Figure 51. Continuous conversion warning

It is not possible to set slow rates too slow if Continuous mode is used. A warning message will appear below the Continuous conversion buttons as shown in Figure 51.

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