NMS4110

Electrochemical Sensor Readout IC

PRELIMINARY
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EVK User Manual

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Revision History

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1 General Description

1.1 General Description

NMS4110 EVK (Evaluation Kit) supports that customer evaluates the performance of NMS4110 with customer's sensor. NMS4110 is a versatile, precision electro-chemical read-out IC, optimized for low-power Continuous Glucose Monitoring (CGM) systems. It supports multiple electrochemical measurement techniques, including amperometry and voltammetry, providing an efficient solution for bio-signal analysis. Equipped with a switch matrix, sensor detector, system timer, and non-volatile memory, NMS4110 is designed to maximize battery life and enhance overall user experience.

Switch Matrix offers flexible configurations of measuring blocks to support various sensors and variable terminology of sensor electrode, such as 2, 3, or 4 electrodes.

Sensor Detector detects insertion and prevents the chip from depleting the battery while in the shelf.

System Timer controls wake-up and sleep/shutdown status of NMS4110 and system to cut down the power consumption.

Non-Volatile Memory supports storing of configuration to make users do not care of reconfiguration at every time the system power-up and save the time and power consumption used for reconfiguration.

1.2 Features

- Flexible configuration for various sensor configurations
  - 2-terminal, 3-terminal, 4-terminal electrochemical sensor
  - Instrumental amplifier for voltage measurement such as wheat stone bridge
- Potentiostat platform supporting four measuring topologies
  - CV (Cyclic Voltammetry)
  - DPV (Differential Pulse Voltammetry),
  - CA (Chrono Amperometry)
  - MA (Multistep Amperometry)
- Support several measuring and test points to interface customer's sensors
- Up to two channel operation (Working 0 and Working 1)
- Graphic User Interface which is compatible with Windows 10 and 11

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1.3 EVK System Contents

- NMS4110 Evaluation Board for Evaluation of NMS4110
- Main Controller Board (ESP32-DevKitM-1) for Controlling and Monitoring NMS4110 using USB
- Strip Sensor Socket Connector

1.4 NMS4110 Evaluation Board

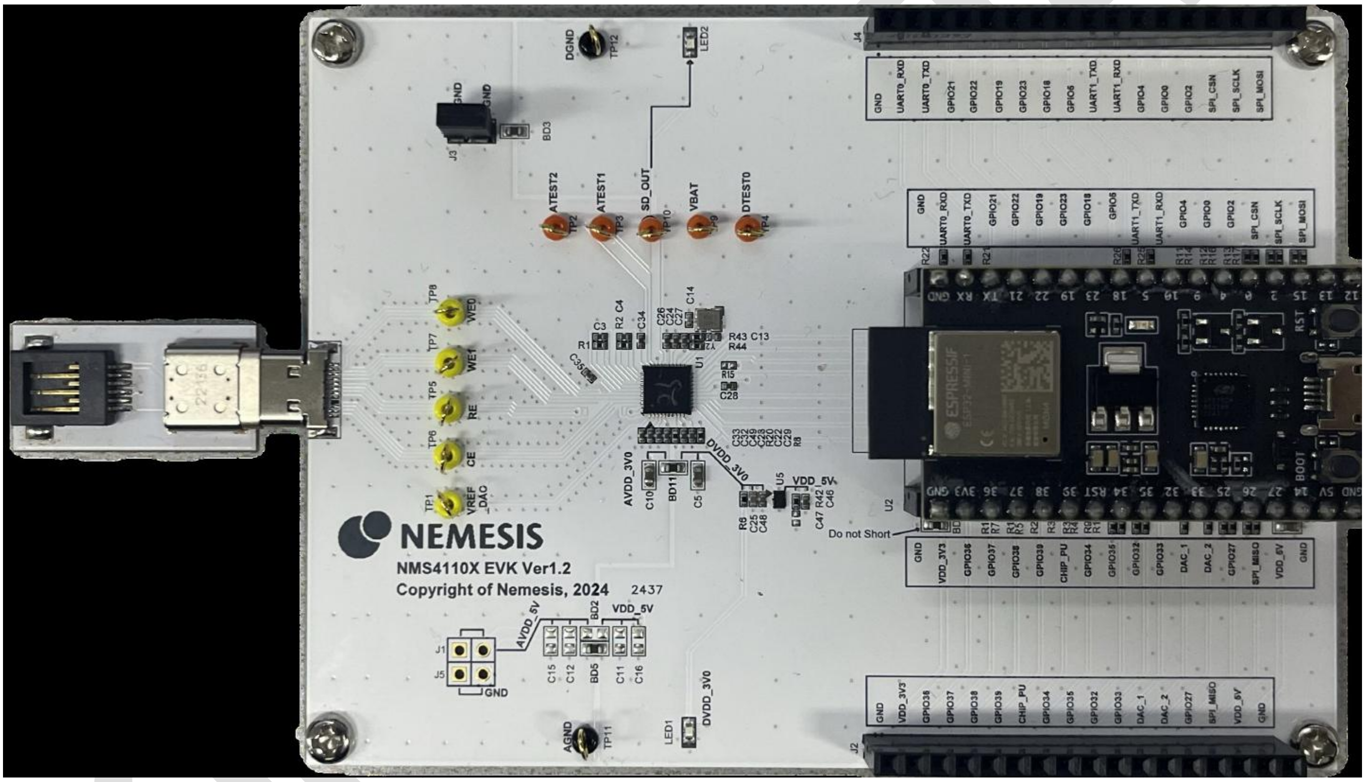

Figure 1 NMS4110 Evaluation Board

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1.5 NMS4110 EVK System Files

FILE	DESCRIPTION
NMS4110 Evaluation Kit.exe	PC GUI PROGRAM
Parameter_Confioguration_INIT.ini	Convenient for parameter configuration

2 Quick Start

- Required Equipment
  - NMS4110 EVK board
  - EPS32-DevkitM-1
  - Micro-USB cable
  - Windows PC with USB port

- Procedure

Here's a concise step-by-step outline for setting up and using the NMS4110 EVK board:

① USB Connection: Connect the ESP32-DevkitM-1 mounted on the EV board to the PC via a Micro-USB cable. Once connected, the device should appear as shown in Figure 2. (Note: The Silicon Labs CP210x driver is required for PC communication with ESP32-DevkitM-1.)

② LED Power Indicator: LED1 on the EVK board should light up, indicating power status (independent of PC communication).

③ Launching GUI(No separate installation required): Run the NMS4110-EVK.exe program. Click the "connect" button in the communication window (shown in Figure 3). The COM port and default baud rate (460800) will be automatically selected, though you may need to manually choose the correct COM port if multiple EVKs are used.

④ Sensor Connection: Connect the jumper to the test point that aligns with the sensor's electrode(shown in Figure 4, Refer to the 6 Configuration for Sensor Connecting for more details).

⑤ Sensor Detection: After connecting, if a sensor with a significant impedance is inserted into the NMS4110 EVK board's sensor slot, LED2 (sensor detector) will light up. The firmware version will be visible at the top left of the GUI (Figure 5).

⑥ Hardware Setup Completion: Once these steps are complete, the hardware setup for sensor evaluation is ready.

⑦ Configuration and Evaluation:

a. Select the sensor's switch configuration in the Switch Config. tab.

b. Choose the desired electrochemical technique in the Topology tab and enter parameters.

c. In the Calibration tab, select the expected current range using the AG combo box.

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d. Start the evaluation by clicking "Run" in the Run tab to view the sensor's results.

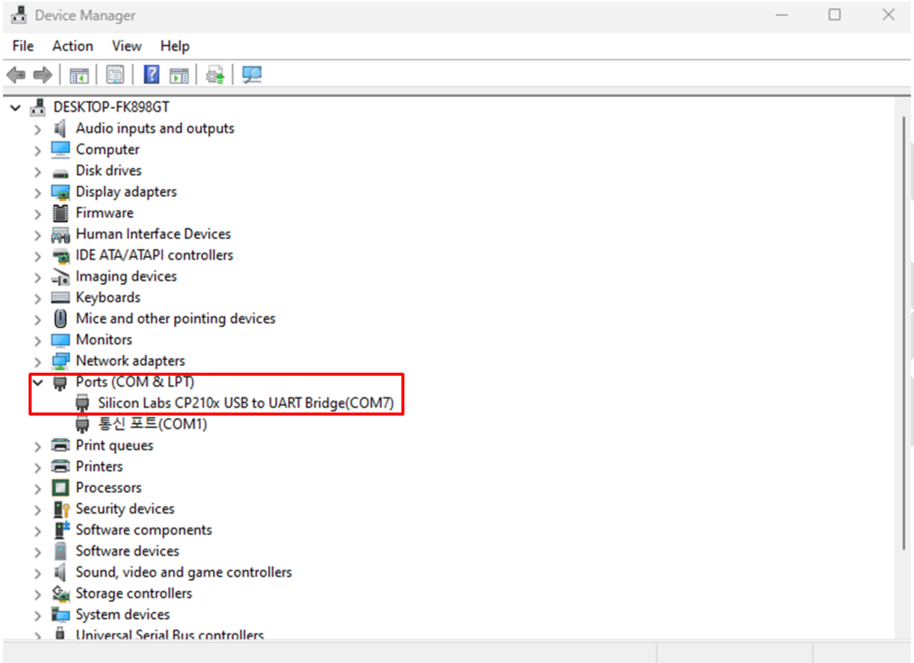

Figure 2 EVK Device on Windows Device Manager

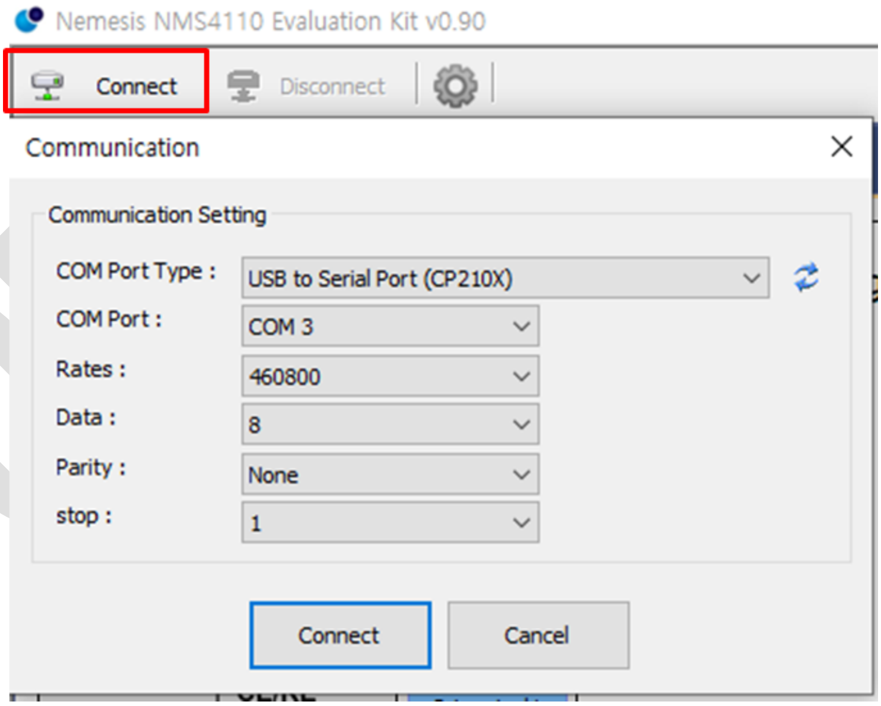

Figure 3 Communication Window

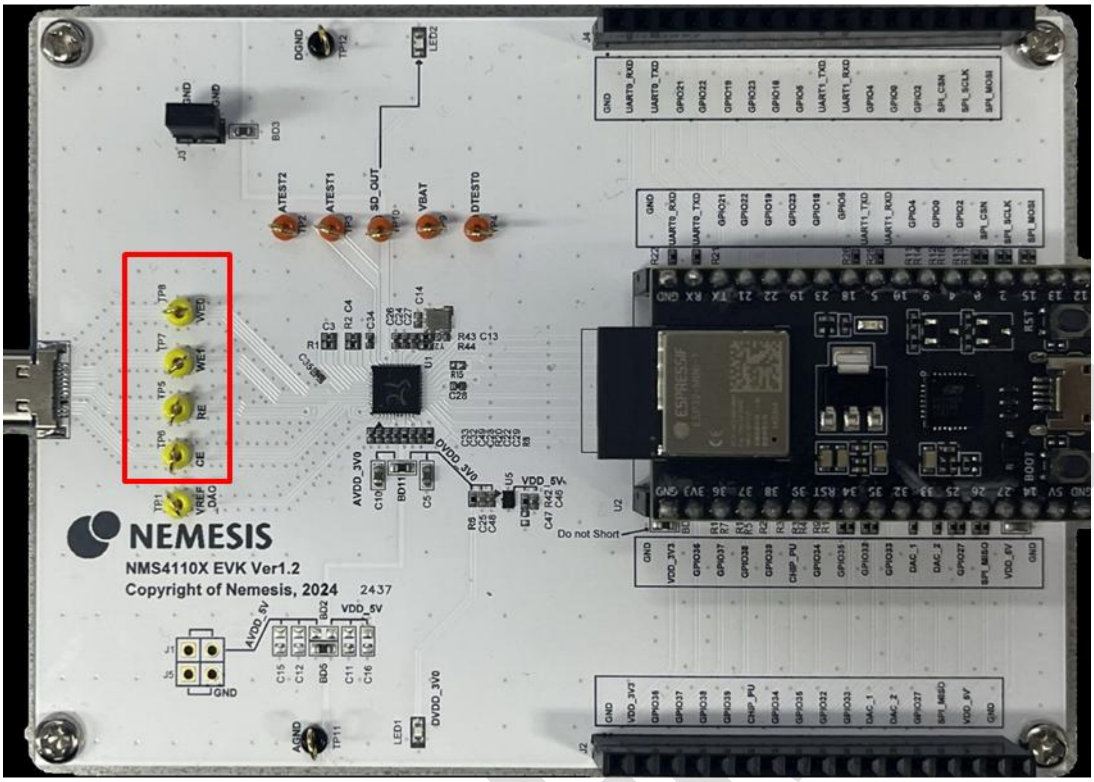

Figure 4 Electrode Test Point

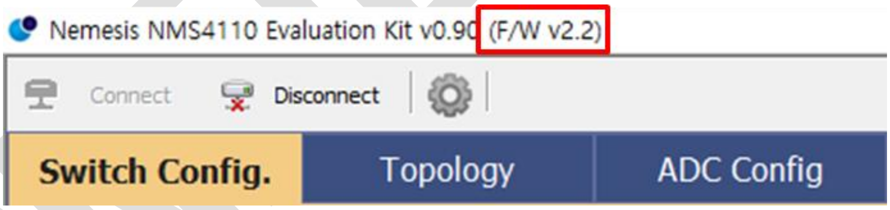

Figure 5 Firmware Version

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3 Test Example

TBD

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4 GUI TAB Description

4.1 Switch Config.

4.1.1 Available Configuration

- 3-terminal-WE0
- 3-terminal-WE1
- 2-terminal-WE0
- 2-terminal-WE1
- 4-terminal-WE0 and WE1

4.1.2 Switch Config. Features

Here's a breakdown of the switch configuration settings on the NMS4110 EVK board:

- Default Switch Configuration: Each switch configuration has a corresponding default setting that can be selected. Once a switch configuration is chosen, it visually represents the internal switch layout of the NMS4110, providing a graphical view.
- Custom Switch Configuration: If the user wishes to apply a different configuration than the default, they can modify the switch settings directly. This customization is done through the switch configuration table on the right, allowing for tailored adjustments as needed.

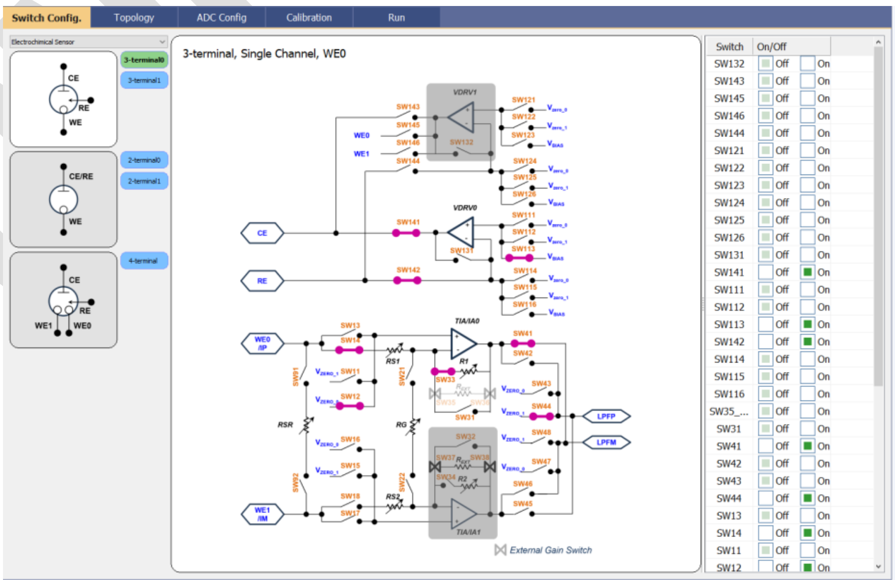

Figure 6 Tab Switch Config

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4.2 Topology

Here's an overview of the settings in the Topology Tab of the NMS4110 EVK board GUI:

- Topology Selection: The Topology Tab offers four main options:
  - Voltammetry
    - Cyclic Voltammetry (CV)
    - Differential Pulse Voltammetry (DPV)
  - Amperometry:
    - Chrono Amperometry (CA)
    - Multistep Amperometry (MA)
- Parameter Display: When a topology is selected, the parameters relevant to that topology are displayed along with a voltage scan wave diagram for easy visualization.
- Default Settings: The parameters shown are set to the GUI's default configuration but can be adjusted based on specific needs.
- Current Consideration for VLOW/VHIGH: If the expected sensor current is 12 μA or higher, ensure that the VLOW and VHIGH settings are within the recommended range of -0.3 mV to +0.3 mV. This helps maintain optimal performance for high-current sensors.

4.2.1 Cyclic Voltammetry (CV)

Here's a summary of additional details regarding Cyclic Voltammetry (CV) in the Topology Tab:

- Cyclic Voltammetry Selection: When CV is selected in the Topology Tab, the interface updates as shown in Figure 7, and relevant parameters can be referred to in Table 1.
- Data Sampling Parameters:
  - TSTEP: Set to 1 second, indicating the time step for each data point.
  - SN (Samples per Second): Set to 2 samples per second (N/S), meaning data is sampled twice per second. Sampling starts from the end of each voltage scan pulse.
  - Recommended TSTEP/SN Values: Ensure that TSTEP/SN values are at least 0.001 seconds to maintain data accuracy.

This setup provides optimal sampling for CV analysis, enabling effective data collection within each voltage scan cycle. Let me know if more details are needed on any specific parameter or configuration!

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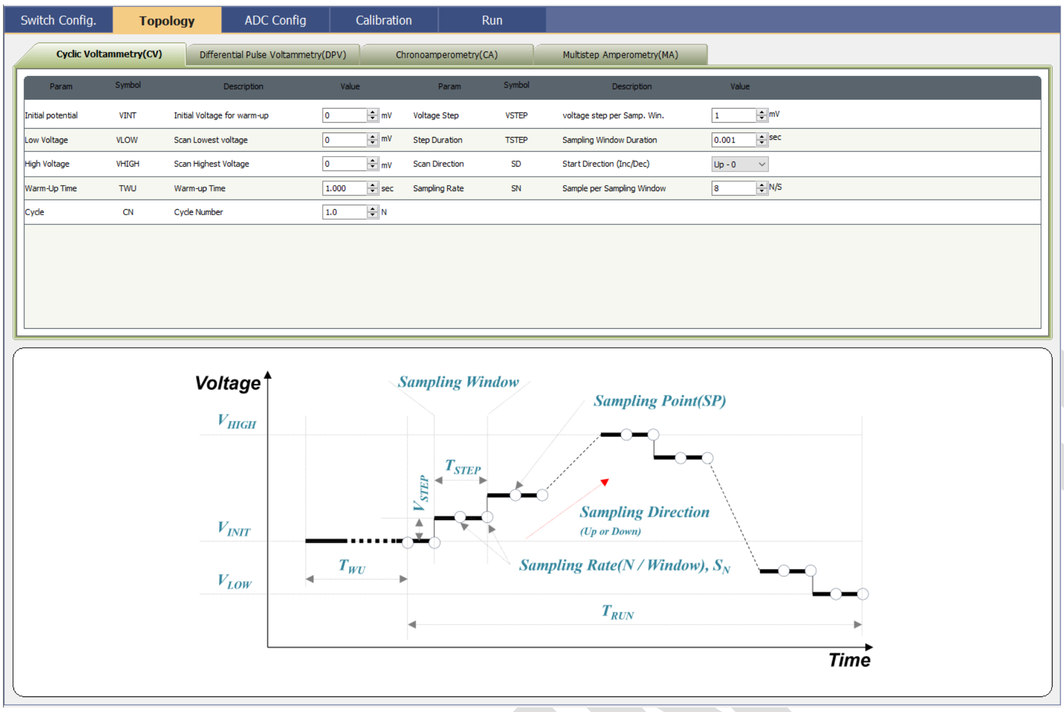

Figure 7 Topology CV

Table 1 CV Parameters

Selection Menu	Menu Parameter	Variable	Unit	Min/Max	Default	Description
CV	Initial potential	V_{INT}	mV	-800/+800	0	Initial Voltage for warm-up (Only for T_{WU} Period)
	Low Voltage	V_{LOW}	mV	-800/+800	0	Scan Lowest voltage
	High Voltage	V_{HIGH}	mV	-800/+800	0	Scan Highest Voltage
	Warm-Up Time	T_{WU}	sec	0.001/100	1	Warm-up Time
	Cycle	C_N	N	0.5/100	1	Number of cycle (increment step=0.5)
	Voltage Step	V_{STEP}	mV	1/1000	1	Voltage step at every T_{STEP}
	Step Duration	T_{STEP}	sec	0.001/10	0.001	Sampling Window Duration
	Scan Direction	S_D		0/1	0	Start Direction (Inc/Dec) [0] Up : start increment from V_{INT} [1] Down : start decrement from V_{INT}
	Sampling Rate	S_N	N/S	1/100	8	Sample per Sampling Window, The number of ADC conversion for T_{STEP}

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4.2.2 Differential Pulse Voltammetry (DPV)

Here's an overview of Differential Pulse Voltammetry (DPV) settings in the Topology Tab:

- DPV Selection: When DPV is chosen in the Topology Tab, the interface updates as shown in Figure 8. For specific DPV parameters, refer to Table 2.
- Data Sampling:
  - TSTEP: The data sampling rate in DPV is determined by the user-defined TSTEP. For instance, if TSTEP is set to 0.1 seconds, the voltage scan rate for VSTEP and VPULSE will be allocated as 0.05 seconds each.
  - SN (Sampling Rate): Fixed at 1 sample per second (1 S/N).
- Recommended TSTEP Value: A minimum TSTEP setting of 0.001 seconds is recommended for optimal accuracy.

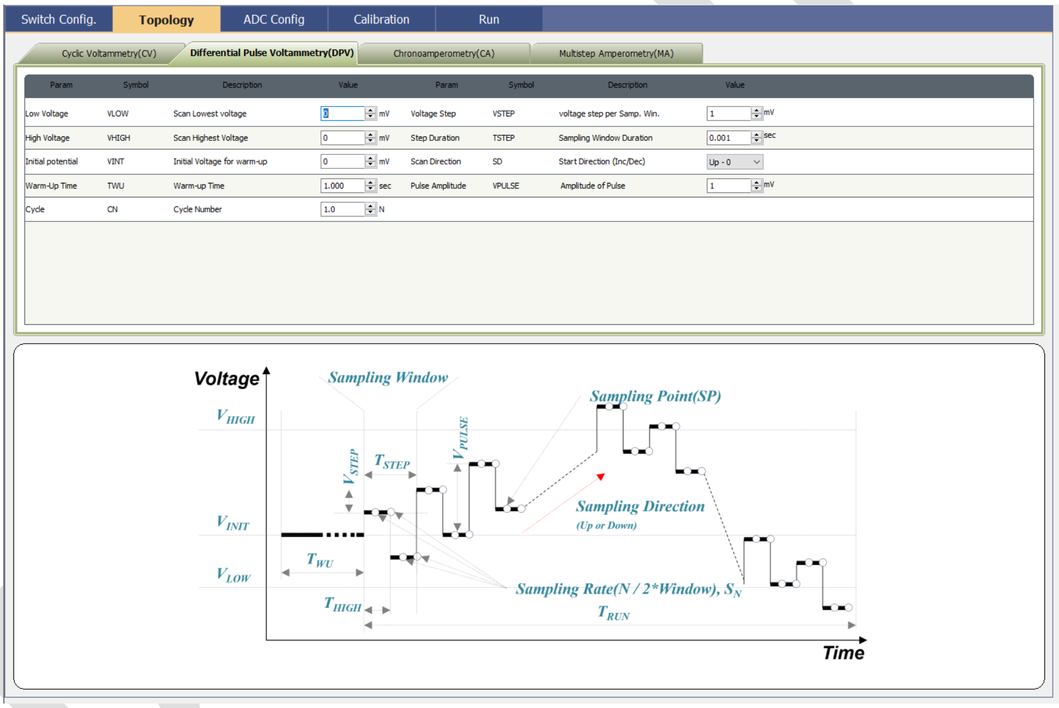

Figure 8 Topology DPV

Table 2 Topology DPV

Selection Menu	Parameter	Variable	Unit	Min/Max	Default	Description
DPV	Low Voltage	V_{LOW}	mV	-800/+800	0	Scan Lowest voltage
	High Voltage	V_{HIGH}	mV	-800/+800	0	Scan Highest voltage
	Initial Voltage	V_{INT}	mV	-800/+800	0	initial voltage for warm up
	Warm-Up	T_{WU}	sec	0.001/100	1	Warm-up Time

	Time					
	Cycle	C_N	N	*0.5/100*	*1*	The number of Cycle (step size = 0.5)
	Voltage Step	V_{STEP}	mV	0/1600	1	Voltage Step Per Sample Window
	Step Duration	T_{STEP}	sec	0.001/10	0.001	Sampling Window Duration
	Scan Direction	S_D		0/1	0	Start Direction (Inc/Dec) [0] Up : start increment from V_{INT} [1] Down : start decrement from V_{INT}
	Pulse Amplitude	V_{PULSE}	mV	1/1000	1	Amplitude of Pulse

4.2.3 Chrono Amperometry (CA)

Here's an outline of Chrono Amperometry (CA) settings in the Topology Tab:

- CA Selection: When CA is selected in the Topology Tab, the interface updates as shown in Figure 9. Refer to Table 3 for specific CA parameters.
- TSTEP Configuration: For CA, ensure that TSTEP is set to be less than the values of T1 and T2. The integer result of T1(T2) / TSTEP determines the number of sampling windows, while any remainder creates a delay after the window ends.
- Recommended TSTEP/SN Value: A minimum setting of 0.001 seconds for TSTEP/SN is recommended to maintain accurate data sampling.

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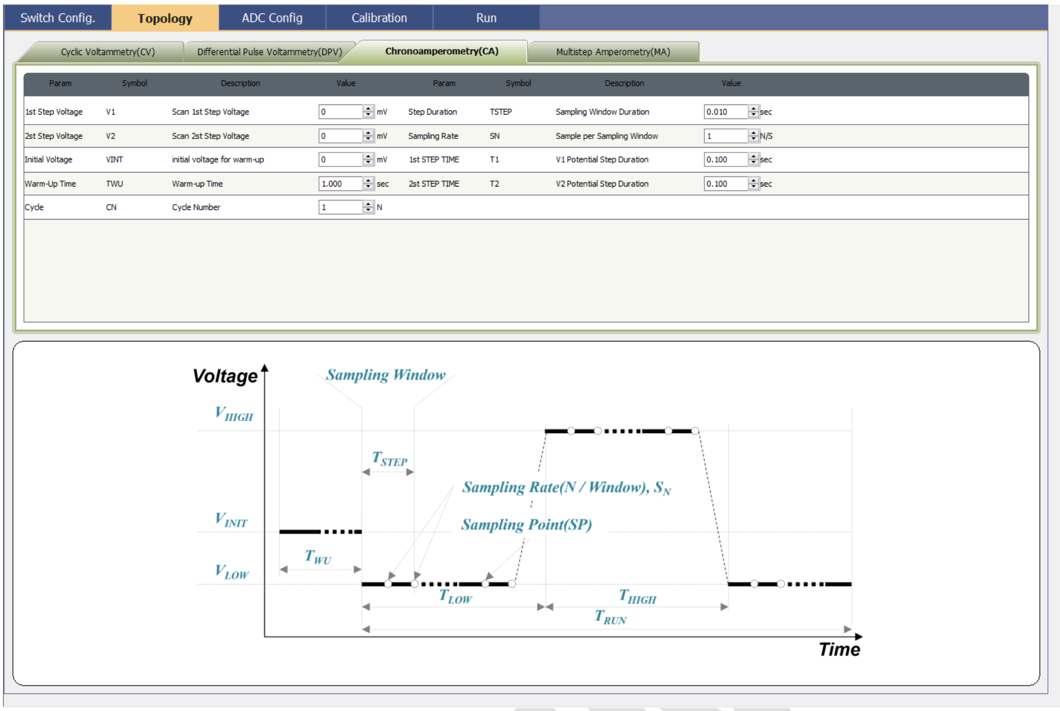

Figure 9 Topology CA

Table 3 CA Parameters

Selection Menu	Parameter	Variable	Unit	Min//Max	Default	Description
CA	1st Step Voltage	V_1	mV	-800/+800	0	Scan 1st Step Voltage
	2nd Step Voltage	V_2	mV	-800/+800	0	Scan 2nd Step Voltage
	Initial Voltage	V_{INT}	mV	-800/+800	0	initial voltage for warm-up (only for T_{WU} period)
	Warm-Up Time	T_{WU}	sec	0.001/100	1	Warm-up Time
	Cycle	C_N	N	1/100	1	The number of Cycle (step size=1)
	Step Duration	T_{STEP}	sec	0.001/10	0.01	Sampling Window Duration (meet $T_{STEP} < T_1$ and $T_{STEP} < T_2$)
	Sampling Rate	S_N		1/100	1	Sample per Sampling Win
	1st STEP TIME	T_1	sec	0.001/10	0.1	V_1 Potential Step Duration
	2nd STEP TIME	T_2	sec	0.001/10	0.1	V_2 Potential Step Duration

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4.2.4 Multistep Amperometry (MA)

Here's an overview of Multistep Amperometry (MA) settings in the Topology Tab:

- MA Selection: When MA is selected in the Topology Tab, the interface updates as shown in Figure 10. Refer to Table 4 for specific MA parameters.
- TSTEP Configuration: Similar to Chrono Amperometry (CA), TSTEP in MA should be less than the values of T1, T2, …, T10 (configurable via CSTEP). The number of sampling windows is determined by the integer result of T1(T2) / TSTEP, and any remainder introduces a delay after the window ends.
- Recommended TSTEP/SN Value: Setting TSTEP/SN to at least 0.001 seconds is recommended for optimal sampling accuracy.

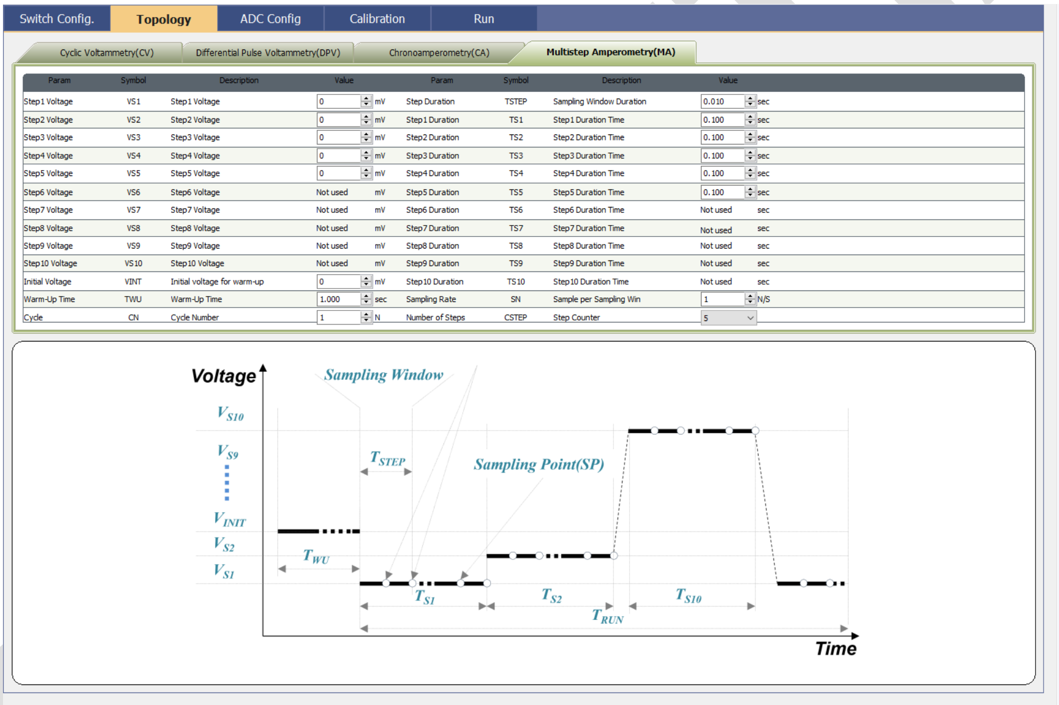

Figure 10 Topology MA

Table 4 MA parameters

Selection Menu	Parameter	Variable	Unit	Min/Max	Default	Description
MA	Step1 Voltage	V_{S1}	mV	-800/+800	0	Step1 Voltage
	Step2 Voltage	V_{S2}	mV	-800/+800	0	Step2 Voltage
	Step3 Voltage	V_{S3}	mV	-800/+800	0	Step3 Voltage
	Step4 Voltage	V_{S4}	mV	-800/+800	0	Step4 Voltage
	Step5 Voltage	V_{S5}	mV	-800/+800	0	Step5 Voltage
	Step6 Voltage	V_{S6}	mV	-800/+800	0	Step6 Voltage
	Step7 Voltage	V_{S7}	mV	-800/+800	0	Step7 Voltage
	Step8 Voltage	V_{S8}	mV	-800/+800	0	Step8 Voltage

	Step9 Voltage	V_{S9}	mV	-800/+800	0	Step9 Voltage
	Step10 Voltage	V_{S10}	mV	-800/+800	0	Step10 Voltage
	Initial voltage	V_{INT}	mV	-800/+800	0	initial voltage for warm-up (only for T_{WU} duration)
	Warm-Up Time	T_{WU}	sec	0.001/100	1	Warm-up Time
	Cycle	C_N	N	1/100	1	The number of Cycle (step size=1)
	Step Duration	T_{STEP}	sec	0.001/1	0.01	Sampling window duration (meet $T_{STEP} < T_{SX}$, X =from 1 to 10)
	Step1 Duration	T_{S1}	sec	0.001/10	0.1	Step1 Duration Time
	Step2 Duration	T_{S2}	sec	0.001/10	0.1	Step2 Duration Time
	Step3 Duration	T_{S3}	sec	0.001/10	0.1	Step3 Duration Time
	Step4 Duration	T_{S4}	sec	0.001/10	0.1	Step4 Duration Time
	Step5 Duration	T_{S5}	sec	0.001/10	0.1	Step5 Duration Time
	Step6 Duration	T_{S6}	sec	0.001/10	0.1	Step6 Duration Time
	Step7 Duration	T_{S7}	sec	0.001/10	0.1	Step7 Duration Time
	Step8 Duration	T_{S8}	sec	0.001/10	0.1	Step8 Duration Time
	Step9 Duration	T_{S9}	sec	0.001/10	0.1	Step9 Duration Time
	Step10 Duration	T_{S10}	sec	0.001/10	0.1	Step10 Duration Time
	Sampling Rate	S_N		1/100	1	Sample per Sampling Win
	Number of Steps	C_{STEP}		1/10	5	Step Counter

4.3 ADC Config

Here’s a summary of the ADC Config Tab settings:

- Filter Type (FT) Selection: In the ADC Config Tab, the user can select the desired filter type (FT). Based on the chosen filter type and calculated filter parameters, a characteristic graph is displayed under Parameters.
- Output Data Rate and Other Parameters: Settings such as Output Data Rate, OSR (Oversampling Ratio), Filter Stage, and Average Sample are determined by the Sampling Window Duration and Samples per Sampling Window configured in the Topology Tab.
- Custom ADC Configurations: If the user wants to customize ADC configuration parameters beyond the default, they can uncheck the USE DEFAULT VALUE option.

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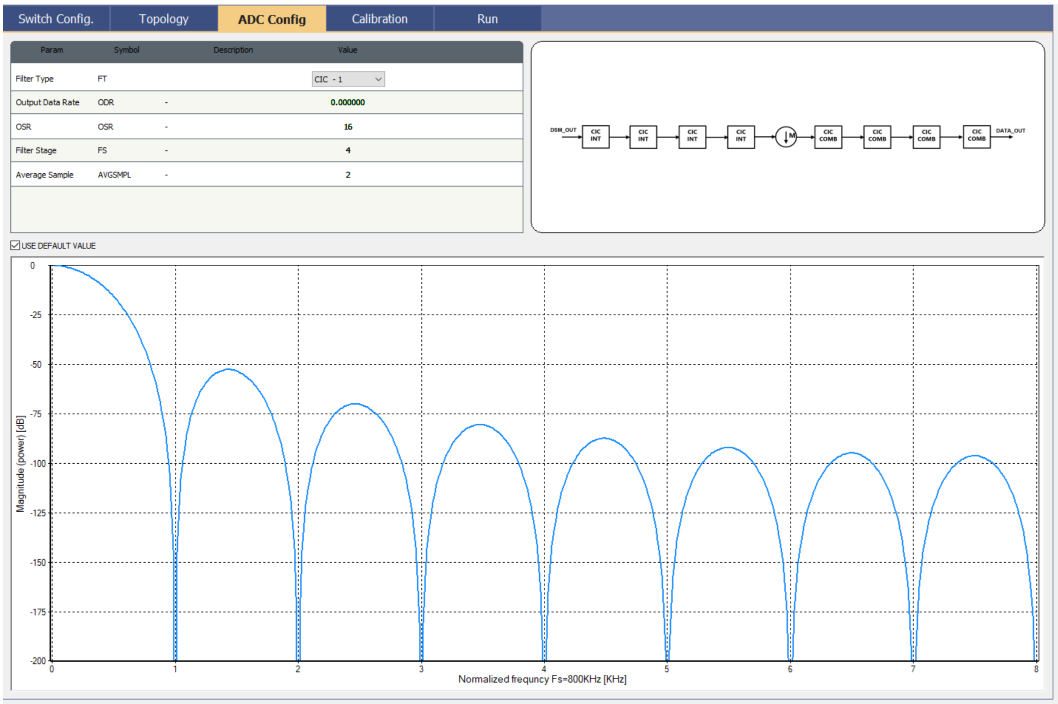

4.4 Calibration

Here's a breakdown of the Calibration Tab settings:

- Current Range and Offset Selection: In the Calibration Tab, the user can choose the Current Range (refer to Table 5 for ranges based on Gain) and set the OFFSET. A block diagram illustrates the Calibration operation.
- Post Processing Gain (GPP): The GPP value is determined by the ADC config parameters. If the user prefers a specific GPP value, they can uncheck the USE DEFAULT VALUE option to customize it.

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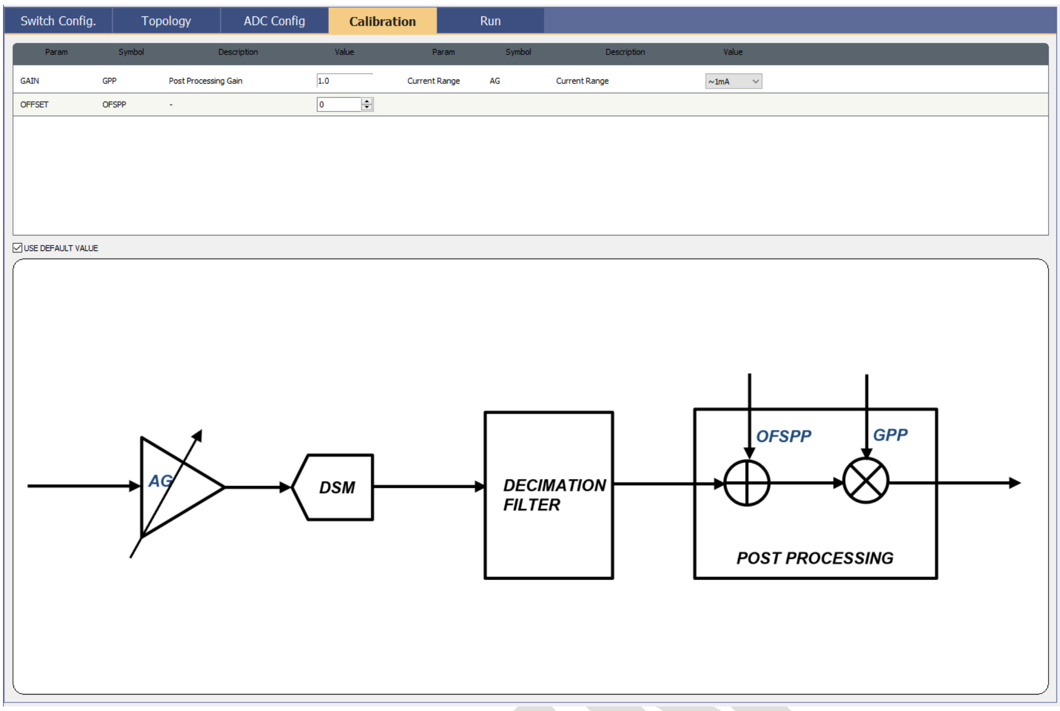

Table 5 Current range by Gain

Analog Gain AG	Graph MIN/MAX	Analog Gain AG	Graph MIN/MAX
1	+/-1.1mA	15	+/-28uA
2	+/-510uA	16	+/-25uA
3	+/-210uA	17	+/-20uA
4	+/-185uA	18	+/-15uA
5	+/-160uA	19	+/-10uA
6	+/-135uA	20	+/-9uA
7	+/-110uA	21	+/-8uA
8	+/-85uA	22	+/-7uA
9	+/-75uA	23	+/-6uA
10	+/-65uA	24	+/-5uA
11	+/-45uA	25	+/-4uA
12	+/-40uA	26	+/-3uA
13	+/-35uA	27	+/-2uA
14	+/-30uA		

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4.5 Run

Here's an overview of the Run Tab features:

- Main Functions: The Run Tab provides various key functions:
  - Save (parameter/configuration save)
  - Load (parameter/configuration load)
  - Save CSV file
  - Clear data (clears run results)
  - Run
  - Hold
  - Restart
  - Stop
- Data Display(Figure 11):
  - The left red box shows the result data table, recording various data details like channel, terminal, cycle, delay, x-axis, y-axis, and more.
  - The right red box displays the result graph.
  - Clicking the blue box button in the bottom left corner resets the parameter values of the Switch Config, Topology, ADC Config, Calibration, and Run tabs to their default settings.
- Graph Navigation:
  - Pan: Hold the right mouse button to move the graph.
  - Zoom In: Drag diagonally down to the right with the left mouse button.
  - Zoom Out: Drag diagonally up to the left with the left mouse button.
- Save/Load function : There are data file extensions and configuration file extensions(Figure 12)
  - Data file(*.nmsd)
  - The results measured data(Red box shown in Figure 13)
  - Parameter values(Switch config, Topology, ADC Config, Calibration Values) used for measurement (Green box shown in Figure 13)
  - Configuration file(*.nmsc)
  - Environment settings(Preferences) and Graph configurations (Color, zoom, pan, X, Y axis Min/Max, etc., red box shown in Figure 14)

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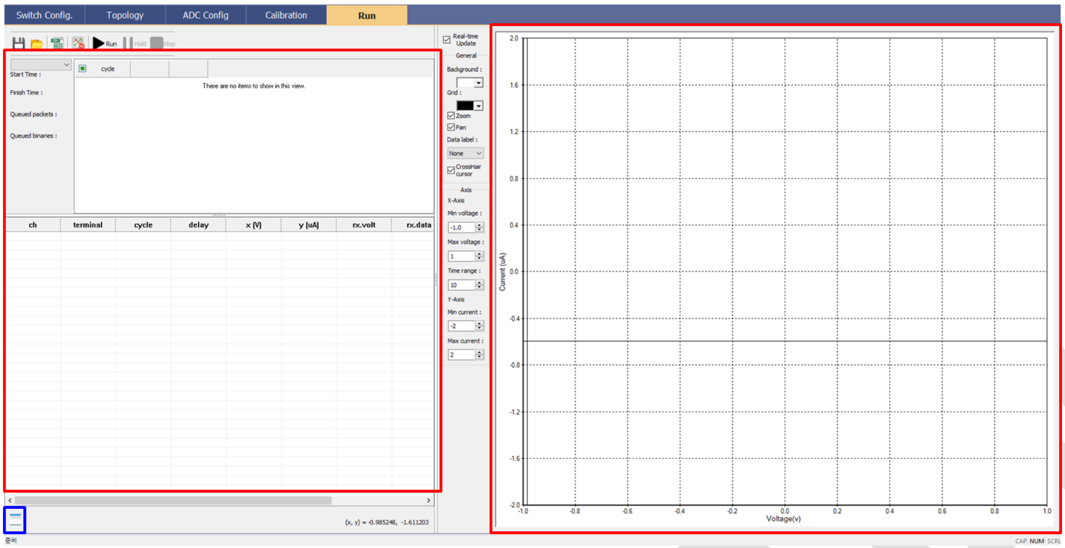

Figure 11 Run tab Data Display

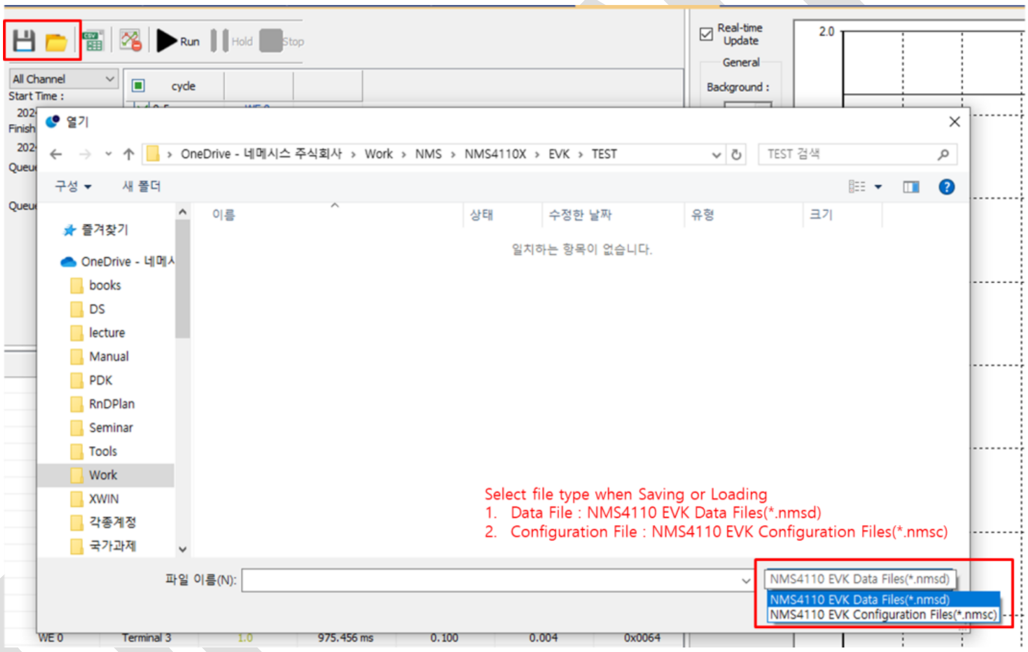

Figure 12 Save/Load Function

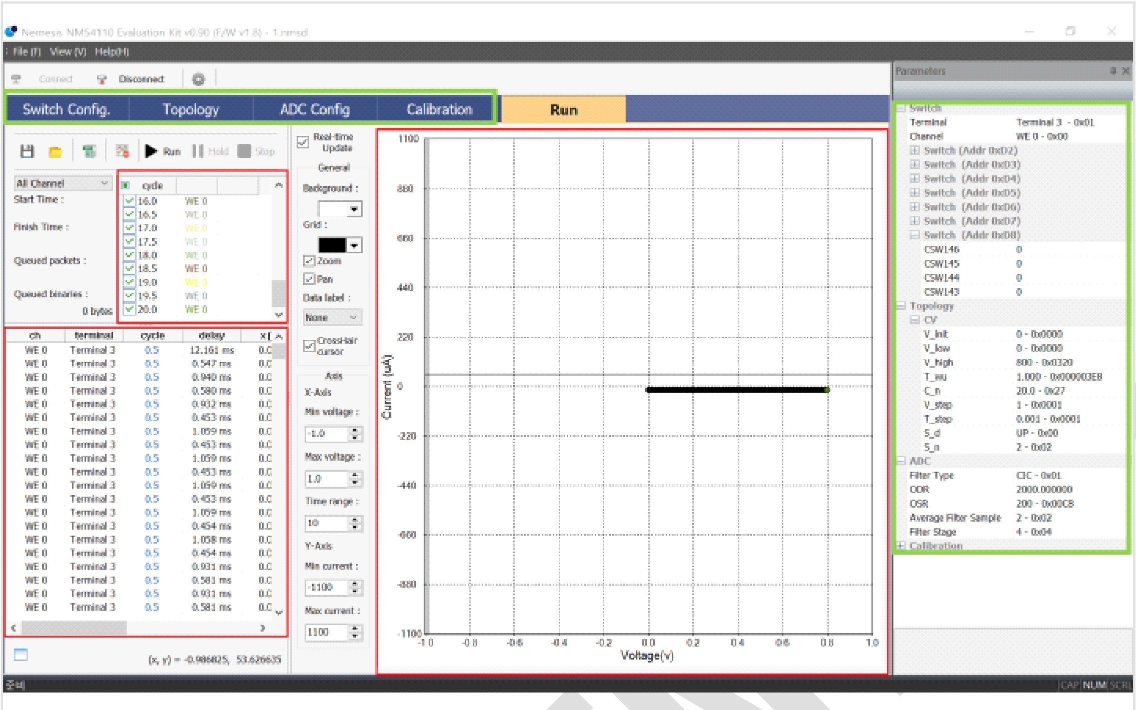

Figure 13 Save/Load Data file(nmsd)

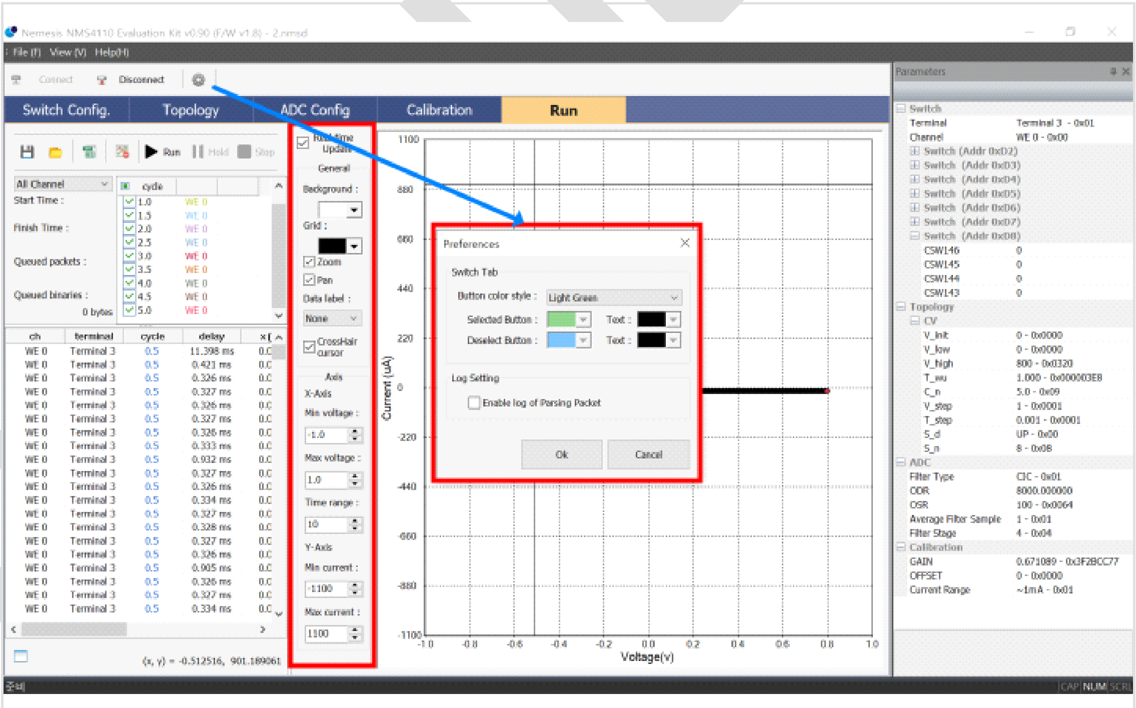

Figure 14 Save/Load Configuration file(nmsc)

5 Description of Hardware

Table 6 Description of Jumpers

JUMPER	SHUNT POSITION	DESCRIPTION
J1	1-2*	Supply 5V to VDD_5V from USB VCC SENSOR
J3	1-2*	Electrically connected to Analog GND and Digital GND
J5	1-2	Supply power to external from USB VCC SENSOR

*Default position

Table 7 Description of Test Points

Test Point	DECRIPTION
TP1(VREF_DAC)	DAC reference voltage test
TP2(ATEST2)	Analog test signal 2
TP3(ATEST1)	Analog test signal 1
TP4(DTEST0)	Digital test signal 0
TP5(RE)	Reference electrode test
TP6(CE)	Counter electrode test
TP7(WE1)	Working electrode 1 test
TP8(WE0)	Working electrode 0 test
TP9(VBAT)	Battery voltage test
TP10(SD_OUT)	Sensor detector test
TP11(AGND)	Analog ground
TP12(DGND)	Digital ground

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5.1 NMS4110 EVK System Bill of Materials

Table 8 NMS4110 EVK System Bill of Materials

ITEM	QTY	REF DES	LOGIC TYPE	PART TYPE	VALUE	DESCRIPTION
1	4	BD1, BD3, BD4, BD5	BEAD	MPZ1608B471ATA00		
2	14	C22-C24, C26-C29, C32-C35, C46	CAP	C-1005	1UF	
3	4	C1, C5, C10, C25	CAP	C-1608	10UF	
4	2	C13, C14	CAP	C-1005	16PF	
5	2	C3, C4	CAP	C-1005	100PF	
6	4	H1-H4	CON	HOLE		
7	3	J1, J3, J5	CON	HEADER_2P_2.54MM		
8	2	J2, J4	CON	HEADER_20PX1_2.54MM		
9	2	LED1,LED2	DIO	LED1608		FC-DA1608BK-470H10(BLUE)
10	1	R1	RES	R-1005	10MΩ	
11	3	R2, R20, R44	RES	R-1005	1 MΩ	
12	20	R3, R4, R9-R14, R16-R19, R21, R22, R25, R26, R29, R30, R42, R43	RES	R-1005	0Ω	
13	12	TP1-TP12		TP-10M		
14	1	U1	QFN	NMS4110X		
15	1	U2	ANA	ESP32_DEVKITM-1		
16	1	U5	PWR	NCP186AMX300TAG		LDO for power system
17	1	USB1	CON	SZH-SDH004		
18	1	Y2	OSC	FA-20H_16.000000MHZ		Crystal(8PF)

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5.2 NMS4110 EVK System Schematic

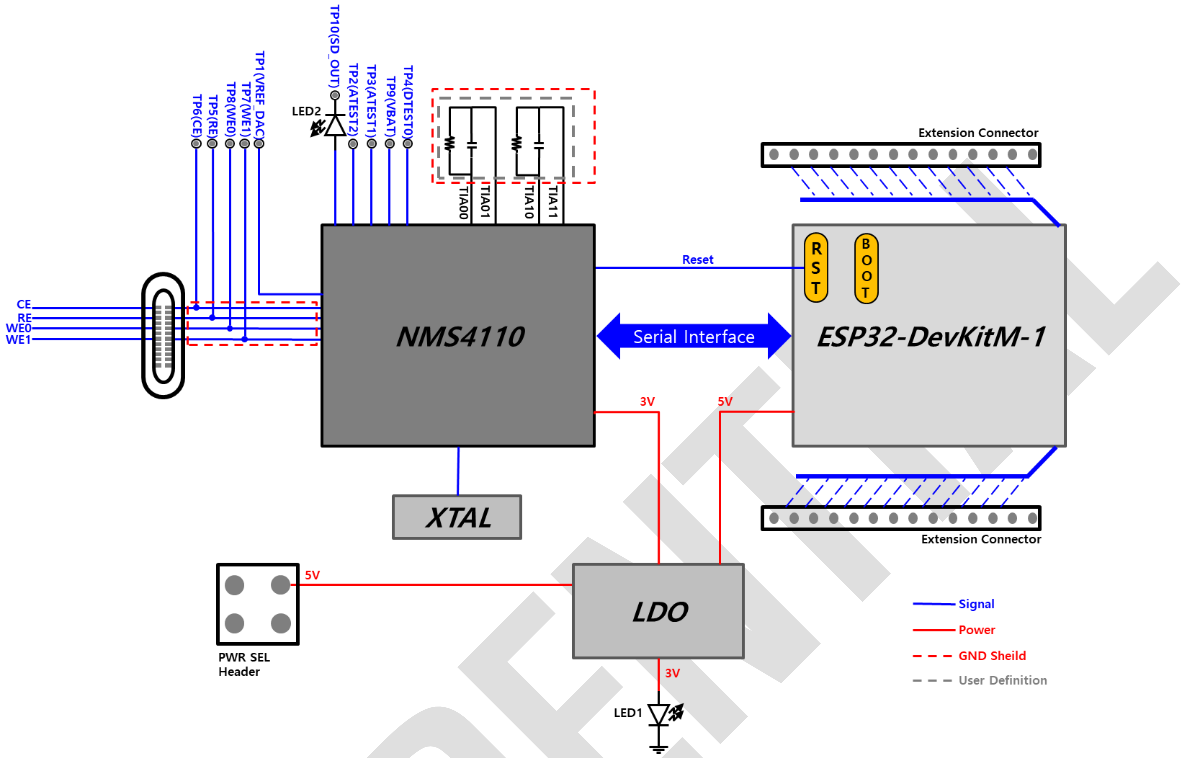

Figure 15 EVK System Schematic Diagram

5.3 NMS4110 EVK Detailed Serial Interface and Event Notification

- Figure 16 is the serial interface connection diagram of the NMS4110 using SPI. The serial interface supports both I2C and SPI, and the protocol operates based on priority.
- INT is an event notification pin that outputs various interrupt signals as an interrupt pin.
- The WAKEUP pin is an event notification pin that provides sleep on and off functions through pin control.

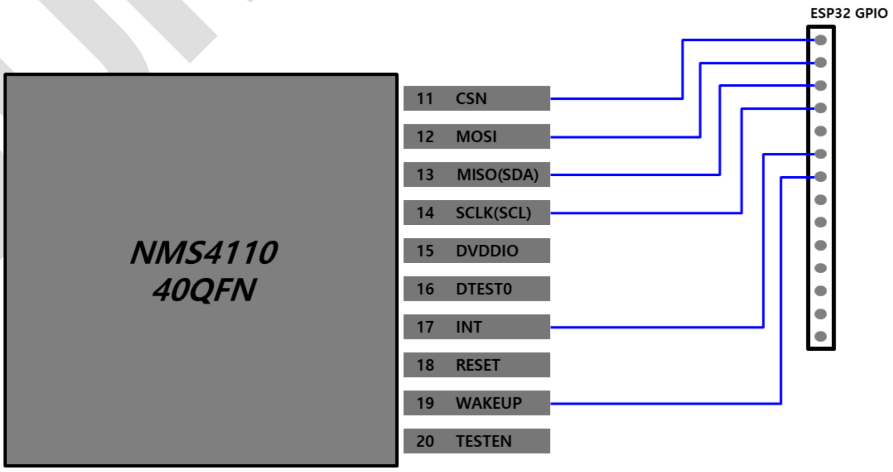

Figure 16 EVK Detailed Serial Interface

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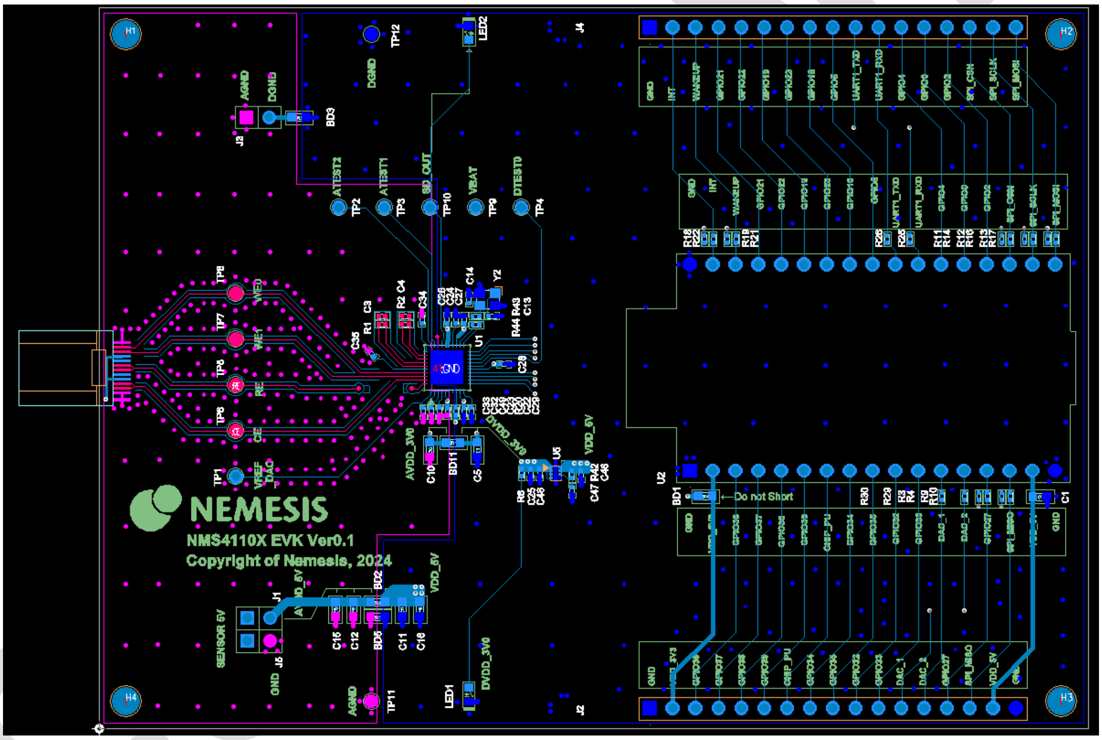
Table 9 Serial Interface Pin

PIN NAME	I2C	SPI	Description
SCL	SCL	SCLK	SPI : clock I2C : clock
SDA	SDA	MISO	SPI : data out I2C : serial data
CSN		CSN	SPI : enable DTSET1
MOSI		MOSI	SPI : data input DTEST2

5.4 NMS4110 EVK System PCB Layout



[Top Layer]

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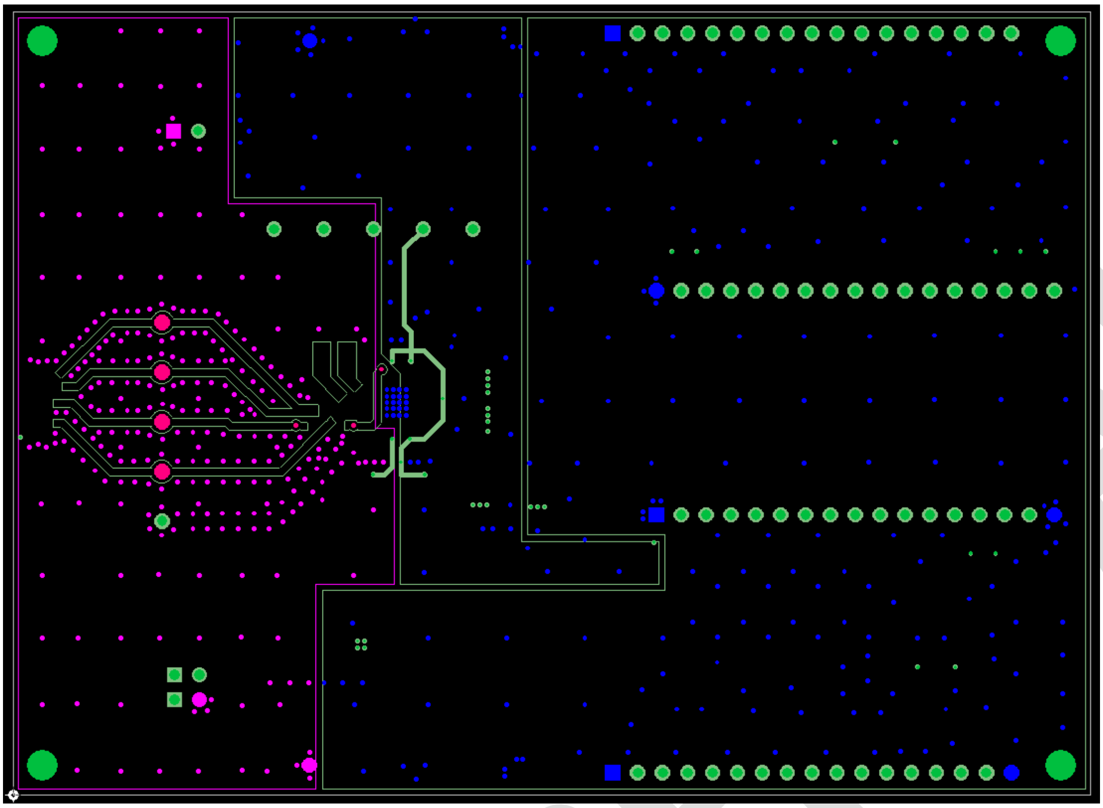
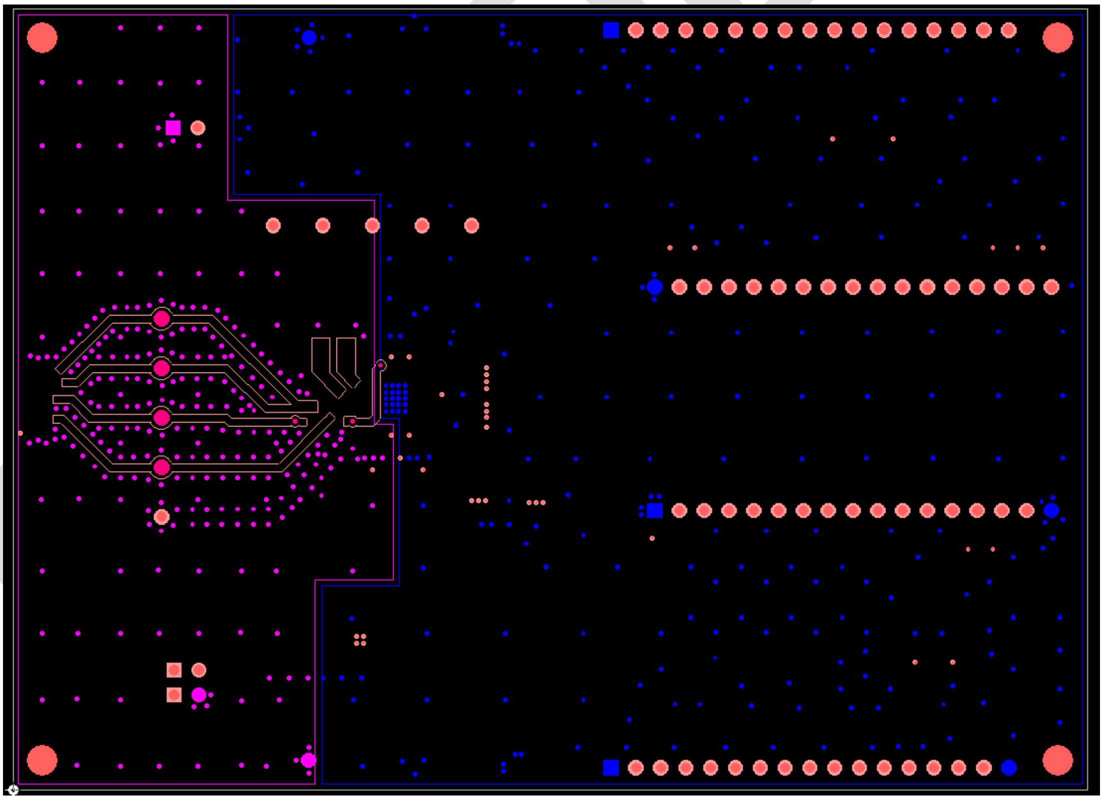
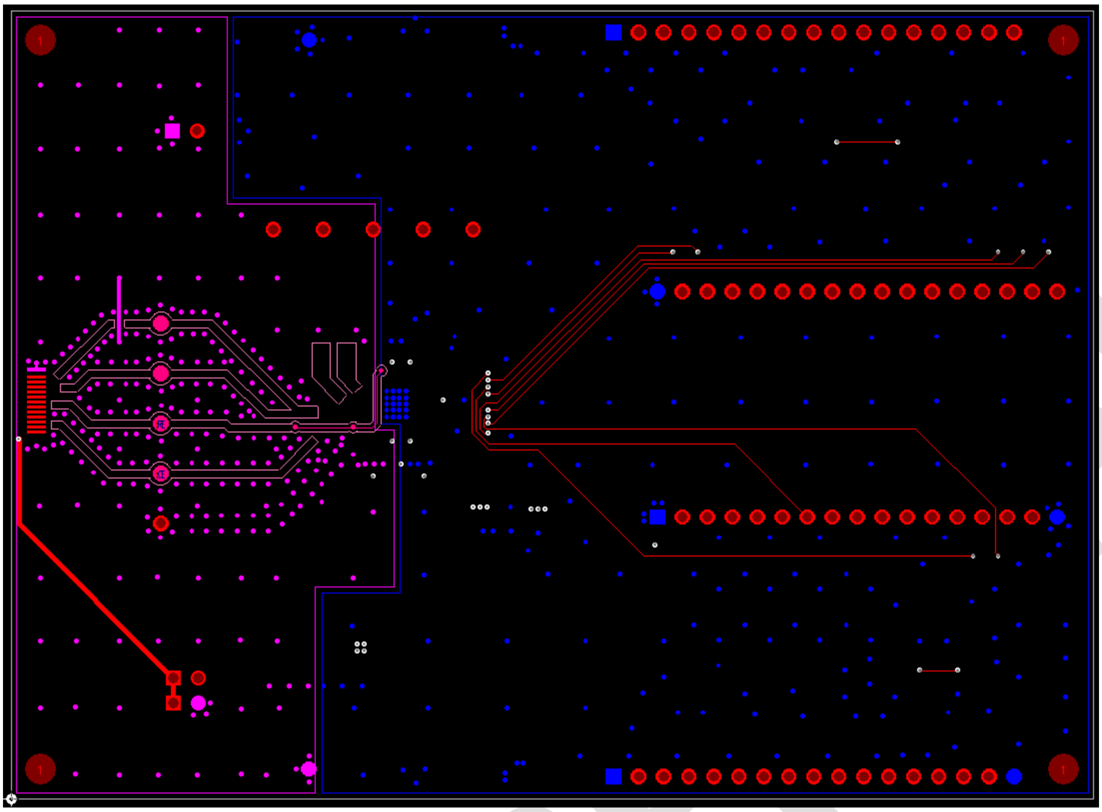


[Inner Layer 1]



[Inner Layer 2]



[Bottom Layer]

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6 Configuration for Sensor Connecting

NMS4110 EVK supports several connection methods to sensor. Users can use the USB-C connector and TP (Test Point) as following sections.

6.1 Connection by USB Type-C (Three Electrode system)

The USB Type-C male connector is placed on the edge of NMS4110 EVK and can be used for making connection between EVK and sensor. The connector pins from A side are assigned to working (WE0=A11, WE1=A10), reference (A6 and A7), and counter (A2 and A3) electrode of sensor as shown in Figure 17. If the contact of sensor matches the thickness and the width of the USB-C connector, it could be directly connected to this USB-C connector.

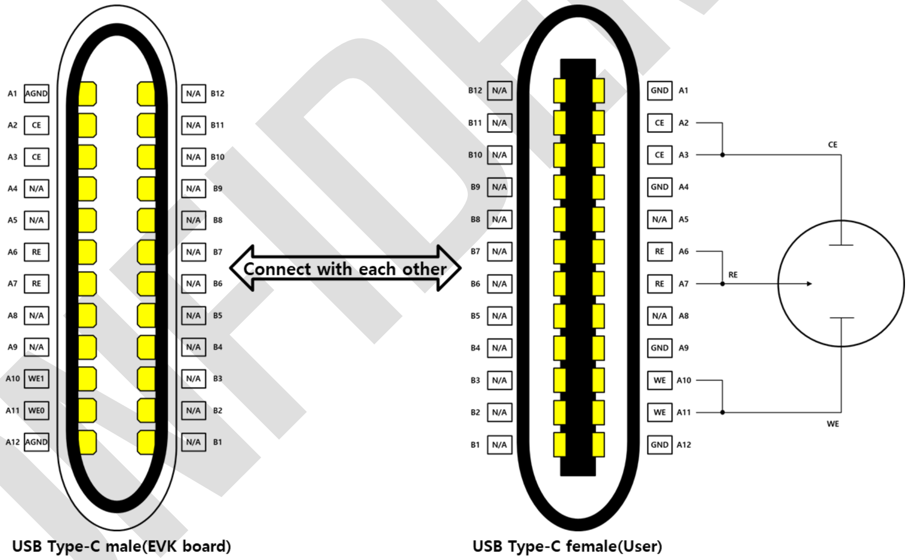

Figure 17 USB Type-C Configuration(Example for 3-electrode)

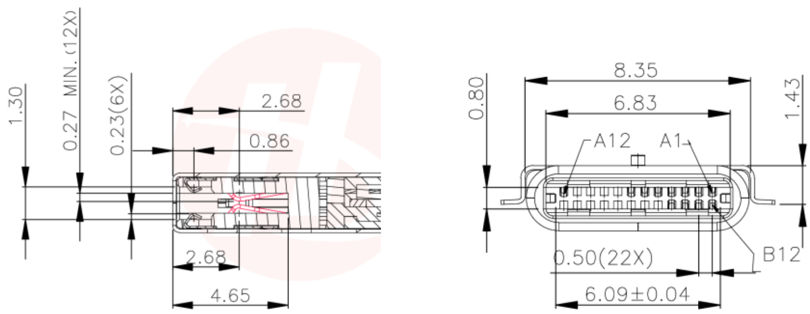

Figure 18 USB Type-C Connector Information

6.2 Connection by TP for Two Electrode System

Below are examples of a two-electrode system connection . The working electrode can be connected to either WE0 or WE1.

6.2.1 Two-electrode Sensor to WE0

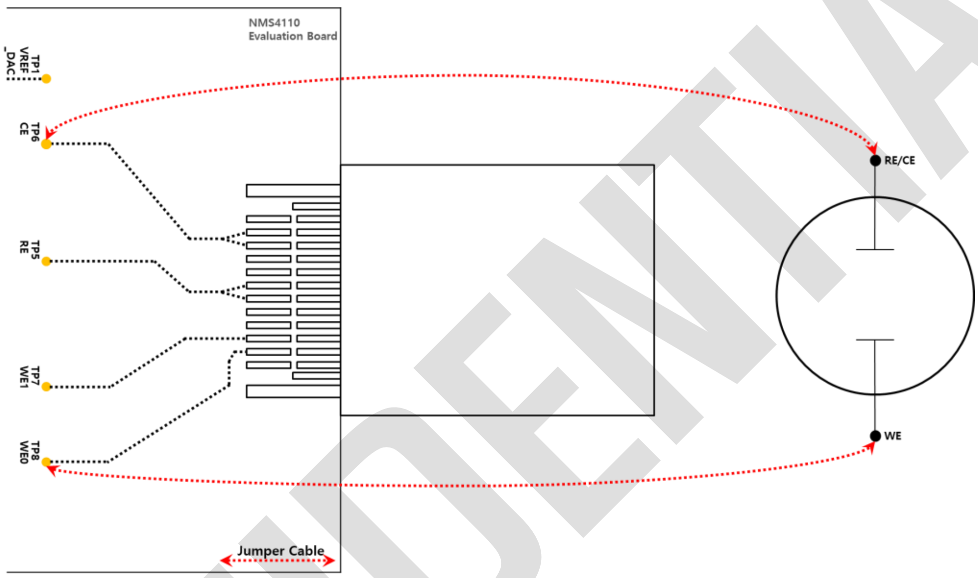

Figure 19 Two-electrode Sensor Connection to WE0

6.2.2 Two-electrode Sensor to WE1

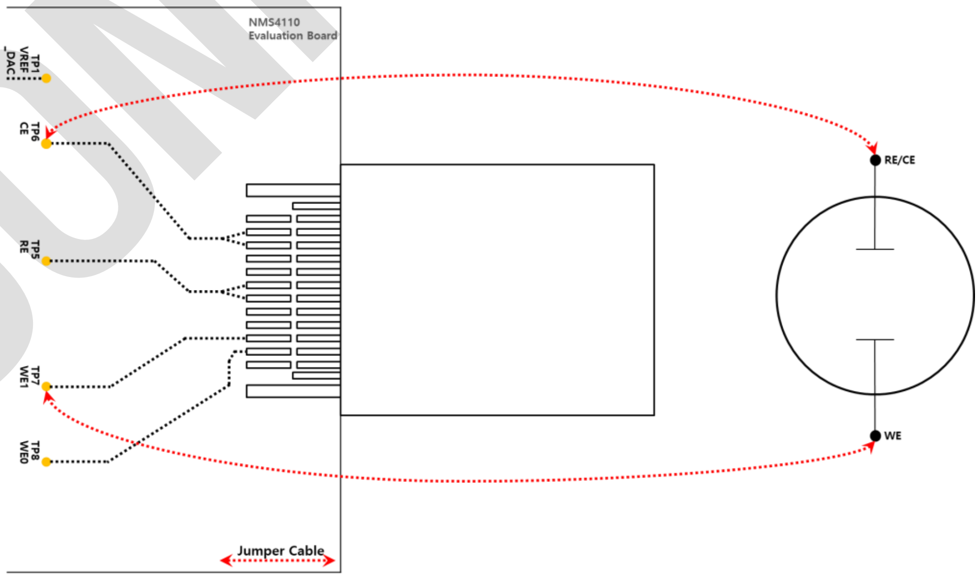

Figure 20 Two-electrode Sensor Connection to WE1

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6.3 Connection by TP for Three Electrode Sensor

Below are examples of a three-electrode system connection. There are two ports in NMS4110 which support the working electrode – WE0 and WE1. The working electrode of sensor can be connected to either WE0 or WE1

6.3.1 Three-electrode Sensor Connection to WE0

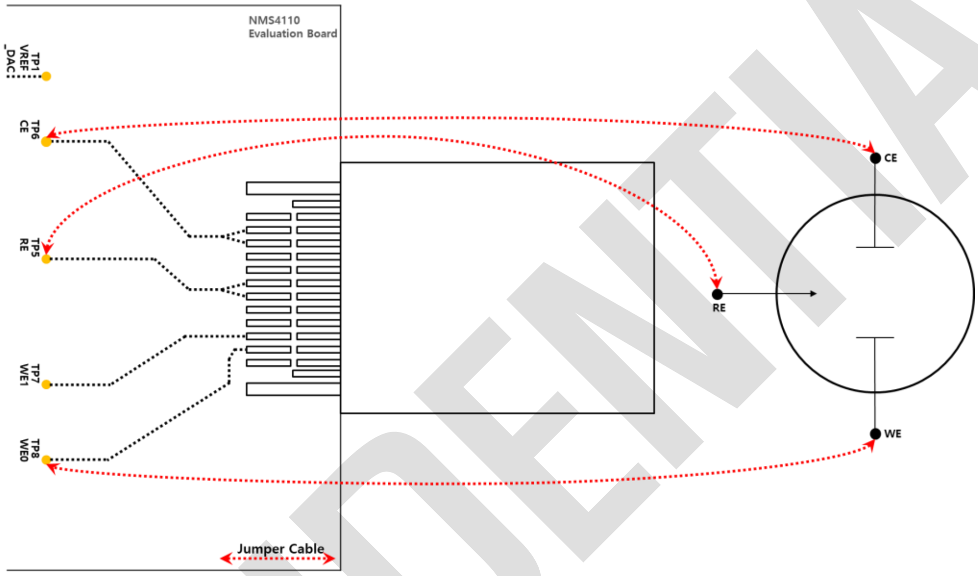

Figure 21 Three-electrode Sensor Connection to WE0

6.3.2 Three-electrode Sensor Connection to WE1

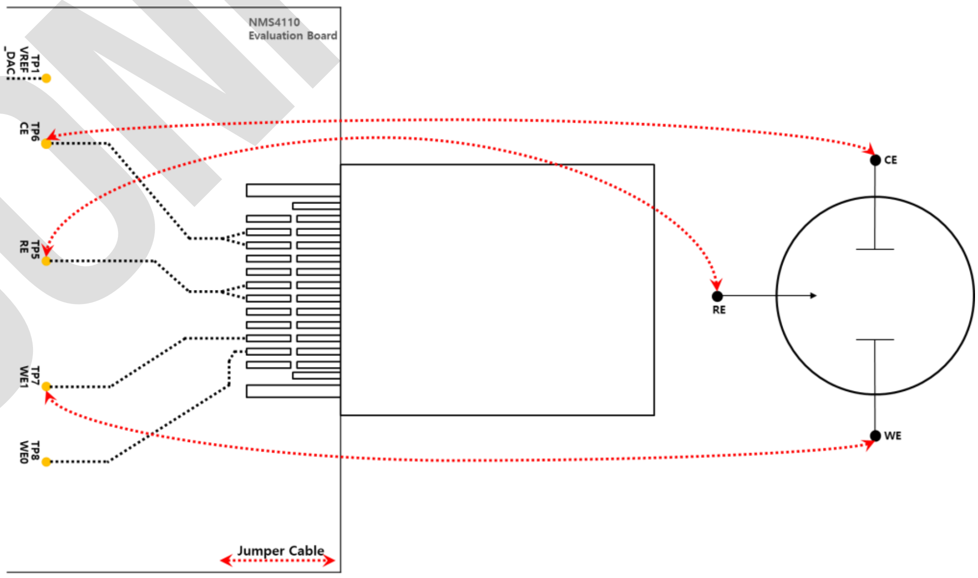

Figure 22 Three-electrode Sensor Connection to WE1

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6.4 Connection by TP for Four Electrode System

Below are examples of a four-electrode system connection. Two working electrodes can be connected to either WE0 or WE1. The sensor shares the reference electrode.

6.4.1 Four-electrode Sensor Connection - 1

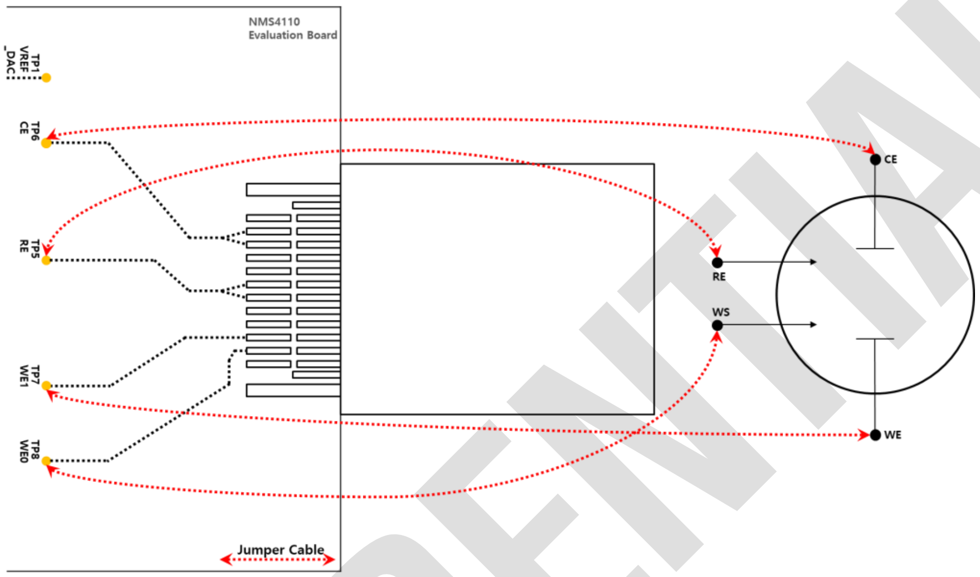

Figure 23 Four-electrode Sensor Connection - 1

6.4.2 Four-electrode Sensor Connection - 2

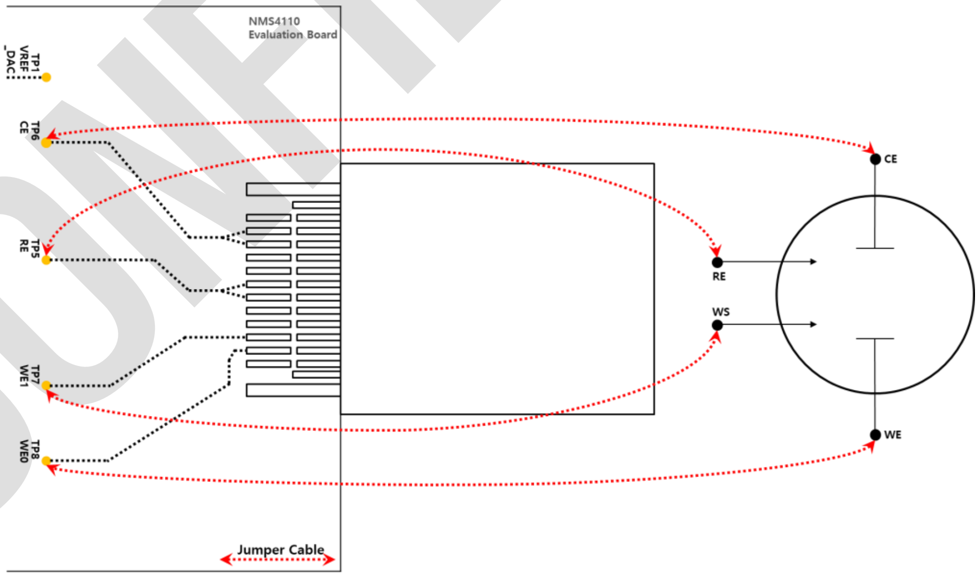

Figure 24 Four-electrode Sensor Connection - 2

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7 Ordering Information

PART	TYPE
NMS4110-EVK	Evaluation System

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