AN4236

WLR089 LoRa® Power Profiling

Introduction

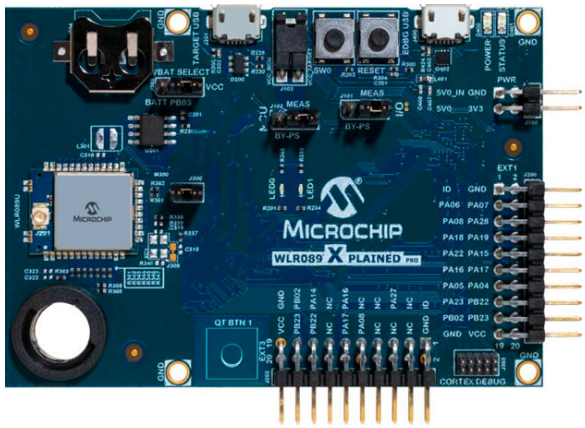
This application note describes the power consumption profile of the WLR089 device under various application scenarios in Long Range (LoRa®) technology. The profiling of the WLR089 device captures various application scenarios based on the following connection types:

- Long Range Wide Area Network (LoRaWAN) (Node <-> Gateway <-> Network Server)
  - Initialization
  - Join Procedure
  - Uplink Data Transmission
  - Downlink Data Reception
  - Sleep Mode Operation
  - Persistent Data Server (PDS) Operation
- LoRa Modulation (Node to Node)
  - Data Transmission
  - Data Reception

This application note:

- Helps the user to estimate the expected power consumption in the WLR089 device based on their tailored application needs
- Details the setup to perform the power measurements using the WLR089 Xplained Pro Evaluation board. This is also a reference to estimate the power consumption with the custom board (using the WLR089 device) in real life applications.
- Briefs the configurable parameters in both the LoRa connection type and the LoRaWAN connection type. The user can fine tune these configurable parameters to optimize further.

Figure 1. WLR089 Xplained Pro Evaluation Kit



Note: This application note captures the measurement results from a random sample. The reported values are only for estimation. The actual value may vary from device to device.

Table of Contents

1. Quick References

1.1 Reference Documentation

For further details, refer to the following:

- *SAM R34/R35 and WLR089U0 Radio Utility Commands Reference Manual* (DS70005376)

1.2 Hardware Requirements

- WLR089 Xplained Pro Evaluation Kit
- LoRaWAN connection type – Multitech Conduit Gateway with EU band supported NS configuration
- Oscilloscope or Power Debugger
- USB micro cables
- Jumper wires

1.3 Software Requirements

Notes: For the following software tools and firmware files, refer to www.microchip.com/en-us/product/WLR089U0:

- LoRaWAN connection type – LoRaWAN Mote Application (demo) from latest Advanced Software Framework (ASF) for SAM devices
- LoRa connection type – WLR089U0 Radio Utility Firmware in WLR089U0 (SAMR34 module) Reference Design Package
- Microchip Studio for AVR® and SAM Devices and Data Visualizer extension
- Tera Term software tool

1.4 Acronyms and Abbreviations

Table 1-1. Acronyms and Abbreviations

Acronyms/Abbreviations	Description
ADR	Adaptive Data Rate
AES	Advanced Encryption Standard
ASF	Advanced Software Framework
DR	Data Rate
EIRP	Equivalent Isotropically Radiated Power
EU	Europe
ISM	Industrial Scientific and Medical
LoRa	Long Range
LoRaWAN	Long Range Wide Area Network
MLS	Microchip LoRaWAN Stack
NVM	Non-volatile Memory
OTAA	Over the Air Activation
PDS	Persistent Data Server

.....continued

Acronyms/Abbreviations	Description
retx	Retransmissions
SW	Software
TX	Transmission

2. Power Measurement Setup

This chapter provides details about the hardware setup, firmware setup, interpretation of each hardware parameter and software attributes for power profiling of the WLR089 device.

2.1 Hardware Setup

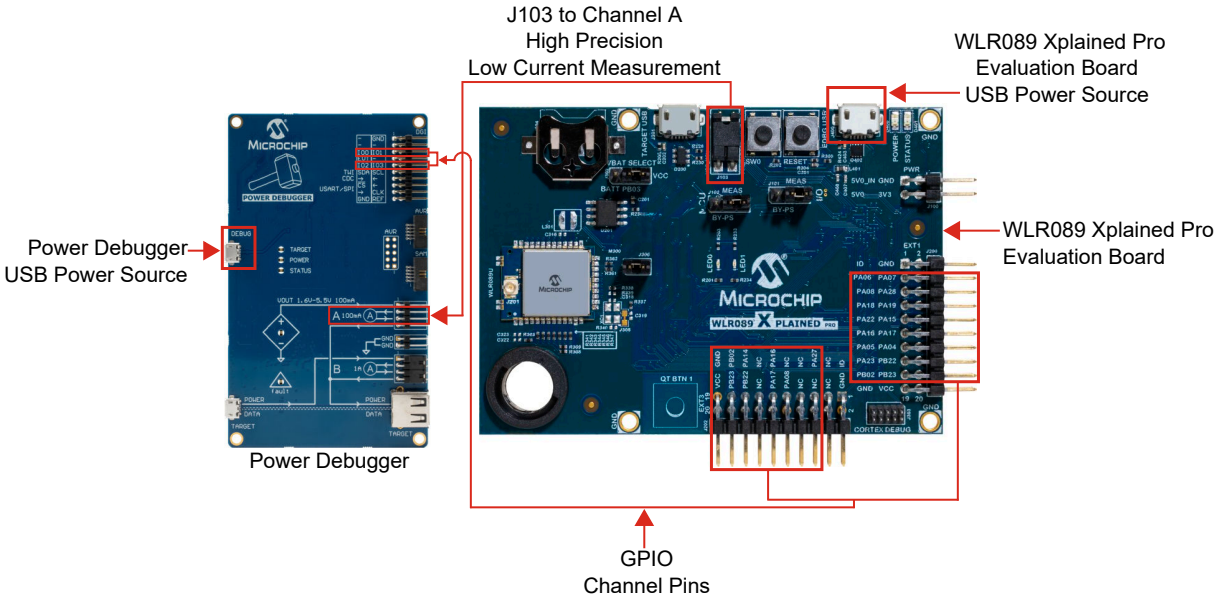
Use a power debugger with the Data Visualizer tool to measure the timing and power consumption parameters of the WLR089 Xplained Pro Evaluation Board.

Perform the following steps for power measurement setup (see the following figure):

1. Connect the current measurement header pins (J103) on the WLR089 Xplained Pro Evaluation Board to the channel A pins of the power debugger using jumper wires.
2. Connect any configured pin from the WLR089 Xplained Pro Evaluation Board to one of the GPIO channel pins on the power debugger to capture the GPIO state functionality.
3. Power the WLR089 Xplained Pro Evaluation Board and the power debugger by connecting a Micro USB cable to the power source (PC).

Note: In the LoRaWAN connection type, a GPIO is toggled during the transition of the MAC state to provide a better overview on the current measurements in each scenario.

Figure 2-1. Power Measurement Setup



2.2 Firmware Setup

In the LoRaWAN connection type, calculate all the measurements with the LoRaWAN Mote Application (demo) in Advanced Software Framework (ASF) 3.50.0.

In the LoRa connection type, calculate all the measurements with the Radio utility firmware available in the WLR089U0 (SAMR34 Module) Reference Design Package.

The following are the steps for the LoRaWAN connection type code modification from default:

- Configure the Activation mode to Over the Air Activation (OTAA) by enabling the `DEMO_APP_ACTIVATION_TYPE` macro and disabling (comment out the line) the same macro defined for Activation by Personalization (ABP) mode in the `conf_app.h` file.

```
#define DEMO_APP_ACTIVATION_TYPE OVER_THE_AIR_ACTIVATION
//#define DEMO_APP_ACTIVATION_TYPE ACTIVATION_BY_PERSONALIZATION
```

- Configure the data transmission type to confirmed type or unconfirmed type based on the scenario in the `conf_app.h` file. The macro `DEMO_APP_TRANSMISSION_TYPE` is defined for both unconfirmed and confirmed types and can be configured by commenting out the unused macro.

```
#define DEMO_APP_TRANSMISSION_TYPE UNCONFIRMED
//#define DEMO_APP_TRANSMISSION_TYPE CONFIRMED
```

- Configure the device class to Class A in the `conf_app.h` file. The macro `DEMO_APP_ENDDEVICE_CLASS` sets the device class and can be configured by commenting out the unused macro.

```
#define DEMO_APP_ENDDEVICE_CLASS CLASS_A
//#define DEMO_APP_ENDDEVICE_CLASS CLASS_C
```

- Configure the join parameters for the OTAA join procedure according to the network server, which is in the `conf_app.h` file.

```
#define DEMO_DEVICE_EUI {0xde, 0xaf, 0xfa, 0xce, 0xde, 0xaf, 0xfa, 0xce}
#define DEMO_JOIN_EUI {0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x12}
#define DEMO_APPLICATION_KEY {0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x12}
```

- Configure the TX data rate based on the scenario in the `conf_regparams.h` file.

```
#define MAC_DEF_TX_CURRENT_DATARATE_EU (DR0 or DR5)
```

Note: In this application note, consider the Industrial Scientific and Medical (ISM) Europe (EU) band to capture the current measurements in various scenarios under the LoRaWAN connection type.

- For profiling the maximum payload size transmit scenario, modify some part of the code in the `sendData()`, add a buffer to store and transmit the maximum application payload in the `enddevice_demo.c` file.

```
#define EU_MAX_PAYLOAD_SIZE_DR5 234
#define EU_MAX_PAYLOAD_SIZE_DR0 43
uint8_t eu_max_payload_buffer_DR5[EU_MAX_PAYLOAD_SIZE_DR5] = {
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA}
```

```
uint8_t eu_max_payload_buffer_DR0[EU_MAX_PAYLOAD_SIZE_DR0] =
{0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,
0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA,0xAA};
```

```
//get_resource_data(TEMP_SENSOR,(uint8_t *)&cel_val);
//fahren_val = convert_celsius_to_fahrenheit(cel_val); //printf("\nTemperature:");
//snprintf(temp_sen_str,sizeof(temp_sen_str),"%.1fC/%.1fF\n",
cel_val,fahren_val);
//printf("%.1f\xf8 C/%.1f\xf8 F\n\r",cel_val, fahren_val);
//data_len = strlen(temp_sen_str);
// lorawanSendReq.buffer = &temp_sen_str;
```

- Add the following code for profiling the max payload scenario in DR5:

```
data_len = EU_MAX_PAYLOAD_SIZE_DR5;
lorawanSendReq.buffer = &eu_max_payload_buffer_DR5;
lorawanSendReq.bufferLength = data_len;
//lorawanSendReq.bufferLength = data_len - 1;
lorawanSendReq.confirmed = DEMO_APP_TRANSMISSION_TYPE;
lorawanSendReq.port = DEMO_APP_FPORT;
```

- Add the following code for profiling the max payload scenario in DR0:

```
data_len = EU_MAX_PAYLOAD_SIZE_DR0;
lorawanSendReq.buffer = &eu_max_payload_buffer_DR0;
lorawanSendReq.bufferLength = data_len;
//lorawanSendReq.bufferLength = data_len - 1;
lorawanSendReq.confirmed = DEMO_APP_TRANSMISSION_TYPE;
lorawanSendReq.port = DEMO_APP_FPORT;
```

  Note: Using the default configuration available in the LoRaWAN Mote Application (demo) is recommended for profiling the minimum payload size scenarios in DR0 and DR5, which transmits the temperature sensor data.

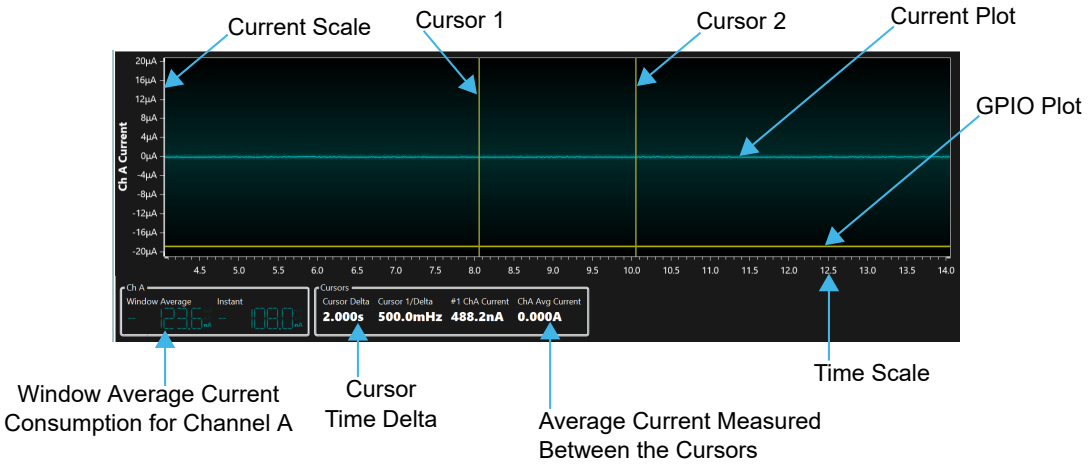
- Configure the number of retransmissions of the confirmed uplink to 2 to emulate the retransmission scenario that is similar to this profile. The `MAC_CONFIRMABLE_UPLINK_REPETITIONS_MAX` macro holds the configuration of the number of retransmissions applicable for the confirmed uplink scenario in the `lorawan_defs.h` file.

```
#define MAC_CONFIRMABLE_UPLINK_REPITITIONS_MAX (2)
```

2.3 Interpreting the Measurement Plots

The following figure illustrates the interpretation of the measurement plot.

Figure 2-2. Interpreting Measurement Plots



The user must toggle the GPIO at the start and end of the event, which represents the period of operation in certain scenarios and the MAC state in remaining scenarios. The interpretation of the GPIO usage details are given for each scenario in the upcoming sections.

Notes:

- In 3.1.2. Join Procedure, 3.1.3.1. Uplink Data Transmission Based on Data Rate and Payload and 3.1.4. Downlink Data Reception, the interpretation of plots is done considering “with period of operation” (represented as `MAC_STATE` under the mentioned sections) and “without period of operation”.
- The scope of providing “without period of operation” plots is to help the user to emulate the scenarios.
- The scope of providing “with period of operation” plots is to help the user with the estimation of time taken by the Microchip LoRaWAN Stack (MLS) to perform the respective tasks in those specific scenarios.

3. Measurement Plots in Different Scenarios

This chapter captures the power profile of the WLR089 device in various scenarios under different connection types and highlights the power consumption values in each scenario under the following types:

- LoRaWAN connection type
- LoRa connection type

3.1 LoRaWAN Connection Type

In the LoRaWAN connection type, the scenarios are based on the Class A device.

Note: For more details regarding the device classes, refer to the LoRaWAN® 1.0.4 Specification Package.

The LoRaWAN connection type captures the following list of scenarios:

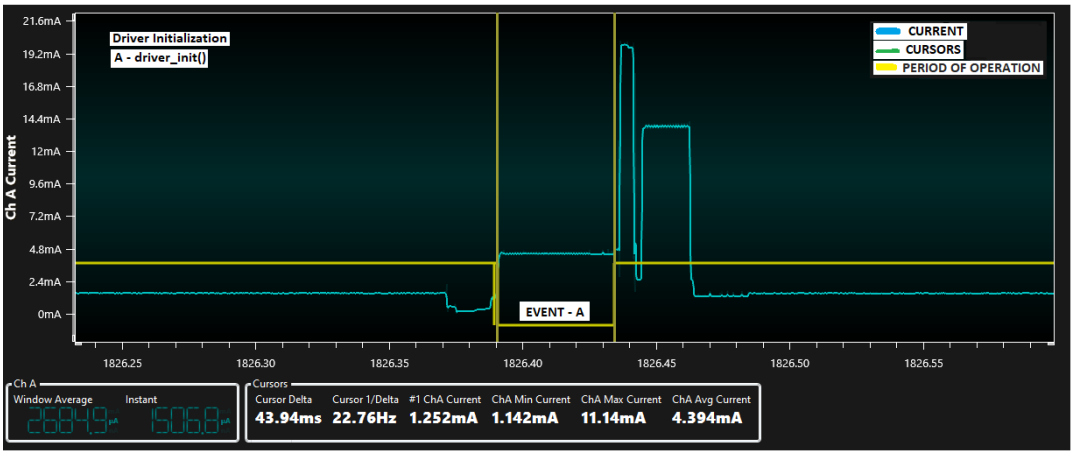
- Initialization
- Join procedure
- Uplink data transmission
- Downlink data reception
- Sleep mode operation
- PDS mode operation

3.1.1 Initialization

This section captures the power consumption of the WLR089 device during the initialization and highlights the profile corresponding to different initialization events. The following plots in this section illustrate the zoomed-in plot of different initialization events.

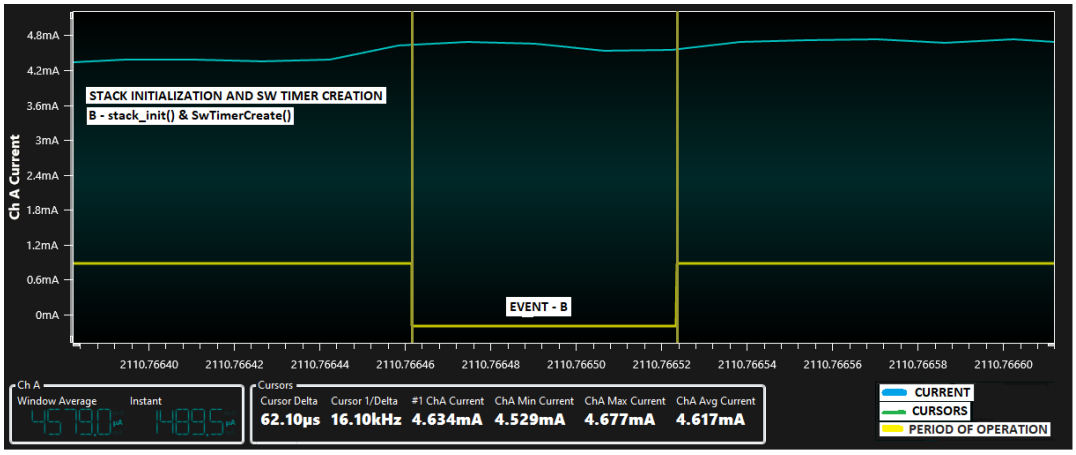
The following figure illustrates the zoomed-in plot driver initialization instance.

Figure 3-1. Zoom in Plot of Driver Initialization Instance



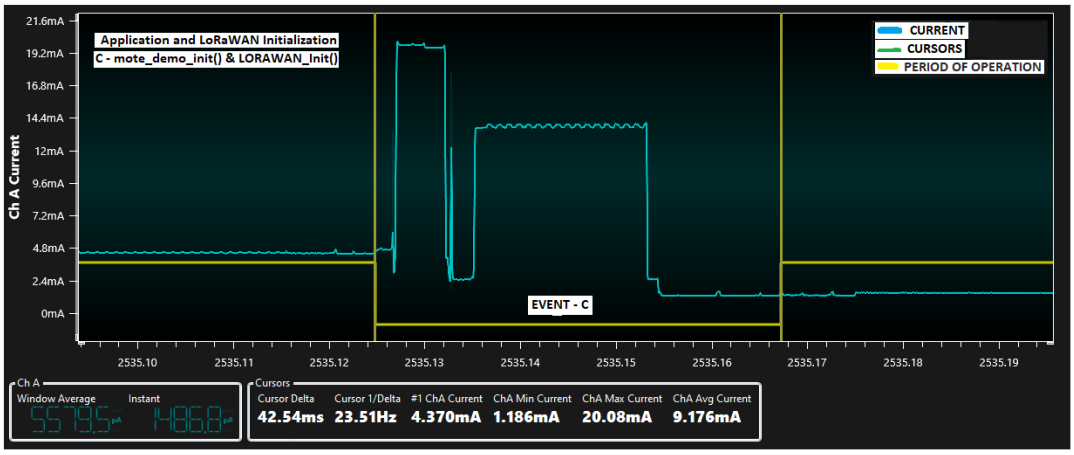
The following figure illustrates the zoomed-in plot of the stack initialization and the software (SW) timer creation instance of the initialization.

Figure 3-2. Zoom in Plot of Stack Initialization and SW Timer Creation Instance



The following figure illustrates the zoomed-in plot of the Application and LoRaWAN initialization instance.

Figure 3-3. Zoom in Plot of Application and LoRaWAN Initialization Instance



The following are the initialization events:

- EVENT – A is a driver initialization event to initialize the radio, SW timer, persistent data server and Advanced Encryption Standard (AES) modules.
- EVENT – B is a stack initialization and SW timer creation event.
- EVENT – C is an application and LoRaWAN initialization event.

Table 3-1. Consumption in Each of the Initialization Event

Attribute	EVENT – A	EVENT – B	EVENT – C	Units
Total duration	43.94	0.0621	42.54	ms
Average current in channel A	4.394	4.617	9.176	mA
Peak current in channel A	11.14	4.677	20.08	mA
Total charge	193.08	0.2870	390.35	mA×ms

3.1.2 Join Procedure

This section captures the power profile during the joining process with the network server, and also highlights the profile on the following modes:

- Join request sent to network server
- Join accept received in RX1 receive window
- Join accept received in RX2 receive window

The following table provides the settings for profiling the join procedure.

Table 3-2. Settings for Profiling the Join Procedure

Attribute	Value
TX data rate	DR0 and DR5
RX1 data rate	Same as TX data rate
RX2 data rate	DR0
Join accept delay 1	5s
Join accept delay 2	6s
TX power(1)	1 (default)

Note:

1. The TX power from the preceding table resembles the offset value from the TX power table as per the RP2-1.0.2 LoRaWAN® Regional Parameters. Calculate the equivalent TX power value at the radio level for the above offset value using the following equation:

   Equation 3-1. Equivalent TX Power

   $$Equivalent\ TX\ Power\ =\ MAX\ EIRP - 2\ dB = 16 - 2 = 14\ dBm$$

   – Join accept delay 1 is the delay between the TX state and RX1 state
   – Join accept delay 2 is the delay between the TX state and RX2 state

The following plots illustrate the transmission of the join request, reception of the join accept in the RX1 window and reception of the join accept in the RX2 at transmission data rates DR0 and DR5 followed by their respective zoomed-in plots with consumption values in each state.

Figure 3-4. Join Request Transmission and Join Accept in RX1 Event “With Period of Operation” at DR0

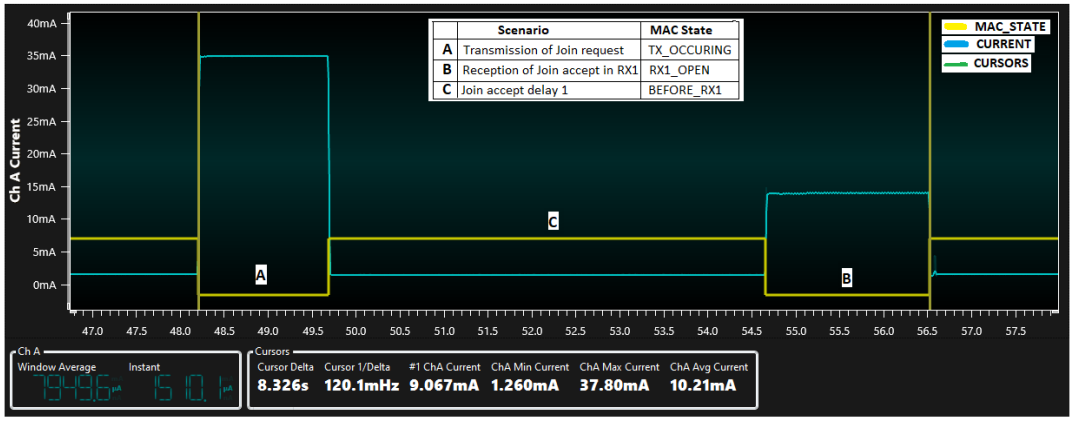


Figure 3-5. Join Request Transmission and Join Accept in RX1 Event "With Period of Operation" at DR5

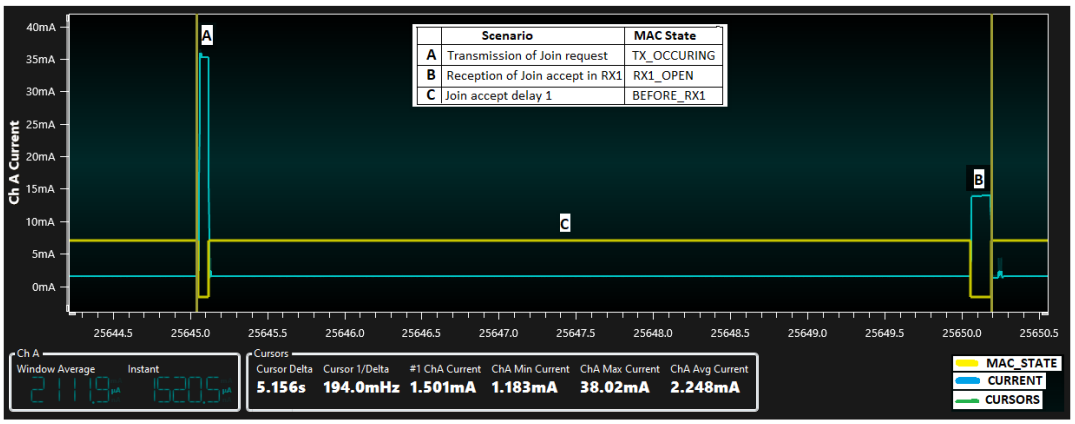


Figure 3-6. Join Request Transmission "With Period of Operation" Zoom in Plot at DR0

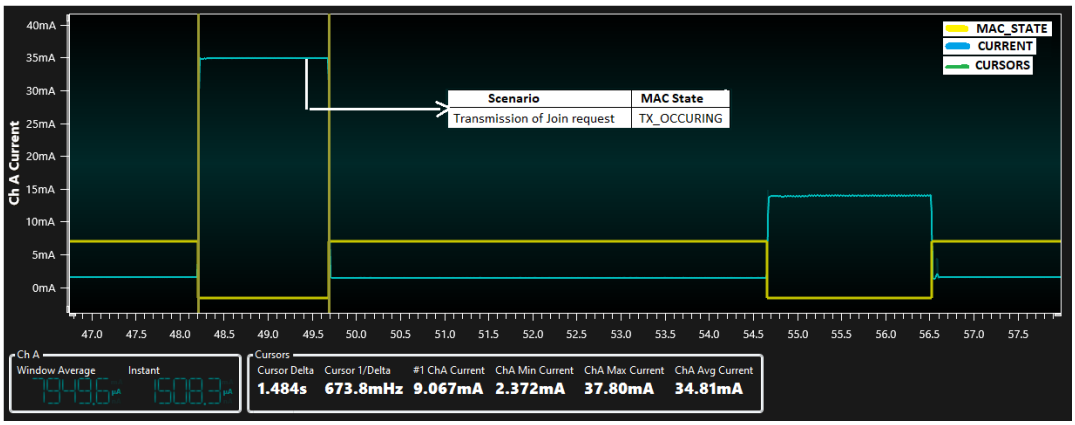


Figure 3-7. Join Request Transmission "With Period of Operation" Zoom in Plot at DR5

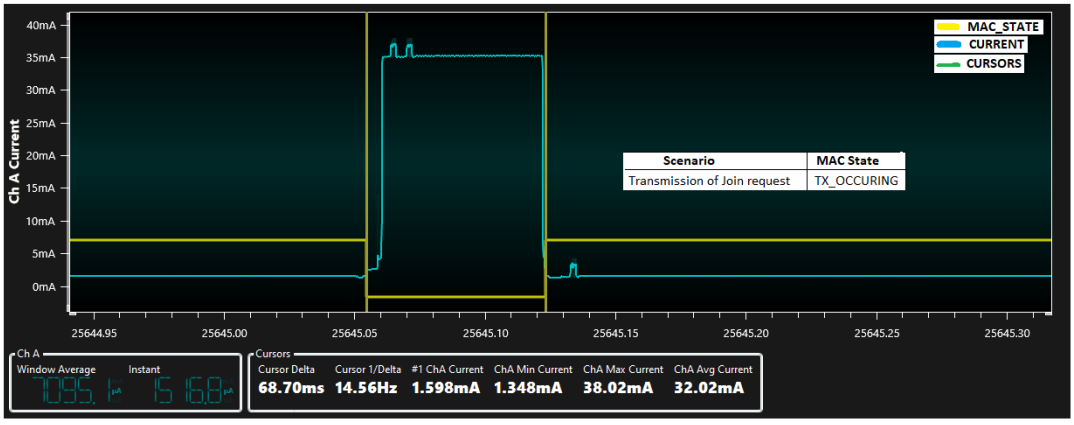


Figure 3-8. Join Accept Reception in RX1 “With Period of Operation” Zoom in Plot at DR0

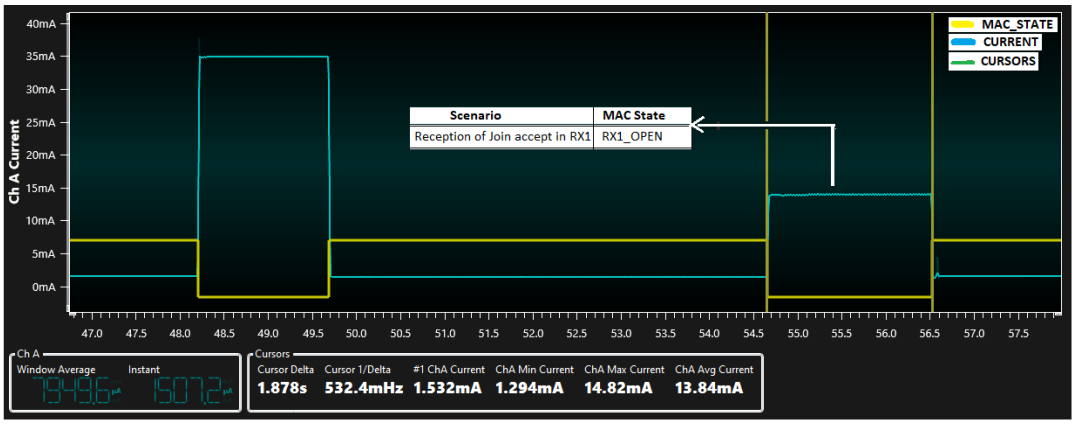


Figure 3-9. Join Accept Reception in RX1 “With Period of Operation” Zoom in Plot at DR5

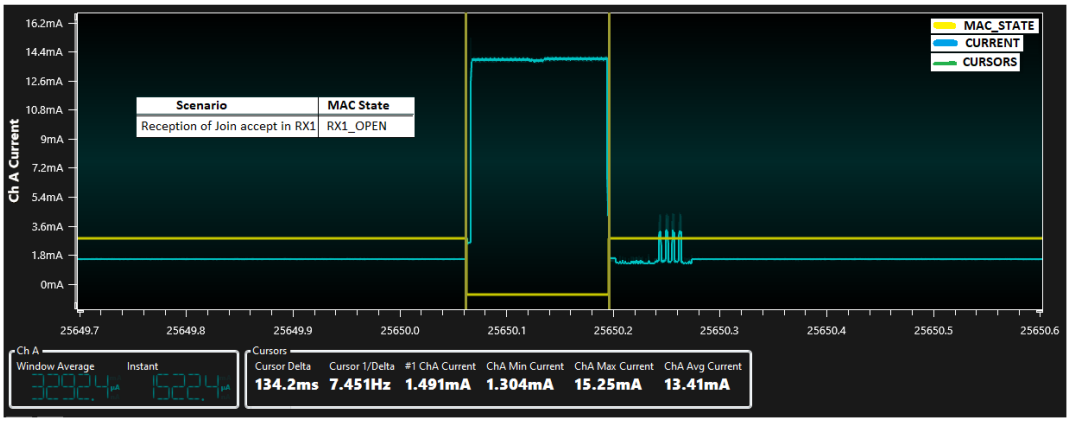


Figure 3-10. Join Accept Delay 1 “With Period of Operation” Zoom in Plot at DR0

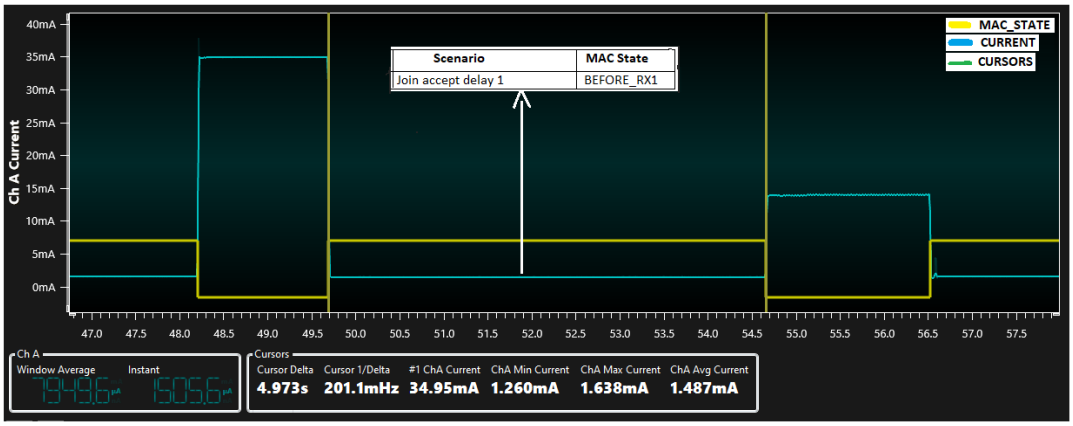


Figure 3-11. Join Accept Delay 1 “With Period of Operation” Zoom in Plot at DR5

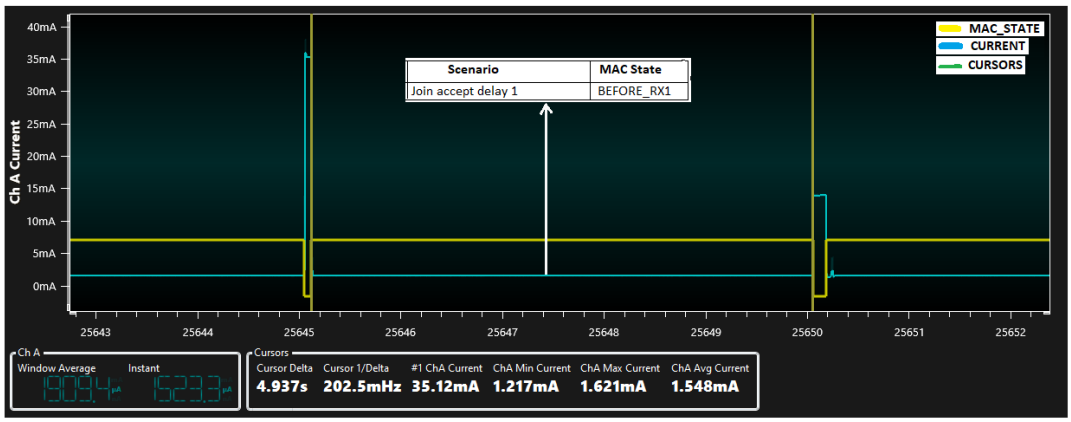


Figure 3-12. Join Request Transmission and Reception of Join Accept in RX2 “With Period Of Operation” at DR0

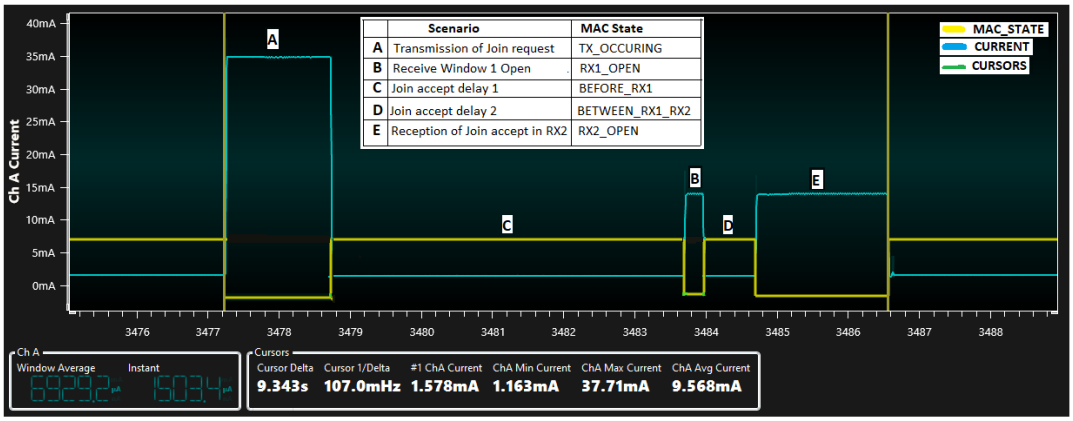


Figure 3-13. Join Request Transmission and Reception of Join Accept In RX2 “With Period Of Operation” at DR5

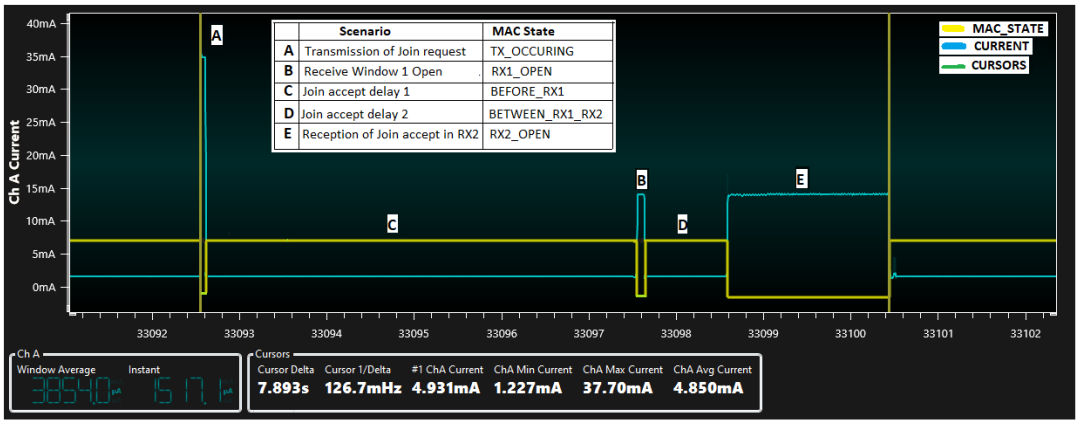


Figure 3-14. Receive Window 1 Open Event "With Period of Operation" Zoom in Plot at DR0

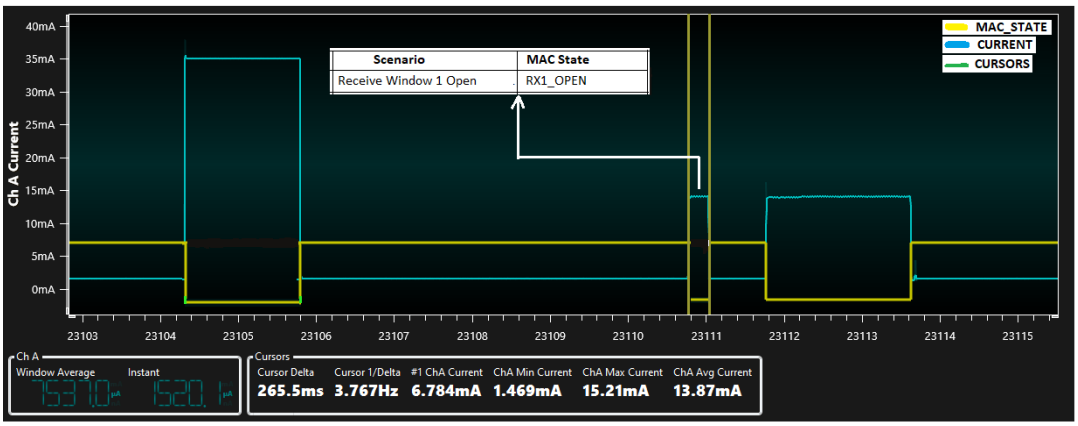


Figure 3-15. Receive Window 1 Open Event "With Period of Operation" Zoom in Plot at DR5

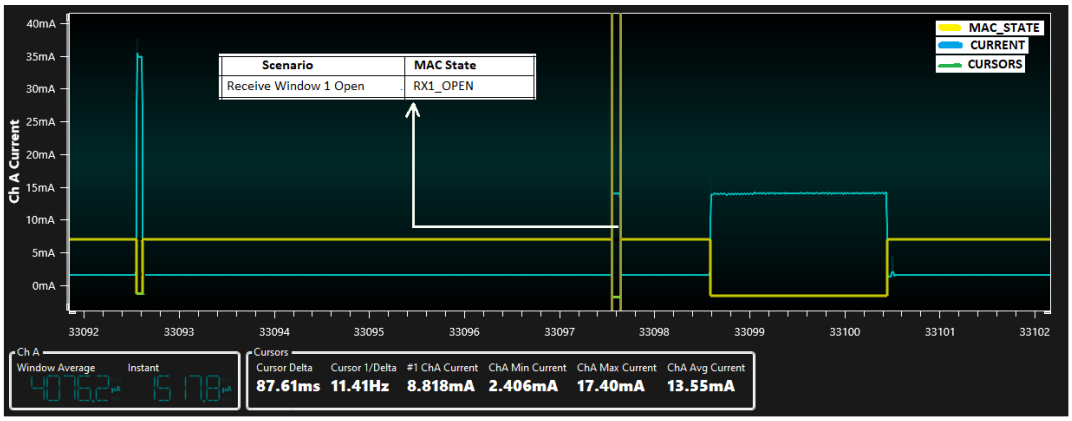


Figure 3-16. Join Accept Delay 2 Event "With Period of Operation" Zoom in Plot at DR0

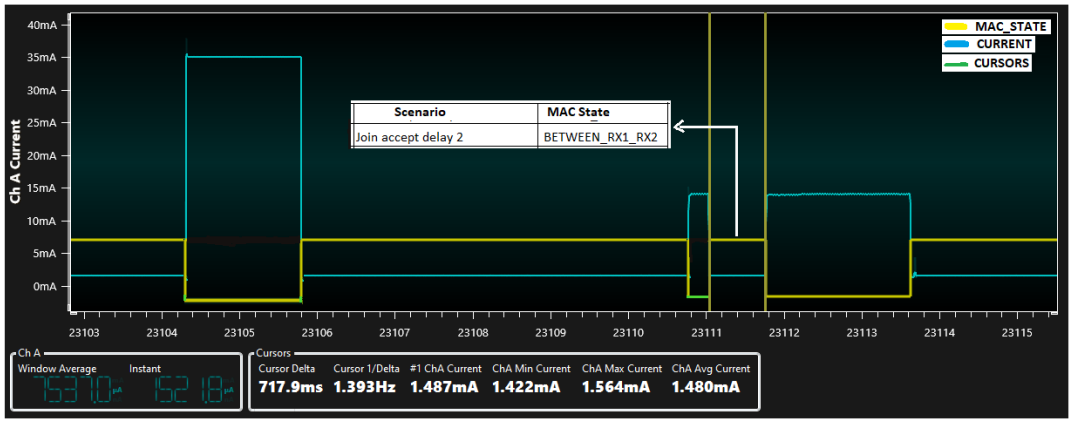


Figure 3-17. Join Accept Delay 2 Event "With Period of Operation" Zoom in Plot at DR5

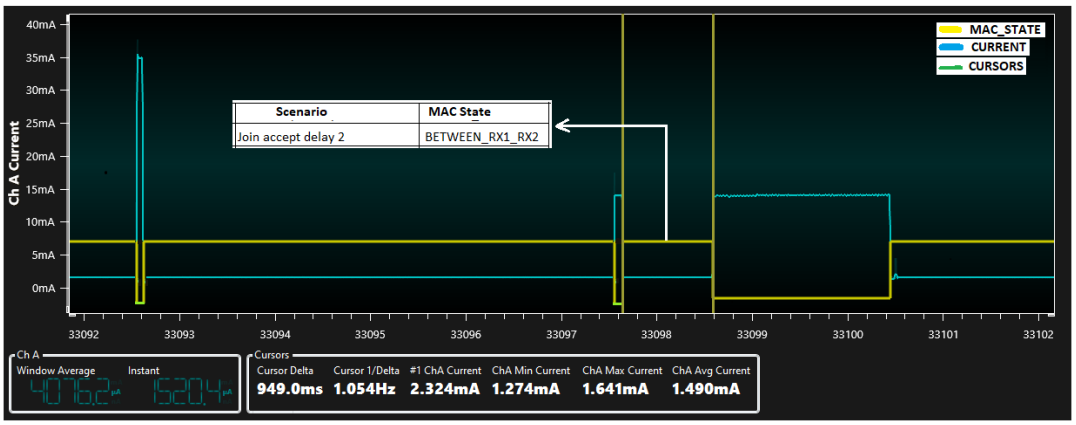


Figure 3-18. Join Accept Reception in RX2 "With Period of Operation" Zoom in Plot at DR0

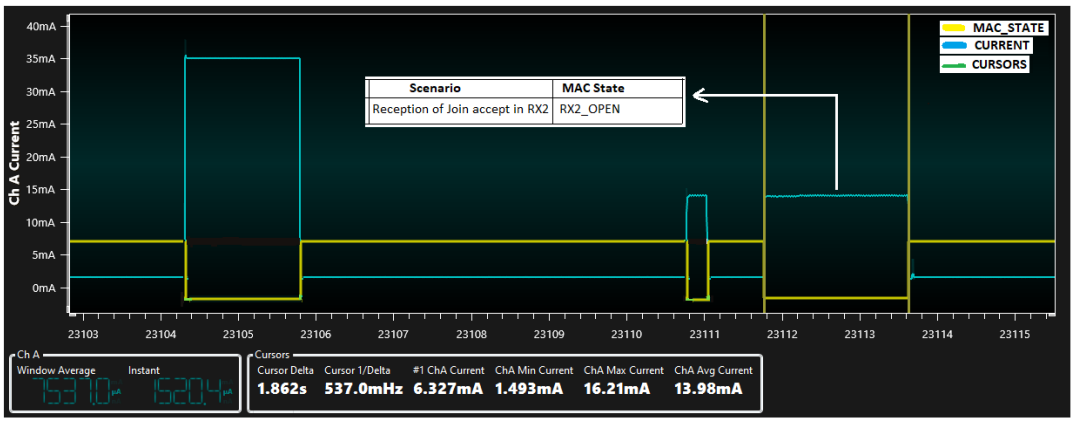


Figure 3-19. Join Accept Reception in RX2 "With Period of Operation" Zoom in Plot at DR5

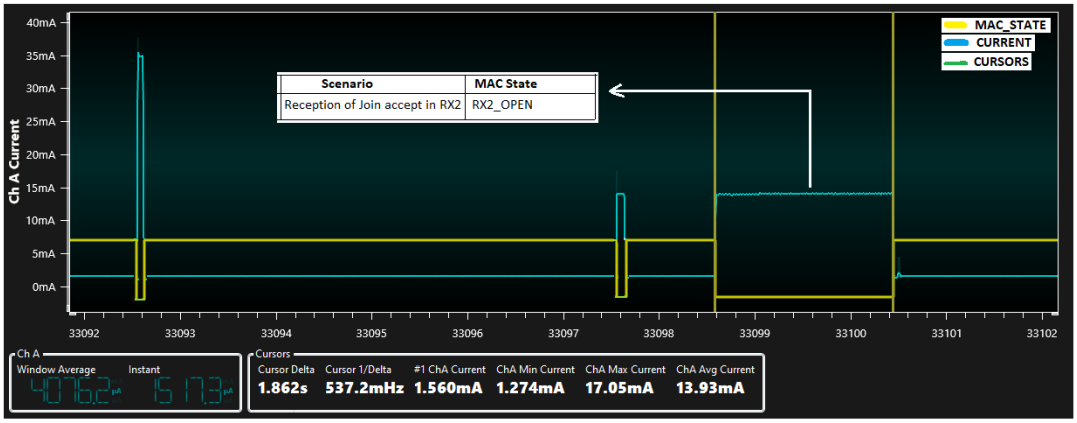


Figure 3-20. Join Request Transmission and Join Accept in RX1 Event "Without Period of Operation" at DR0

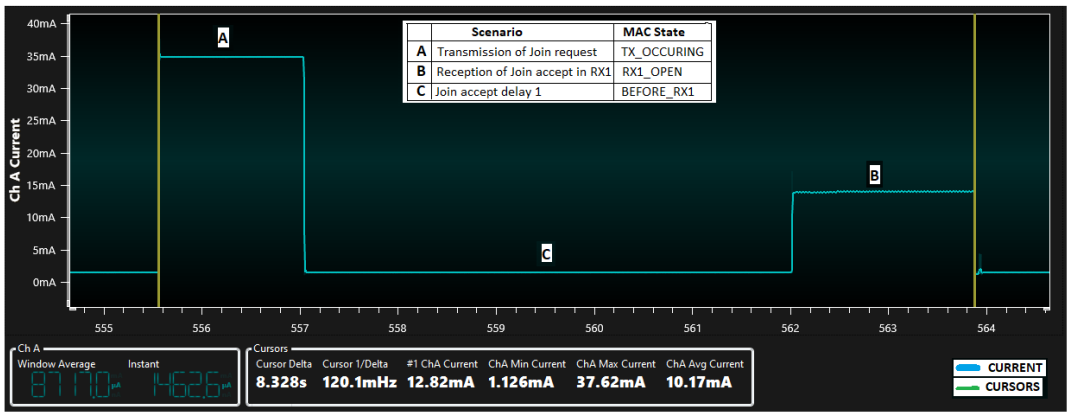


Figure 3-21. Join Request Transmission and Join Accept in RX1 Event "Without Period of Operation" at DR5

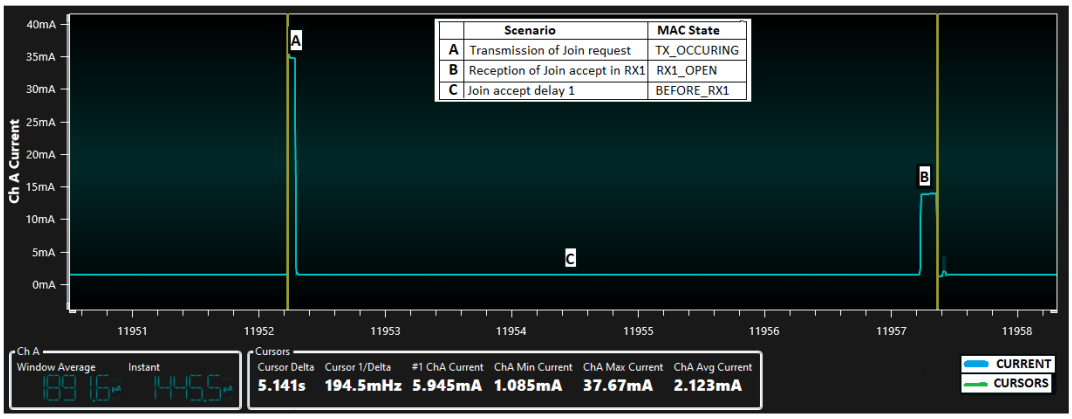


Figure 3-22. Join Request Transmission "Without Period of Operation" Zoom in Plot at DR0

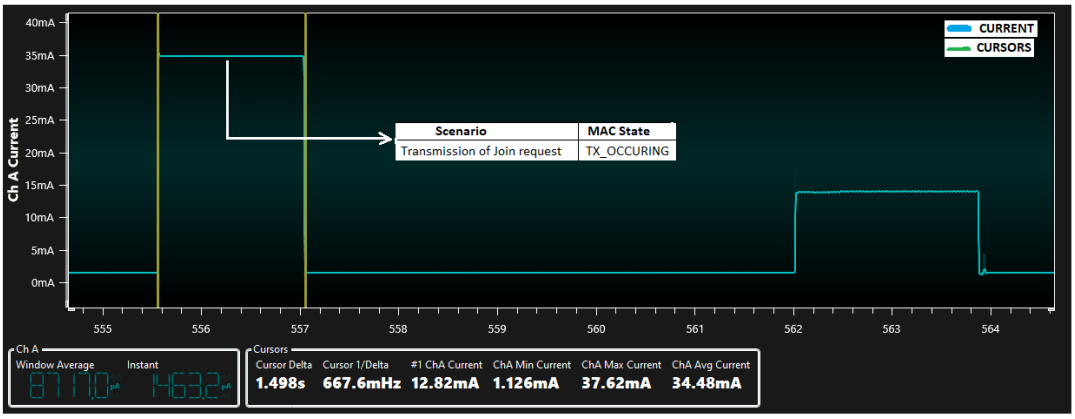


Figure 3-23. Join Request Transmission "Without Period of Operation" Zoom in Plot at DR5

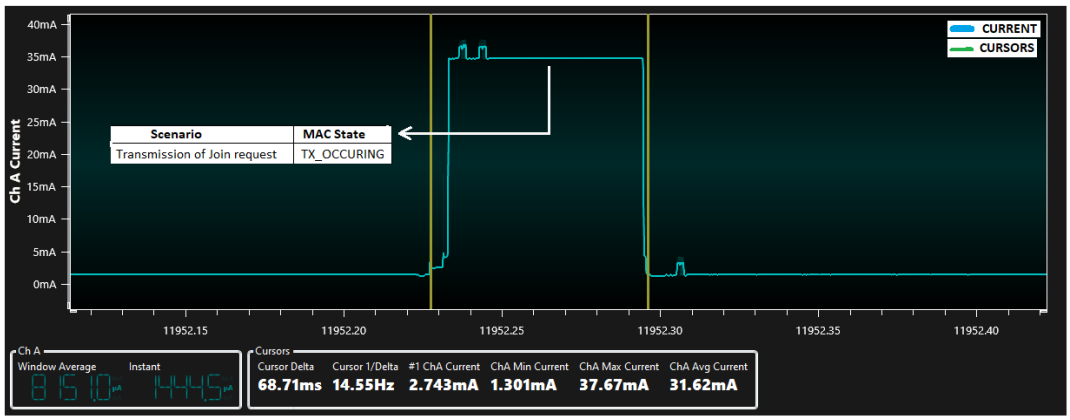


Figure 3-24. Join Accept Reception in RX1 "Without Period of Operation" Zoom in Plot at DR0

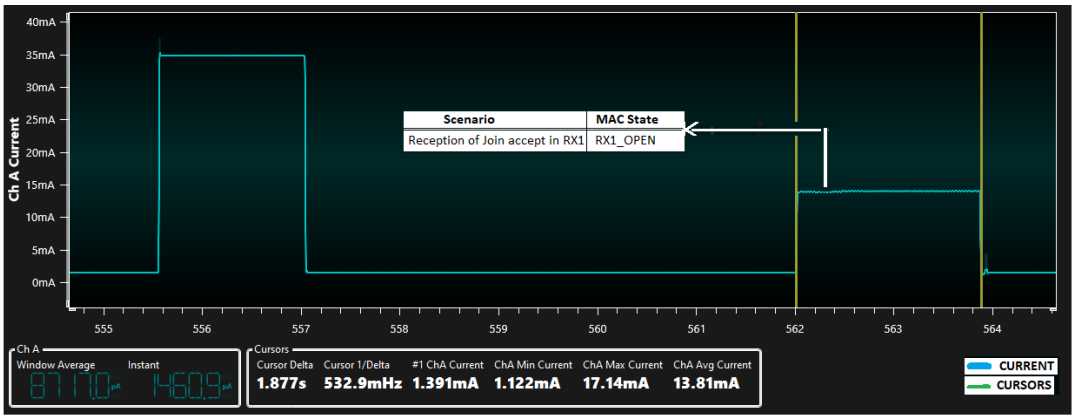


Figure 3-25. Join Accept Reception in RX1 "Without Period of Operation" Zoom in Plot at DR5

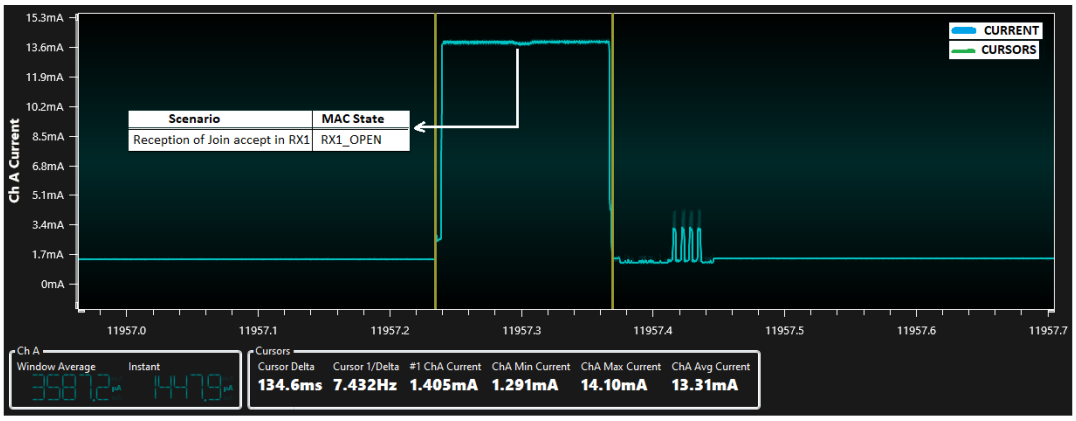


Figure 3-26. Join Accept Delay 1 “Without Period of Operation” Zoom in Plot at DR0

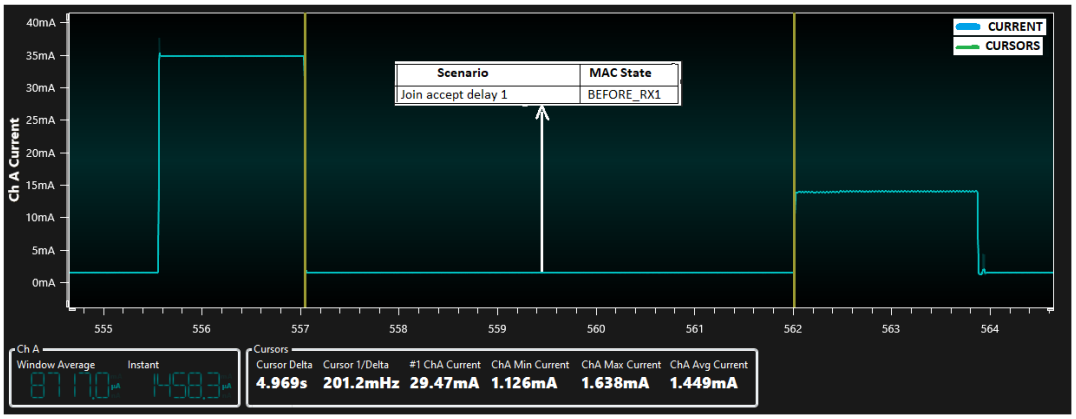


Figure 3-27. Join Accept Delay 1 “Without Period of Operation” Zoom in Plot at DR5

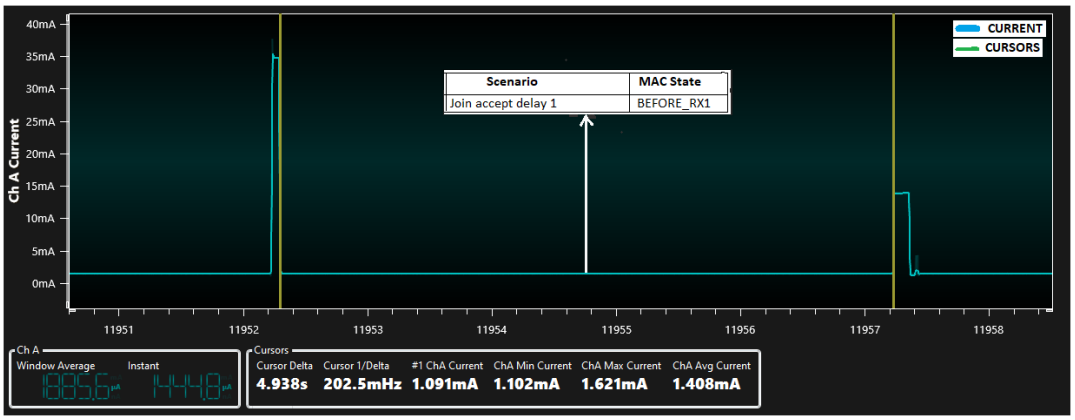


Figure 3-28. Join Request Transmission and Reception of Join Accept in RX2 “Without Period of Operation” at DR0

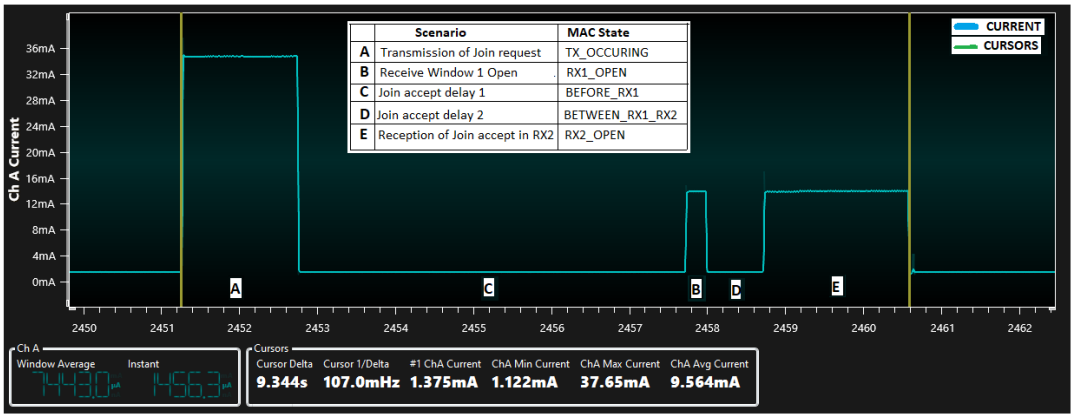


Figure 3-29. Join Request Transmission & Reception of Join Accept in RX2 "Without Period of Operation" DR5

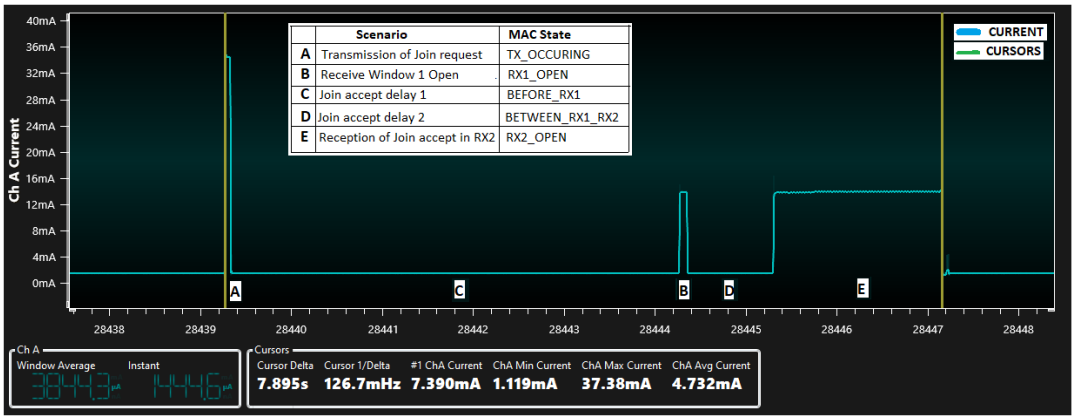


Figure 3-30. Receive Window 1 Open Event "Without Period of Operation" Zoom in Plot at DR0

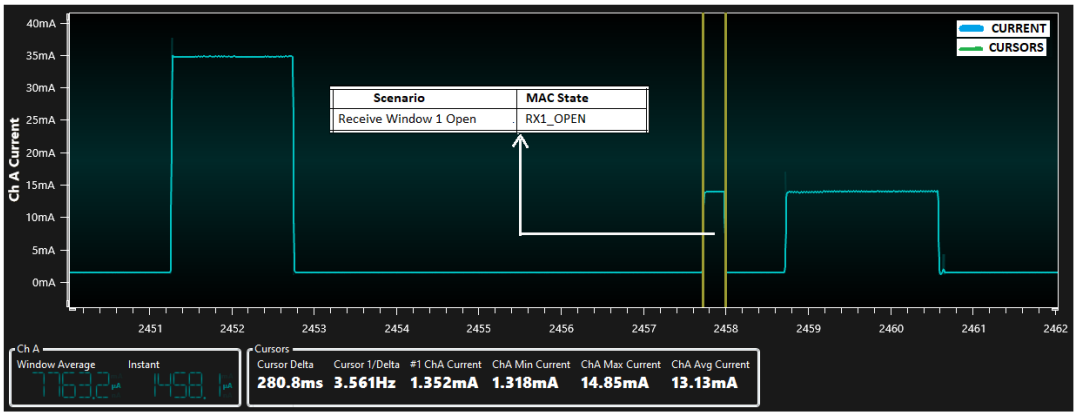


Figure 3-31. Receive Window 1 Open Event "Without Period of Operation" Zoom in Plot at DR5

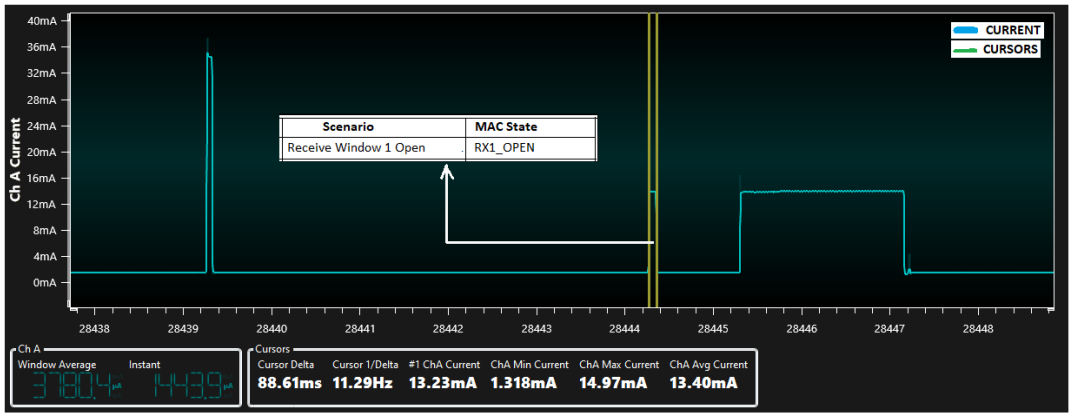


Figure 3-32. Join Accept Delay 2 Event "Without Period of Operation" Zoom in Plot at DR0

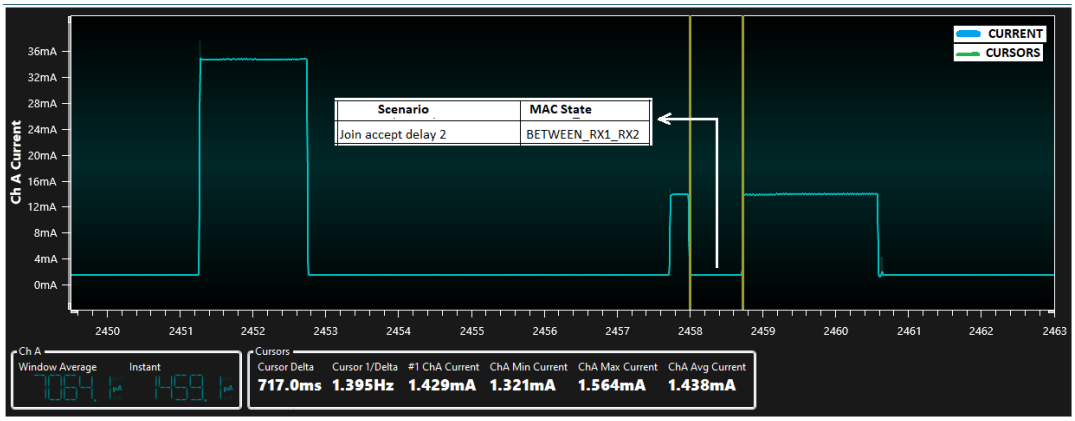


Figure 3-33. Join Accept Delay 2 Event "Without Period of Operation" Zoom in Plot at DR5

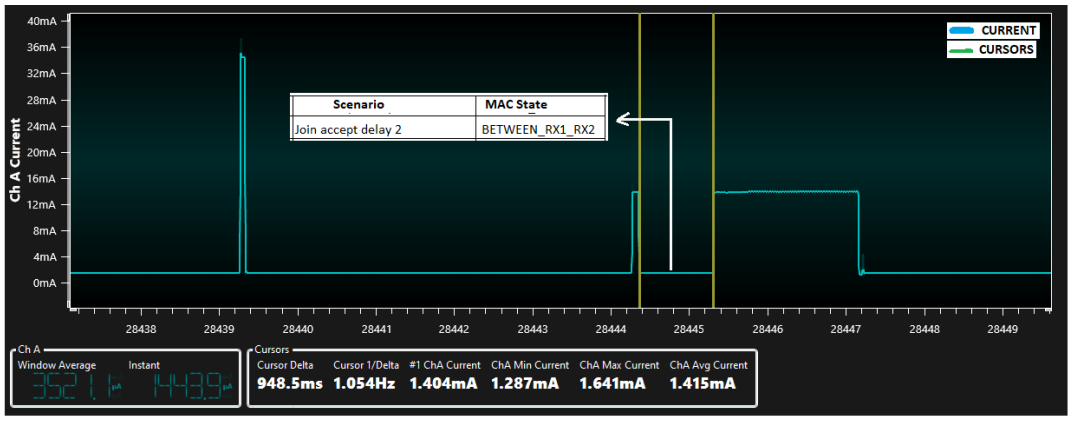


Figure 3-34. Join Accept Reception in RX2 "Without Period of Operation" Zoom in Plot at DR0

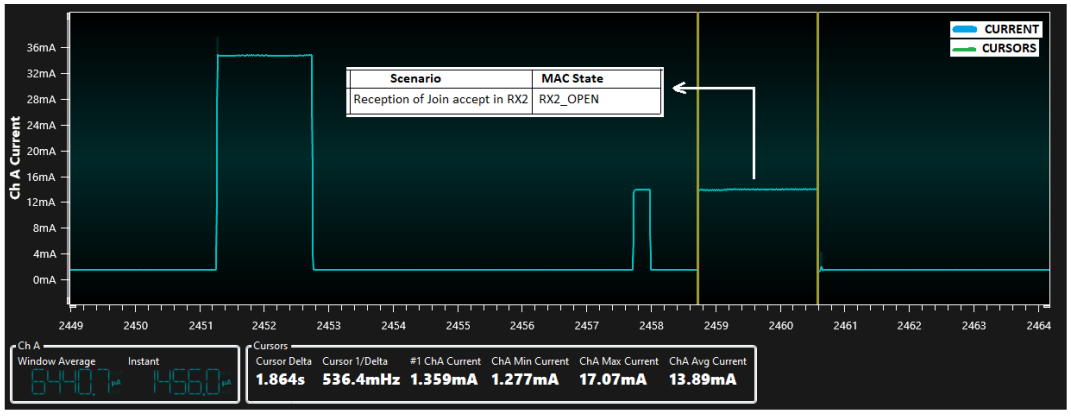
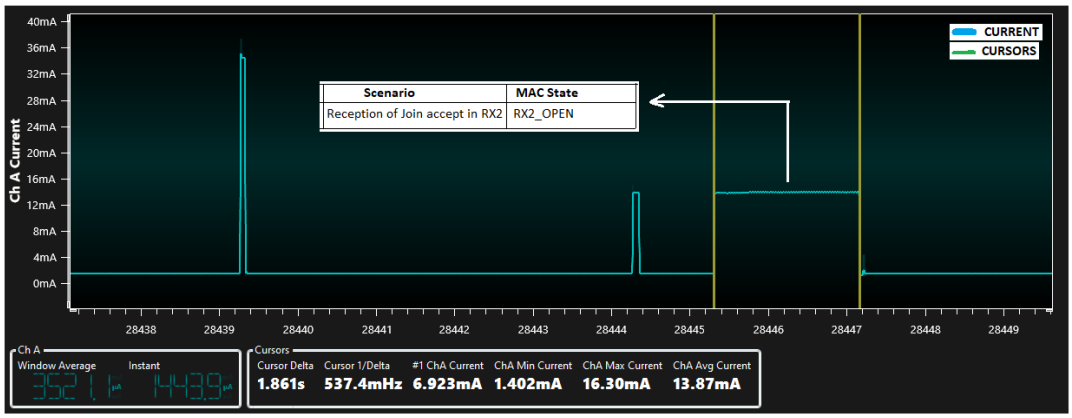


Figure 3-35. Join Accept Reception in RX2 “Without Period of Operation” Zoom in Plot at DR5



From the preceding plots, the total time taken to complete the transaction at different data rate scenarios is given in the following table.

Table 3-3. Total Time Taken to Complete the Transaction

Data Rate	Total Time Taken to Complete the Transaction		Units
	Join Request Transmission and Join Accept in RX1 (Transaction Event 1)	Join Request Transmission and Join Accept in RX2 (Transaction Event 2)	
DR0	8.33	9.35	seconds
DR5	5.15	7.90	seconds

Notes: The MAC state sequence (inside MLS) during transaction event 1 and transaction event 2 are as follows:

- Transaction event 1 – TX_OCCURING + BEFORE_RX1 + RX1_OPEN
- Transaction event 2 – TX_OCCURING + BEFORE_RX1 + RX1_OPEN + BETWEEN_RX1_RX2 + RX2_OPEN

Table 3-4. Join Request Transmission Event (TX) – MAC STATE: TX_OCCURING

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	1484	68.70	ms
Average current	34.81	32.02	mA
Peak current	37.80	38.02	mA
Total charge	51658.04	2199.78	mA×ms

Table 3-5. Join Accept Delay 1 – MAC STATE: BEFORE_RX1

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	4973	4937	ms
Average current	1.487	1.548	mA
Peak current	1.638	1.621	mA

.....continued			
Attribute	Measured Value		Units
	DR0	DR5	
Total charge	7394.86	7642.48	mA×ms

Table 3-6. Join Accept Reception in RX1 Receive Window – MAC STATE: RX1_OPEN

Attribute	Measured Value		Units
	DR0	DR5	
Total duration (ms)	1878	134.2	ms
Average current (mA)	13.84	13.41	mA
Peak current (mA)	14.82	15.25	mA
Total charge (mA×ms)	25991.52	1799.63	mA×ms

Table 3-7. Join Accept Delay 2 – MAC STATE: BETWEEN_RX1_RX2

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	717.9	949	ms
Average current	1.440	1.490	mA
Peak current	1.564	1.641	mA
Total charge	1033.78	1414.01	mA×ms

Table 3-8. Join Accept Reception in RX2 Receive Window – MAC STATE: RX2_OPEN

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	1862	1862	ms
Average current	13.98	13.3	mA
Peak current	16.21	17.05	mA
Total charge	26030.8	24764.6	mA×ms

Table 3-9. Receive Window 1 Open When Reception of Join Accept in RX2 Window – MAC STATE: RX1_OPEN

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	265.5	87.61	ms
Average current	13.87	13.55	mA
Peak current	15.21	17.40	mA

.....continued			
Attribute	Measured Value		Units
	DR0	DR5	
Total charge	3682.5	1187.12	mA×ms

The following table provides the time stamp reference for each join request sent and join accept received in RX1 and RX2 reception windows.

Note: Initiate multiple join requests to capture the reception of the join accept frame in each of the receive windows (RX1 and RX2). Disable the join accept 1 (RX1) window on the network server side to receive the join accept packet in the RX2 receive window in the WLR089 device.

Table 3-10. Join Request and Join Accept in RX1 Snippet

Packet N	Packet Type	Time Stamp		Source	Destination
		DR0	DR5		
Packet 1	Join request 1	12:56:23.457	12:34:43.860	End device (WLR089)	Network server
Packet 2	Join accept in RX1	12:56:32.788	12:34:49.005	Network server	End device (WLR089) – RX1

Table 3-11. Join Request and Join Accept in RX2 Snippet

Packet N	Packet Type	Time Stamp		Source	Destination
		DR0	DR5		
Packet 1	Join request 2	12:57:53.677	12:37:04.189	End device (WLR089)	Network server
Packet 2	Join accept in RX2	12:57:03.002	12:37:12.095	Network server	End device (WLR089) – RX2

3.1.3 Uplink Data Transmission

This section captures the power profile of the WLR089 device measured during the uplink data transmission, and highlights the power consumption based on the following parameter variations:

- Payload size
- Data rate
- Data retransmission (only valid for confirmed uplink message)

3.1.3.1 Uplink Data Transmission Based on Data Rate and Payload

The following figures illustrate the uplink data transmission based on the combination of payload size and data rate.

Note: Consider using the unconfirmed packet type as the results are the same for confirmed and unconfirmed packet types.

The following table provides the settings and payload sizes considered to profile the payload and data rate-based uplink data transmission scenarios.

Table 3-12. Payload and Data Rate Based Uplink Data Transmission Scenarios

Attribute	Value
TX power(1)	1 (default)
TX data rate	DR0 and DR5
Default payload	11 bytes (temperature sensor data)
Max payload	DR0 = 43 bytes and DR5 = 234 bytes

.....continued

Attribute	Value

Note:

1. The TX power from the preceding table resembles the offset value from the TX power table as per the RP2-1.0.2 LoRaWAN® Regional Parameters. Calculate the actual TX power value at the radio level for the above offset value using the following equation:

   Equation 3-2. Actual TX Power

   $$Actual\,TX\,Power\; = \; MAX\,EIRP - 2\,dB = 16 - 2 = 14\,dBm$$

Figure 3-36. Uplink Data (Default Payload Size) Transmission "With Period of Operation" at DR0 Zoom in Plot

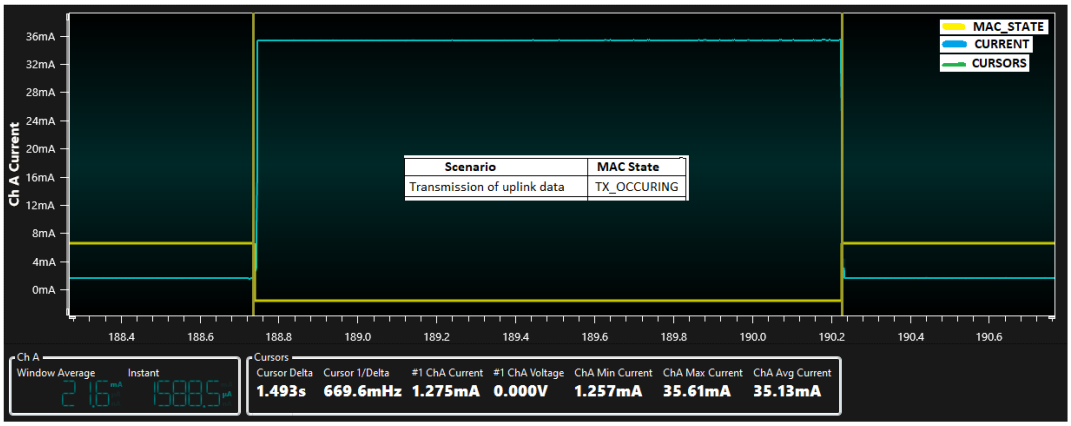


Figure 3-37. Uplink Data (Max Payload Size) Transmission "With Period of Operation" at DR0 Zoom in Plot

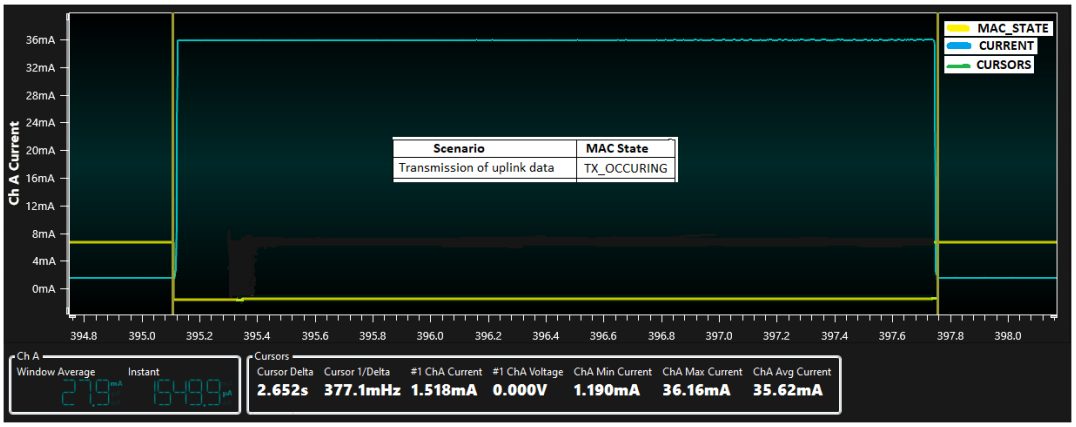


Figure 3-38. Uplink Data (Default Payload Size) Transmission "With Period of Operation" at DR5 Zoom in Plot

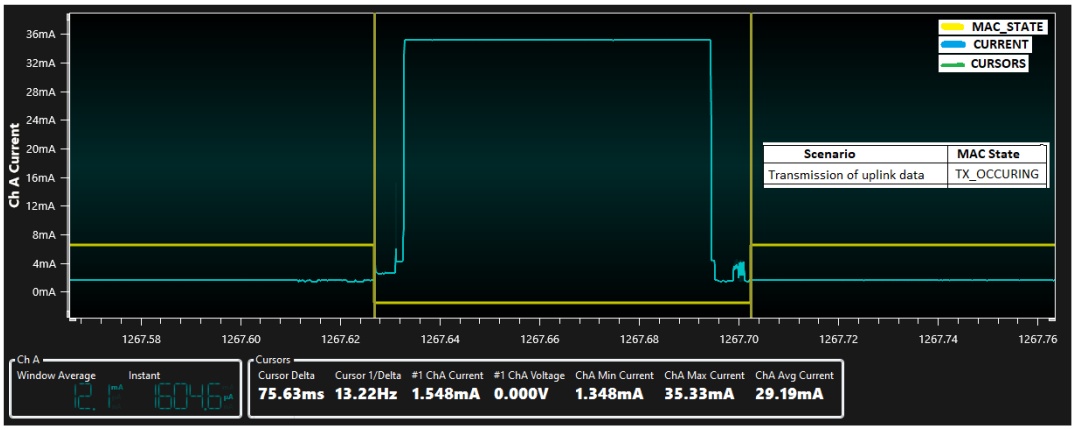


Figure 3-39. Uplink Data (Max Payload Size) Transmission "With Period of Operation" at DR5 Zoom in Plot

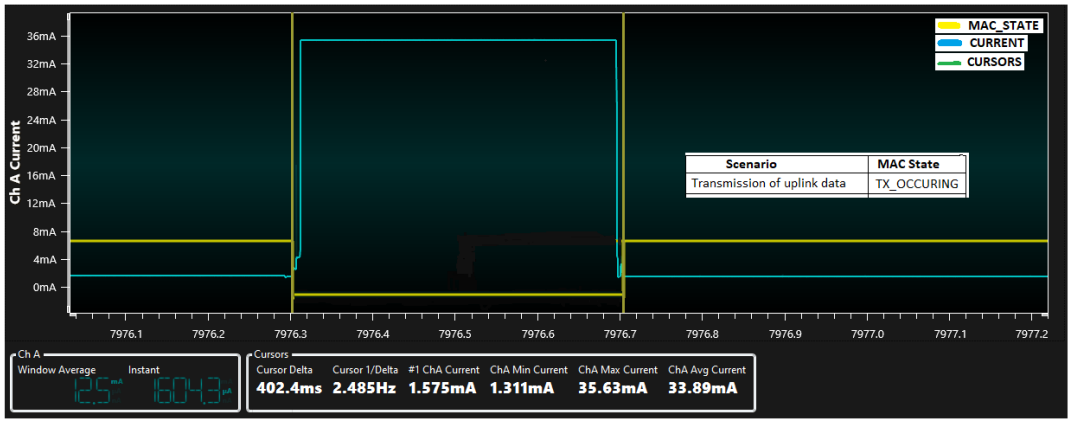


Figure 3-40. Uplink Data (Default Payload Size) Transmission "Without Period of Operation" at DR0 Zoom in Plot

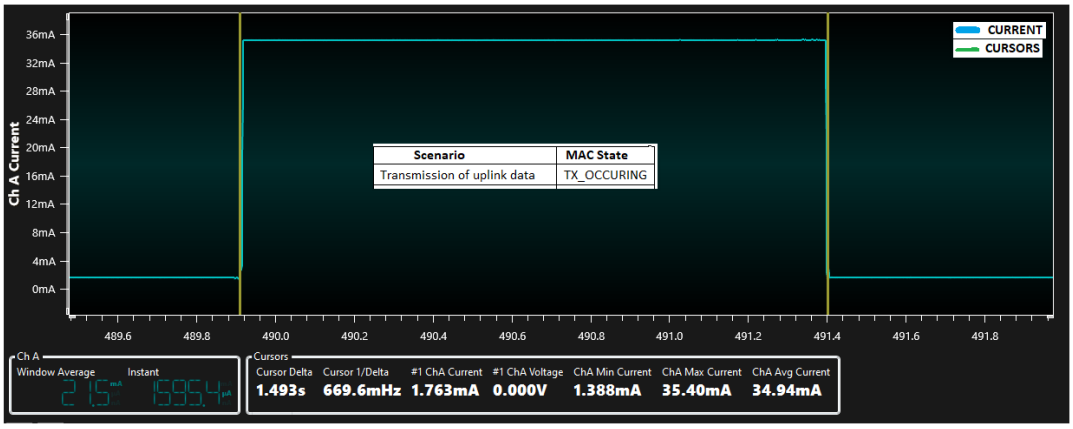


Figure 3-41. Uplink Data (Max Payload Size) Transmission "Without Period of Operation" at DR0 Zoom in Plot

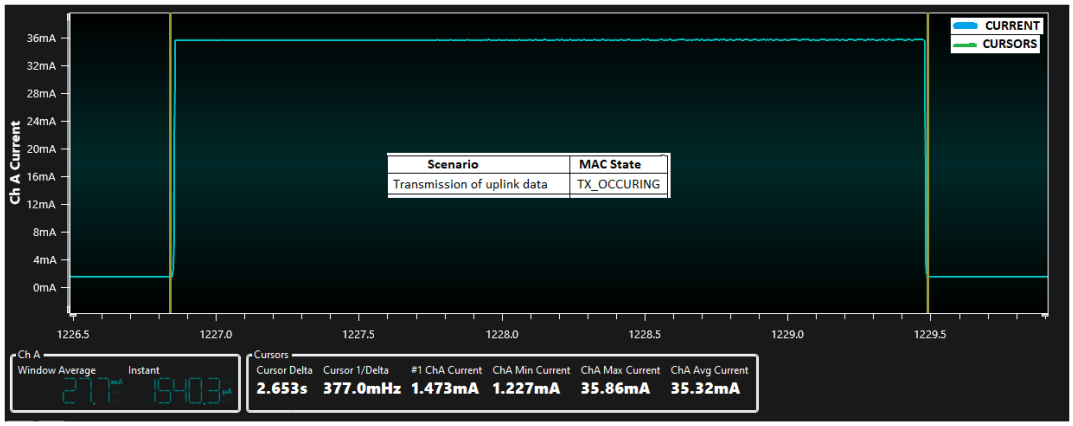


Figure 3-42. Uplink Data (Default Payload Size) Transmission "Without Period of Operation" at DR5 Zoom in Plot

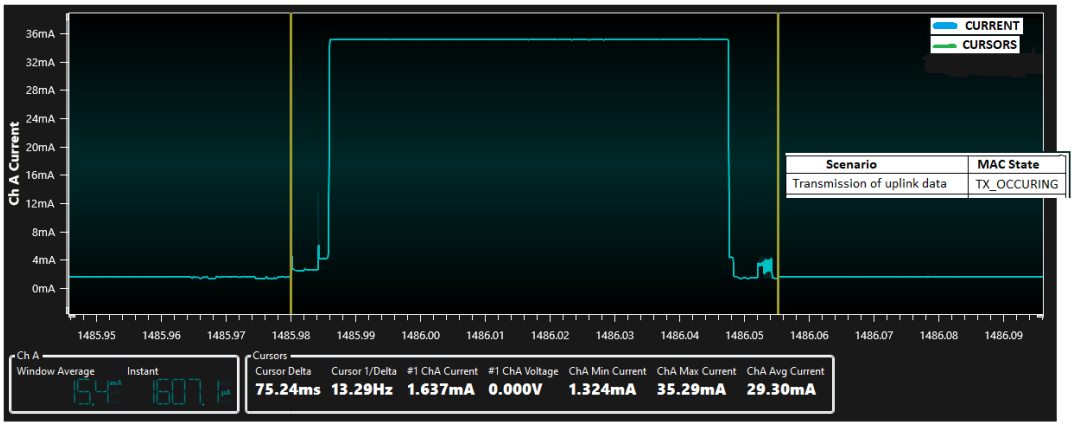
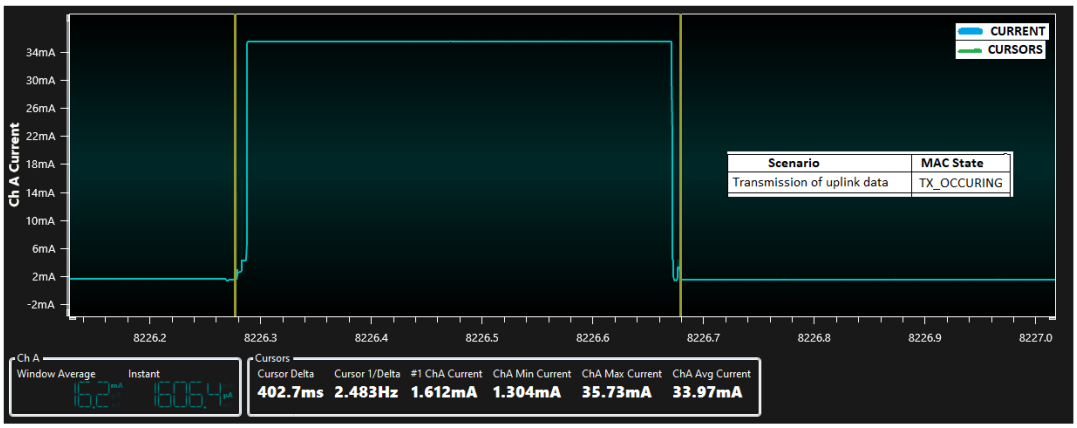


Figure 3-43. Uplink Data (Max Payload Size) Transmission "Without Period of Operation" at DR5 Zoom in Plot



The following table provides the consumption values during the uplink transmission in various scenarios from the preceding plots.

Table 3-13. Uplink Transmission in Various Scenarios

Attribute	Measured Values				Units
	Default Payload Size (12 bytes)		Max Payload Size (234 bytes)		
	DR0	DR5	DR0	DR5	
Total duration	1493	75.34	2653	402.7	ms
Average current	34.94	29.30	35.32	33.97	mA
Peak current	35.40	35.29	35.86	35.73	mA
Total charge	52165.42	2207.47	93703.96	13679.72	mA×ms

3.1.3.2 Data Retransmission

The following figures illustrate the details on the retransmission cycle and highlights on the consumption values for one retransmission cycle. The following table provides details about the settings for profiling the retransmission scenario in the WLR089 device.

Table 3-14. Profile Retransmission Settings in the WLR089 Device

Attribute	Value
TX Data Rate	DR0 and DR5
RX1 delay	1s (considered from end of TX)
RX1 data rate	Same as TX data rate
RX2 delay	2s (considered from end of TX)
RX2 data rate	DR0
Number of retransmissions (retx)	2
TX power(1)	1 (default)

Note:

1. The TX power from the preceding table resembles the offset value from the TX power table as per the RP2-1.0.2 LoRaWAN® Regional Parameters. Calculate the actual TX power value at the radio level for the above offset value using the following equation.

   Equation 3-3. Actual TX Power

   $$Actual\,TX\,Power = MAX\,EIRP - 2\,dB = 16 - 2 = 14\,dBm$$

To perform this scenario, disable the RX1 and RX2 receive windows on the network server side to restrict the ack reception in the WLR089 device receive windows, and the MLS proceeds to perform the retransmission cycle.

Note: Consider the packet type as a confirmed type because the retransmission feature is only applicable to the confirmed type data transmission.

The following table provides the plot reference that signifies the scenario and MAC state at that instance inside all the data retransmission plots.

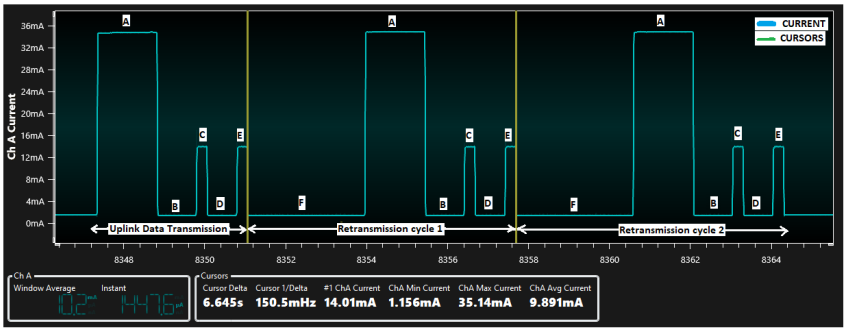
Table 3-15. Scenario and MAC_STATE

	Scenario	MAC_STATE
A	Transmission of uplink	TX_OCCURING

.....continued		
	Scenario	**MAC_STATE**
B	RX1 delay	BEFORE_RX1
C	RX1 receive window	RX1_OPEN
D	RX2 delay	BETWEEN_RX1_RX2
E	RX2 receive window open	RX2_OPEN
F	Retransmission delay	RETRANSMISSION_DELAY

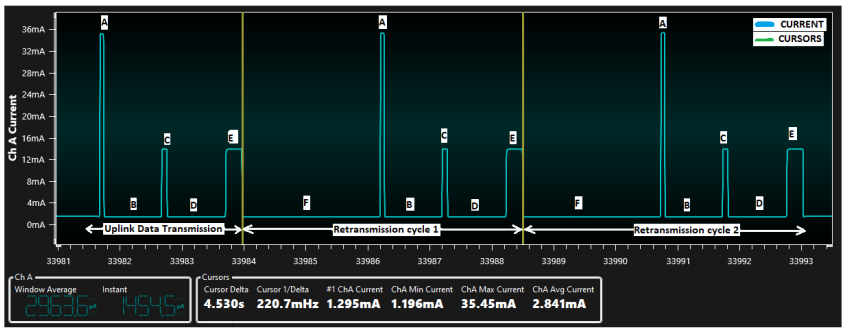
The following figure illustrates the data retransmission with time delta on one retransmission cycle at DR0.

Figure 3-44. Data Retransmission with Time Delta on Retransmission Cycle 1 at DR0



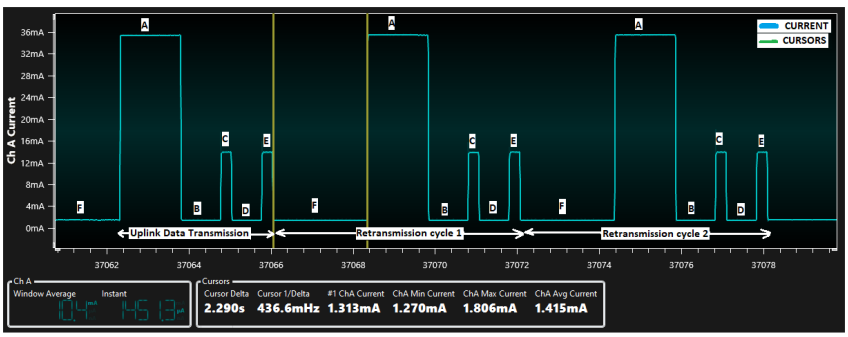
The following figure illustrates the data retransmission with time delta on one retransmission cycle at DR5.

Figure 3-45. Data Retransmission with Time Delta on Retransmission Cycle 1 at DR5



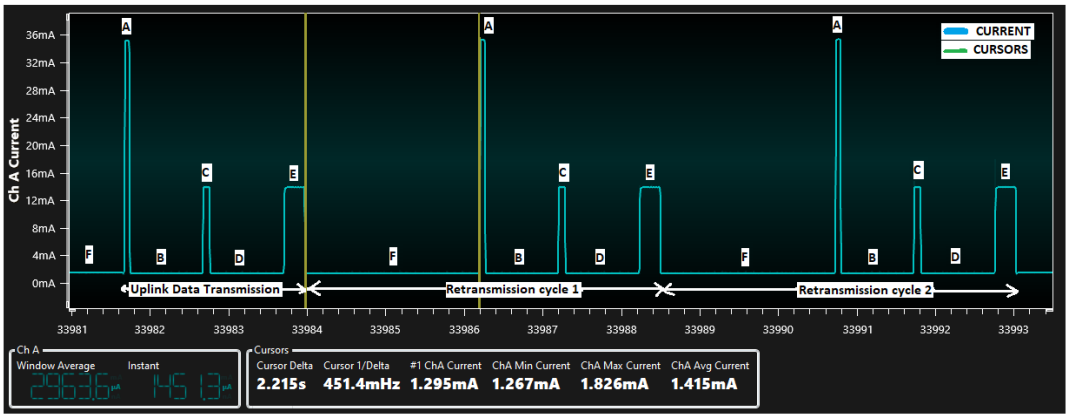
The following figure illustrates the data retransmission with time delta on the retransmission delay slot at DR0.

Figure 3-46. Data Retransmission with Time Delta on Retransmission Delay Slot at DR0



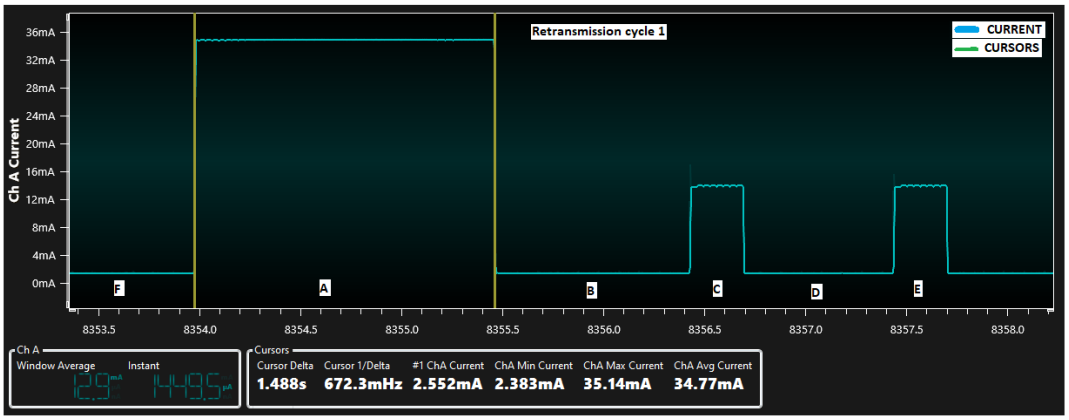
The following figure illustrates the data retransmission with time delta on the retransmission delay slot at DR5.

Figure 3-47. Data Retransmission with Time Delta on Retransmission Delay Slot at DR5



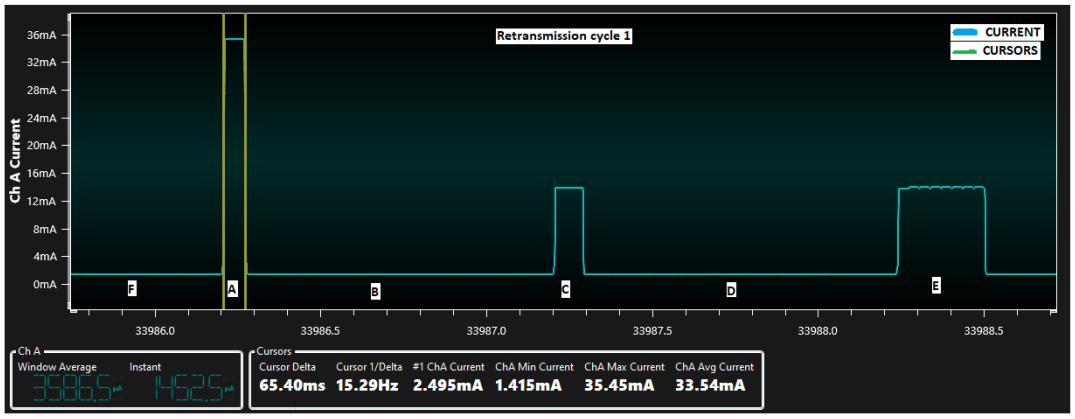
The following figure illustrates the zoomed-in plot of retransmission cycle 1 with time delta on the transmission of the uplink slot at DR0.

Figure 3-48. Retransmission Cycle 1 Zoom in Plot with Time Delta on Transmission of Uplink Slot at DR0



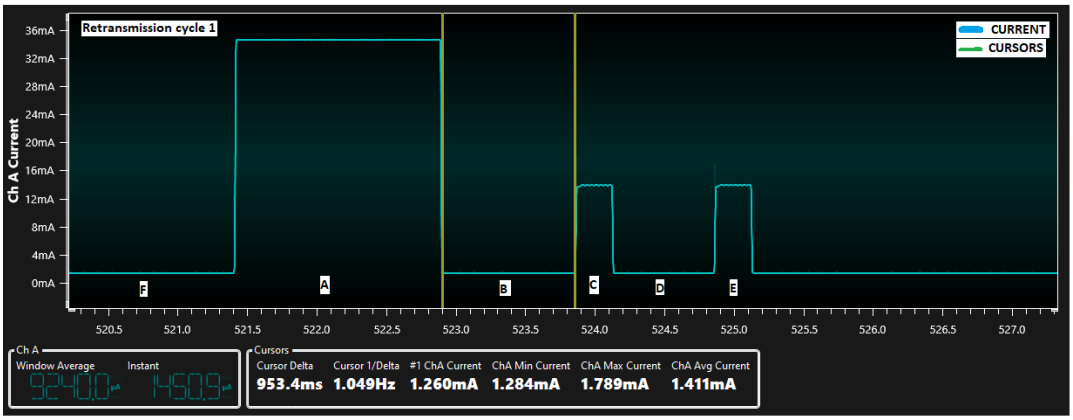
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the transmission of the uplink slot at DR5.

Figure 3-49. Retransmission Cycle 1 Zoom in Plot with Time Delta on Transmission of Uplink Slot At DR5



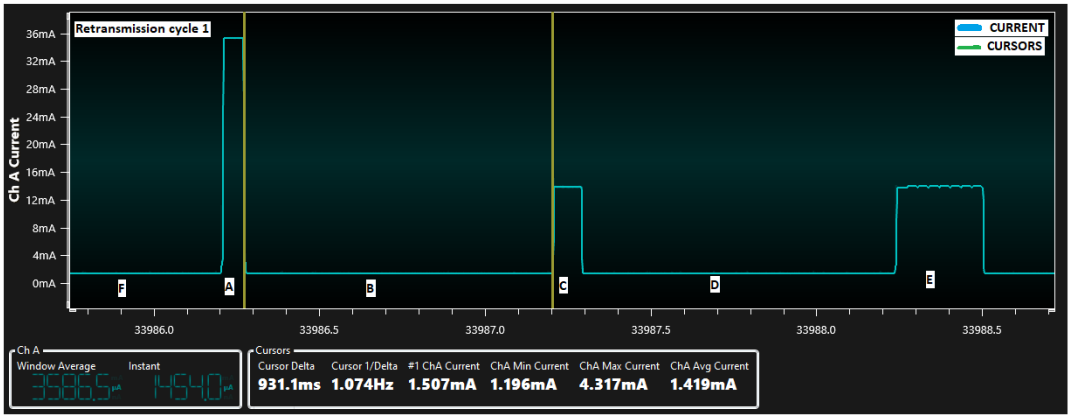
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX1 delay slot at DR0.

Figure 3-50. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX1 Delay Slot at DR0



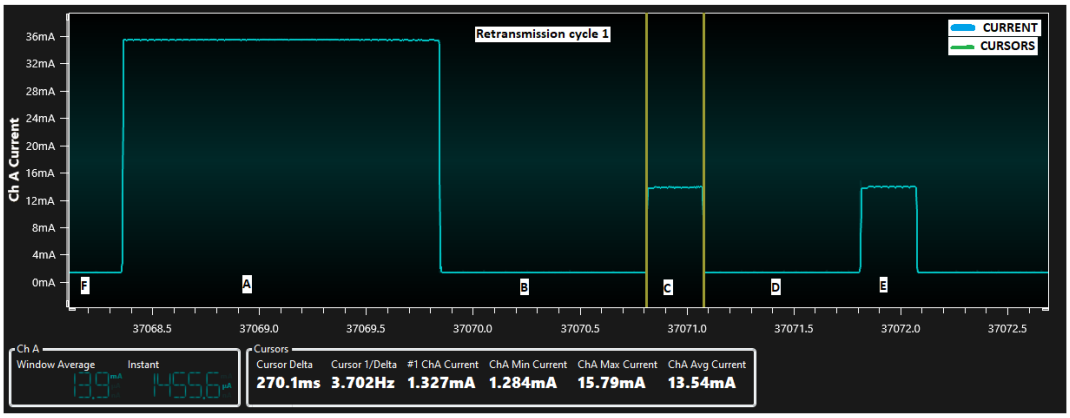
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX1 delay slot at DR5.

Figure 3-51. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX1 Delay Slot At DR5



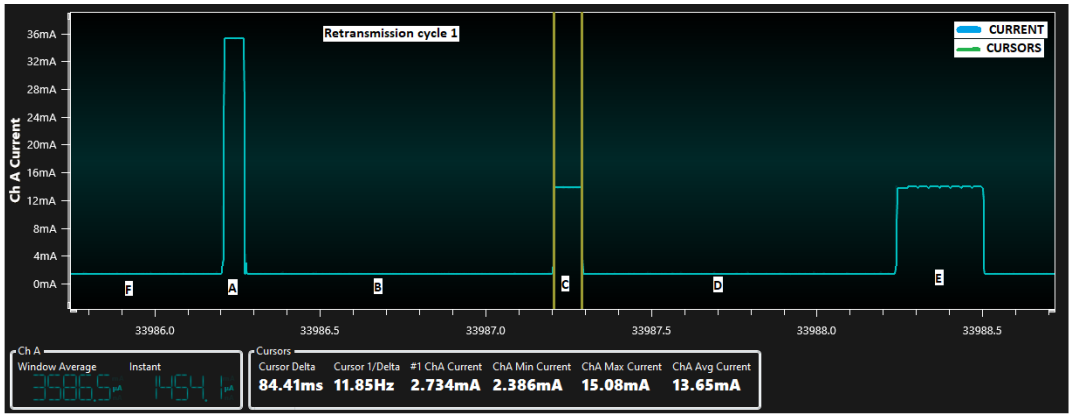
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX1 reception window slot at DR0.

Figure 3-52. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX1 Reception Window Slot at DR0



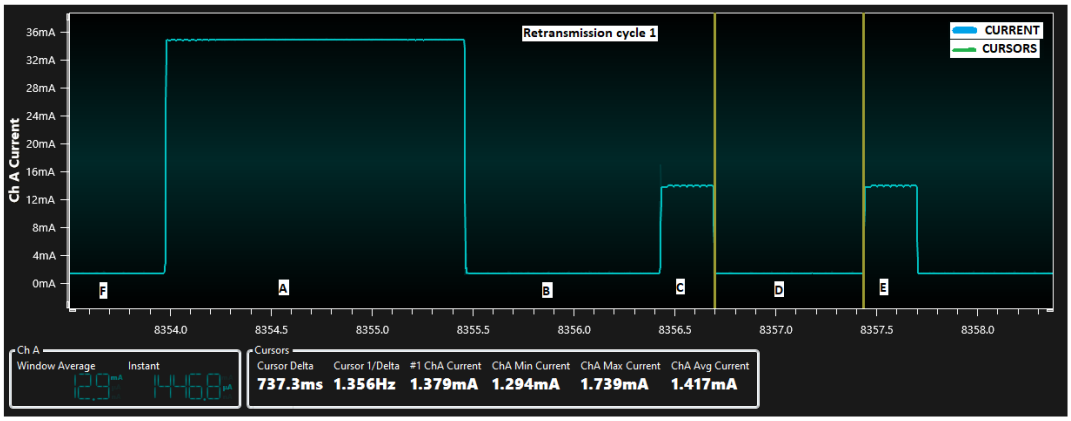
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX1 reception window slot at DR5.

Figure 3-53. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX1 Reception Window Slot at DR5



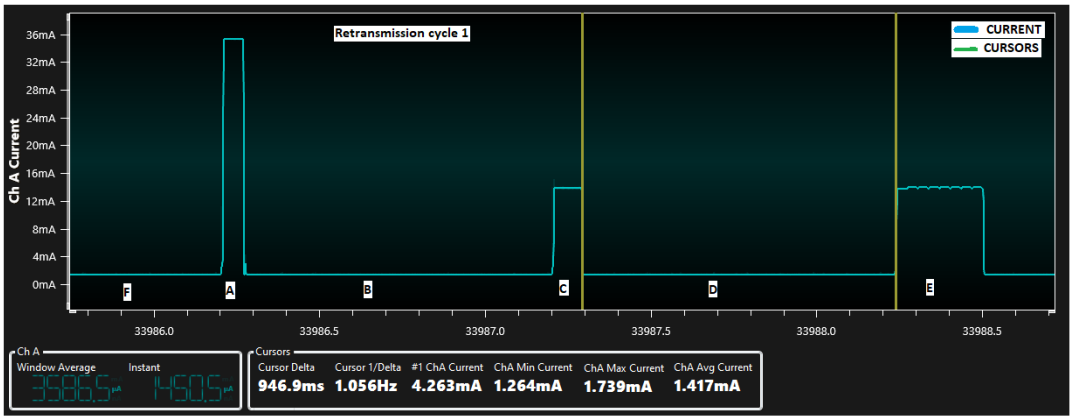
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX2 delay slot at DR0.

Figure 3-54. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX2 Delay Slot at DR0



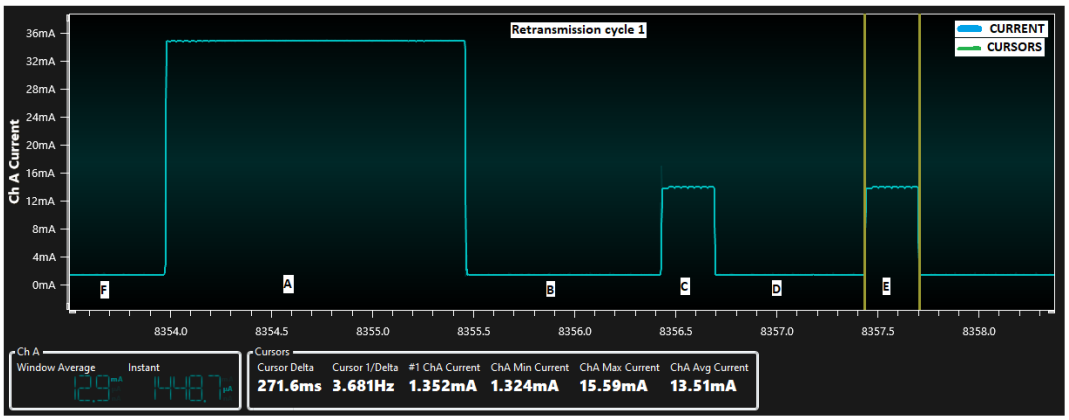
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX2 delay slot at DR5.

Figure 3-55. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX2 Delay Slot at DR5



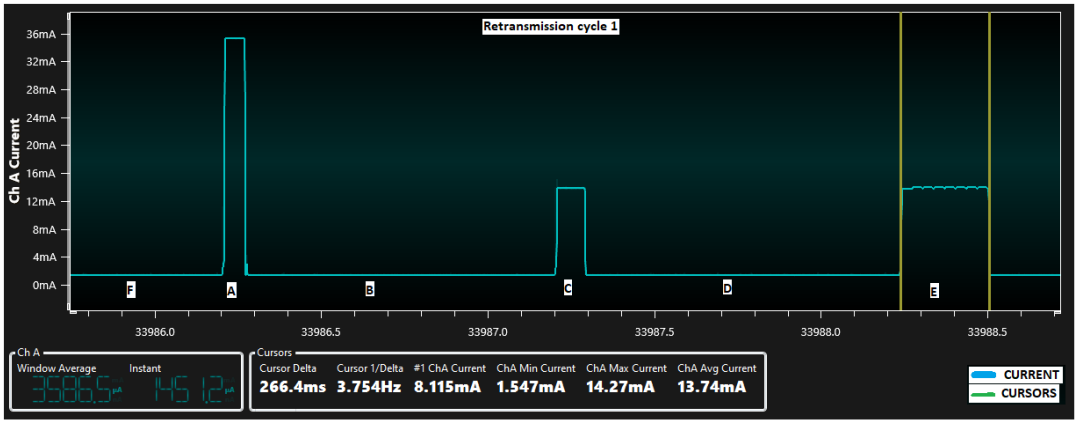
The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX2 reception window slot at DR0.

Figure 3-56. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX2 Reception Window Slot at DR0



The following figure illustrates the zoomed-in plot of the retransmission cycle 1 with time delta on the RX2 reception window slot at DR5.

Figure 3-57. Retransmission Cycle 1 Zoom in Plot with Time Delta on RX2 Reception Window Slot at DR5



The following tables provide the consumption values in each instance of retransmission, including the retransmission delay and total power consumption for one transmission cycle.

Table 3-16. Transmission of Uplink Instance – MAC_STATE: TX_OCCURING

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	1488	65.40	ms
Average current	34.77	33.54	mA
Peak current	35.14	35.45	mA
Total charge	51737.76	2193.52	mA×ms

Table 3-17. Retransmission Delay Instance – MAC_STATE: RETRANSMISSION_DELAY

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	2290	2215	ms
Average current	1.415	1.415	mA
Peak current	1.806	1.826	mA
Total charge	3240.35	3134.26	mA×ms

Table 3-18. RX1 Delay Instance – MAC_STATE: BEFORE_RX1

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	953.4	931.1	ms
Average current	1.411	1.419	mA
Peak current	1.789	4.317	mA
Total charge	1345.25	1321.24	mA×ms

Table 3-19. RX1 Receive Window Open Instance – MAC_STATE: RX1_OPEN

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	270.1	84.41	ms
Average current	13.54	13.65	mA
Peak current	15.79	15.08	mA
Total charge	3657.16	1152.20	mA×ms

Table 3-20. RX2 Delay Instance – MAC_STATE: BETWEEN_RX1_RX2

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	737.3	946.9	ms
Average current	1.417	1.417	mA
Peak current	1.739	1.739	mA
Total charge	1044.76	1341.76	mA×ms

Table 3-21. RX2 Receive Window Open Instance – MAC_STATE: RX2_OPEN

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	271.6	266.4	ms
Average current	13.51	13.74	mA
Peak current	15.59	14.27	mA
Total charge	3669.32	3660.34	mA×ms

The following is the MAC state sequence for one retransmission cycle:

RETRANSMISSION_DELAY + TX_OCCURING + BEFORE_RX1 + RX1_OPEN + BETWEEN_RX1_RX2 + RX2_OPEN

Table 3-22. Total Consumption in One Retransmission Cycle

Attribute	Measured Value		Units
	DR0	DR5	
Total duration	6645	4530	ms
Average current	9.891	2.841	mA
Peak current	35.14	35.45	mA
Total charge	65725.70	12869.73	mA×ms

3.1.4 Downlink Data Reception

This section captures the power profile of the WLR089 device measured during the downlink data reception in the RX1 and RX2 reception window, and highlights the power consumption based on the following parameter variations.

- Data Rate
- Payload Size

3.1.4.1 Downlink Data Reception Based on Payload and Data Rate

The following figures illustrate the downlink data reception based on the combination of payload size and data rate.

Note: Consider using the unconfirmed packet type as the results are the same for confirmed and unconfirmed packet types.

The following table displays the settings and payload sizes to profile the payload and data rate-based downlink data reception scenarios.

Table 3-23. Downlink Data Reception Scenarios

Attribute	Value
TX power(1)	1 (default)
RX1 receive window data rate	DR0 and DR5
RX2 receive window data rate	DR0
Default payload	11 bytes (temperature sensor data)
Max payload	DR0 = 43 bytes and DR5 = 234 bytes

.....continued

Attribute	Value

Note:

1. The TX power from the preceding table resembles the offset value from the TX power table as per the RP2-1.0.2 LoRaWAN® Regional Parameters. Calculate the actual TX power value at the radio level for the above offset value using the following equation.

   Equation 3-4. Actual TX Power

   $$Actual\,TX\,Power\ =\ MAX\,EIRP - 2\,dB = 16 - 2 = 14\,dBm$$

Figure 3-58. Downlink Data (Default Payload Size) Reception in RX1 at DR0 “With Period of Operation” Zoom in Plot

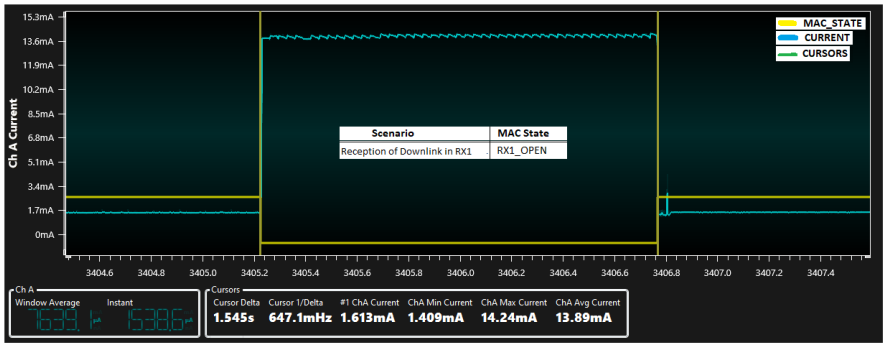


Figure 3-59. Downlink Data (Default Payload Size) Reception in RX1 at DR5 “With Period of Operation” Zoom in Plot

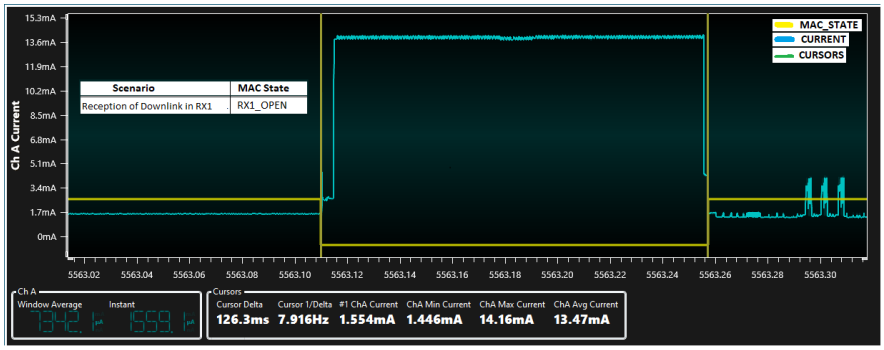


Figure 3-60. Downlink Data (Default Payload Size) Reception in RX2 at DR0 “With Period of Operation” Zoom in Plot

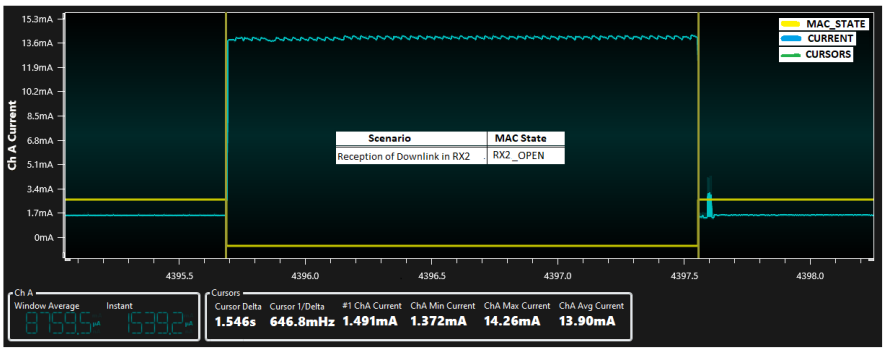


Figure 3-61. Downlink Data (Max Payload Size) Reception in RX1 at DR0 “With Period of Operation” Zoom in Plot

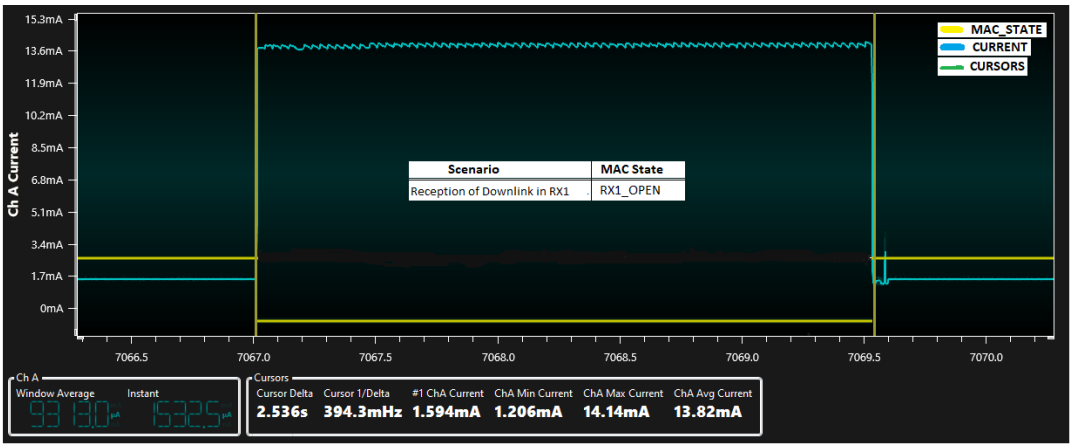


Figure 3-62. Downlink Data (Max Payload Size) Reception in RX1 at DR5 “With Period of Operation” Zoom In Plot

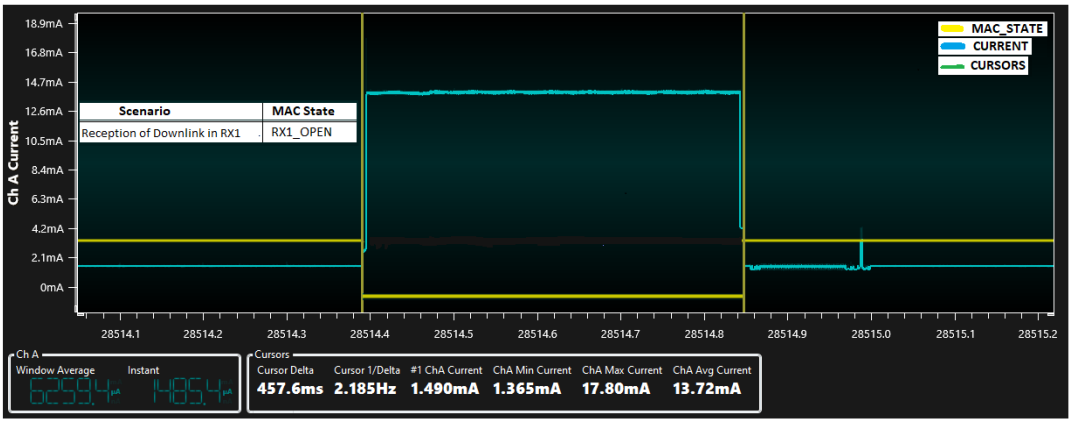


Figure 3-63. Downlink Data (Max Payload Size) Reception in RX2 at DR0 “With Period of Operation” Zoom in Plot

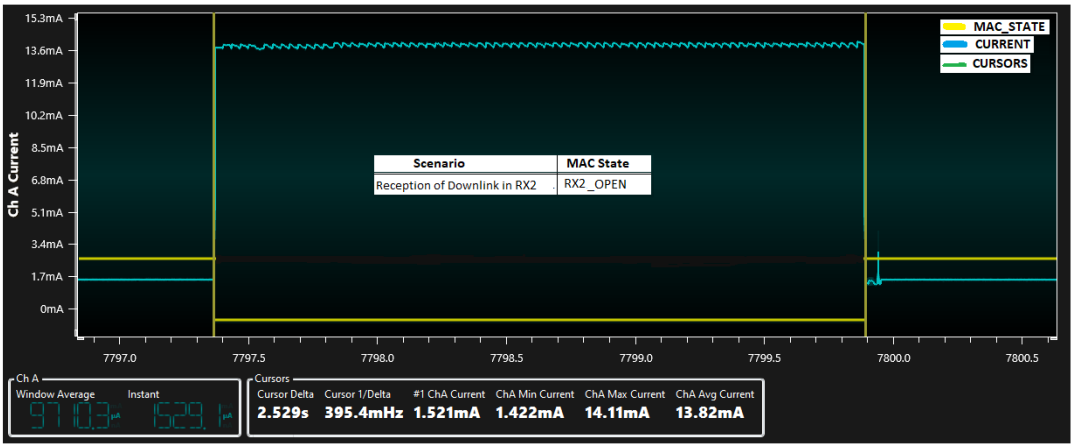


Figure 3-64. Downlink Data (Default Payload Size) Reception in RX1 at DR0 “Without Period of Operation” Zoom in Plot

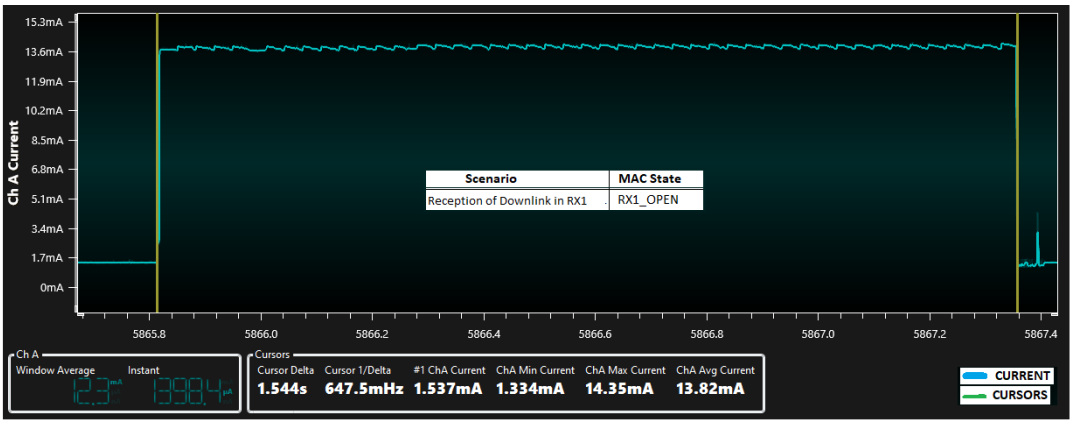


Figure 3-65. Downlink Data (Default Payload Size) Reception in RX1 At DR5 “Without Period of Operation” Zoom in Plot

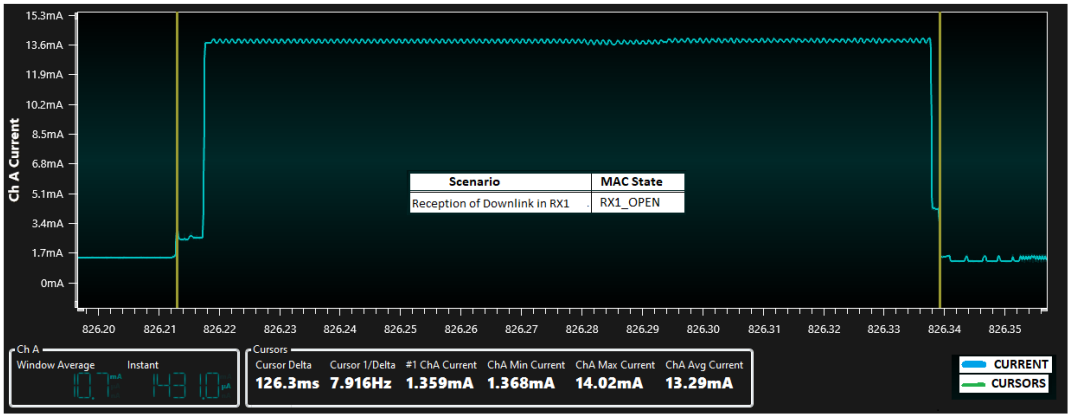


Figure 3-66. Downlink Data (Default Payload Size) Reception in RX2 At DR0 “Without Period of Operation” Zoom in Plot

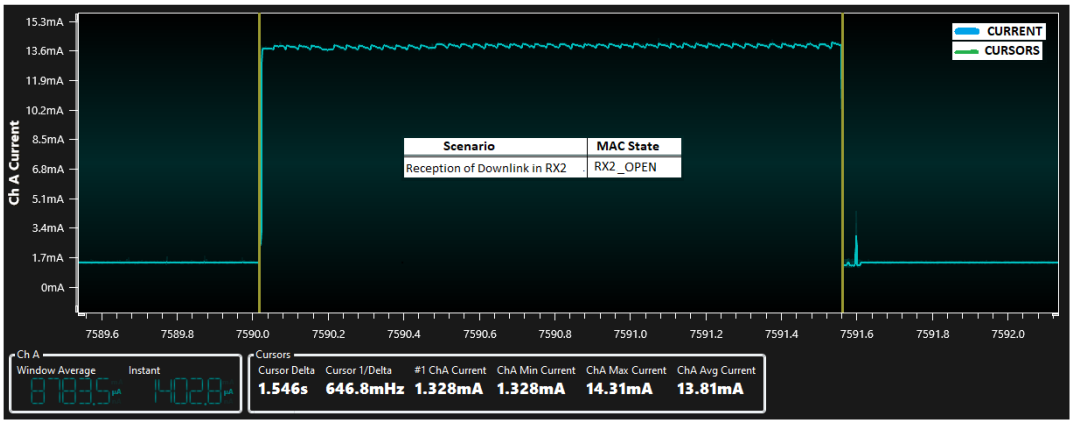


Figure 3-67. Downlink Data (Max Payload Size) Reception in RX1 At DR0 "Without Period of Operation" Zoom in Plot

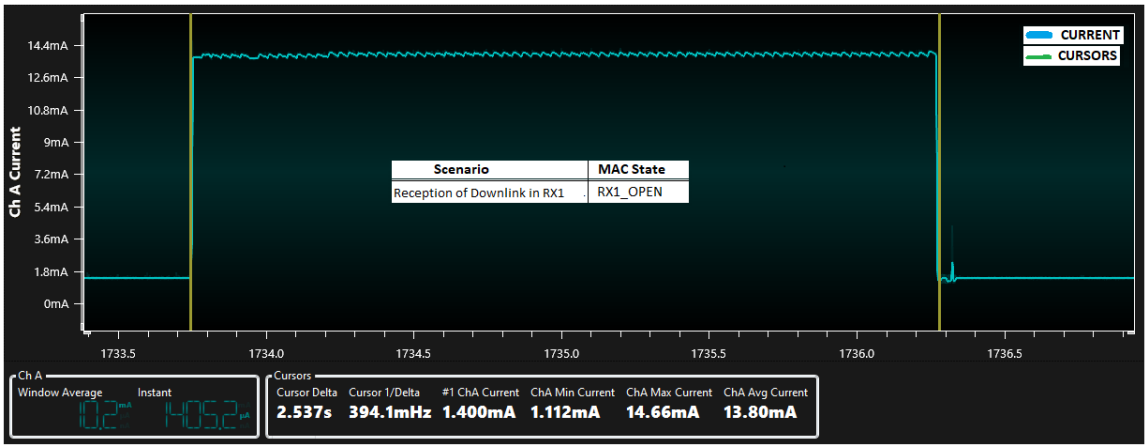


Figure 3-68. Downlink Data (Max Payload Size) Reception in RX1 At DR5 "Without Period of Operation" Zoom in Plot

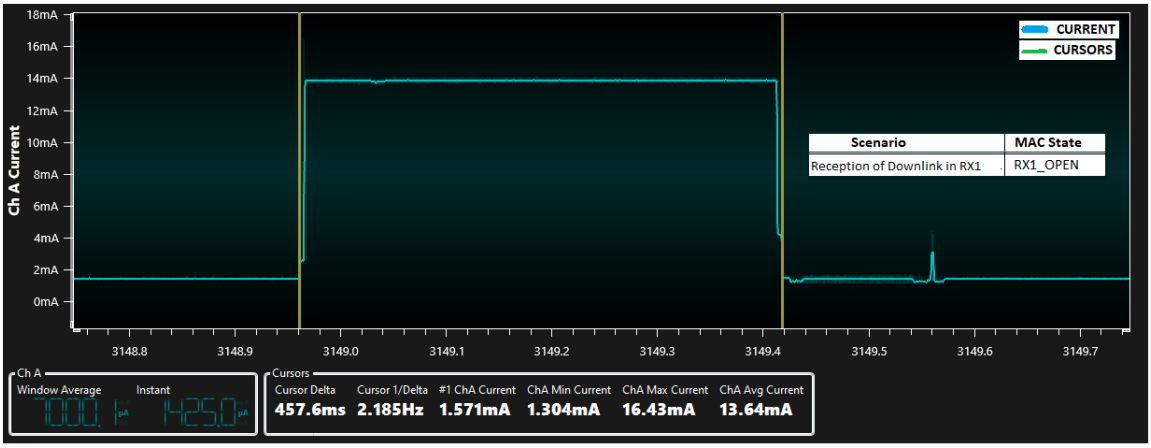
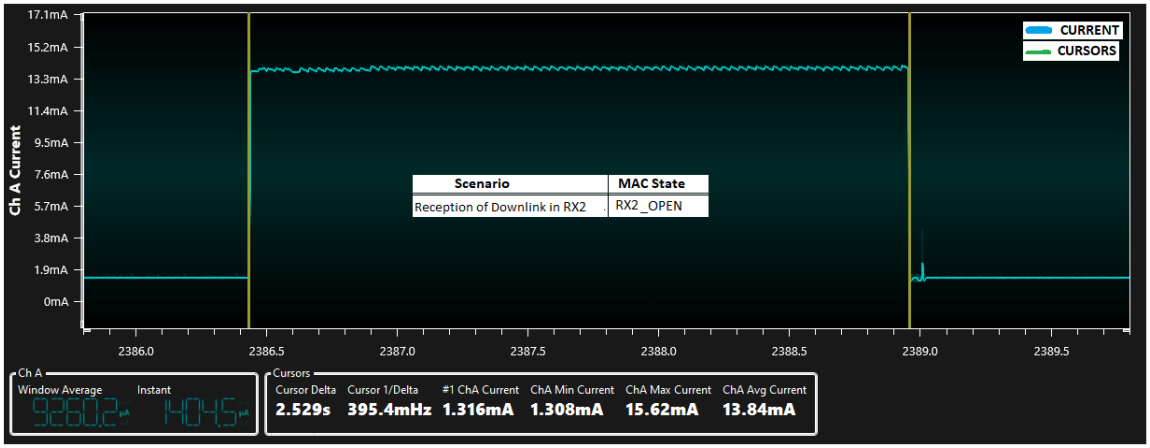


Figure 3-69. Downlink Data (Max Payload Size) Reception in RX2 At DR0 "Without Period of Operation" Zoom in Plot



The following table provides the consumption values during the downlink data reception in various scenarios captured in the above plots.

Table 3-24. Downlink Data Reception in Various Scenarios

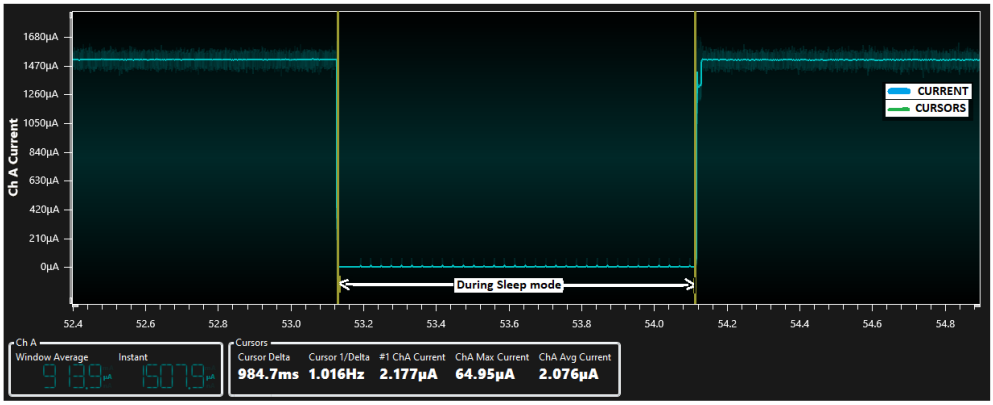
Attribute	Downlink Data Reception in RX1				Downlink Data Reception in RX2		Units
	DR0		DR5		DR0		
	Default Payload Size (12 bytes)	Max Payload Size (43 bytes)	Default Payload Size (12 bytes)	Max Payload Size (234 bytes)	Default Payload Size (12 bytes)	Max Payload Size (43 bytes)	
Total duration	1545	2537	126.3	457.6	1546	2529	ms
Average current	13.89	13.80	13.5	13.70	13.90	13.80	mA
Peak current	14.35	14.70	14.20	17.80	14.30	15.60	mA
Total charge	21460.05	35010.6	1705.05	6269.12	21489.4	34900.2	mA×ms

3.1.5 Sleep Mode Operation

This section captures the power profile of the WLR089 device measured during the Standby Sleep mode under various clock sources for the RTC and the main clock. The following plots illustrate the power consumption values captured during the Standby Sleep mode with various clock sources used for the RTC and main clock.

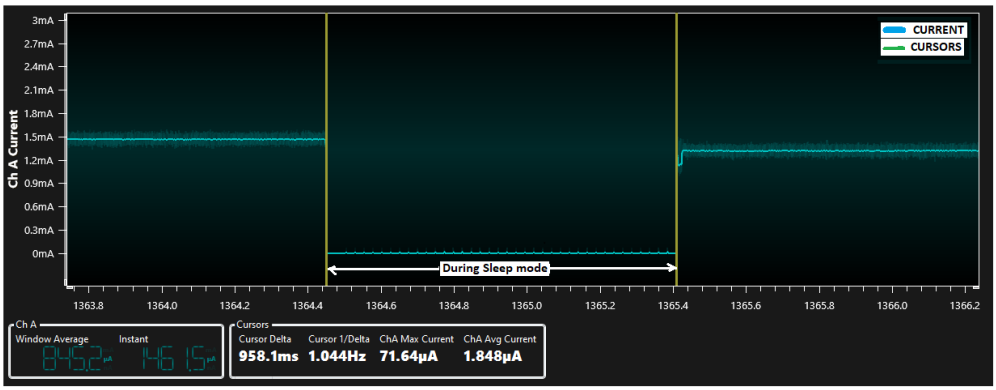
- Case 1
  - Main clock source (GCLK0) – DFLL (pre-scaled to 8 MHZ with XOSC32K as a reference)
  - RTC clock source – XOSC32K

Figure 3-70. Standby Sleep Mode Operation with DFLL Source to Main Clock and XOSC32K Source to RTC



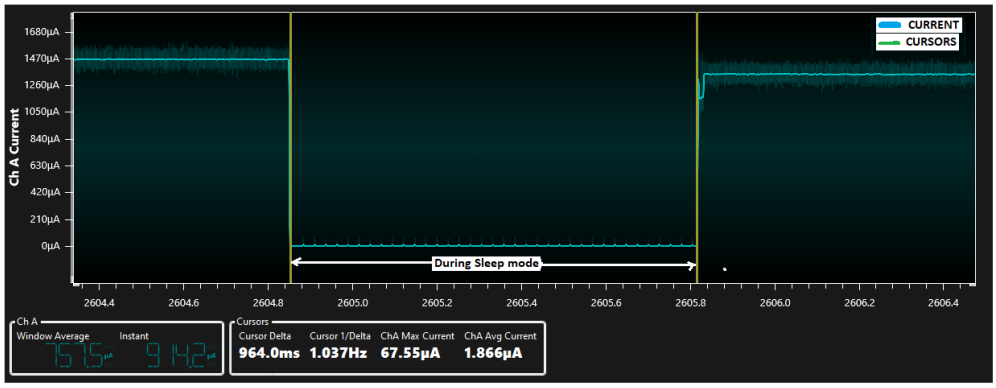
- Case 2
  - Main clock source (GCLK0) – DFLL (pre-scaled to 8 MHZ with XOSC32K as reference)
  - RTC clock source – ULP32K

Figure 3-71. Standby Sleep Mode Operation with ULP32K Source to RTC and DFLL Source to Main Clock



- Case 3
  - Main clock source – OSC16M
  - RTC clock source – ULP32K

Figure 3-72. Standby Sleep mode Operation with ULP32K Source to RTC and OSC16M Source to Main Clock



The following table provides the consumption values during the Standby Sleep modes under various clock sources captured in the above plots.

Table 3-25. Consumption Values During the Standby Sleep Modes Under Various Cock Sources

Attribute	Measured Value		
	Case 1	Case 2	Case 3
Total duration (ms)	984.7	958.1	964.0
Average current (mA)	0.002076	0.001848	0.001866
Peak current (mA)	0.06495	0.07164	0.06755
Total charge (mA×ms)	2.045	1.78	1.79

3.1.6 Persistent Data Server (PDS) Operation

This section captures the power profile of the WLR089 device measured while performing Persistent Data Server (PDS) operations and highlights the profile on the following PDS operations.

- `PDS_Store` – Stores a specified and individual MLS attribute into Non-Volatile Memory (NVM)

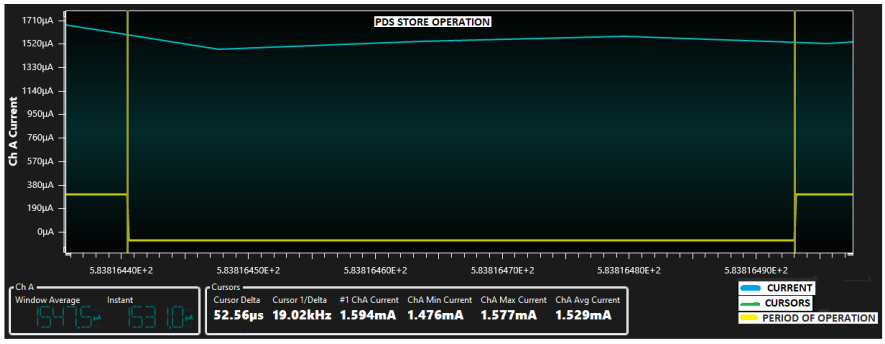
- `PDS_StoreAll` – Stores all the attributes that are registered into PDS at the time of initialization
- `PDS_RestoreAll` – Restores all the stored attributes of MLS and helps to resume the operation from the last stored state
- `PDS_DeleteAll` – Erases all the stored attribute data of MLS

The PDS is a feature implemented to store the attributes of MLS into NVM and restore and resume the operation after a Reset condition.

The following figures illustrate the profile captured during the `PDS_Store`, `PDS_StoreAll`, `PDS_RestoreAll` and `PDS_DeleteAll` operations and highlights on the power consumption values during these operations.

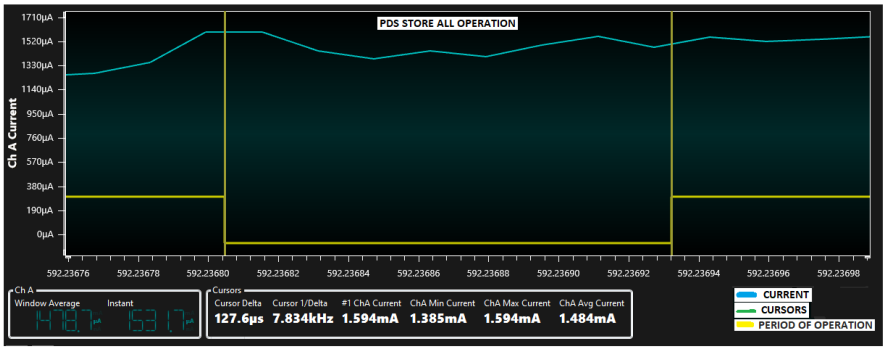
The following figure illustrates the PDS store operation.

Figure 3-73. PDS Store Operation



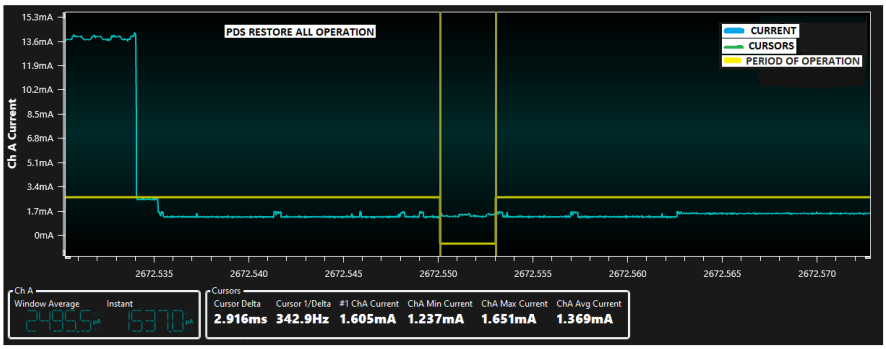
The following figure illustrates the PDS store all operation.

Figure 3-74. PDS Store All Operation



The following figure illustrates the PDS restore all operation.

Figure 3-75. PDS Restore All Operation



The following figure illustrates the PDS delete all operation.

Figure 3-76. PDS Delete All Operation

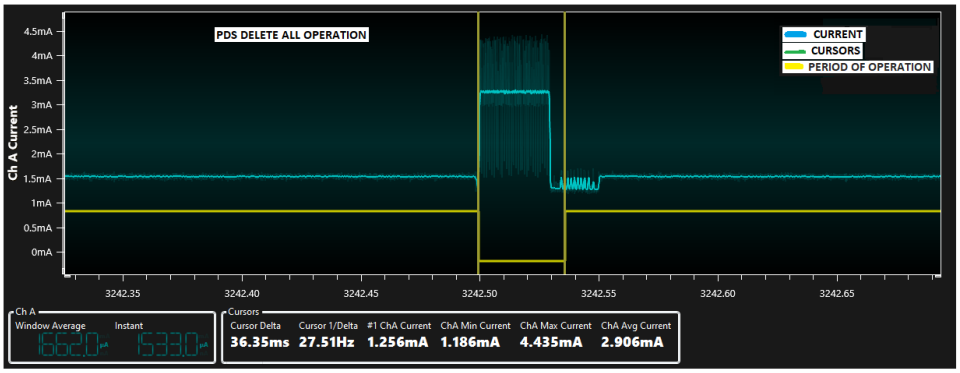


Table 3-26. PDS Store Operation

Attribute	Measured Value	Units
Total duration	0.053	ms
Average current	1.529	mA
Peak current	1.577	mA
Total charge	0.0804	mA×ms

Table 3-27. PDS Store All Operation

Attribute	Measured Value	Units
Total duration	0.1276	ms
Average current	1.484	mA
Peak current	1.594	mA
Total charge	0.190	mA×ms

Table 3-28. PDS Restore All Operation

Attribute	Measured Value	Units
Total duration	2.916	ms
Average current	1.369	mA
Peak current	1.651	mA
Total charge	3.993	mA×ms

Table 3-29. PDS Delete All Operation

Attribute	Measured Value	Units
Total duration	36.35	ms
Average current	2.906	mA

.....continued		
Attribute	Measured Value	**Units**
Peak current	4.435	mA
Total charge	105.64	mA×ms

3.2 LoRa Modulation Connection Type

This section captures the power profile of the WLR089 device under LoRa connection type communication and highlights the profile on the following scenarios:

- Data Transmission
- Data Reception

Note: Use the radio level commands to set the attributes to profile the scenarios, available in the WLR089U0 radio utility firmware (*Radio Utility>Radio Utility WLR089 Ver 2.00*).

The following table provides the radio attribute settings considered to profile the data transmission and data reception scenarios under the LoRa modulation connection type.

Table 3-30. Radio Attribute Settings to Profile the Data Transmission and Data Reception

Attribute	Setting Value	Command Used
Modulation	LoRa (default)	`radio set mod lora`
Frequency	868100000 (default)	`radio set freq 868100000`
Spreading factor	SF7 (default)	`radio set sf sf7`
Preamble length	8 (default)	`radio set prlen 8`
Coding rate	4/5 (default)	`radio set cr 4/5`
afcbw	41.7 (default)	`radio set afcbw 41.7`
CRC	on (default)	`radio set crc on`
Rxbw	25 (default)	`radio set rxbw 25`
IQI	off (default)	`radio set iqi off`
PA BOOST (pa)	off (default)	`radio set pa off`
Sync	34 (default)	`radio set sync 34`
Bandwidth (bw)	125 kHz (data transmission scenario and data reception scenario 1) default	`radio set bw 125`
	250 kHz (data reception scenario 2)	`radio set bw 250`
TX power (pwr)	1 (data reception scenario 1 and data reception scenario 2) default	`radio set pwr 1`
	15 (data transmission scenario)	`radio set pwr 15`

Note: When PA Boost is turned off, the actual output power for the TX power setting considered for transmission and reception scenarios are as follows.

Table 3-31. TX Power Setting for Transmission and Reception Scenarios

TX Power Setting	Output Power (dBm)
1	-0.6
15	14.1

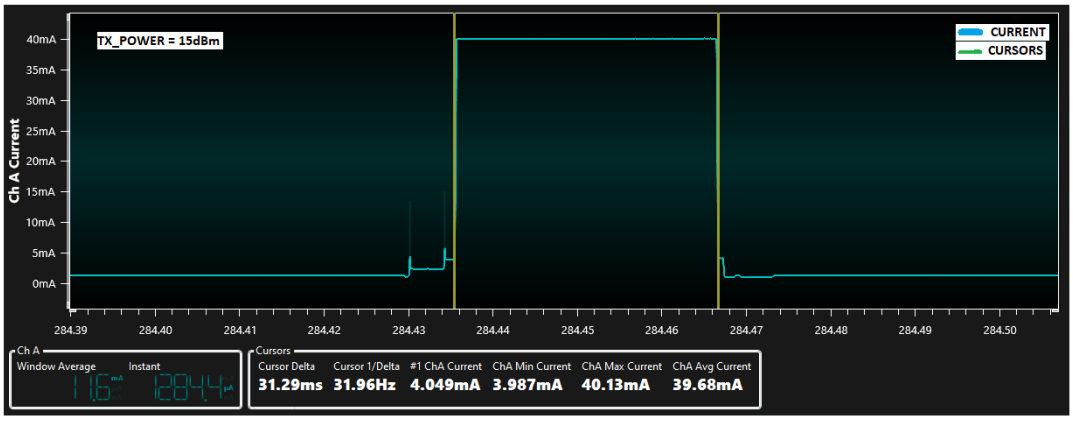
For more details on the actual output power to the TX power setting value, refer to the *SAM R34/R35 and WLR089U0 Radio Utility Commands Reference Manual* (DS70005376).

Note: The *SAM R34/R35 and WLR089U0 Radio Utility Commands Reference Manual* (DS70005376) is available inside the WLR089U0 (SAMR34 Module) Reference Design Package.

3.2.1 Data Transmission

This section captures the power profile of the WLR089 device measured during the data transmission with TX power set to 15 dBm. The following plot illustrates the power consumption values during data transmission at the TX power setting = 15 dBm.

Figure 3-77. Transmission of Data at TX Power Setting = 15 dBm



The following table provides the power consumption values obtained while performing the data transmission scenario.

Table 3-32. Power Consumption Values Obtained while Performing the Data Transmission Scenario

Attribute	Measured Values
Total duration (ms)	31.29
Average current (mA)	39.68
Peak current (mA)	40.13
Total charge (mA×ms)	1241.60

3.2.2 Data Reception

This section captures the power profile of the WLR089 device measured during the data reception and highlights the profile on the following scenarios.

- Continuous Reception mode at bandwidth 125 kHz
- Continuous Reception mode at bandwidth 250 kHz

Figure 3-78. Continuous Reception Mode at Bandwidth 125 kHz

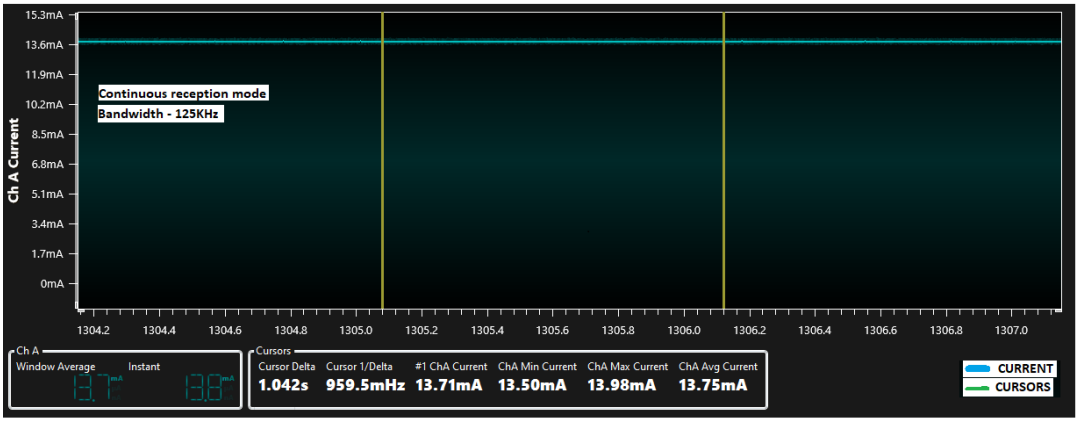
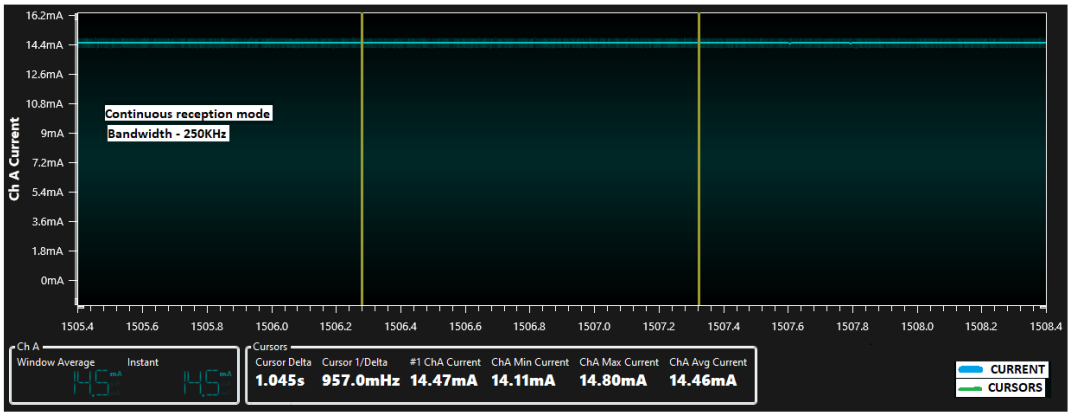


Figure 3-79. Continuous Reception Mode at Bandwidth 250 kHz



The following table provides the power consumption values obtained in each of the data reception scenarios.

Table 3-33. Power Consumption Values in Each of the Data Reception Scenarios

Attribute	Continuous Reception Window		Units
	At Bandwidth – 125 kHz	At Bandwidth – 250 kHz	
Total duration	1042	1045	ms
Average current	13.75	14.46	mA
Peak current	13.98	14.80	mA
Total charge	14327.5	15110.7	mA×ms

4. Optimizing Power Consumption

This chapter details the optimization of power consumption in the WLR089 device. Also, this provides the optimization tips, estimation and best settings to use on the WLR089 device for maximum battery expected lifetime.

Note: The following points are only suggestions from Microchip for better optimization of power consumption in the WLR089 device.

- Maintain the data rate to maximum for transmitting the uplink packet (`MAC_DEF_TX_CURRENT_DATARATE_EU`) because the average current consumption in transmission scenarios are approximately same at every data rate. This has a direct impact in reducing the power consumption and increasing the expected battery lifetime.
- Set the device to Sleep mode whenever the device is not transmitting and remains in IDLE mode. This has a direct impact on the overall power consumption and improves the battery lifetime. The trade-off on setting the device to Sleep mode during the IDLE condition is only possible in the Class A device and not in the Class C device.
- When transmitting the non-critical application data, set the device to transmit the unconfirmed packet type, which drops off the retransmission cycle. This has a direct impact on the overall power consumption and improves the battery lifetime. The trade-off on transmitting unconfirmed packets leads to data loss in case of heavy gateway traffic or non-reachable gateway conditions.
- The data rate to receive the downlink in RX1 follows the TX data rate. The maximum value of the TX data rate (`MAC_DEF_TX_CURRENT_DATARATE_EU`) reduces the uplink transmit time followed by the lesser reception time in the RX1 reception window slot in the WLR089 device.
- Enable the Adaptive Data Rate (ADR) feature on the WLR089 device through which the network server controls the data rate of the WLR089 device. By enabling ADR, the network is optimized to use the fastest data rate possible without loss of connection with the network server.

5. Consolidated Measurement Values

The following table provides the summary of the WLR089 device current and time measurements.

Table 5-1. LoRaWAN Connection Type

Scenario			Time Duration (ms)	Average Current (mA)
Initialization				
Event A – Driver initialization event			43.94	4.394
Event B – Stack initialization and SW timer creation			0.0621	4.617
Event C – Application and LoRaWAN initialization			42.54	9.176
Join Procedure				
Join request transmission		DR0	1484	34.81
		DR5	68.70	32.02
Join accept in RX1 receive window		DR0	1878	13.84
		DR5	134.2	13.41
Join accept in RX2 receive window		DR0	1862	13.98
		DR5	1862	13.3
Join accept delay 1		DR0	4973	1.487
		DR5	4973	1.548
Join accept delay 2		DR0	717.9	1.440
		DR5	949	1.490
Uplink Data Transmission				
Uplink data transmission (default payload)		DR0	1493	34.94
		DR5	75.34	29.30
Uplink data transmission (max payload)		DR0	2653	35.32
		DR5	402.7	33.97
Retransmission Procedure				
For one retransmission cycle		DR0	6645	9.891
		DR5	4530	2.841
Downlink Data Reception				
Downlink data reception in RX1	Default payload size	DR0	1545	13.89
		DR5	126.3	13.5
	Max payload size	DR0	2537	13.80
		DR5	457.6	13.70
Downlink data reception in RX2	Default payload size	DR0	1546	13.90
	Max payload size	DR0	2529	13.80
Standby Sleep Mode				
Case 1: Main clock source – DFLL and RTC source – XOSC32K			984.7	0.002076

.....continued		
Scenario	**Time Duration (ms)**	**Average Current (mA)**
Initialization		
Case 2: Main clock source – DFLL and RTC source – ULP32K	958.1	0.001848
Case 3: Main clock source – OSC16M and RTC source – ULP32K	964.0	0.001866
PDS Operations		
PDS store operation	0.053	1.529
PDS store all operation	0.1276	1.484
PDS restore all operation	2.916	1.369
PDS delete all operation	36.35	2.906

Table 5-2. LoRa Modulation Connection Type

Scenario		Time duration (ms)	Average Current (mA)
Data transmission at TX power – 15 dBm		31.29	39.68
Continuous Reception mode	Bandwidth – 125 kHz	1042	13.75
	Bandwidth – 250 kHz	1045	14.46

6. Document Revision History

Revision	Date	Section	Description
A	11/2021	Document	Initial Revision

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