AN12459

Kinetis KW38 Power Consumption Analysis

Rev. 0 — April 2020

Application Note

Contents

1 Introduction

This document provides information about:

- Power consumption of Kinetis KW39/38/37 wireless MCU.
- How the hardware is designed and optimized for low-power operation.
- How the software shall be configured to achieve the best low-power profile.

The role of this document is to offer an overview and guidance on how to achieve the best low-power profile while still keeping the high performance of the system. The setup and the procedures to measure the current consumption of the KW38 chip is also described in this document.

The power consumption of wireless devices is a critical requirement for the fast-coming Internet of Things (IoT) world. As a result, the hardware has been gradually improved and optimized from the power consumption perspective and new communication standards have been developed. Bluetooth Smart (also known as Bluetooth Low-Energy or Bluetooth LE) is part of these new standards that have been developed for long-term battery operation, typically years.

Kinetis KW38 is a radio wireless MCU that supports Bluetooth LE v5.0 protocol.

The prerequisites for understanding this document are that the reader has a good knowledge about Bluetooth Smart protocol, as well as basic knowledge about Arm®MCU architecture and radio communication basics.

2 Bluetooth smart power metrics

- FRDM-KW38 board is used to perform the several current measurements.
- Low power reference design application software is used (similar to the Temperature sensor in low power mode) to set the device in different modes for the current measurements. For this preliminary document, the analysis is only performed on Advertising and connect events.
- MCU state could be run in LLS2 or Stop mode and Link Layer could be in RUN or Deep Sleep Mode 2 (stop) or Ilde. The time spent in deep sleep is the longest time compared to all other operation modes.
- The MCU is woken up and performs system initialization and some pre-processing.
- The transceiver is woken up and ready to operate. The MCU may enter STOP mode if the software allows it.
- The transceiver is performing one or more RX/TX sequences.
- The MCU is processing the received or transmitted packets.
- The transceiver is put back in sleep mode.
- The MCU enters low-power (deep sleep).

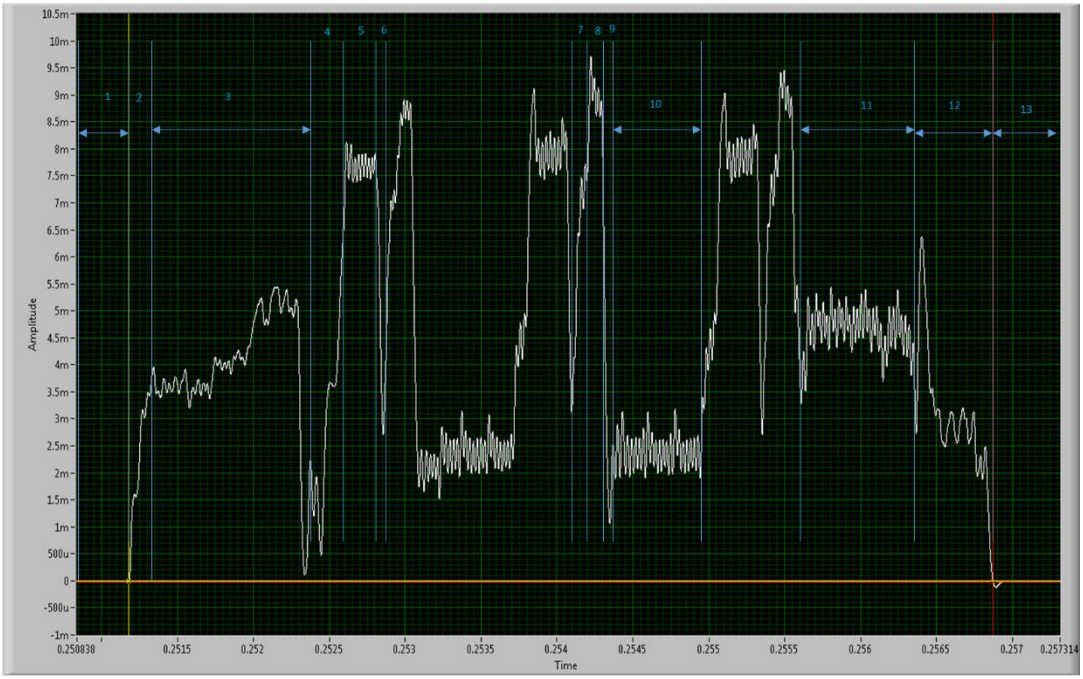

Figure 1. Typical operation cycle of a wireless low-power end device

Figure 1 shows how current consumption varies over time for each operation cycle of the device.

At power-up, the system performs the so-called power-on reset and then the system initialization. After the initialization is completed, the system enters the low-power mode. There are several low-power modes available for both MCU and the radio, but usually the software defines only the most suitable combinations of MCU and XCVR low power modes (e.g., LLS2 for MCU and DSM for LL).

Table 1 describes all the timings in Figure 1.

Table 1. Timings of a typical low-power device

No.	Event
1	SoC in Sleep mode
2	SoC awakes from SLEEP mode
3	MCU run: Pre-processing
4	XCVR TX warmup
5	XCVR Active TX
6	XCVR TX warm down
7	XCVR RX warmup
8	XCVR Active RX
9	XCVR Rx warm down
10	MCU STOP: RX to TX
11	MCU RUN: Post-processing
12	SoC goes back to SLEEP mode
13	SoC in SLEEP mode

The time the transceiver switches from RX to TX is called RX to TX turnaround time and it's an important parameter of the transceiver.

NOTE

When the radio is operational, the MCU may also perform various tasks, like serving interrupts or controlling various peripherals.

The best metric to be applied is current consumption over time, taking into consideration the average current of all the entities that are implied.

2.1 Bluetooth Smart (LE)

Bluetooth Smart (Bluetooth LE) is a promising candidates for low power communication and a good candidate for the IoT deployments. Bluetooth LE is operating in 2.4 GHz ISM band and uses GFSK modulation. The bandwidth bit period product is 0.5 and the modulation index is 0.5 (between 0.45 and 0.55)

Bluetooth LE uses 40 × 1 MHz channels, each separated by 2 MHz, or 2 MHz wide channels or Long Range (S=2/S=8), three channels for advertising packets and 37 channels for data exchange. The channels are numbered from 0 to 39.

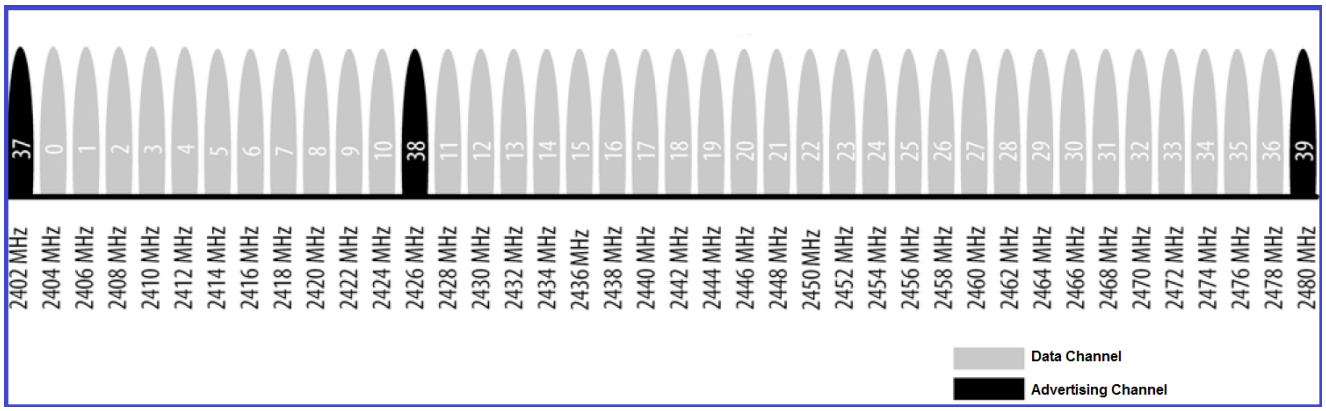

Figure 2. Bluetooth LE radio channels

The low energy is achieved by having a low duty cycle of transmission and/or reception of data and by using short advertising and data packets. Asynchronous and connection-less link layer ensures low latency and fast transactions.

At the GAP layer level, the roles that Bluetooth LE devices may have are GAP Central and GAP Peripheral, as shown in Figure 3.

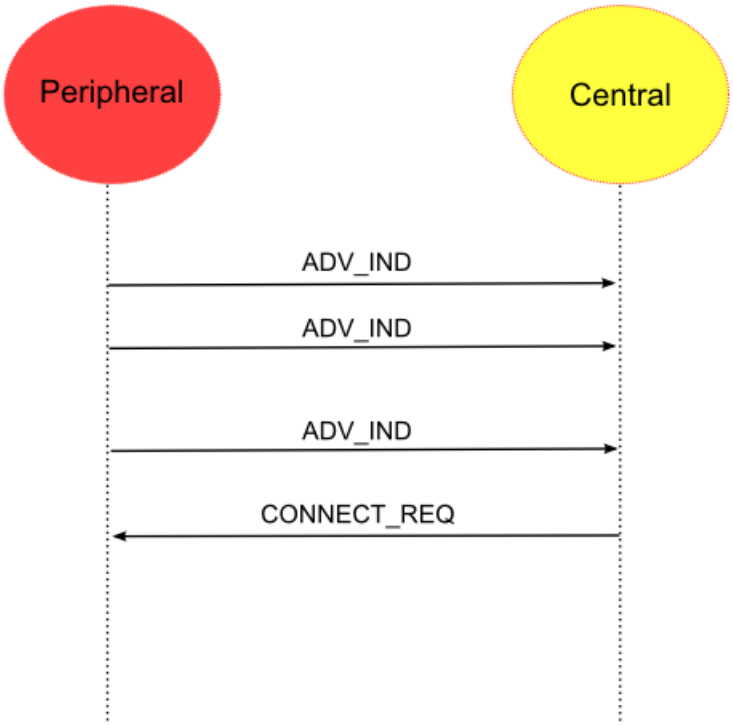

Figure 3. GAP peripheral and central

The Peripheral starts sending advertising data to Central. If Central is willing to establish a connection with the Peripheral, it will send back to advertiser a connection request. After the connection is established, data exchange may start.

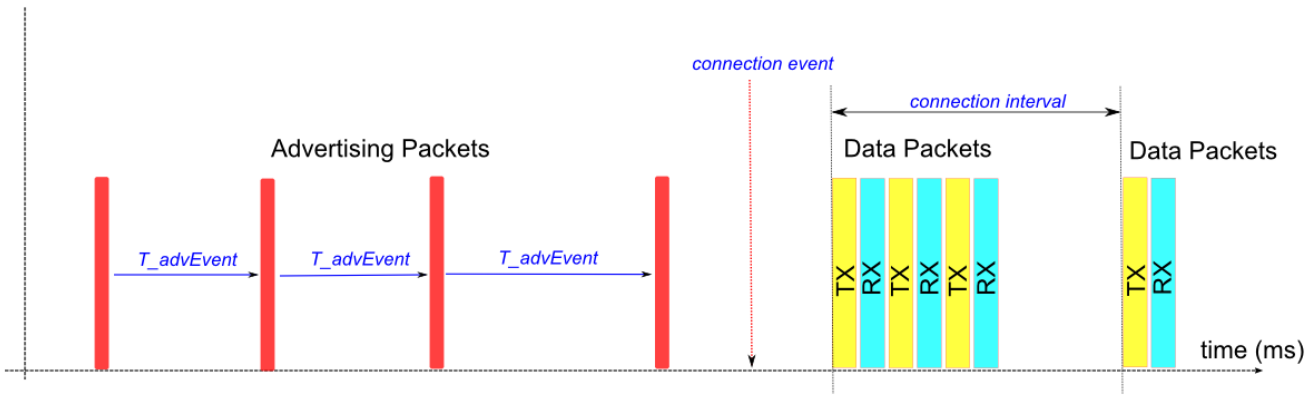

Figure 4. Bluetooth LE advertising and connection events

According to Bluetooth LE specifications, there are four types of advertising packets:

- `ADV_IND`: Connectable Undirected Advertising
- `ADV_DIRECT_IND`: Connectable Directed Advertising
- `ADV_NONCONN_IND`: Non-connectable Undirected Advertising
- `ADV_SCAN_IND`: Scannable Undirected Adverising (formerly known as `ADV_DISCOVER_IND`)

All the four types, except the non-connectable advertising, are using a TX followed by an RX sequence, as shown in Figure 5. The reason is after sending the advertising packet, the device is waiting for a Scan Request or Connect Request from a peer device, if any.

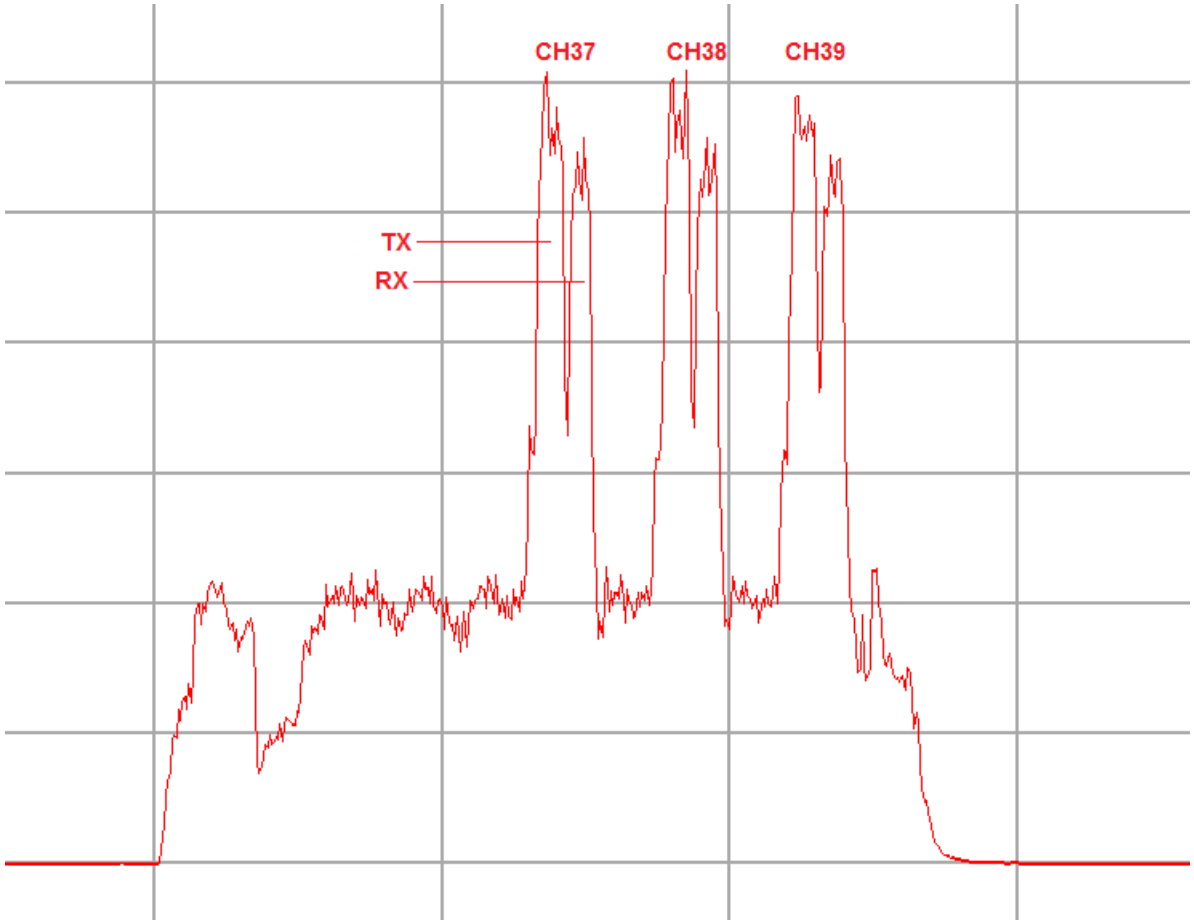

Figure 5. Current consumption vs. time in ADV phase for a Bluetooth LE peripheral device

Figure 6 shows the current variation in time when the system is in a typical advertising event. All the three advertising channels are used. For each channel, a TX operation followed by an RX operation is performed.

Another noteworthy feature of Bluetooth LE is that the advertising events have a random temporal component, according to Bluetooth LE specifications.

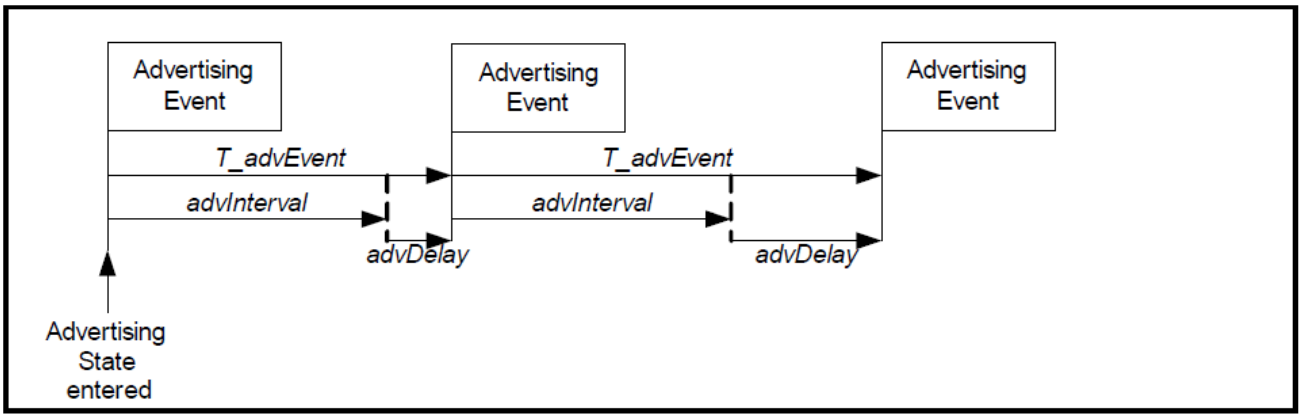

Figure 6. Advertising events occurring at unequal intervals

In *T_advEvent = advInterval + advDelay*,

- *advInterval* is an integer multiple of 0.625 ms, with a range from 20 ms to 10.24 s.
- *advDelay* is a pseudo-random value generated by the Link Layer, with a range from 0 to 10 ms.
- Thus, a minimum advertising event interval is 20 ms and a maximum interval is 10.25 s.

Bluetooth LE is designed and implemented for ultra-low power battery operated devices, but the actual power consumption of a real Bluetooth LE device strongly depends on:

- Bluetooth LE application profile
- Application duty cycle
- TX power
- Software management of low-power modes
- Board design and layout

3 Kinetis MKW38 low-power features

The KW39/38/37 (called KW38 throughout this document) is an ultra-low power, highly integrated single-chip device that enables Bluetooth Low Energy (Bluetooth LE - 1 Msps, 2 Msps, 500 Ksps (LR S=2), 125 Ksps (LR S=8)) ver 5.0 and Generic FSK (at 250, 500, 1000 and 2000 kbps) RF connectivity for portable, extremely low-power embedded systems (Z version) and automotive (A version). KW38 supports up to eight simultaneous Bluetooth LE connections as either a master, a slave or any combination. The KW38 is designed for applications that center on bridging the embedded world to smartphones to enhance the human interface experience, share embedded data with the cloud, or enable wireless firmware updates.

Leading the automotive applications is the Digital Key where the smartphone not only can be used as an alternative to the key FOB for unlocking and personalizing the driving experience but also to provide select and authorized access when a key is not needed like you might see in car sharing.

KW38 integrates a Bluetooth LE 5.0 compliant radio transceiver operating in the 2.4 GHz ISM band supporting a range of Generic FSK, an ARM Cortex-M0+ CPU, up to 512 KB Flash and up to 64 KB SRAM, Bluetooth LE Link Layer hardware and peripherals optimized to meet the requirements of the target applications. The RF section of KW38 is optimized to require very few external components, achieving the smallest RF footprint possible on a printed circuit board. NXP provides a certified Bluetooth LE Stack to support KW38.

Extremely long battery life is achieved though efficiency of code execution in the Cortex-M0+ CPU core and the multiple low power operating modes of the KW38. Additionally, an integrated DC-DC converter enables a wide operating range from 2.1 V to 3.6 V in buck mode and 1.76 V to 3.6 V in bypass mode. The DC-DC in Buck mode allows KW38 to operate from a single coin

cell battery with a significant reduction of peak RX and TX current consumption. The DC-DC in buck mode allows a single alkaline battery to be used throughout its entire useful voltage range of 2.1 V to 3.6 V.

3.1 MKW38 Hardware support for low-power operation

Kinetis MKW38 SoC was designed and built with hardware features that allows the chip to operate in various low power modes. Noteworthy features are:

- Multiple MCU power modes including low leakage with memory retention modes
- Bluetooth LE Link Layer sleep mode support
- Peripheral modules clock gating
- Several peripheral doze mode
- DC to DC converter
- Transceiver Sequence Manager (TSM) that assures that transceiver analog and digital blocks are not consuming power when no RX/TX sequence is in progress
- Dedicated Power Management Controller (PMC)
- Low-power peripherals (LPTMR, LPUART) than can be configured as wake-up sources to exit a particular low-power state

The software is responsible for configuring all the hardware in order to achieve the best power scheme required by the applications. As is presented in the following sections, the chip low power modes are combinations of MCU and LL/Packet Processor sleep modes. The clock gating of peripherals as well as GPIO states before entering low-power are in charge of application developer. The connectivity software package provides callbacks that are called before entering low-power mode and after exiting low-power mode. The system shall enter low-power when the system is in idle and all the software layers agree on that. The system shall exit from low-power each time a synchronous or asynchronous event is happening and requires to be processed.

3.1.1 KW38 MCU power modes

The PMC module provides a variety of power options to allow the user to optimize and personalize the power consumption with respect to the level of functionality that the application requests. Based on Arm® architecture power modes, there are two power modes defined: sleep mode and deep sleep mode. From the Connectivity Software perspective, only deep sleep modes are of interest. These modes are:

- STOP
- LLS2
- VLLS0
- VLLS1
- VLLS2
- PSWITCH

The CPU recovery method is by Wakeup Interrupt for Stop for Low-Leakage Stop modes and by Wakeup Reset for Very Low-Leakage Stop modes.

For details about the power modes, refer to *KW38 Reference Manual*.

3.1.2 KW38 Link Layer power modes

The Bluetooth Link Layer (BTLL) has the following power modes available:

- IDLE
- RUN
- Deep Sleep Mode (DSM)

For Bluetooth LE, the Connectivity Software Package implements six low-power modes for the KW38 SoC, as described in Table 2.

Table 2. KW38 Low Power Modes for Bluetooth LE applications

Power mode	MCU state	BLE LL state	Wake up source
PWR_APP_STATE_NO_ACTIVITY	VLLS0/1	IDLE	LLWU enabled GPIO, or DCDC PSwitch
PWR_APP_STATE_ADV	Least consuming mode, LLS2 and VLLS2 in PRCx release	DSM	GPIO, BLE LL or LPTMR
WR_APP_STATE_CONN	Least consuming mode, LLS2 and VLLS2 in the PRCx release	DSM	GPIO, BLE LL or LPTMR

NOTE

Bluetooth LE is using a common radio transceiver digital block. The TSM is used to sequence ON/OFF the analog regulators and circuits needed for RX/TX operations so that these circuits only consume power during RX/TX.

3.1.3 Deep Sleep Mode summary

Table 3. DSM summary

DSM (as defined in connectivity framework)	MCU state	BTLL state	BTE_LL reference clock source	Typical use case
DSM1	LLS2	DSM2 (stop)	32 KHz oscillator	LLS2 between RF activities
DSM2	LLS2	IDLE	NA	LLS2 when no RF activity
DSM3	LLS2	IDLE	NA	LLS2 when no RF activity
DSM4	VLLS0/1	IDLE	NA	VLLS0 when DCDC bypass VLLS1 when DCDC buck
DSM5	VLLS2	IDLE	NA	VLLS2 when no RF activity
DSM6	STOP	NA	NA	Only MCU in STOP
DSM7	LLS2	Genfsk DSM	NA	Genfsk specfic
DSM8	VLLS2	DSM	32 KHz oscillator	VLLS2 between RF activities
DSM9	VLLS2/3	Idle	NA	Advertising interval larger than 10.24 seconds
RAM OFF (during Advertising)	VLLS1	Idle	NA	Ultra fast wake-up
Pswitch	OFF	OFF	NA	Leakage current only

For more details, refer to *connectivity framework KW38*.

3.1.4 KW38 XCVR power modes

Being a SoC, the KW38 transceiver is tightly coupled with the MCU. Therefore, the transceiver analog regulators will be powered off whenever the MCU enters a low-power mode. Depending on the low-power mode, transceiver digital logic is power-gated or has its state retained.

3.1.5 KW38 DC-to-DC converter

The DCDC module is a Switched Mode Power Supply (SMPS) DC-to-DC converter that has two operational modes:

- **Buck**: Vin = 2.1 V to 3.6 V
- **Bypass**: Vin=1.71 V to 3.6 V

The module is configurable through internal registers to operate in continuous or pulsed mode and provides two voltage outputs in Buck mode: `VDD_1P8OUT` = 1.8 V and `VDD_1P5OUT` = 1.5 V, with MCU in RUN mode, peripherals disabled.

The converter may be started by means of the PSWITCH pin or can be set to auto-start mode.

For detais about DCDC converter, refer to *MKW4xZ/3xA/2xZ DCDC Power Management* (document AN5025).

3.1.6 GPIO, analog pins and clock gating

Clock gating mechanism was implemented to reduce power dissipation. For example, whenever a peripheral is not used it can be turned off using SCGCx registers in the SIM module. Clock gating applies to each peripheral, including the GPIO module. Pruning the clock to a peripheral assures that the peripheral internal circuitry does not have switch states and therefore no power consumption, except the leakage currents.

After reset, the clock gating bits are cleared and this implies that before using any peripheral the corresponding clock gating bit must be set. Otherwise any access to peripheral registers will cause a hardware fault. To turn a peripheral clock off (gate OFF), the peripheral must be turned off prior to clock.

The user application must control and set the state of the GPIO ports before the device goes to sleep as well as after the device is exiting the low-power state. The Connectivity Software provides callback functions that are called before the device enters a low power state and after it wakes up.

Related to the analog pins, the device has several analog blocks that have selectable reference voltages. The main blocks are the 16-bit SAR ADC and CMP. The board design shall consider the chip analog pins and use them appropriately.

The external analog inputs are typically shared with digital I/O. To improve the performance in the presence of noise or when the source impedance is high, it is recommended to use capacitors on these inputs. The capacitors shall be placed as close as possible to chip analog pins.

For more details, refer to NXP reference designs for KW39/8/7 and the chip reference manual.

3.2 Software configuration for low-power operation

3.2.1 Bluetooth smart application configuration

The connectivity software package offers a variety of Bluetooth LE demo projects. The Low Power (LP) project is used to perform the current profile measurements. This project is located at the following relative path:

```
<installation_path><SDK revision>\boards\frdmkw38\reference_design\bluetooth\lp\bm\iar
```

The LP in the reference design application folder (based on temperature sensor in low power mode) included in the KW38 PRC2.0 is used to set the device for advertising and connect current measurements. It requires some changes to allow the application to enter and leave Low Power mode. Baremetal or Freertos versions of the application can be used.

The relative project path is:

```
<installation_path> mcu-sdk\boards\frdmkw38\reference_design\bluetooth\lp\bm\iar\lp.eww
```

NOTE

More information are available in the KW3x Low Power connectivity design user's guide to set the different Low Power mode. This document is located in the SDK set of documents.

In Power measurement and timing analysis, different built are described to set the FRDM-KW38 in different states:

Low power application:

- Advertising and connection events: (default software setting @+5dBm)
  - MCU Stop, Flash Doze, RF output power = +5 dBm (default)
- DSM

The FRDM-KW38 board is used to perform the current consumption. It is programmed with the LP binary (advertising and connect events).

Two different ways to flash the FRDM-KW38:

- Drag and drop the binary using OpenSDA.
- Using J-Link for Arm as programming/debug tool.

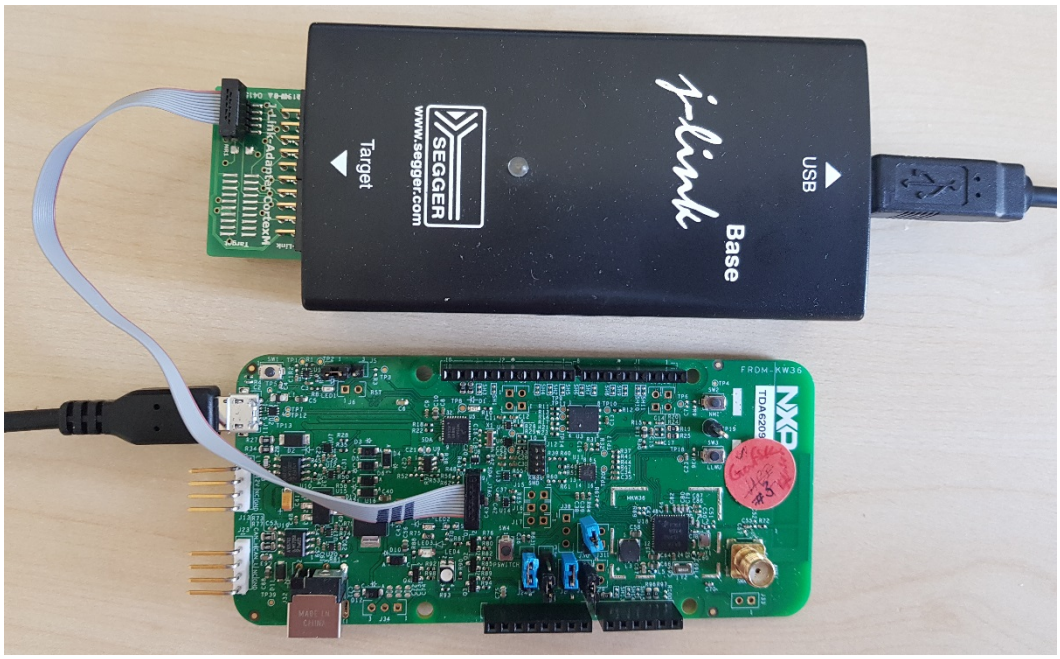

Figure 7. J-Link for Arm programmer/debugger

3.2.2 Preparing the software

Refer to *Low Power Connectivity Design User's Guide* to set all the different modes measured in this report. This document is available in the SDK document package which could be downloaded via the MCUXpresso portail.

Table 4 describes DSM covered in PRC2.1.

Table 4. Deep sleep modes available

Deep sleep mode (as defined in connectivity framework)	MCU state	BTLL state	BTE_LL reference clock source	Typical use case
DSM1	LLS3	DSM2 (stop)	32 KHz oscillator	LLS3 between RF activities
DSM2	LLS2	IDLE	NA	LLS2 when no RF activity
DSM3	LLS3	IDLE	NA	LLS3 when no RF activity
DSM4	VLLS0/1	IDLE	NA	VLLS0 when DCDC bypass VLLS1 when DCDC buck
DSM5	VLLS2	IDLE	NA	VLLS2 when no RF activity
DSM6	STOP	NA	NA	Only MCU in STOP
DSM7	LLS3	Genfsk DSM	NA	Genfsk specfic
DSM8	VLLS2	DSM	32 KHz oscillator	VLLS2 between RF activities
DSM9	VLLS2/3	IDLE	NA	Advertising interval larger than 10.24 seconds
RAM OFF (during Advertising)	VLLS1	IDLE	NA	Ultra fast wake-up from VLLS1
RAM OFF (during Advertising)	VLLS1	IDLE	NA	Ultra fast wake-up from Pswitch
Pswitch	OFF	OFF	NA	Leakage current only

4 Power measurements and timing analysis

4.1 Setup test environment and DUT

This section describes how to set up the test environment, what hardware tools and boards are required, and all the necessary operations that are needed to be done before performing the measurements.

All the measurements are performed using:

- A Power Analyzer, CX3322A
- A current probe, CX1101A from Keysight, formerly Agilent Technology.

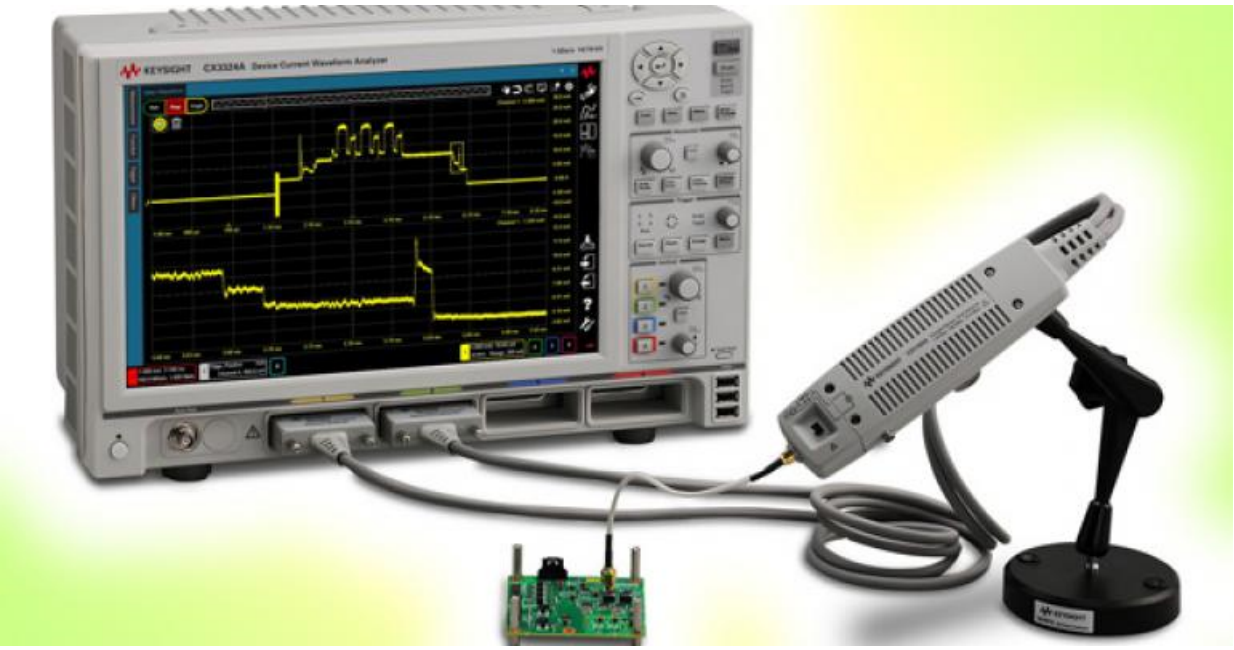

Figure 8. Keysight CX3322A power analyzer and CX1101A current probe

External power source was used to supply the FRDM-KW38 board while the Power Analyser module 1 was used as Ampere meter. The power supply was set to provide 3.6V DC. Two pairs of high quality cables are required, one for supplying the board and one for current measurement. The connections between Power Analyzer and the FRDM board must be perfect to avoid unwanted spikes or power loses or resets of the board.

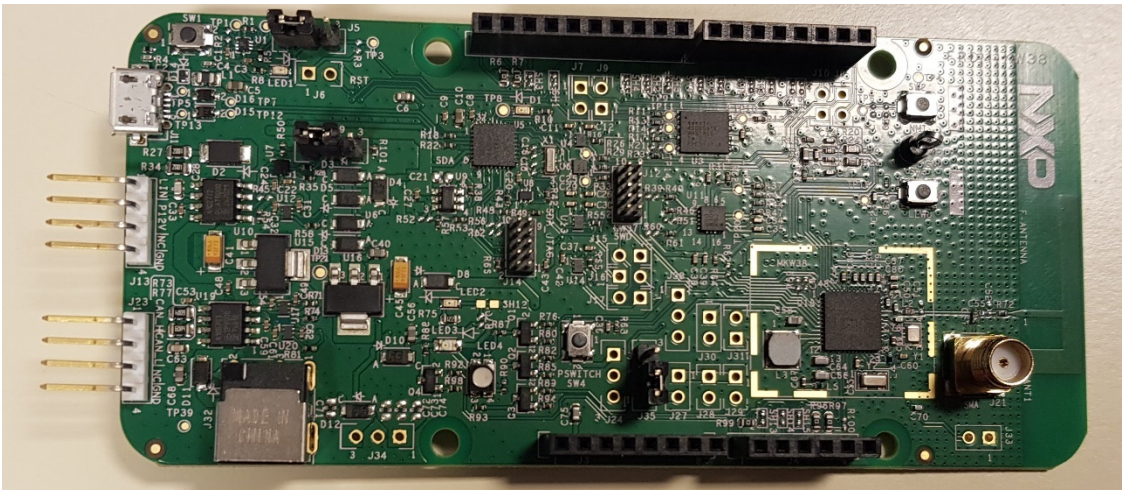

Figure 9. FRDM-KW38 board

The current measurements are performed in two setup modes using the FRDM-KW38 board: Bypass mode and Buck mode. A minimum of jumpers is soldered into the PCB to avoid radio disturbance.

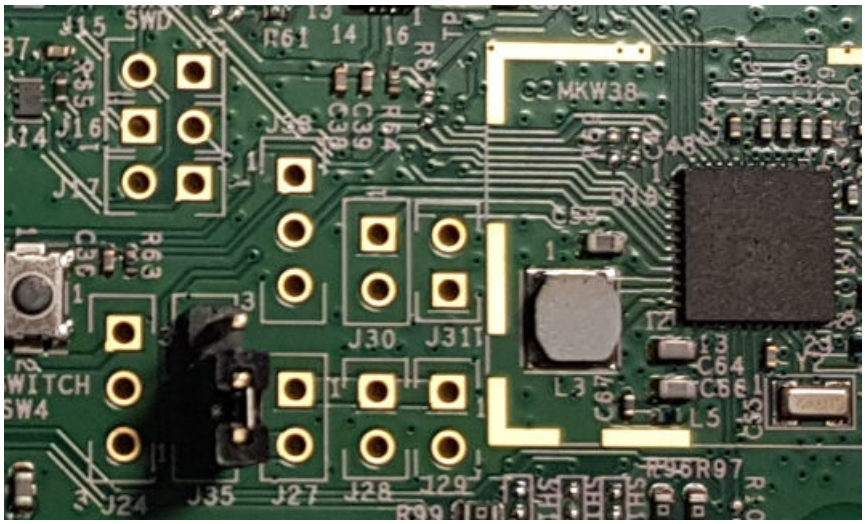

Figure 10. FRDM-KW38 board, default jumper setup – Top view

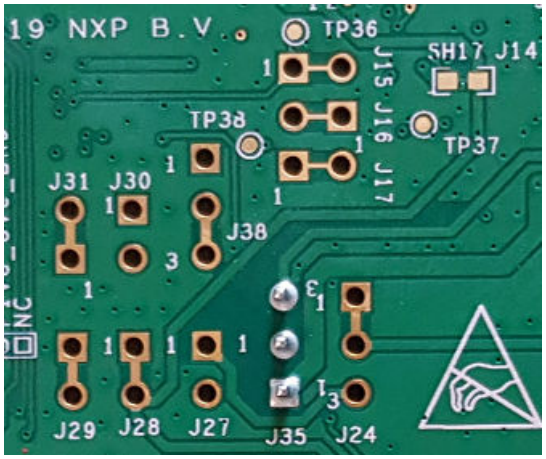

Figure 11. FRDM-KW38 board, default copper shunt setup – Bottom view

4.1.1 Preparing the hardware

The FRDM-KW38 is configured by default in Buck mode with several hard-wired connections and the proper space to add jumpers in case of switching to bypass Mode is needed.

To make the board capable of entering low power modes and measure the lowest possible values of the SOC and XCVR, perform some changes on the board as below:

1. Locate four copper shunts on the back side of the board and cut the trace on J24, J28, J29 and J38.
   - **J24**: This will isolate `P_LED` line, removing the power to the LED's.
   - **J28**: This will isolate `P1V8_3V3_BRD` line, removing the power of the peripherals.
     - M20 device will be not supplied anymore. It is used for flashing the KW38 through the USB connector J11.
   - **J29**: This will isolate `VDD_MCU` from `DCDC_in`.
   - **J38**: This will disconnect the default buck mode. Choice of Bypass or Buck mode could be set depending of the jumper J38 position.

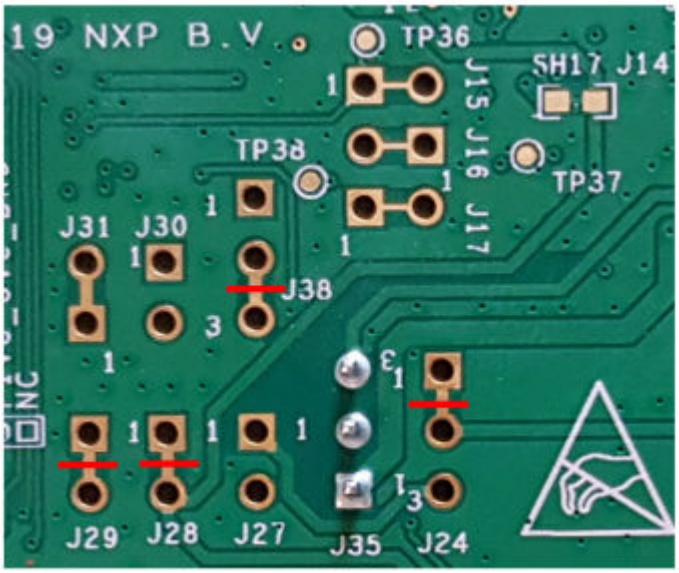

Figure 12. Cut traces to the bottom side of the FRDM-KW38 board, rev. B

2. Populate the head connectors to the following jumpers: J24, J27, J28, J29, J30 and J38.

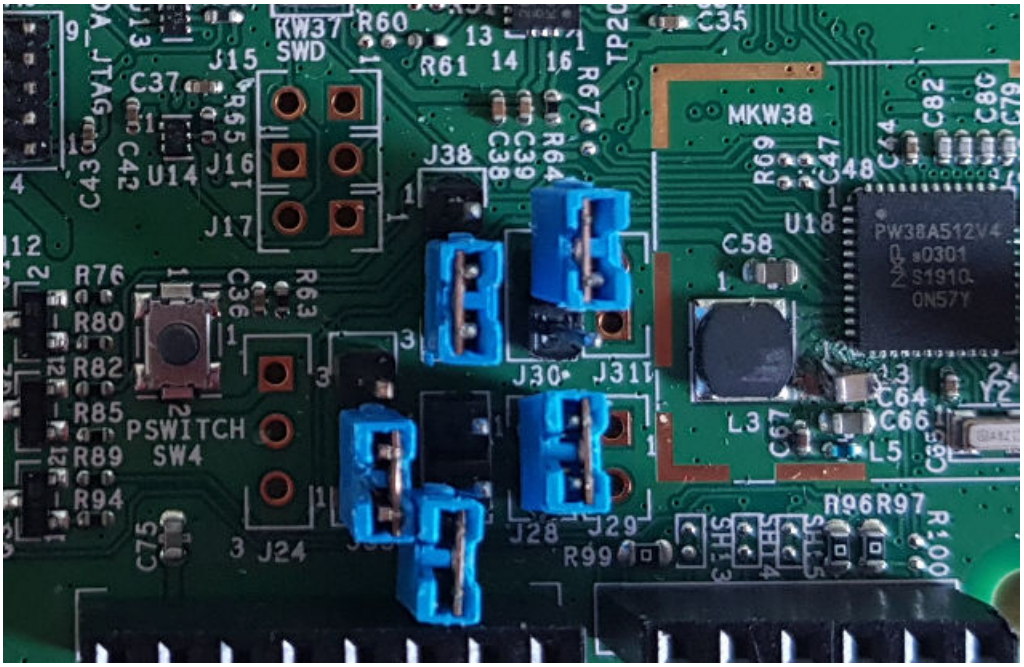

Figure 13. Header connector setup on FRDM-KW38 board

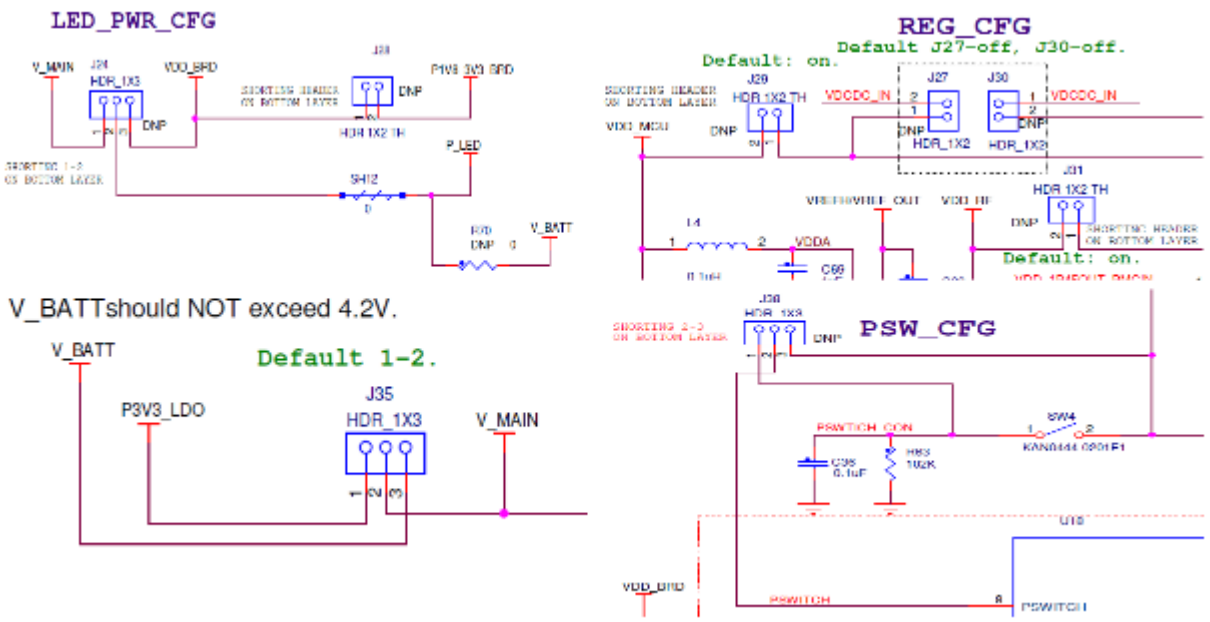

Figure 14. FRDM-KW38 board setup

3. The FRDM-KW38 is now ready for the different Buck or Bypass configuration.

NOTE

For flashing the KW38 via the USB connector J11, the jumper J35 must be shunt to the 2-3 position.

Current measurement in Buck mode and Current measurement in Bypass mode explain how to set the jumpers for the buck or bypass mode configuration.

4.1.1.1 Current measurement in Buck mode

The jumpers must be placed as shown in Figure 15 to measure the KW38 current consumption in buck mode.

- Jumper J38 needs to be shunt at 2-3 position to allow Pswitch connected to the `V_main` (`DCDC_in` in the Buck mode).
- Jumper J29 needs to be shunt at 1-2 position to allow `VDD_1P8out` to be connected to the Analog and Digital power supply of the KW38.
- Remove the jumper J35 completely.

The current measurement is performed at J35-2 pin.

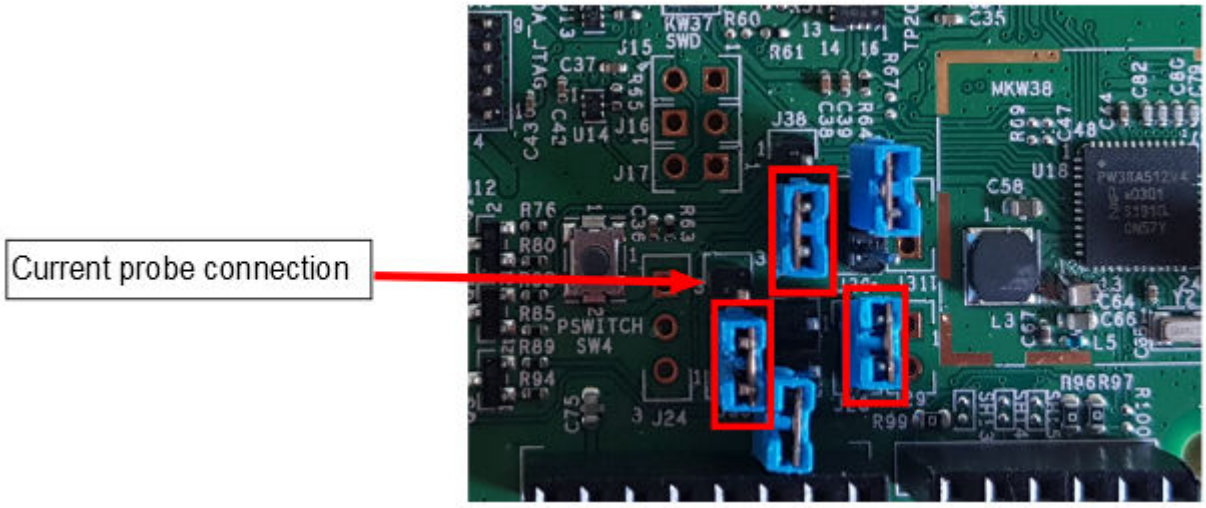

Figure 15. FRDM-KW38 board, buck mode

NOTE

When programming the board, J35 has the jumper on 1-2 position. After programming the board, remove the jumper.

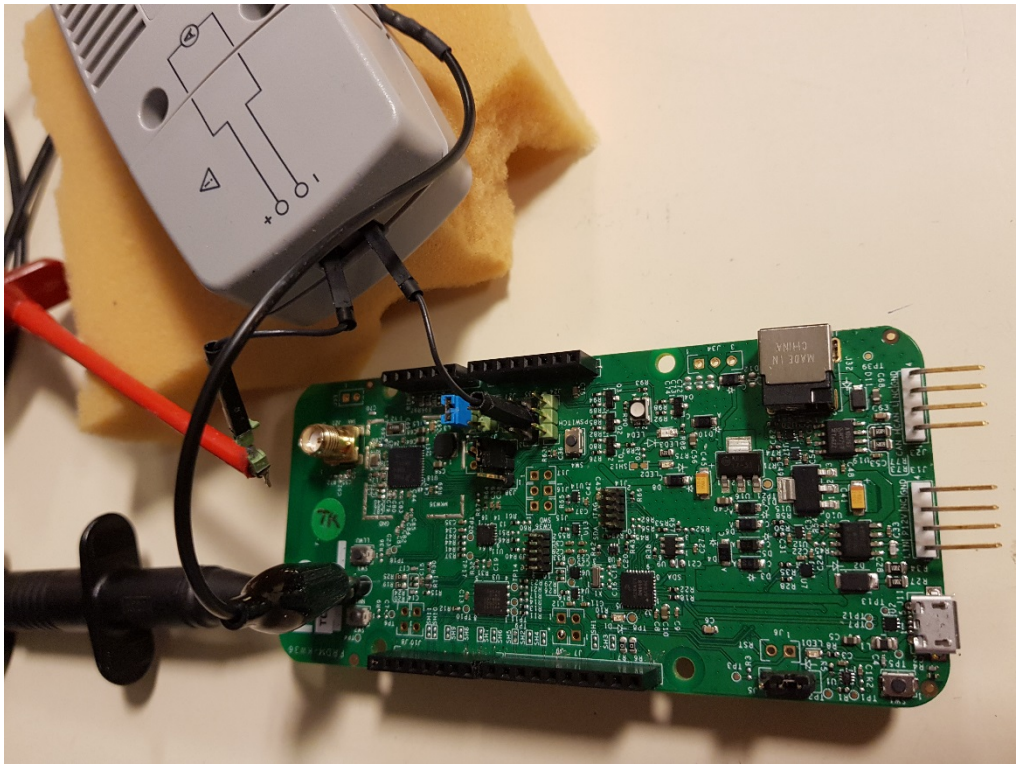

Figure 16. FRDM-KW38 board, buck mode with current probe

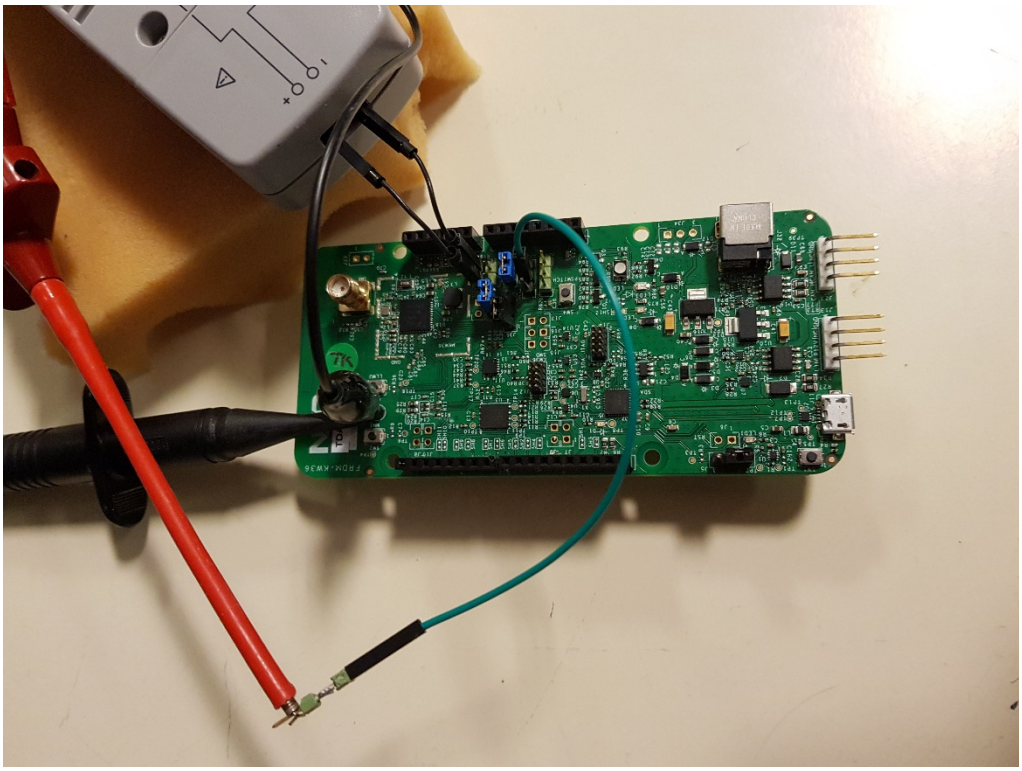

Figure 17. FRDM-KW38 board, buck mode with current probe on MCU (J29)

4.1.1.2 Current measurement in Bypass mode

The jumpers must be placed as shown in Figure 18 to measure the KW38 current consumption in Bypass mode.

- Jumper J38 needs to be shunt at 1-2 position to allow Pswitch connected to the ground (`DCDC_in` in bypass mode).
- Jumpers J27, J29 and J30 need to be shunt at 1-2 position to allow `V_MAIN` to be connected to the Analog and Digital power supply of the KW38.
- Remove the jumper J35 completely.

The current measurement is performed at J35-2 pin.

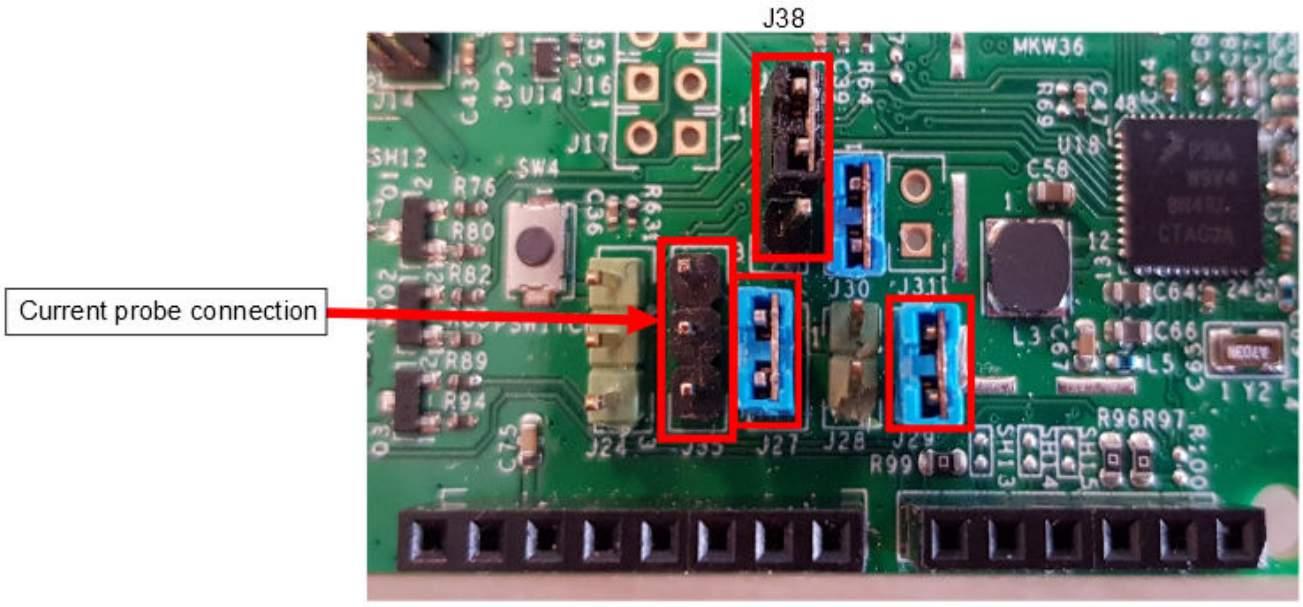

Figure 18. FRDM-KW38 board, Bypass mode

NOTE

When programming the board, J35 has the jumper on 1-2 position. After programming the board, remove the jumper.

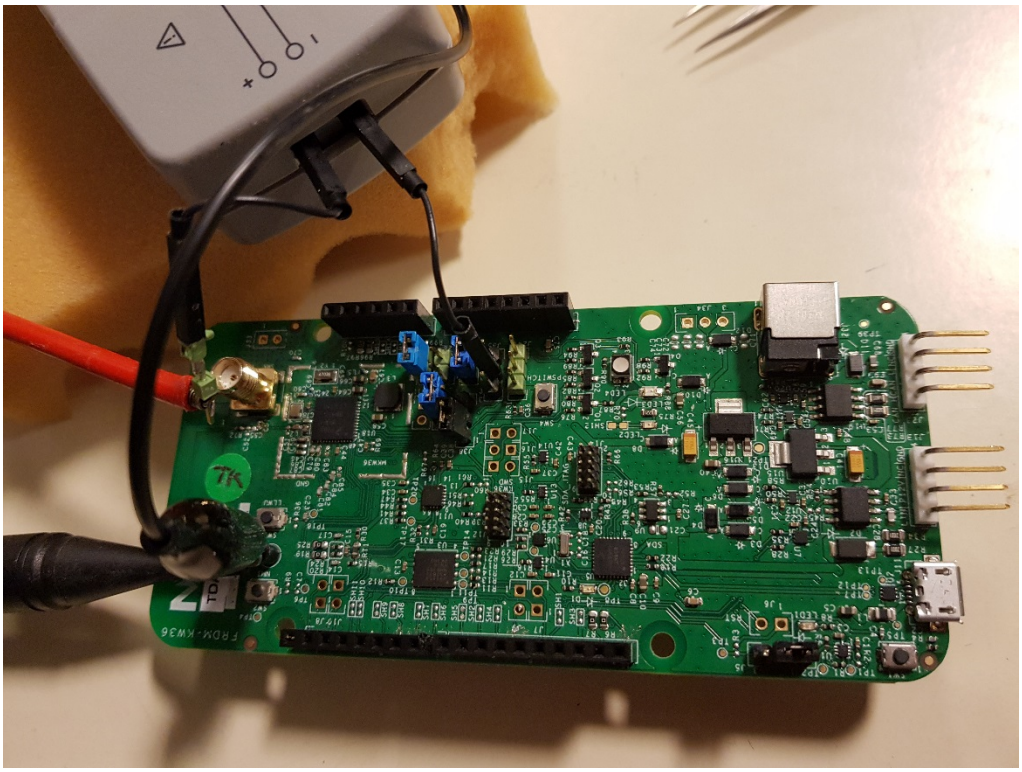

Figure 19. FRDM-KW38 board, bypass mode with current probe

If the board has SMA connector, C57 capacitor is populated and C55 not populated, then a SMA antenna is required to be connected to the board.

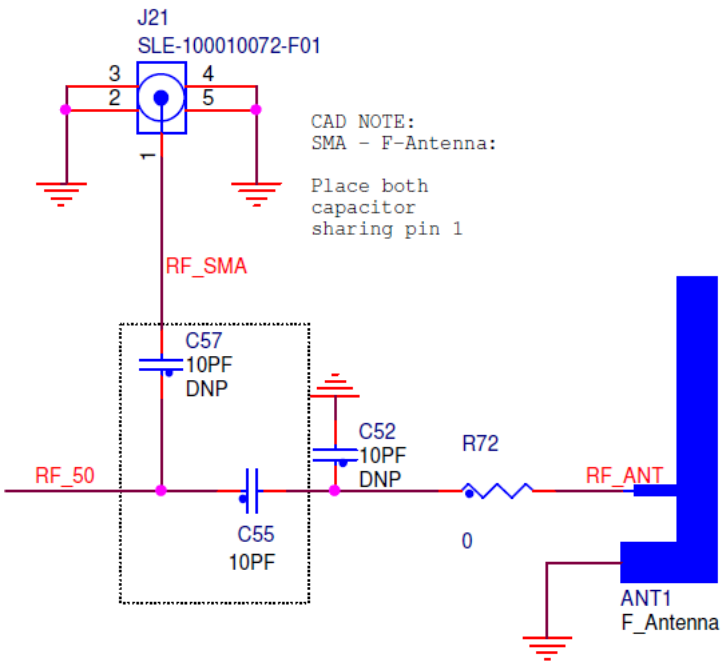

Figure 20. SMA configuration

4.2 Measuring the current consumption

This section will guide you to set up the hardware and software to measure the current consumption using the FRDM-KW38.

4.2.1 Instruction

1. Choose the Buck mode (refer to Current measurement in Buck mode) or Bypass mode (refer to Current measurement in Bypass mode).
2. Place the jumper J24 in 1-2 position, J28 in 1-2 position and J35 in 1-2 position.
3. Connect the board to a PC and download the Heart Rate Sensor project created in Software configuration for low-power operation to the board.
4. Once the board is programmed, disconnect the board from the PC and remove the jumpers from J24, J28 and J35.
5. Remove any external debugger if connected.
6. Set the output voltage of the power source to 3.0 V.

NOTE

Voltage range must be within 2.1 V and 3.6 V.

7. Connect TP19 (GND) to the Power Source. Make sure to disable the output of the power source to avoid any damage to the board.
8. Connect the Keysight CX3322A Power Analyzer and CX1101A Current Probe to J35-2 and to the Power Source.

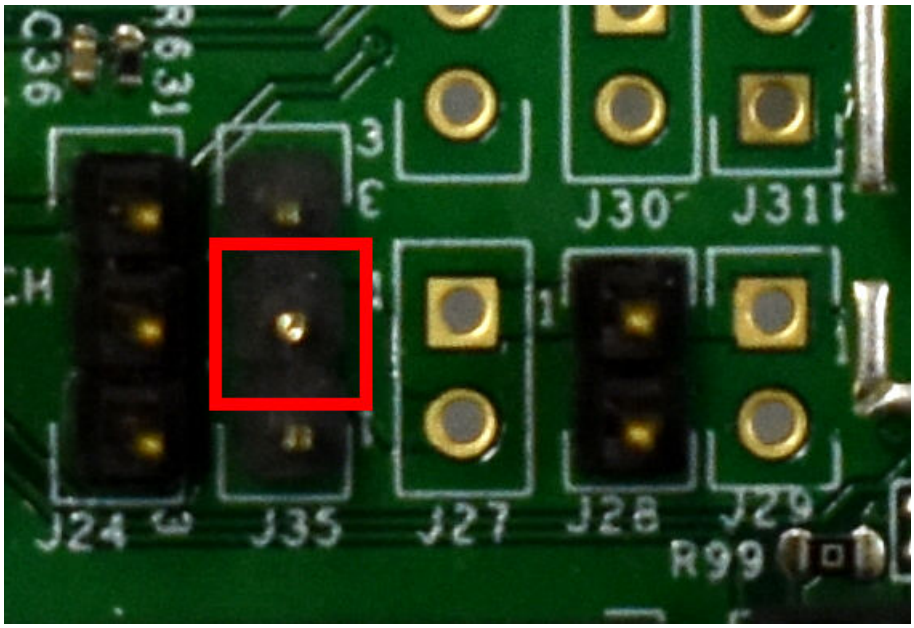

Figure 21. J35-2

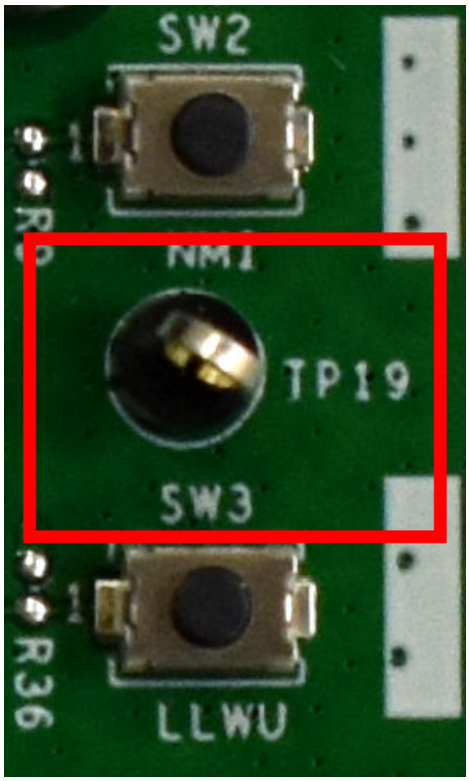

Figure 22. GND TP19

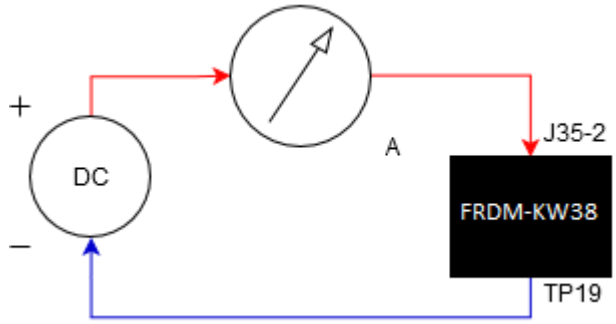

Figure 23. Connection block diagram

9. Apply voltage to the board.

   The current measurement is performed by using the Power Analyzer built-in display and an USB flash memory stick to save the results.

4.2.2 Measurements and results

All the measurements within this subchapter are done with MCU in stop mode, the flash in doze mode, RF output at **+5 dBm** (1 mW) (see the `controller_interface.h` header file), power supplies at 3.0 V and room temperature (25 °C). KW38 device is coming from typical process. All the phases from above figure are analyzed and measured. In Reports, all measurement results are presented in both buck and bypass mode with 1 RF output power (+5 dBm).

How to use the Power Analyzer is not part of this document.

4.2.2.1 Overview

Follow the steps in Software configuration for low-power operation. Figure 24 shows partial Bluetooth LE scenario (Low Power application) captured. The main events and phases are documented within the capture. All the plots that follows depicts current consumption (y-axis) vs. time (x-axis).

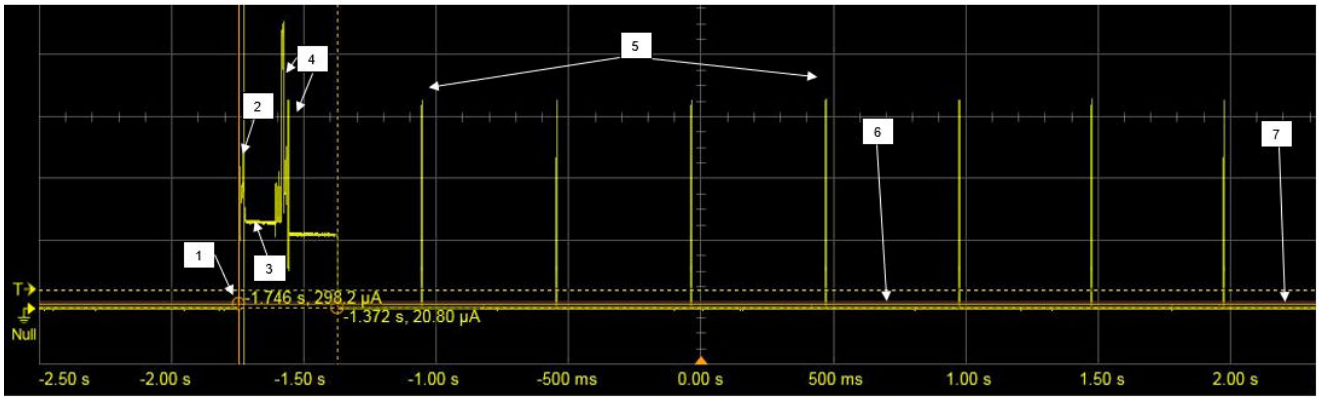

Figure 24. KW38 SoC current consumption sequense

Table 5 describes the current consumption of the KW38 SoC during different operational phases.

Table 5. Different operational phase current consumption

Phase	Description
1	Power On Reset (POR), just after the SoC is connected to power supply. The spike from the figure is about 26 mA and is because of the coupling capacitors as well as the SoC internal circuitry (regulators, clock oscillators, MCU, radio digital, radio analog and so on).
2	MCU is initialized among all the software: low-level drivers, framework, RTOS, Bluetooth LE stack, application.
3	MCU running
4	The MCU leaves low power mode 3 (by pushing the SW3 button) and resumes its execution. The Bluetooth LE link layer goes to RUN state.
5	Fast advertising is started. Between advertising events the system enters in one of the low power modes (Pswitch, VLLS0, VLLS1, VLLS2 or LLS2).
6	Between advertising events the system enters in one of the power modes (Pswitch, VLLS0, VLLS1, VLLS2 or LLS2)
7	After a disconnection, the SoC enters in one of the low power modes (Pswitch, VLLS0, VLLS1, VLLS2 or LLS2).

4.2.2.2 Deep sleep modes

When the SoC is connected to the power supply, a power up spike occurs due to coupling of the board to power supply. After MCU POR, the software execution begins, the clocks and peripherals are enabled and configured, the Connectivity Framework is initialized, RTOS tasks are initialized and started, the Bluetooth LE stack is up and running, and the Bluetooth LE application is started. After all these are completed, the system could enter different deep sleep modes (sort list from lowest to highest current consomption) :

- DSM4: SoC Pswitch, MCU OFF, BLE LL OFF
- DSM4: MCU VLLS0 (POR=1), BLE LL OFF, DCDC bypass
- DSM4: MCU VLLS0 (POR=0), BLE LL OFF, DCDC bypass
- DSM4: MCU VLLS1, BLE LL OFF, DCDC buck
- DSM1: MCU LLS2, BLE LL DSM2 (stop), BLE LL reference clock 32 KHz oscillator, DCDC buck
- DSM1: MCU LLS2, BLE LL DSM2 (stop), BLE LL reference clock 32 KHz oscillator, DCDC bypass
- DSM6: MCU stop, BLE LL active (*FEE 48 MHz, MCU STOP, Flash dozed)*, BLE LL reference clock 32 MHz, DCDC buck *(Vdcdc_in=3 V, 1P8=1,8 V, 1P5=1,5 V)*
- DSM6: MCU stop, BLE LL active (*FEE 48 MHz, MCU STOP, Flash dozed)*, BLE LL reference clock 32 MHz, DCDC bypass *(Vdcdc_in=3 V, 1P8=3 V, 1P5=3 V)*

The initialization phase before the system enters deep sleep takes several milliseconds depending of the deep sleep mode chosen.

In the different use cases, the device will operate in deep sleep mode x until SW3 key is pressed. By pressing SW3 the system will wake up because the GPIO associated to SW3 is configured as interrupt source in Low-leakage Wake-up Unit (LLWU) module.

4.2.2.3 Power On Reset

The FRDM-KW38 board is set in Buck mode configuration.

The binary file setting used is: Buck mode, LLS2, FEE 48 MHz clock mode, automatic start advertising

The very first POR timing is **373 ms** from power up to first Tx advertising.

Figure 25. KW38 SoC first POR timing

Table 6. KW38 SoC first POR timing

Type of wakeup	Timing (ms) (HW+SW initialisation)
POR	373 ms

The other POR timings are **342 ms** from power up to first Tx advertising.

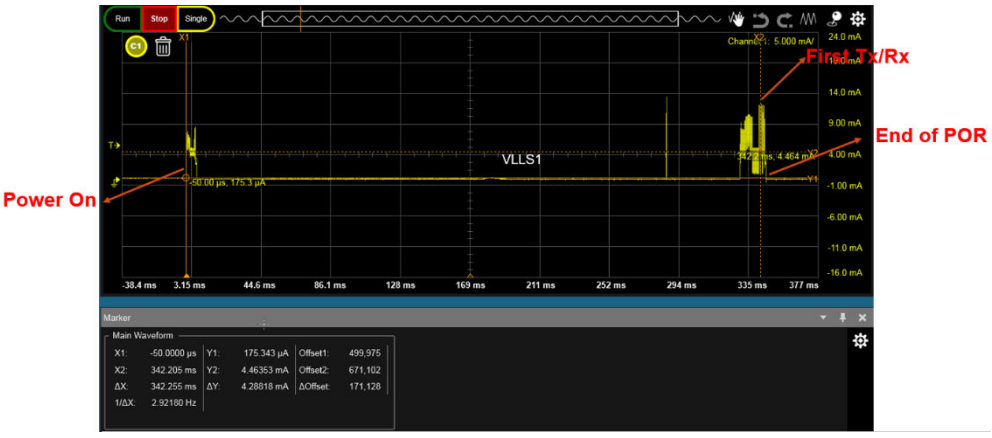

Figure 26. KW38 SoC POR timing

Table 7. KW38 SoC POR timing

Type of wakeup	Timing (ms) (HW+SW initialization)
POR	342 ms

4.2.2.4 Pswitch

To select the Pswitch mode on the FRDM-KW38, J38 must be in position 1-2. All others jumpers must be in buck mode position.

At power up, the KW38 device enter in advertising mode automatically. To enter in Pswitch mode off, the SW4 must be pressed. Pressing the SW4 again will wakeup the KW38 to enter in advertising mode.

The binary file setting used are:

Buck mode, LLS2, FEE 48 MHz clock mode, Pswitch on/off when SW4 is pressed, Advertising at POR, advertising interval 30 ms with 37 bytes payload and connectable.

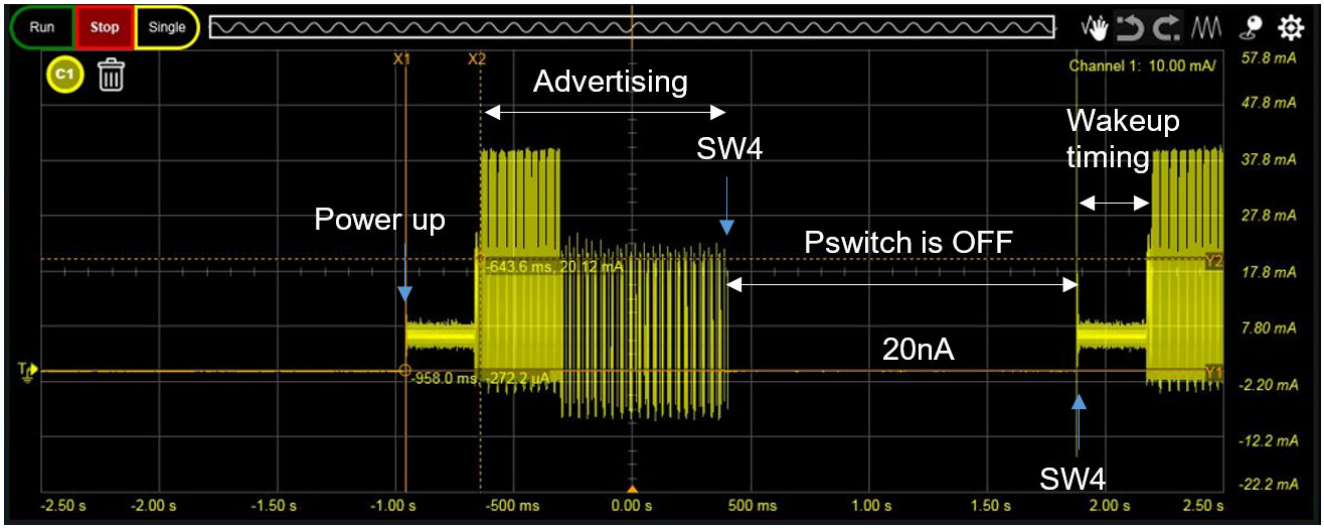

Figure 27. KW38 SoC current consumption sequence in Pswitch mode

The low power current consumption is measured at 20nA @3V.

Table 8. Pswitch low power consumption

Type of DSM mode	Consumption (nA @3 V)
Pswitch	20 nA

Figure 28. KW38 Pswitch – Wakeup timing

The wakeup timing is 16.8 ms from KW38 Pswitch off to first Tx advertising event.

Table 9. Wakeup Pswitch timing

Type of wakeup	Timing (ms)
Pswitch	16.8 ms

4.2.2.5 VLLS0

VLLS0 mode is used in bypass mode. The FRDM-KW38 jumpers are in bypass configuration.

The KW38 device enter in VLLS0 low power mode automatically at power up. The device enter in advertising mode when the SW3 button is pressed.

Depending of the POR setting (SMC_STOPCTRL[PORPO] = 0 or 1), the consumption is different.

The binary files setting used are:

- **Bypass mode**: VLLS0 (POR=0), FEE 48 MHz clock mode, advertising period 30 ms with payload and connectable at POR
- **Bypass mode**: VLLS0 (POR=1), FEE 48 MHz clock mode, advertising period 30 ms with payload and connectable at POR

4.2.2.5.1 VLLS0, POR=1, DCDC bypass

The low power current consumption is measured at **200nA @3V** between advertising events.

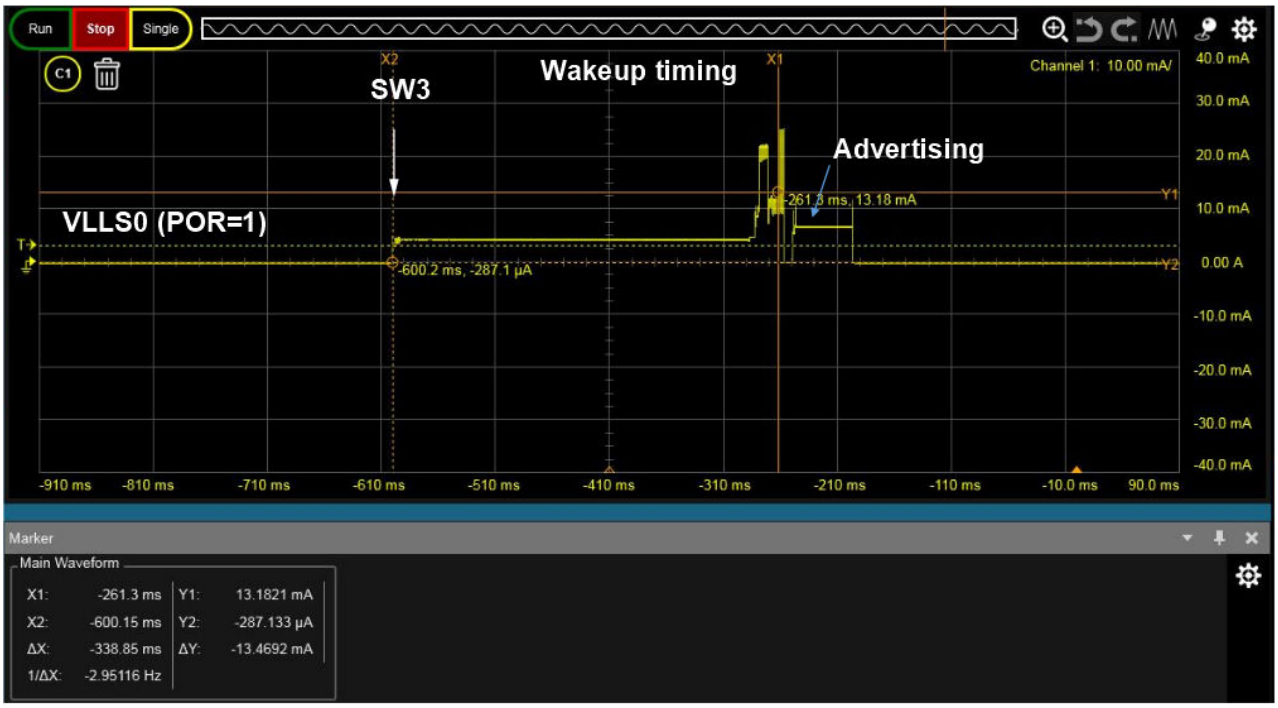

Figure 29. KW38 VLLS0 (POR=1) – Wakeup timing

The wakeup timing is **338.8 ms** from KW38 VLLS0 POR=1 to first Tx advertising event.

Table 10. VLLS0 (POR=1) consumption

Deep sleep mode	MCU state	BLE LL state	BLE_LL reference clock source	Typical use case	KW38 current consumption @3V
Mode 4	VLLS0 (POR=1)	OFF	NA	VLLS0 when DCDC Bypass	200 nA

Table 11. VLLS0 (POR=1) timing

Type of wakeup	Timing (ms)
VLLS0 (POR=1)	339 ms

4.2.2.5.2 VLLS0, POR=0, DCDC bypass

The low power current consumption is measured at **391nA @3V** between advertising events.

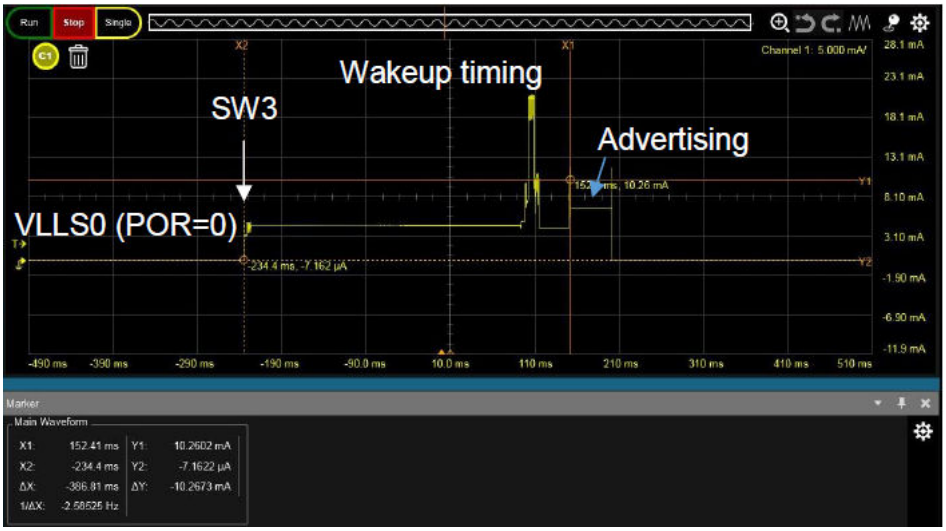

Figure 30. KW38 VLLS0 (POR=0) – Wakeup timing

The wakeup timing is **386.8 ms** from KW38 VLLS0 POR=0 to first Tx advertising event.

Table 12. VLLS0 (POR=0) consumption

Deep sleep mode	MCU state	BLE LL state	BLE_LL reference clock source	Typical use case	KW38 current consumption @3V
Mode 4	VLLS0 (POR=0)	OFF	NA	VLLS0 when DCDC Bypass	391 nA

Table 13. VLLS0 (POR=0) timing

Type of wakeup	Timing (ms)
VLLS0 (POR=0)	387 ms

4.2.2.6 VLLS1

VLLS1 mode is used in buck mode. The FRDM-KW38 jumpers are in buck configuration.

The KW38 device enter in VLLS1 low power mode automatically after power up. The KW38 enter in advertising mode when the SW3 button is pressed.

The binary file setting used are:

- **Buck mode**: VLLS1, FEE 48MHz clock mode, advertising period 30ms with payload and connectable at POR

The low power current consumption is measured at **0.88µA @3V** between advertising events.

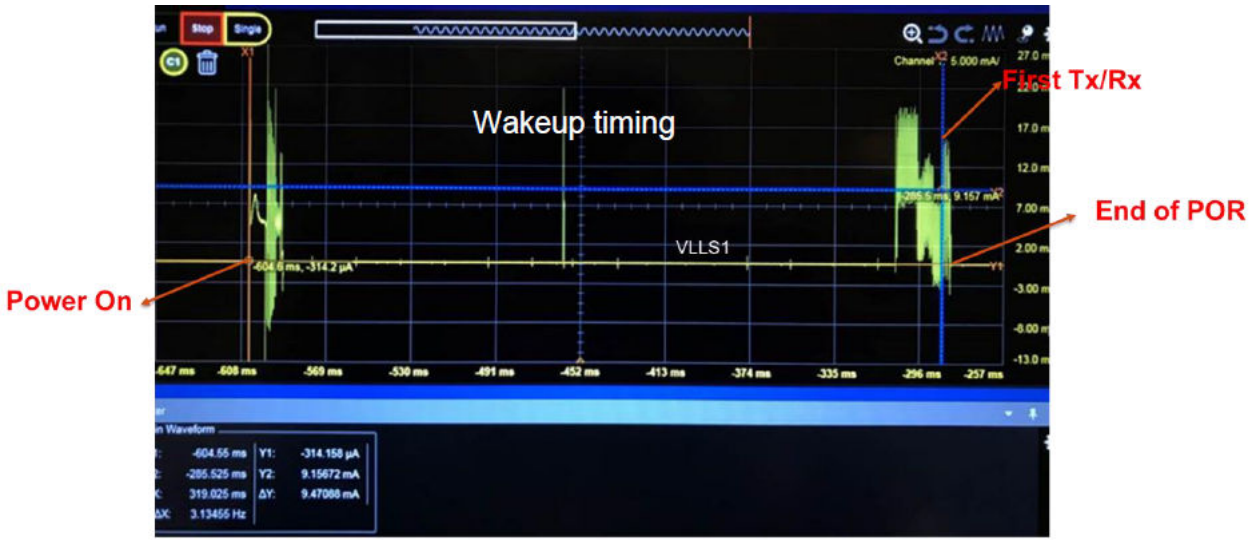

Figure 31. KW38 VLLS1 – Wakeup timing

The wakeup timing is **319 ms** from KW38 VLLS1 to first Tx advertising event.

Table 14. VLLS1 consumption

Deep sleep mode	MCU state	BLE LL state	BLE_LL reference clock source	Typical use case	KW38 current consumption @3V
Mode 4	VLLS1	OFF	NA	VLLS1 when DCDC Buck	0.88 µA

Table 15. VLLS1 timing

Type of wakeup	Timing (ms)
VLLS1	319 ms

4.2.2.7 LLS2

4.2.2.7.1 Buck

LLS2 mode is used. The FRDM-KW38 jumpers are in buck configuration.

The KW38 device enter in LLS2 low power mode automatically after power up. The KW38 enter in advertising mode when the SW3 button is pressed.

The binary file setting used is:

- **Buck mode**: LLS2, FEE 48 MHz clock mode, advertising period three seconds with payload and connectable

Figure 32. KW38 LLS2 – Buck mode

As show in Table 16, the spikes are at the moments when DCDC is refreshing. This will result into a higher average current consumption performed with a current differential probe.

Table 16. LLS2 current consumption between events supplied with an external power supply

	Measured current between two advertising events		
DCDC voltage	Avg.	Max.	Min.
3.0 V	2.71 µA	31.8 mA	-9.7 mA

The low power current consumption is measured at **2.71µA @3V** between advertising events.

Coin cell 3.0 V power supply

Deep Sleep Mode current measurement is performed on the FRDM-KW38 board supplied with a coin cell 3.0 V (CR2032 Lithium). The direct impact is on the peak current.

Figure 33. KW38 LLS2 - Buck mode - coin cell CR2032

Table 17. LLS2 current consumption between events supplied with a coin cell

DCDC_IN=3.0 V	Measured current between two advertising events		
	Avg.	Max.	Min.
2.73 µA	27.8 mA	-0.969 mA	

4.2.2.7.2 Bypass

LLS2 mode is used. The FRDM-KW38 jumpers are in bypass configuration.

The KW38 device enter in LLS2 low power mode automatically after power up. The KW38 enter in advertising mode when the SW3 button is pressed.

The binary file setting used is:

- **Bypass mode**: LLS2, FEE 48 MHz clock mode, advertising period three seconds with payload and connectable

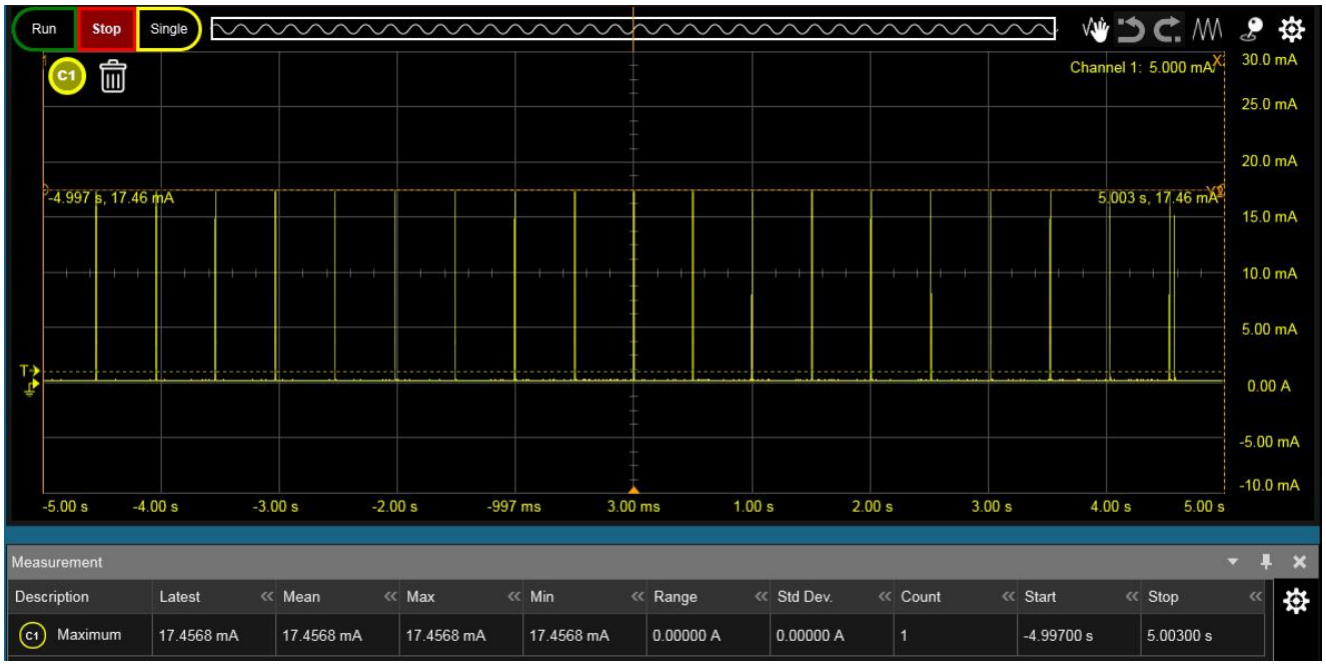

Figure 34. KW38 LLS2 – Bypass mode

Table 18. LLS2 current consumption between events in bypass mode

DCDC_IN=3.0 V	Measured current between two advertising events		
	Avg.	Max.	Min.
3.7 µA	17.5 mA	-178 µA	

The low power current consumption is measured at **3.7µA @3V** between advertising events.

Table 19. LLS2 current consumption between events in buck and bypass modes

Deep sleep mode	MCU state	BLE LL state	BLE_LL reference clock source	Typical use case	KW38 current consumption @3V
Mode 1	LLS2 buck LLS2 bypass	DSM2 (Stop)	32 KHz oscillator	LLS2 between RF activities	2.71 µA 3.7 µA

4.2.2.8 VLLS2

4.2.2.8.1 Buck

VLLS2 mode is used. The FRDM-KW38 jumpers are in buck configuration.

The KW38 device enter in VLLS2 low power mode automatically after power up. The KW38 enter in advertising mode when the SW3 button is pressed.

The binary file setting used is:

- **Buck mode**: VLLS2, FEE 48 MHz clock mode, advertising period three seconds with payload and connectable

Figure 35. KW38 VLLS2 – Buck mode

As shown in Table 20, the spikes are at the moments when DCDC is refreshing. This will result to a higher average current consumption performed with a current differential probe.

Table 20. VLLS2 current consumption between events supplied with an external power supply

	Measured current between two advertising events		
DCDC voltage	Avg.	Max.	Min.
3.0 V	2.12 µA	18.7 mA	-6.3 mA

The low power current consumption is measured at **2.12µA @3V** between advertising events.

4.2.2.8.2 Bypass

VLLS2 mode is used. The FRDM-KW38 jumpers are in bypass configuration.

The KW38 device enter in VLLS2 low power mode automatically after power up. The KW38 enter in advertising mode when the SW3 button is pressed.

The binary file setting used is:

- **Bypass mode**: VLLS2, FEE 48 MHz clock mode, advertising period three seconds with payload and connectable

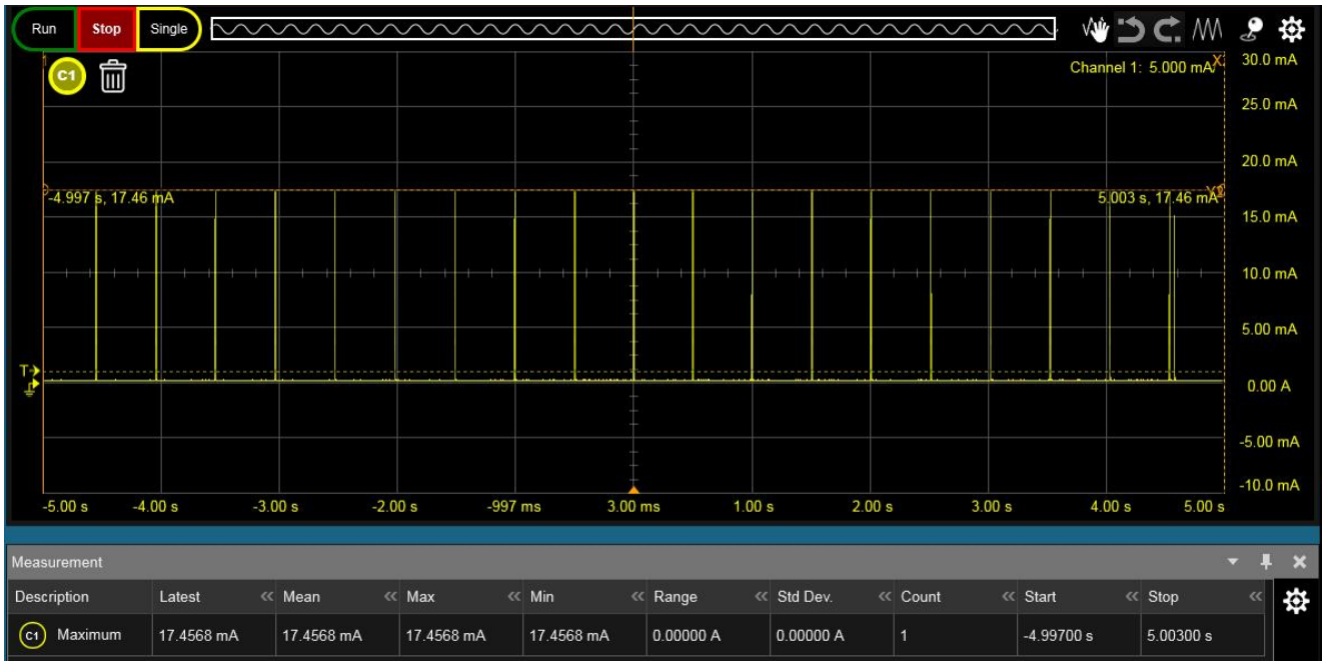

Figure 36. KW38 VLLS2 – Bypass mode

Table 21. VLLS2 current consumption between events in bypass mode

DCDC_IN=3.0 V	Measured current between two advertising events		
	Avg.	Max.	Min.
2.35 µA	16.5 mA	-159 µA	

The low power current consumption is measured at **2.35µA @3V** between advertising events.

Table 22. VLLS2 current consumption between events in buck and bypass modes

Deep sleep mode	MCU state	BLE LL state	BLE_LL reference clock source	Typical use case	KW38 current consumption @3V
Mode 1	VLLS2 buck VLLS2 bypass	DSM2 (Stop)	32 KHz oscillator	VLLS2 between RF activities	2.12 µA 2.35 µA

NOTE

The DCDC peaks occurs every 350 to 400 ms. Figure 37 shows the nominal DCDC peak. One exception is during the first DCDC peak after an event (Advertising, Scan or Connect) which is longer. In case of long advertising period (> 4 seconds), the first DCDC peak (with higher consumption) could be marginal on the total consumption during the low power mode between events. In case of short advertising events, the DCDC peak becomes more significant. The worst case low power consumption is when the advertising event is between 500 ms to 1 second. Only one DCDC peak occurs between events.

Figure 37 and Figure 38 show the 1P8 voltage (green curve) and the DCDC current on the SoC (yellow curve). Nominal DCDC peak timing is around 125 µs. It becomes longer during the first DCDC peak: ~300 µs.

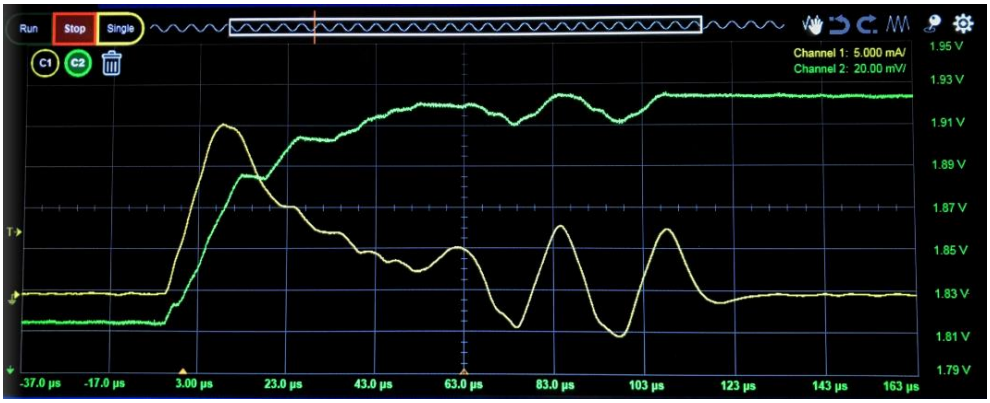

Figure 37. Nominal DCDC peak – Buck mode

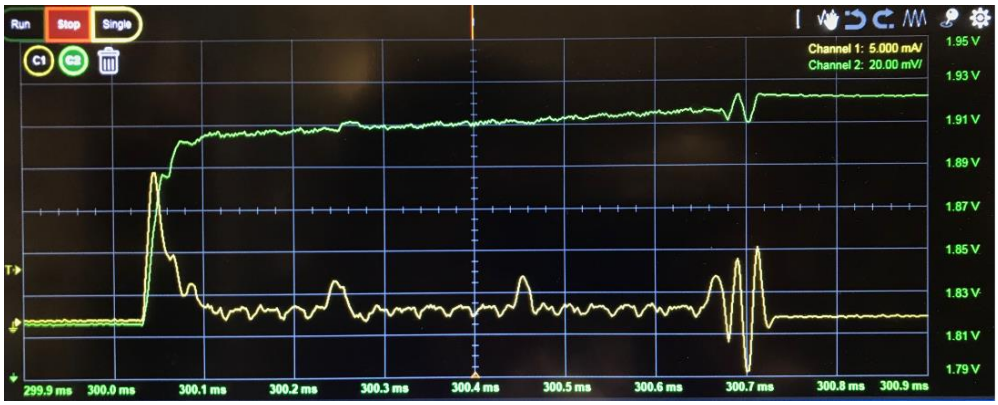

Figure 38. First DCDC peak after an Advertising event – Buck mode

4.2.2.9 Advertising interval larger than 10.24 seconds

SoC is in Mode 9 (Advertising interval larger than 10.24 seconds). The FRDM-KW38 jumpers are in buck configuration.

The KW38 device enter in advertising mode automatically after power up.

The binary file setting used are:

- **Buck mode**: LLS2, FEE 48 MHz clock mode, advertising period 15secondswith payload and connectable

Table 23. Mode 9 current consumption between Advertising events in buck mode

Deep Sleep Mode	Current consumption between Advertising events (15 seconds interval)
Mode 9	2.05 uA

4.2.2.10 MCU stop

SoC is in mode 6 (MCU stop & BLE LL active state [FEE 48MHz]). The FRDM-KW38 jumpers are in buck configuration.

The KW38 device enter in advertising mode automatically after power up.

The binary file setting used is:

- **Buck mode**: LLS2, FEE 48 MHz clock mode, advertising period 30 ms with payload and connectable

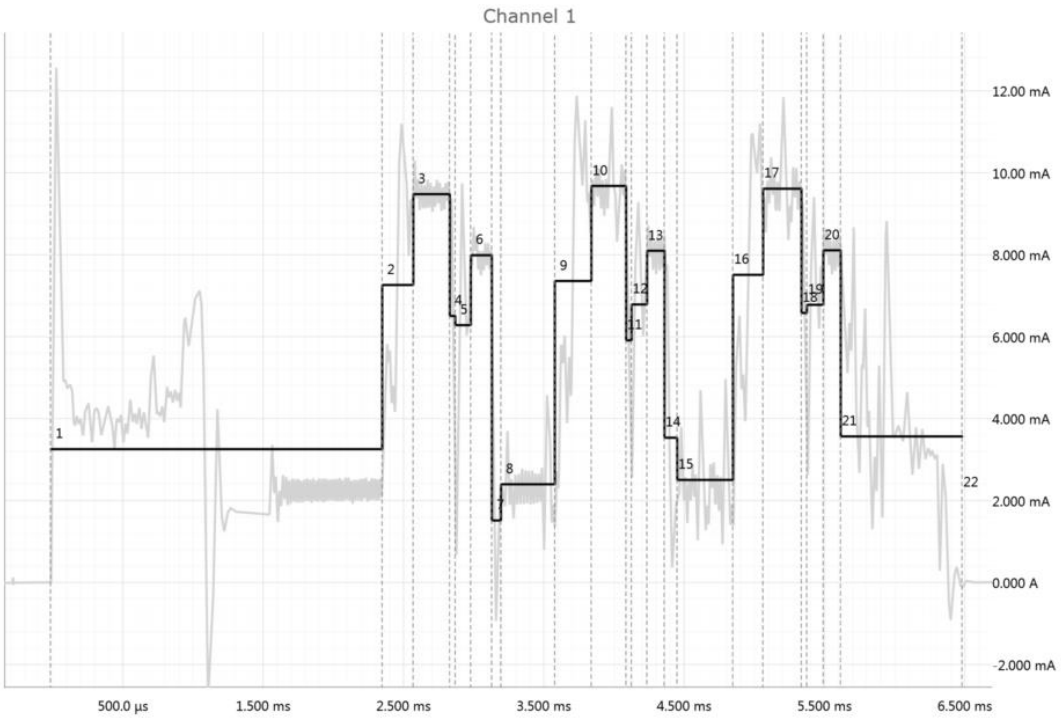

Figure 39. KW38 - MCU stop - Buck mode

Table 24. MCU stop current consumption in buck mode

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
8	–	3.194 ms	384.0 us	2.278 mA	3.791 mA	-164.8 uA	257.3 pAh	2.88
15	–	4.450 ms	397.0 us	2.216 mA	3.954 mA	-772.0 uA	254.7 pAh	3.11

MCU stop current could be measured between two TX/RX radio events (timing 8 & 15 in Figure 39), but BLE LLH is in RUN during all this time.

MCU stop average consumption : **2.25 mA**

Table 25. MCU stop current consumption in buck mode

Deep sleep mode	MCU state	BLE LL state	BLE_LL reference clock source	Typical use case	KW38 current consumption @3V
Mode 6	STOP	Active[1]	32 MHz	Only MCU in stop	2.25 mA
1. Active mode: Buck mode (Vdcdc_in=3 V, 1P8=1,8 V, 1P5=1.5 V), FEE 48 MHz, MCU STOP, Flash dozed Condition of measurement: Vdcdc_in=3 V, 25°C (Ambient)					

4.2.2.11 Low power mode summary results

Table 26. Low Power mode summary results

Deep sleep mode (as defined in Connectivity framework)	MCU state	BLE LL state	BLE_LL reference clock source	Typical use case	KW38 current consumption @3V
Mode 6	STOP	Active[1]	32 MHz	Only MCU in stop	2.25 mA
Mode 1	VLLS2 Buck VLLS2 Bypass	DSM2 (stop)	32 kHz oscillator	VLLS2 between RF activities	2.06 µA 2.35 µA
Mode 1	LLS2 Buck LLS2 Bypass	DSM2 (stop)	32 kHz oscillator	LLS2 between RF activities	2.71 µA 3.7 µA
Mode 9	VLLS2/3 buck	OFF	NA	Advertising interval larger than 10.24 sec	2.05 µA
Mode 4	VLLS1	OFF	NA	VLLS1 when DCDC buck	0.88 µA
Mode 4	VLLS0 (POR=0)	OFF	NA	VLLS0 when DCDC bypass	391 nA
Mode 4	VLLS0 (POR=1)	OFF	NA	VLLS0 when DCDC bypass	200 nA
DSM9	VLLS2/3	IDLE	NA	Advertising interval larger than 10.24 seconds	2.05 µA
RAM OFF (during Advertising)	VLLS1	IDLE	NA	Ultra fast wake-up, VLLS1	1.65 µA
RAM OFF (during Advertising)	VLLS1	IDLE	NA	Ultra fast wake-up, Pswitch	20 nA
Mode 4	Pswitch	OFF	NA	Pswitch to ground	20 nA
1. Active mode: Buck mode (Vdcdc_in=3 V, 1P8=1.8 V, 1P5=1.5 V), FEE 48 MHz, MCU STOP, Flash dozed Condition of measurement: Vdcdc_in=3 V, 25°C (Ambient)					

4.2.2.12 Advertising mode

An advertising event is where the Bluetooth LE peripheral device broadcasts some information in order to either share it or become connected to a Bluetooth LE Central device, such as a smart phone. The device wakes up and broadcasts packets on three separate channels and listens on each of these channels for Scan Requests or Connection Requests.

Figure 40 shows the current consumption during the advertising event.

The binary file settings used are: FEE 48 MHz clock, Advertising with 37 bytes payload and connectable, RF output +5 dBm

- **Buck mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2
- **Bypass mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2

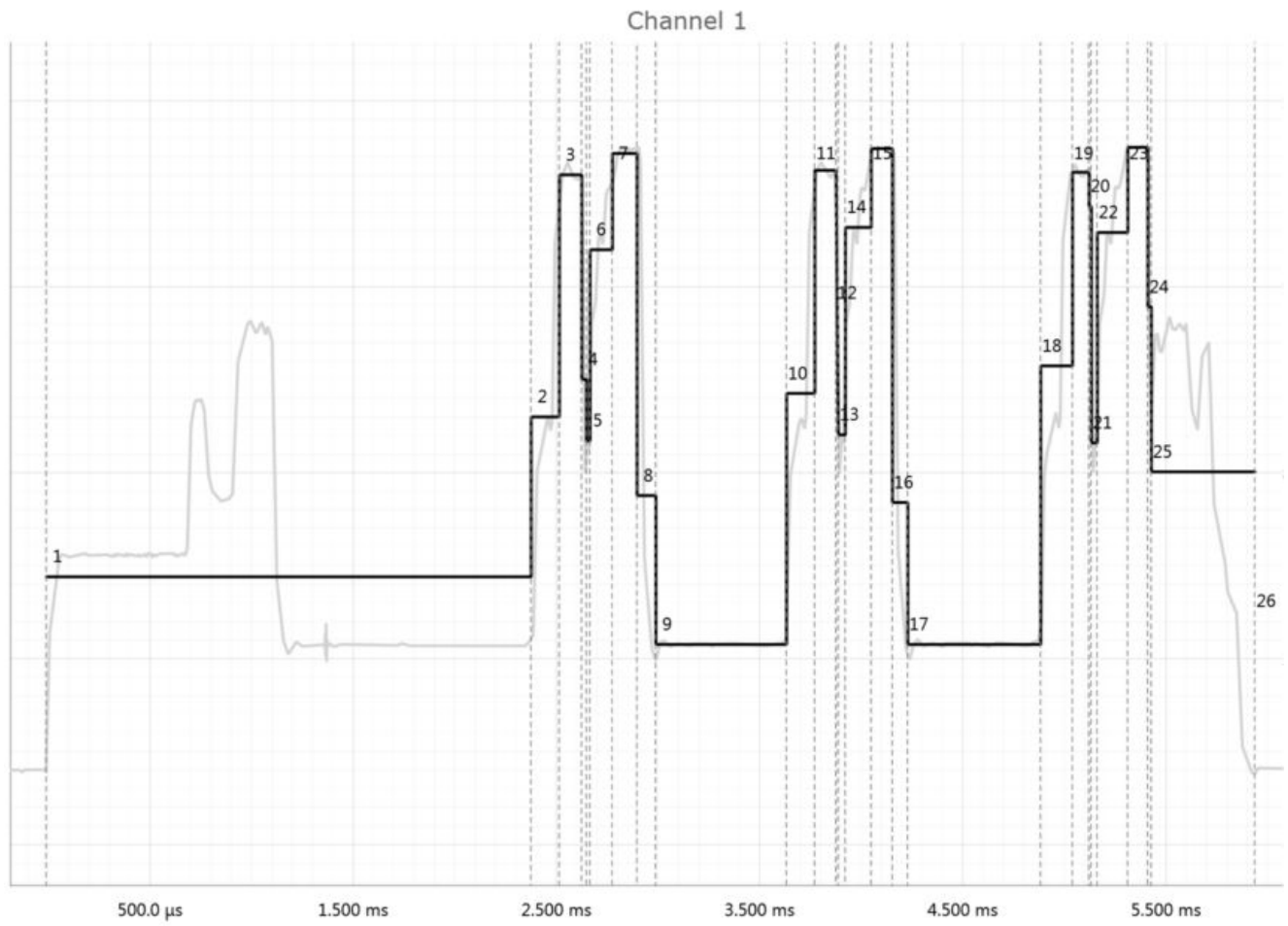

Figure 40. Current consumption - advertising event period

Table 27. Advertising events

Phase	Advertising event timing
1	Pre-processing
2	Tx warm-up
3	Active Tx
4	Tx warm-down
5	Tx to Rx transition
6	Rx warm-up
7	Active Rx
8	Rx warm-down
9	MCU stop
10	Tx warm-up
11	Active Tx
12	Tx warm-down
13	Tx to Rx transition
14	Rx warm-up
15	Active Rx
16	Rx warm-down
17	MCU stop
18	Tx warm-up
19	Active Tx
20	Tx warm-down
21	Tx to Rx transition
22	Rx warm up
23	Active Rx
24	Rx warm-down
25	Post-processing

4.2.2.12.1 Test environment LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	

Table continues on the next page...

Table continued from the previous page...

RAM size	16 K
Data rate	1 Mbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Advertising Interval = 30 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC3 release)

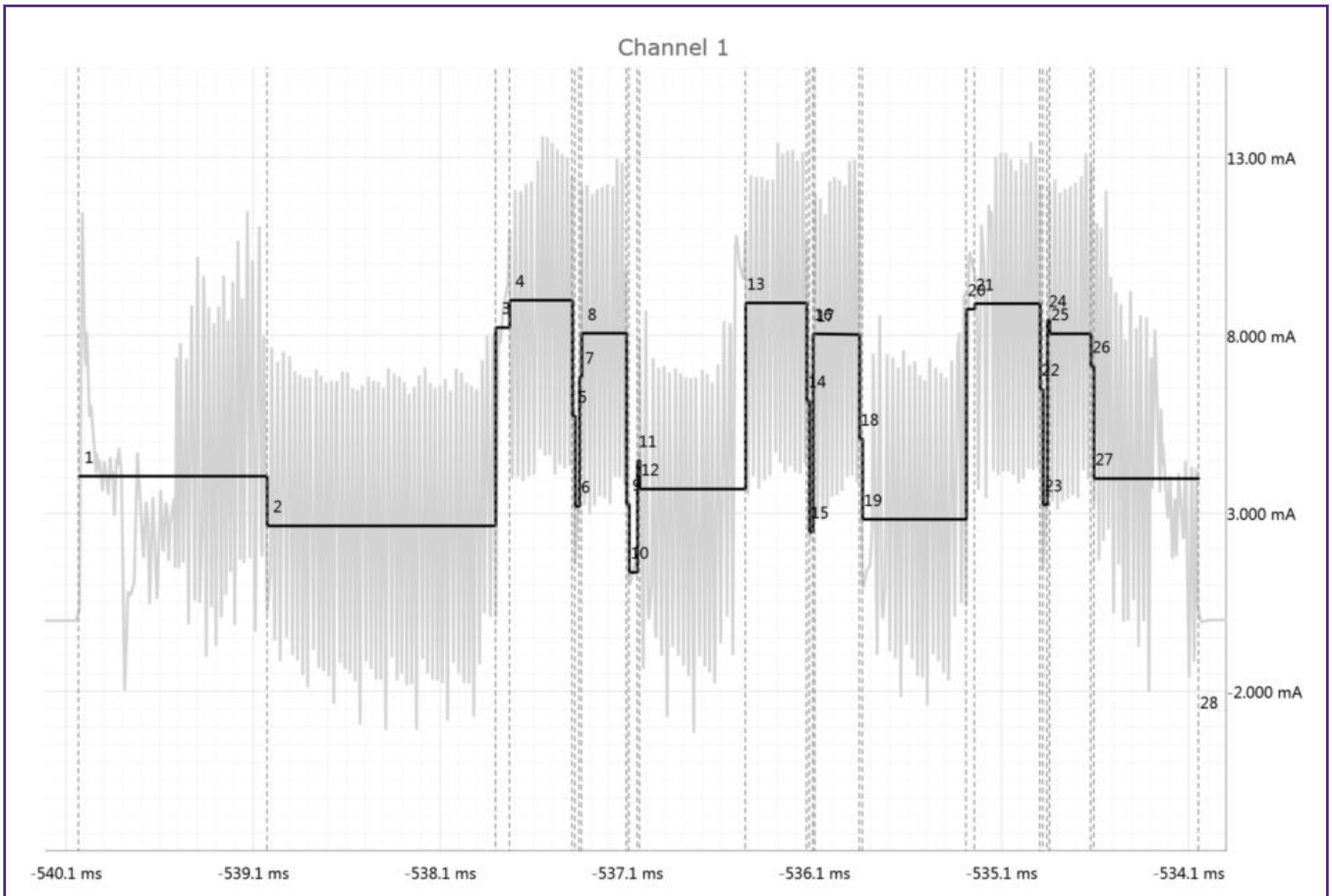

Figure 41. Advertising current profile event after LLS2 mode, Buck mode

Table 28. Advertising current profile event after LLS2 mode, Buck mode

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-540.0 ms	1.008 ms	4.041 mA	11.50 mA	-2.052 mA	1.131 nAh	13.60
2	—	-539.0 ms	1.221 ms	2.647 mA	8.135 mA	-3.083 mA	897.7 pAh	10.79
3	—	-537.8 ms	74.86 µs	8.216 mA	10.96 mA	87.77 µA	170.9 pAh	2.05
4	—	-537.7 ms	334.9 µs	8.985 mA	13.58 mA	3.901 mA	835.7 pAh	10.05
5	—	-537.4 ms	15.17 µs	5.737 mA	11.99 mA	1.503 mA	24.18 pAh	0.29
6	—	-537.4 ms	22.26 µs	3.193 mA	3.758 mA	2.093 mA	19.74 pAh	0.23
7	—	-537.4 ms	13.15 µs	6.830 mA	11.73 mA	3.838 mA	24.95 pAh	0.30
8	—	-537.3 ms	238.8 µs	8.056 mA	12.96 mA	2.980 mA	534.3 pAh	6.42
9	—	-537.1 ms	15.17 µs	3.257 mA	7.988 mA	1.054 mA	13.73 pAh	0.16
10	—	-537.1 ms	43.50 µs	1.343 mA	1.589 mA	939.4 µA	16.23 pAh	0.19
11	—	-537.0 ms	12.14 µs	4.447 mA	7.925 mA	1.555 mA	15.10 pAh	0.18
12	—	-537.0 ms	565.8 µs	3.681 mA	11.00 mA	-3.161 mA	578.6 pAh	6.95
13	—	-536.5 ms	326.4 µs	8.909 mA	13.41 mA	3.528 mA	807.9 pAh	9.71
14	—	-536.1 ms	14.72 µs	6.157 mA	10.74 mA	2.168 mA	25.18 pAh	0.30
15	—	-536.1 ms	19.05 µs	2.475 mA	3.067 mA	2.185 mA	13.09 pAh	0.15
16	—	-536.1 ms	11.26 µs	8.043 mA	11.64 mA	3.381 mA	25.15 pAh	0.30
17	—	-536.1 ms	237.2 µs	8.020 mA	12.95 mA	2.807 mA	528.4 pAh	6.35
18	—	-535.9 ms	16.53 µs	5.094 mA	11.64 mA	1.047 mA	23.39 pAh	0.28
19	—	-535.8 ms	554.5 µs	2.833 mA	9.163 mA	-2.392 mA	436.4 pAh	5.24
20	—	-535.3 ms	43.98 µs	8.738 mA	10.44 mA	648.6 µA	106.7 pAh	1.28
21	—	-535.2 ms	350.4 µs	8.890 mA	14.43 mA	3.423 mA	865.3 pAh	10.40
22	—	-534.9 ms	16.13 µs	6.483 mA	12.23 mA	1.431 mA	29.04 pAh	0.34
23	—	-534.9 ms	21.99 µs	3.236 mA	3.808 mA	1.747 mA	19.77 pAh	0.23
24	—	-534.9 ms	13.19 µs	8.428 mA	12.17 mA	3.851 mA	30.89 pAh	0.37
25	—	-534.8 ms	219.9 µs	8.044 mA	13.10 mA	3.033 mA	491.4 pAh	5.90
26	—	-534.6 ms	16.13 µs	7.132 mA	12.78 mA	3.248 mA	31.95 pAh	0.38
27	—	-534.6 ms	560.0 µs	3.976 mA	12.06 mA	-2.053 mA	618.5 pAh	7.43
28	Summary	-534.0 ms	5.986 ms	5.001 mA	13.58 mA	-3.161 mA	8.315 nAh	100

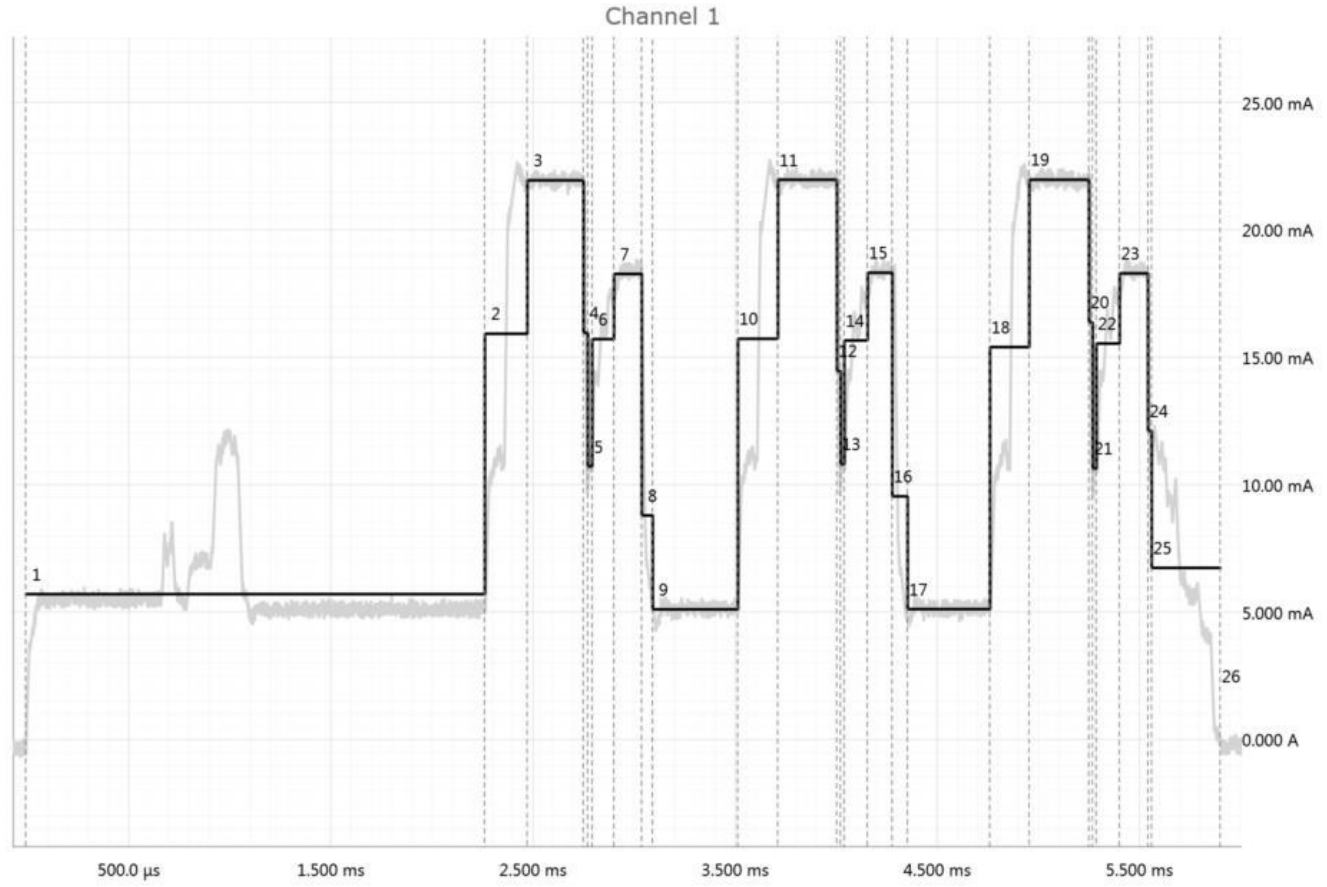

Figure 42. Advertising current profile event after LLS2 mode, bypass mode

Table 29. Advertising current profile event after LLS2 mode, bypass mode

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-9.114 µs	2.271 ms	5.706 mA	12.18 mA	-582.7 µA	3.599 nAh	20.41
2	—	2.262 ms	210.0 µs	15.92 mA	22.69 mA	4.942 mA	928.8 pAh	5.26
3	—	2.472 ms	277.5 µs	21.94 mA	22.43 mA	21.37 mA	1.692 nAh	9.59
4	—	2.749 ms	21.63 µs	15.96 mA	22.07 mA	9.541 mA	95.87 pAh	0.54
5	—	2.771 ms	21.63 µs	10.71 mA	11.45 mA	9.575 mA	64.34 pAh	0.36
6	—	2.793 ms	108.1 µs	15.71 mA	17.78 mA	10.65 mA	471.9 pAh	2.67
7	—	2.901 ms	137.0 µs	18.27 mA	18.87 mA	17.09 mA	695.1 pAh	3.94
8	—	3.038 ms	54.07 µs	8.789 mA	18.72 mA	5.003 mA	132.0 pAh	0.74
9	—	3.092 ms	421.7 µs	5.103 mA	5.661 mA	4.230 mA	597.8 pAh	3.39
10	—	3.514 ms	198.2 µs	15.72 mA	22.91 mA	5.027 mA	865.9 pAh	4.91
11	—	3.712 ms	292.0 µs	21.96 mA	22.45 mA	21.35 mA	1.781 nAh	10.10

Table continues on the next page...

Table 29. Advertising current profile event after LLS2 mode, bypass mode (continued)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
12	—	4.004 ms	18.02 µs	14.45 mA	22.37 mA	9.521 mA	72.36 pAh	0.41
13	—	4.022 ms	18.02 µs	10.80 mA	11.50 mA	9.765 mA	54.06 pAh	0.30
14	—	4.040 ms	115.3 µs	15.66 mA	17.80 mA	10.43 mA	501.6 pAh	2.84
15	—	4.155 ms	122.1 µs	18.31 mA	18.89 mA	17.27 mA	621.1 pAh	3.52
16	—	4.277 ms	76.15 µs	9.540 mA	18.78 mA	4.513 mA	201.8 pAh	1.14
17	—	4.353 ms	407.3 µs	5.114 mA	5.640 mA	4.292 mA	578.6 pAh	3.28
18	—	4.761 ms	194.6 µs	15.40 mA	22.70 mA	4.911 mA	832.4 pAh	4.72
19	—	4.955 ms	295.6 µs	21.96 mA	22.44 mA	21.38 mA	1.803 nAh	10.22
20	—	5.251 ms	18.02 µs	16.37 mA	22.36 mA	9.446 mA	81.95 pAh	0.46
21	—	5.269 ms	18.02 µs	10.64 mA	11.48 mA	9.530 mA	53.24 pAh	0.30
22	—	5.287 ms	115.3 µs	15.54 mA	17.87 mA	10.42 mA	497.8 pAh	2.82
23	—	5.402 ms	140.6 µs	18.29 mA	18.85 mA	17.05 mA	714.2 pAh	4.05
24	—	5.543 ms	18.02 µs	12.11 mA	17.40 mA	10.14 mA	60.61 pAh	0.34
25	—	5.561 ms	339.4 µs	6.733 mA	12.40 mA	-272.3 µA	634.7 pAh	3.59
26	Summary	5.900 ms	5.909 ms	10.74 mA	22.91 mA	-582.7 µA	17.63 nAh	100

4.2.2.12.2 Test environment VLLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
RAM size	16 k	
Data rate	1 Mbps	
Payload	31 bytes	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Advertising Interval = 30 ms Advertise from low power VLLS2 Slave to Master	

Table continues on the next page...

Table continued from the previous page...

Software	Low Power (PRC3 release)

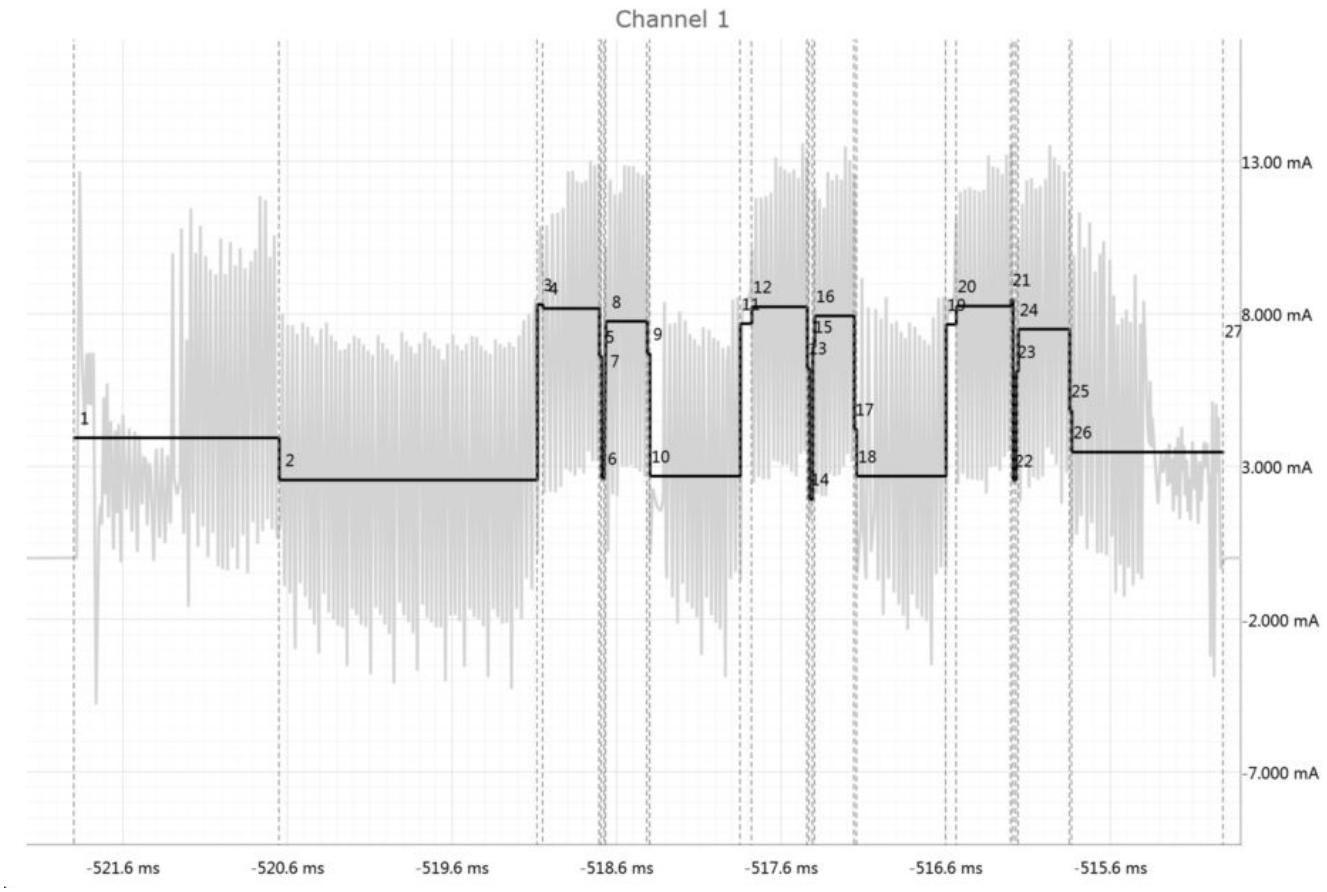

Figure 43. Advertising current profile event after VLLS2 mode, Buck mode

Table 30. Advertising current profile event after VLLS2 mode, Buck mode

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-521.9 ms	1.247 ms	3.941 mA	12.85 mA	-4.796 mA	1.365 nAh	15.49
2	—	-520.6 ms	1.568 ms	2.556 mA	8.586 mA	-4.292 mA	1.113 nAh	12.63
3	—	-519.1 ms	33.74 µs	8.305 mA	10.95 mA	136.1 µA	77.83 pAh	0.88
4	—	-519.0 ms	343.0 µs	8.175 mA	13.03 mA	2.120 mA	779.0 pAh	8.84
5	—	-518.7 ms	13.61 µs	6.609 mA	12.63 mA	3.120 mA	24.98 pAh	0.28
6	—	-518.7 ms	17.16 µs	2.620 mA	2.600 mA	2.389 mA	12.49 pAh	0.14
7	—	-518.7 ms	8.873 µs	5.813 mA	9.365 mA	3.436 mA	14.33 pAh	0.16
8	—	-518.7 ms	250.8 µs	7.754 mA	12.91 mA	137.0 µA	540.2 pAh	6.13

Table continues on the next page...

Table 30. Advertising current profile event after VLLS2 mode, Buck mode (continued)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
9	—	-518.4 ms	17.16 µs	6.692 mA	12.45 mA	578.5 µA	31.89 pAh	0.36
10	—	-518.4 ms	548.9 µs	2.683 mA	8.576 mA	-3.896 mA	409.0 pAh	4.64
11	—	-517.8 ms	69.72 µs	7.678 mA	9.804 mA	-702.7 µA	148.7 pAh	1.68
12	—	-517.8 ms	336.7 µs	8.230 mA	13.58 mA	2.462 mA	769.7 pAh	8.73
13	—	-517.4 ms	12.84 µs	6.218 mA	12.50 mA	1.207 mA	22.18 pAh	0.25
14	—	-517.4 ms	20.18 µs	1.928 mA	2.654 mA	1.113 mA	10.81 pAh	0.12
15	—	-517.4 ms	12.84 µs	6.921 mA	11.60 mA	2.910 mA	24.69 pAh	0.28
16	—	-517.4 ms	239.4 µs	7.931 mA	13.47 mA	2.022 mA	527.5 pAh	5.98
17	—	-517.2 ms	15.59 µs	4.223 mA	11.16 mA	-40.55 µA	18.29 pAh	0.20
18	—	-517.1 ms	542.2 µs	2.684 mA	9.167 mA	-3.509 mA	404.2 pAh	4.58
19	—	-516.6 ms	62.96 µs	7.651 mA	11.16 mA	-273.9 µA	133.8 pAh	1.51
20	—	-516.5 ms	331.4 µs	8.253 mA	13.31 mA	2.115 mA	759.8 pAh	8.62
21	—	-516.2 ms	13.99 µs	8.458 mA	13.54 mA	3.192 mA	32.87 pAh	0.37
22	—	-516.2 ms	17.49 µs	2.543 mA	2.719 mA	2.361 mA	12.35 pAh	0.14
23	—	-516.2 ms	13.99 µs	6.118 mA	10.43 mA	2.662 mA	23.78 pAh	0.26
24	—	-516.2 ms	311.3 µs	7.496 mA	13.53 mA	1.694 mA	648.3 pAh	7.25
25	—	-515.8 ms	13.80 µs	3.832 mA	10.75 mA	978.3 µA	18.53 pAh	0.21
26	—	-515.8 ms	918.9 µs	3.471 mA	11.32 mA	-3.887 mA	885.9 pAh	10.05
27	Summary	-514.9 ms	6.981 ms	4.542 mA	13.58 mA	-4.796 mA	8.809 nAh	100

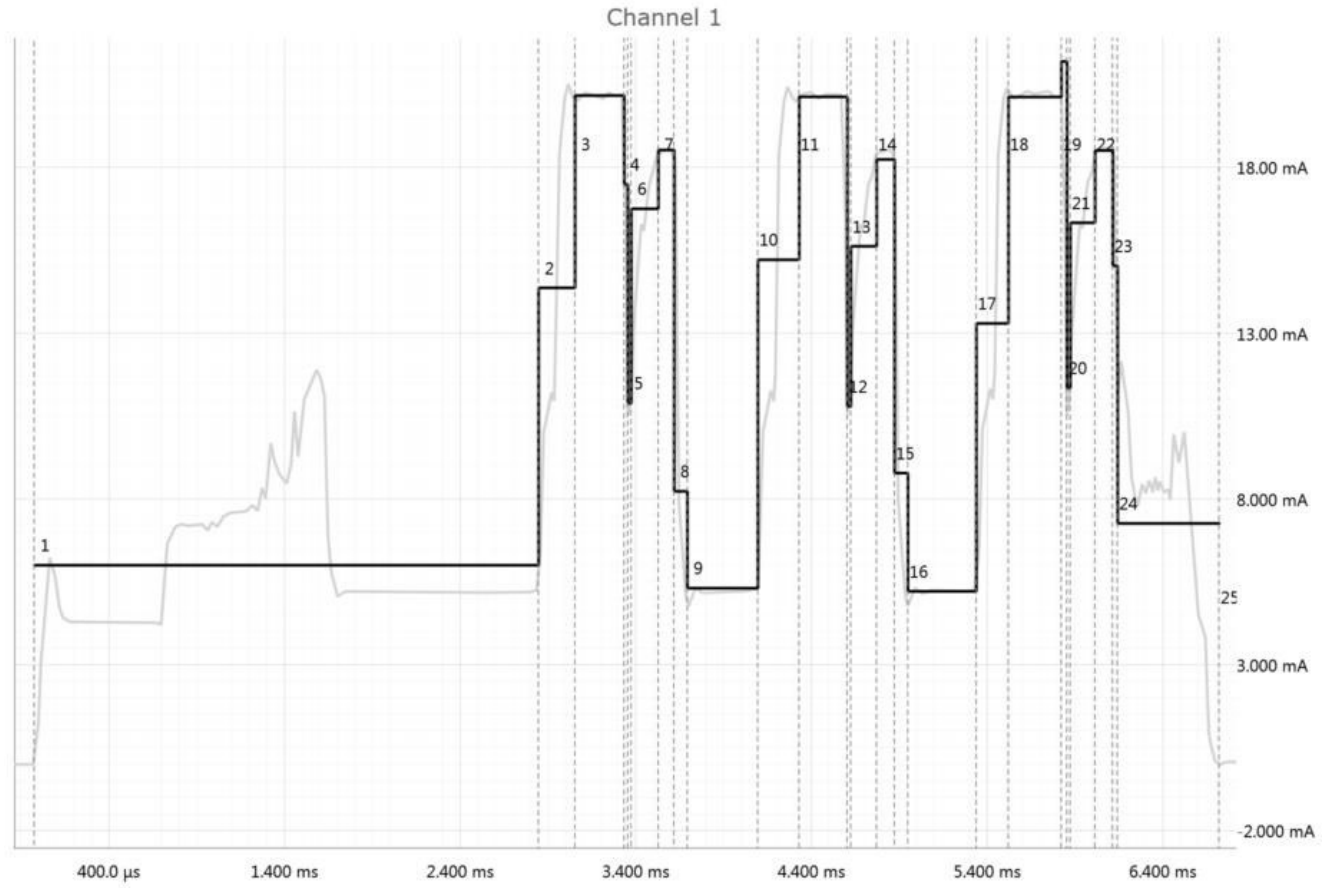

Figure 44. Advertising current profile event after VLLS2 mode, Bypass mode

Table 31. Advertising current profile event after VLLS2 mode, Bypass mode

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-24.12 µs	2.871 ms	6.000 mA	11.89 mA	-12.62 µA	4.784 nAh	25.43
2	—	2.846 ms	207.5 µs	14.37 mA	20.63 mA	6.381 mA	828.2 pAh	4.40
3	—	3.054 ms	279.6 µs	20.17 mA	20.30 mA	19.97 mA	1.566 nAh	8.32
4	—	3.334 ms	20.75 µs	17.48 mA	20.07 mA	16.25 mA	100.8 pAh	0.53
5	—	3.354 ms	19.66 µs	10.89 mA	10.94 mA	10.49 mA	59.47 pAh	0.31
6	—	3.374 ms	154.0 µs	16.75 mA	18.44 mA	10.93 mA	716.6 pAh	3.80
7	—	3.528 ms	89.82 µs	18.52 mA	18.54 mA	18.45 mA	462.1 pAh	2.45
8	—	3.618 ms	75.75 µs	8.232 mA	18.21 mA	5.067 mA	173.2 pAh	0.92
9	—	3.694 ms	401.2 µs	5.308 mA	5.386 mA	4.748 mA	591.5 pAh	3.14
10	—	4.095 ms	235.2 µs	15.21 mA	20.51 mA	6.414 mA	994.0 pAh	5.28
11	—	4.330 ms	274.0 µs	20.13 mA	20.33 mA	10.55 mA	1.532 nAh	8.14

Table continues on the next page...

Table 31. Advertising current profile event after VLLS2 mode, Bypass mode (continued)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
12	—	4.604 ms	20.30 µs	10.79 mA	10.97 mA	10.95 mA	60.84 pAh	0.32
13	—	4.624 ms	146.7 µs	15.62 mA	18.34 mA	13.09 mA	636.4 pAh	3.38
14	—	4.771 ms	101.5 µs	18.24 mA	18.57 mA	18.48 mA	514.1 pAh	2.73
15	—	4.873 ms	76.57 µs	8.781 mA	18.26 mA	4.765 mA	186.8 pAh	0.99
16	—	4.949 ms	389.5 µs	5.215 mA	5.360 mA	4.799 mA	564.2 pAh	2.99
17	—	5.339 ms	183.0 µs	13.29 mA	20.43 mA	5.314 mA	675.8 pAh	3.59
18	—	5.522 ms	300.9 µs	20.12 mA	20.33 mA	20.00 mA	1.682 nAh	8.93
19	—	5.822 ms	31.67 µs	21.19 mA	20.19 mA	10.51 mA	186.5 pAh	0.99
20	—	5.854 ms	19.36 µs	11.34 mA	10.99 mA	10.99 mA	60.99 pAh	0.32
21	—	5.873 ms	140.8 µs	16.33 mA	18.38 mA	13.10 mA	638.5 pAh	3.39
22	—	6.014 ms	100.3 µs	18.51 mA	18.63 mA	18.54 mA	515.6 pAh	2.74
23	—	6.115 ms	28.15 µs	15.03 mA	18.30 mA	11.03 mA	117.6 pAh	0.62
24	—	6.143 ms	577.7 µs	7.261 mA	12.15 mA	-64.14 µA	1.165 nAh	6.19
25	Summary	6.720 ms	6.745 ms	10.04 mA	20.63 mA	-64.14 µA	18.82 nAh	100

4.2.2.12.3 Advertising connectable vs non-connectable comparison

DCDC: mode	BYPASS
Supply	VDDRF = 3.6 V VDDMCU = 3.6 V
RF output power	+0 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	1 Mbps
Payload	31 bytes
Connectable	Yes vs No
Flash	Doze
MCU	Stop
Setting	Advertising Interval = 30 ms Advertise from low power VLLS2 Slave to Master
Software	Low Power (PRC3 release)

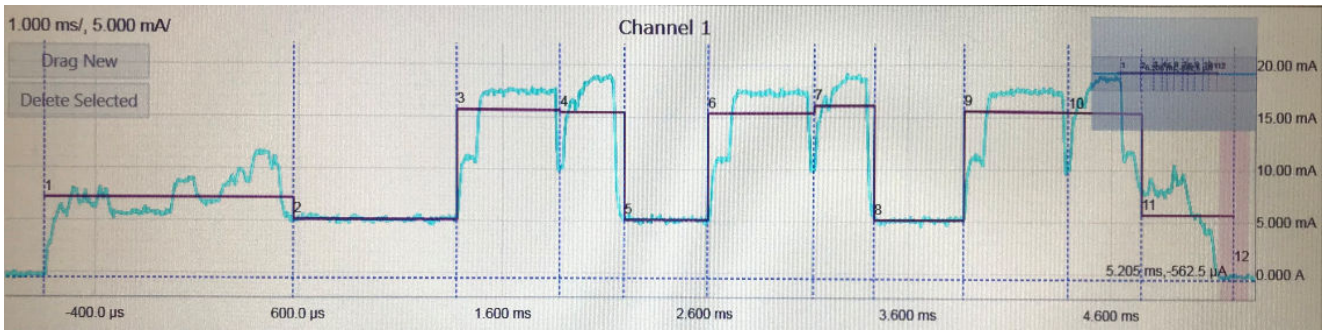

Figure 45. Advertising current profile event after VLLS2 mode, bypass mode, connectable

Table 32. Advertising current profile event after VLLS2 mode, bypass mode, connectable

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio (%)
1	—	-647.3 µs	1.224 ms	7.173 mA	12.14 mA	-723.2 µA	2.439 nAh	14.86
2	—	576.6 µs	797.0 µs	5.102 mA	5.753 mA	4.315 mA	1.130 nAh	6.88
3	—	1.374 ms	506.7 µs	15.64 mA	18.05 mA	4.844 mA	2.201 nAh	13.41
4	—	1.880 ms	318.8 µs	15.46 mA	19.21 mA	4.736 mA	1.369 nAh	8.34
5	—	2.199 ms	415.6 µs	5.115 mA	5.681 mA	4.452 mA	590.4 pAh	3.60
6	—	2.615 ms	523.7 µs	15.39 mA	18.00 mA	4.720 mA	2.238 nAh	13.64
7	—	3.138 ms	296.0 µs	16.10 mA	19.25 mA	5.024 mA	1.324 nAh	8.07
8	—	3.434 ms	438.3 µs	5.129 mA	5.772 mA	4.459 mA	624.5 pAh	3.81
9	—	3.873 ms	512.3 µs	15.57 mA	18.05 mA	4.805 mA	2.216 nAh	13.50
10	—	4.385 ms	364.3 µs	15.41 mA	19.29 mA	7.661 mA	1.559 nAh	9.50
11	—	4.749 ms	455.4 µs	5.677 mA	10.53 mA	-798.3 µA	718.2 pAh	4.38
12	Summary	5.205 ms	5.852 ms	10.09 mA	19.29 mA	-798.3 µA	16.41 nAh	100.00

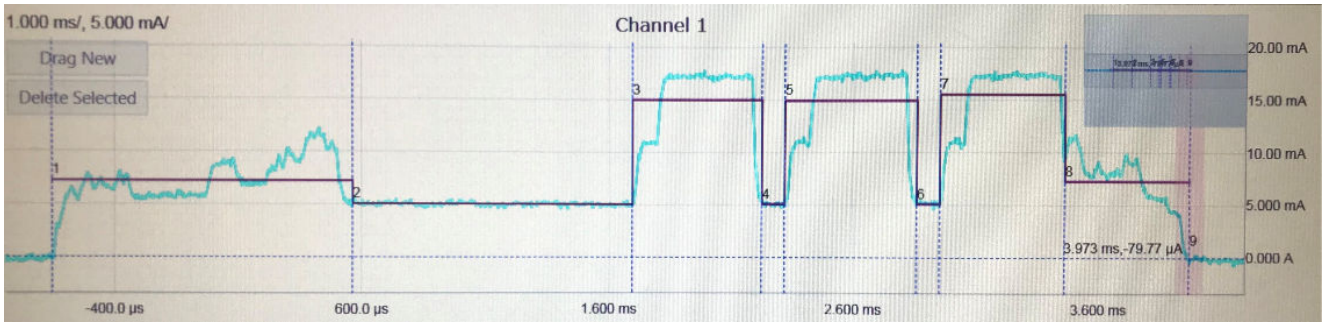

Figure 46. Advertising current profile event after VLLS2 mode, bypass mode, non-connectable

Table 33. Advertising current profile event after VLLS2 mode, bypass mode, non-connectable

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio (%)
1	—	-648.6 µs	1.213 ms	7.205 mA	12.25 mA	-661.1 µA	2.427 nAh	20.33

Table continues on the next page...

Table 33. Advertising current profile event after VLLS2 mode, bypass mode, non-connectable (continued)

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio (%)
2	—	564.0 µs	1.133 ms	5.034 mA	5.720 mA	4.344 mA	1.585 nAh	13.28
3	—	1.697 ms	531.7 µs	15.01 mA	17.91 mA	4.707 mA	2.217 nAh	18.57
4	—	2.229 ms	93.28 µs	5.068 mA	5.805 mA	4.439 mA	131.3 pAh	1.10
5	—	2.322 ms	536.4 µs	14.93 mA	17.89 mA	4.655 mA	2.225 nAh	18.64
6	—	2.859 ms	93.28 µs	5.068 mA	5.628 mA	4.518 mA	131.3 pAh	1.10
7	—	2.952 ms	508.4 µs	15.51 mA	17.91 mA	4.743 mA	2.190 nAh	18.34
8	—	3.460 ms	513.0 µs	7.239 mA	12.06 mA	-445.4 µA	1.032 nAh	8.64
9	Summary	3.973 ms	4.622 ms	9.298 mA	17.91 mA	-661.1 µA	11.94 nAh	100.00

Advertising connectable power consumption is equal to 10.09 mA during 5.85 ms (16.41 nAh).

Advertising non-connectable power consumption is equal to 9.3 mA during 4.62 ms (11.94 nAh).

Table 34. Connectable vs non-connectable advertising comparison

Connectable	Duration event (ms)	Power consumption (mA)	Total power (nAh)
No	5.85	10.09	16.41
Yes	4.62	9.3	11.94

4.2.2.12.4 RAM OFF

Two power modes can be used for RAM off during Advertising: VLLS1 or Pswitch mode.

NOTE

For both VLLS1 and Pswitch modes, DCDC shall be configured in buck mode.

- RAM OFF in VLLS1 mode
- RAM OFF in Pswitch mode

4.2.2.12.4.1 Pswitch

When using Pswitch mode, the device advertises on wake-up from Pswitch IO wake-up only.

The FRDM-KW38 jumpers are in buck configuration.

The KW38 device enter in advertising mode automatically after power up.

The binary file setting used are:

- **Buck mode**: FEE 48 MHz clock mode, advertising wakeup after Pswitch with payload and connectable

DCDC: mode	BUCK
Supply	VDDRF = 3.6 V VDDMCU = 3.6 V
RF output power	+5 dBm

Table continues on the next page...

Table continued from the previous page...

MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	1 Mbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Advertising Interval = 30 ms Advertise from low power VLLS2 Slave to Master
Software	Low Power (PRC3 release)

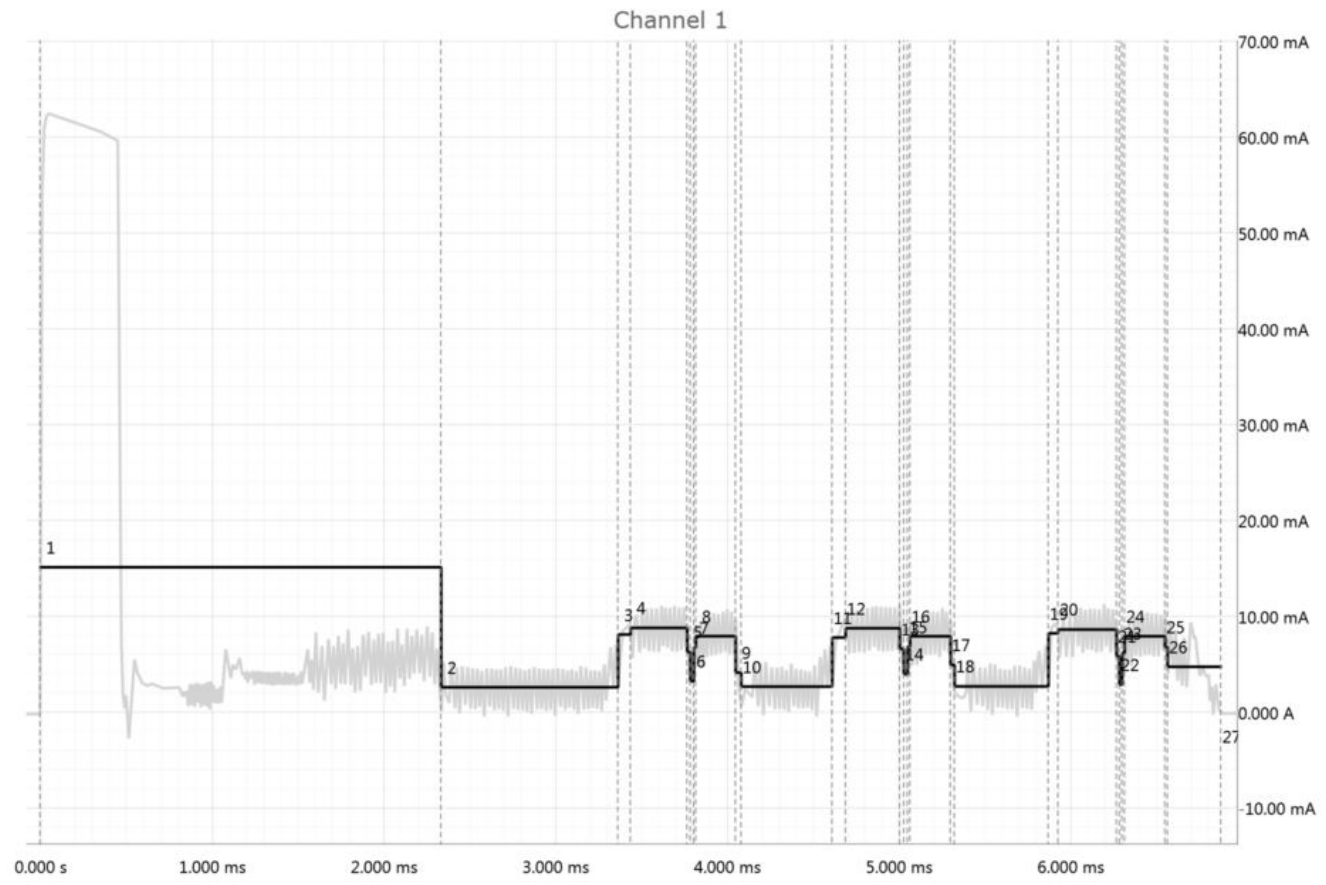

Figure 47. RAM OFF Pswitch Advertising event after VLLS2 mode, buck mode, connectable

Table 35. RAM OFF Pswitch Advertising event after VLLS2 mode, buck mode, connectable

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-3.858 µs	2.336 ms	15.12 mA	62.78 mA	-3.231 mA	9.807 nAh	59.48
2	—	2.332 ms	1.031 ms	2.593 mA	7.586 mA	-997.6 µA	742.2 pAh	4.50
3	—	3.362 ms	72.86 µs	8.093 mA	9.606 mA	2.552 mA	163.8 pAh	0.99
4	—	3.435 ms	329.4 µs	8.792 mA	11.73 mA	5.251 mA	804.4 pAh	4.87
5	—	3.765 ms	18.96 µs	6.268 mA	9.786 mA	3.196 mA	33.02 pAh	0.20
6	—	3.784 ms	19.96 µs	3.228 mA	3.727 mA	2.799 mA	17.90 pAh	0.10
7	—	3.803 ms	11.98 µs	6.735 mA	9.427 mA	3.348 mA	22.41 pAh	0.13
8	—	3.815 ms	231.6 µs	7.932 mA	11.12 mA	4.307 mA	510.2 pAh	3.09
9	—	4.047 ms	32.94 µs	4.128 mA	10.18 mA	310.9 µA	37.77 pAh	0.22
10	—	4.080 ms	529.4 µs	2.674 mA	7.241 mA	-932.3 µA	393.2 pAh	2.38
11	—	4.609 ms	78.13 µs	7.784 mA	10.52 mA	2.265 mA	168.9 pAh	1.02
12	—	4.687 ms	315.6 µs	8.755 mA	11.49 mA	5.588 mA	767.5 pAh	4.65
13	—	5.003 ms	23.98 µs	6.590 mA	11.22 mA	4.168 mA	43.90 pAh	0.26
14	—	5.027 ms	21.66 µs	3.968 mA	4.632 mA	3.521 mA	23.88 pAh	0.14
15	—	5.049 ms	14.70 µs	6.832 mA	9.744 mA	3.495 mA	27.89 pAh	0.16
16	—	5.063 ms	235.2 µs	7.922 mA	11.23 mA	4.349 mA	517.5 pAh	3.13
17	—	5.299 ms	23.98 µs	4.926 mA	9.945 mA	1.827 mA	32.81 pAh	0.19
18	—	5.323 ms	546.5 µs	2.691 mA	7.460 mA	-922.5 µA	408.5 pAh	2.47
19	—	5.869 ms	56.67 µs	8.230 mA	9.745 mA	2.284 mA	129.6 pAh	0.78

Table continues on the next page...

Table 35. RAM OFF Pswitch Advertising event after VLLS2 mode, buck mode, connectable (continued)

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
20	—	5.926 ms	340.0 µs	8.625 mA	11.71 mA	5.236 mA	814.7 pAh	4.94
21	—	6.266 ms	17.20 µs	5.828 mA	9.503 mA	2.959 mA	27.85 pAh	0.16
22	—	6.283 ms	15.18 µs	2.862 mA	3.325 mA	2.412 mA	12.07 pAh	0.07
23	—	6.298 ms	15.18 µs	6.162 mA	9.275 mA	2.654 mA	25.99 pAh	0.15
24	—	6.313 ms	234.8 µs	7.921 mA	10.87 mA	4.269 mA	516.6 pAh	3.13
25	—	6.548 ms	15.18 µs	6.776 mA	10.30 mA	3.804 mA	28.57 pAh	0.17
26	—	6.563 ms	310.7 µs	4.738 mA	9.784 mA	-716.6 µA	408.9 pAh	2.48
27	—	6.874 ms	6.878 ms	8.630 mA	62.78 mA	-3.231 mA	16.49 nAh	100

Table 36. RAM OFF Advertising event current consumption after Pswitch in buck mode

`Vdcdc_in` = 3.6 V		ms	mA	nAh
Advertising	buck	6.88	8.63	16.49

4.2.2.12.4.2 VLLS1

When using VLLS1, the device wakes up on low-power timer expiration given by the usual flag `gAppAdvertisingInterval`. The device also wakes up and Advertise on any other wake-up source such as IO wake-up as for mode 9.

DCDC: mode	BUCK
Supply	VDDRF = 3.6 V VDDMCU = 3.6 V
RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	1 Mbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop

Table continues on the next page...

Table continued from the previous page...

Setting	Advertising Interval = 30 ms Advertise from low power VLLS1 Slave to Master
Software	Low Power (PRC3 release)

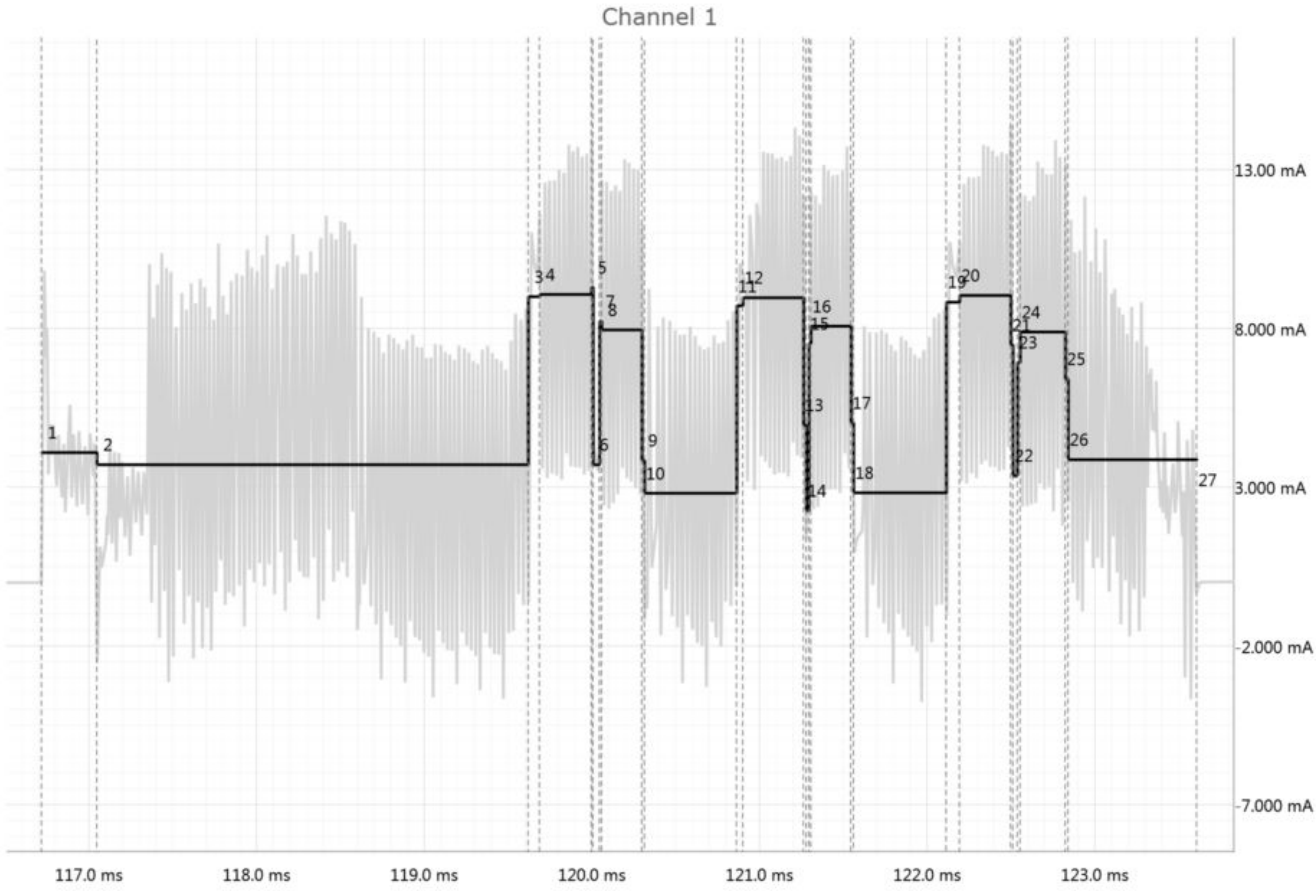

Figure 48. RAM OFF Pswitch Advertising event after VLLS1 mode, buck mode, connectable

Table 37. RAM OFF Pswitch Advertising event after VLLS1 mode, buck mode, connectable

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	116.7 ms	330.1 µs	4.088 mA	9.885 mA	-2.416 mA	374.9 pAh	3.91
2	—	117.0 ms	2.572 ms	3.705 mA	11.70 mA	-3.700 mA	2.647 nAh	27.66
3	—	119.6 ms	67.54 µs	8.996 mA	11.31 mA	-629.5 µA	168.8 pAh	1.76

Table continues on the next page...

Table 37. RAM OFF Pswitch Advertising event after VLLS1 mode, buck mode, connectable (continued)

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
4	—	119.7 ms	309.1 µs	9.067 mA	13.86 mA	3.163 mA	778.6 pAh	9.13
5	—	120.0 ms	10.39 µs	9.286 mA	14.01 mA	4.862 mA	26.80 pAh	0.28
6	—	120.0 ms	38.10 µs	3.703 mA	4.417 mA	3.368 mA	39.19 pAh	0.40
7	—	120.0 ms	12.99 µs	8.225 mA	12.65 mA	3.602 mA	29.68 pAh	0.31
8	—	120.1 ms	239.9 µs	7.951 mA	13.45 mA	2.286 mA	529.8 pAh	5.53
9	—	120.3 ms	15.91 µs	3.846 mA	10.96 mA	-1.301 mA	17.00 pAh	0.17
10	—	120.3 ms	549.2 µs	2.807 mA	9.356 mA	-3.393 mA	428.2 pAh	4.47
11	—	120.9 ms	37.72 µs	8.709 mA	10.14 mA	412.2 µA	91.26 pAh	0.95
12	—	120.9 ms	361.2 µs	8.964 mA	14.33 mA	2.886 mA	899.3 pAh	9.40
13	—	121.3 ms	16.03 µs	4.950 mA	12.06 mA	1.310 mA	22.04 pAh	0.23
14	—	121.3 ms	16.03 µs	2.264 mA	2.895 mA	1.489 mA	10.08 pAh	0.10
15	—	121.3 ms	12.26 µs	7.521 mA	12.24 mA	3.024 mA	25.61 pAh	0.26
16	—	121.3 ms	238.6 µs	8.068 mA	13.76 mA	2.136 mA	534.7 pAh	5.58
17	—	121.5 ms	16.03 µs	5.026 mA	12.22 mA	791.9 µA	22.38 pAh	0.23
18	—	121.6 ms	552.7 µs	2.819 mA	8.728 mA	-3.762 mA	432.8 pAh	4.52
19	—	122.1 ms	79.27 µs	8.824 mA	10.81 mA	-1.068 mA	194.3 pAh	2.03
20	—	122.2 ms	305.0 µs	9.036 mA	14.41 mA	3.015 mA	765.6 pAh	8.00
21	—	122.5 ms	13.79 µs	7.478 mA	13.76 mA	3.657 mA	28.64 pAh	0.29
22	—	122.5 ms	25.85 µs	3.360 mA	3.563 mA	3.128 mA	24.12 pAh	0.25

Table continues on the next page...

Table 37. RAM OFF Pswitch Advertising event after VLLS1 mode, buck mode, connectable (continued)

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
23	—	122.5 ms	17.03 µs	6.923 mA	12.39 mA	3.386 mA	32.74 pAh	0.34
24	—	122.6 ms	269.0 µs	7.886 mA	14.04 mA	1.722 mA	589.3 pAh	6.16
25	—	122.8 ms	17.23 µs	6.398 mA	13.23 mA	2.418 mA	30.62 pAh	0.32
26	—	122.8 ms	766.8 µs	3.864 mA	12.24 mA	-3.686 mA	823.1 pAh	8.60
27	—	123.6 ms	6.890 ms	4.998 mA	14.41 mA	-3.762 mA	9.567 nAh	100

Table 38. RAM OFF Advertising event current consumption after Pswitch in buck mode

Vdcdc_in = 3.6 V		ms	mA	nAh
Advertising	buck	6.89	5.0	9.57

4.2.2.12.5 Summary

Table 39. Detail current profile during advertising event

48 MHz FEE mode using 32 KHz crystal	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
Advertising consumption on 1 event @ +5dBm	6.46 ms	7 ms	5.9 ms	6.75 ms
	4.63 mA	4.54 mA	10.74 mA	8.08 mA
	8.3 nAh	**10.04 nAh**	**17.6 nAh**	**18.81 nAh**
Advertising consumption details @+5dBm				
TX Active (+5dBm, PA_POWER = 0x62) + MCU STOP	**7.86**	**7.85**	**21.52**	**21.14**
RX Active + MCU STOP	**6.34**	**6.22**	**17.29**	**17.42**
TX Warm-up + MCU STOP	4.87	2.40	9.67	9.12
TX Warm-down + MCU STOP	4.11	5.43	13.69	14.23
RX warm-up + MCU STOP	3.89	4.86	10.94	11.50
Rx warm-down + MCU STOP	1.51	1.65	8.79	8.23
Tx to Rx transition + MCU STOP (Advertising event)	2.40	2.08	10.71	10.89

Table 40. Pre and post processing timing during advertising

Radio/Profile timing parameters (ms)	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
48 MHz FEE mode using 32 KHz crystal	T = 25 °C			
ADV pre-processing time (ms)	2.36	2.86	2.27	2.87
ADV post-processing time (µs)	865	922	339	578

Table 41. Pre and post processing and MCU consumption during advertising

48 MHz FEE mode using 32 KHz crystal	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
ADV pre-processing (mA)	3.01	3.31	6.01	5.66
Radio post-processing (mA)	3.1	3.44	5.86	6.9
MCU STOP (mA)	2.39	2.42	5.52	5.25

Table 42. Advertising current consumption event

Vdcdc_in = 3.6 V		LLS2 (ms)	LLS2 (mA)	LLS2 (nAh)	VLLS2 (ms)	VLLS2 (mA)	VLLS2 (nAh)
Advertising	buck	6.46	4.63	8.31	7.30	4.15	8.41
	bypass	5.90	10.74	17.60	6.75	9.54	17.89

4.2.2.13 MCU consumption

MCU consumption measurement is performed by placing the current probe on jumper J29. The power supply is always applied on jumper J35-2.

Figure 49 shows the current consumption of the MCU (1P8) during the advertising event.

The binary file settings used are: FEE 48 MHz clock, Advertising with 37 bytes payload and connectable, RF output +5 dBm

- **Buck mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2
- **Bypass mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2

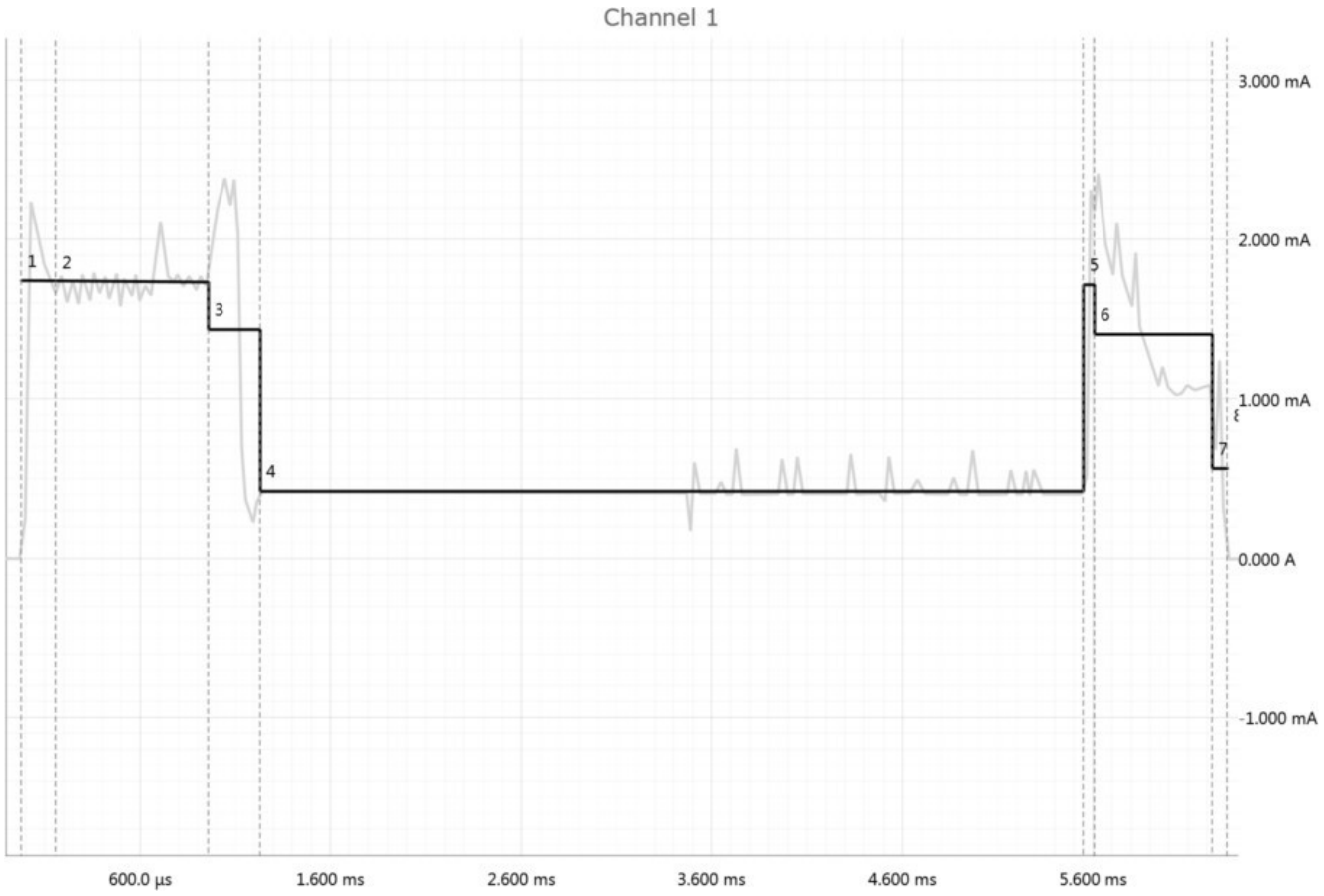

Figure 49. MCU current consumption

Table 43. MCU events

Phase	MCU event timing
1	Pre-processing rise time
2	Pre-processing
3	Pre-processing fall time
4	MCU stop
5	Post-processing rise time
6	Post-processing
7	Post-processing fall time

4.2.2.13.1 Test environment MCU LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V

Table continues on the next page...

Table continued from the previous page...

RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 K
DAta rate	1 Mbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Advertising Interval = 30 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC3 release)

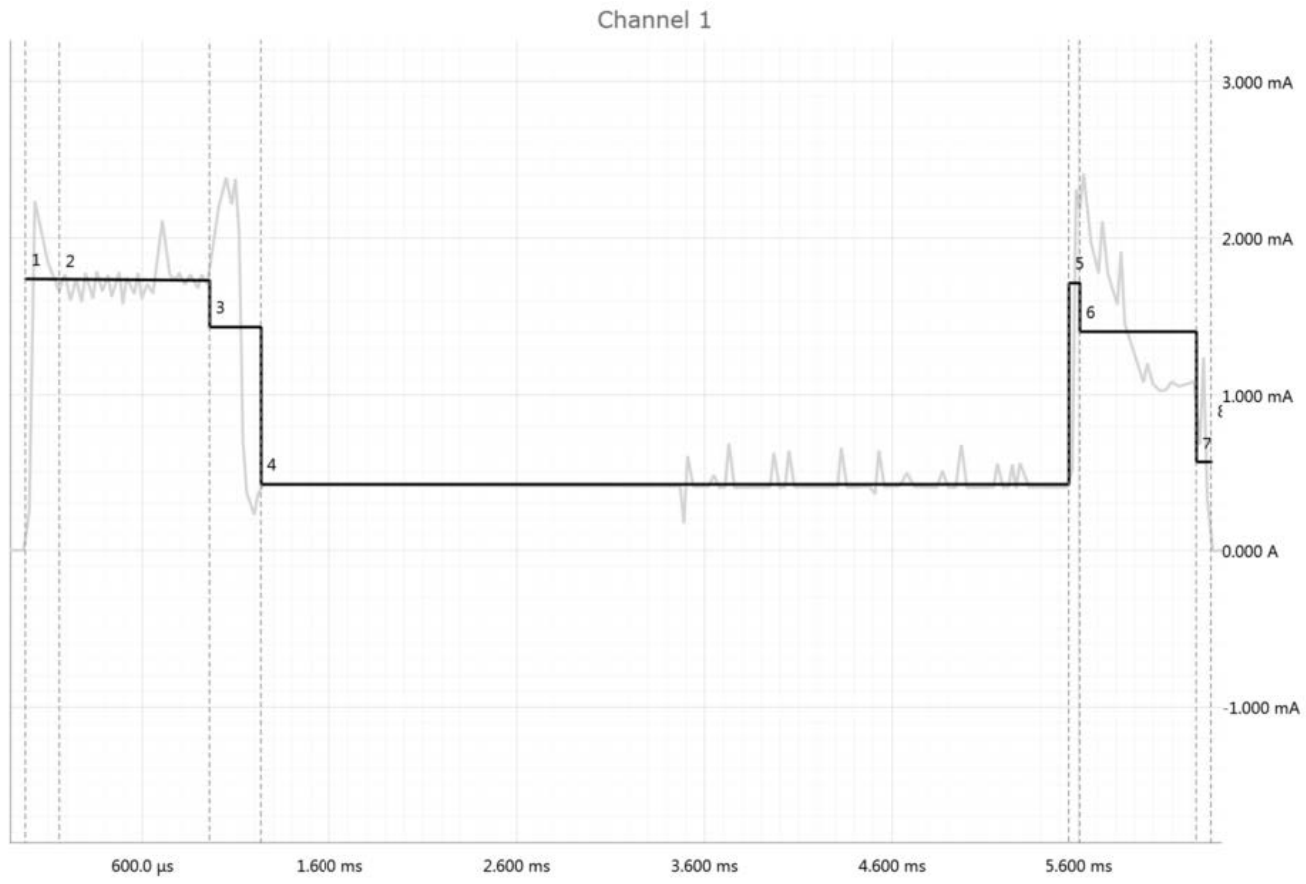

Figure 50. MCU profile in Buck mode, LLS2 (MCU Stop, Flash Doze)

Table 44. MCU current consumption in Buck mode, LLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-22.41 µs	180.9 µs	1.739 mA	2.252 mA	246.7 µA	87.39 pAh	6.39
2	—	185.5 µs	799.7 µs	1.730 mA	2.126 mA	1.578 mA	384.3 pAh	28.11
3	—	958.2 µs	273.5 µs	1.432 mA	2.399 mA	226.3 µA	108.8 fAh	7.96
4	—	1.232 ms	4.316 ms	420.7 µA	689.1 µA	173.0 µA	504.5 pAh	36.90
5	—	5.548 ms	58.23 µs	1.713 mA	2.311 mA	512.0 µA	27.71 pAh	2.02
6	—	5.606 ms	620.6 µs	1.403 mA	2.412 mA	1.012 mA	241.8 pAh	17.69
7	—	6.227 ms	78.97 µs	563.7 µA	1.240 mA	-7.432 µA	12.37 pAh	0.90
8	Summary	6.306 ms	6.328 ms	777.6 µA	2.412 mA	-7.432 µA	1.367 nAh	100

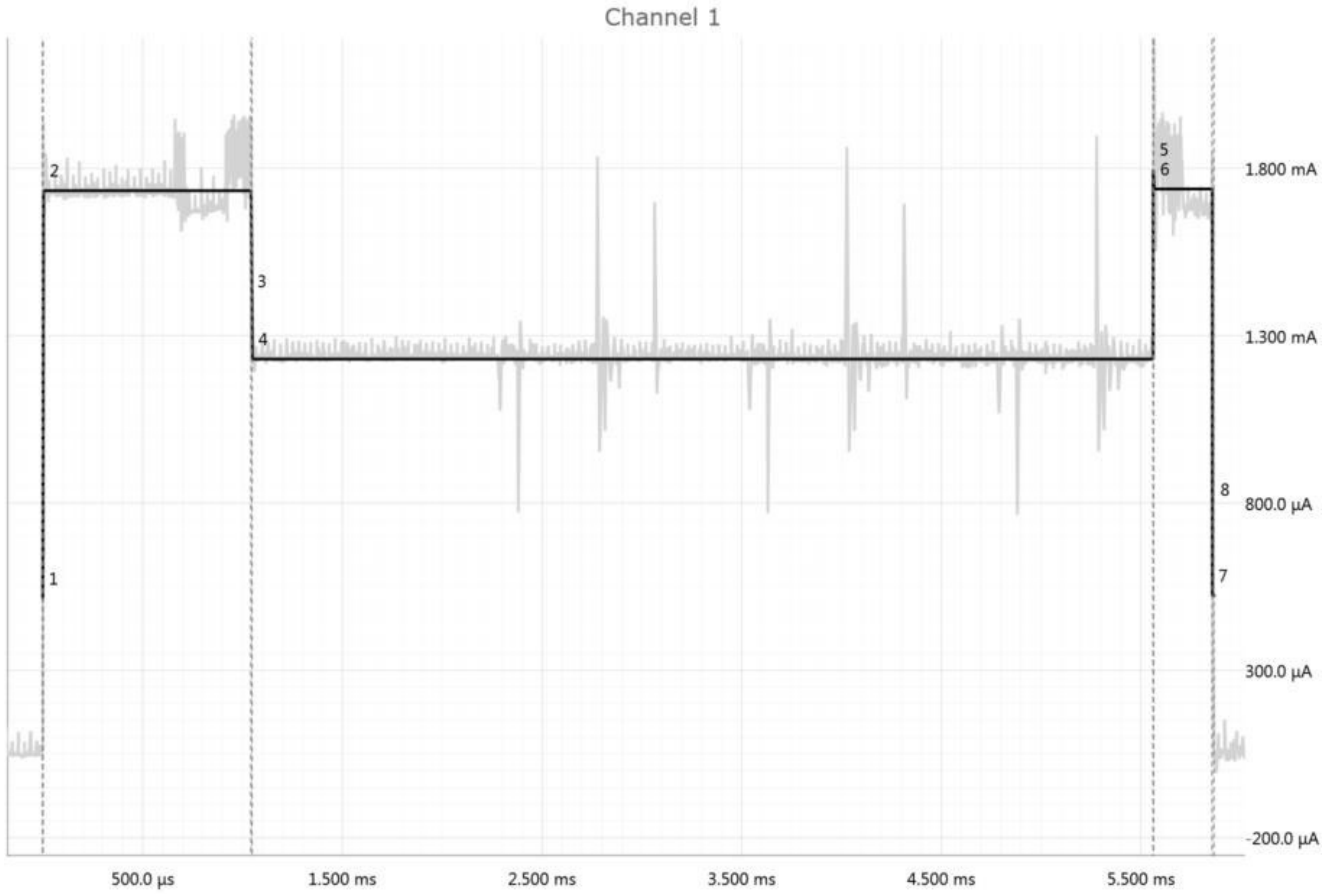

Figure 51. MCU profile in Bypass mode, LLS2 (MCU Stop, Flash Doze)

Table 45. MCU current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-837.9 ns	3.676 µs	514.7 µA	1.947 mA	31.87 µA	525.6 fAh	0.02
2	—	2.838 µs	1.040 ms	1.733 mA	1.973 mA	624.7 µA	500.9 pAh	22.87
3	—	1.043 ms	6.126 µs	1.403 mA	1.905 mA	1.235 mA	2.387 pAh	0.10
4	—	1.049 ms	4.512 ms	1.230 mA	1.907 mA	755.9 µA	1.542 nAh	70.39
5	—	5.561 ms	3.946 µs	1.796 mA	2.718 mA	1.227 mA	1.969 pAh	0.08
6	—	5.565 ms	292.0 µs	1.738 mA	2.138 mA	1.544 mA	141.0 pAh	6.43
7	—	5.857 ms	9.584 µs	523.4 µA	1.852 mA	38.13 µA	1.393 pAh	0.06
8	Summary	5.867 ms	5.868 ms	1.344 mA	2.718 mA	31.87 µA	2.190 nAh	100

4.2.2.13.2 Test environment MCU VLLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
Payload	31 bytes	
RAM	16 k	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Advertising Interval = 30 ms Advertise from low power VLLS2 Slave to Master	
Software	Low Power (PRC3 release)	

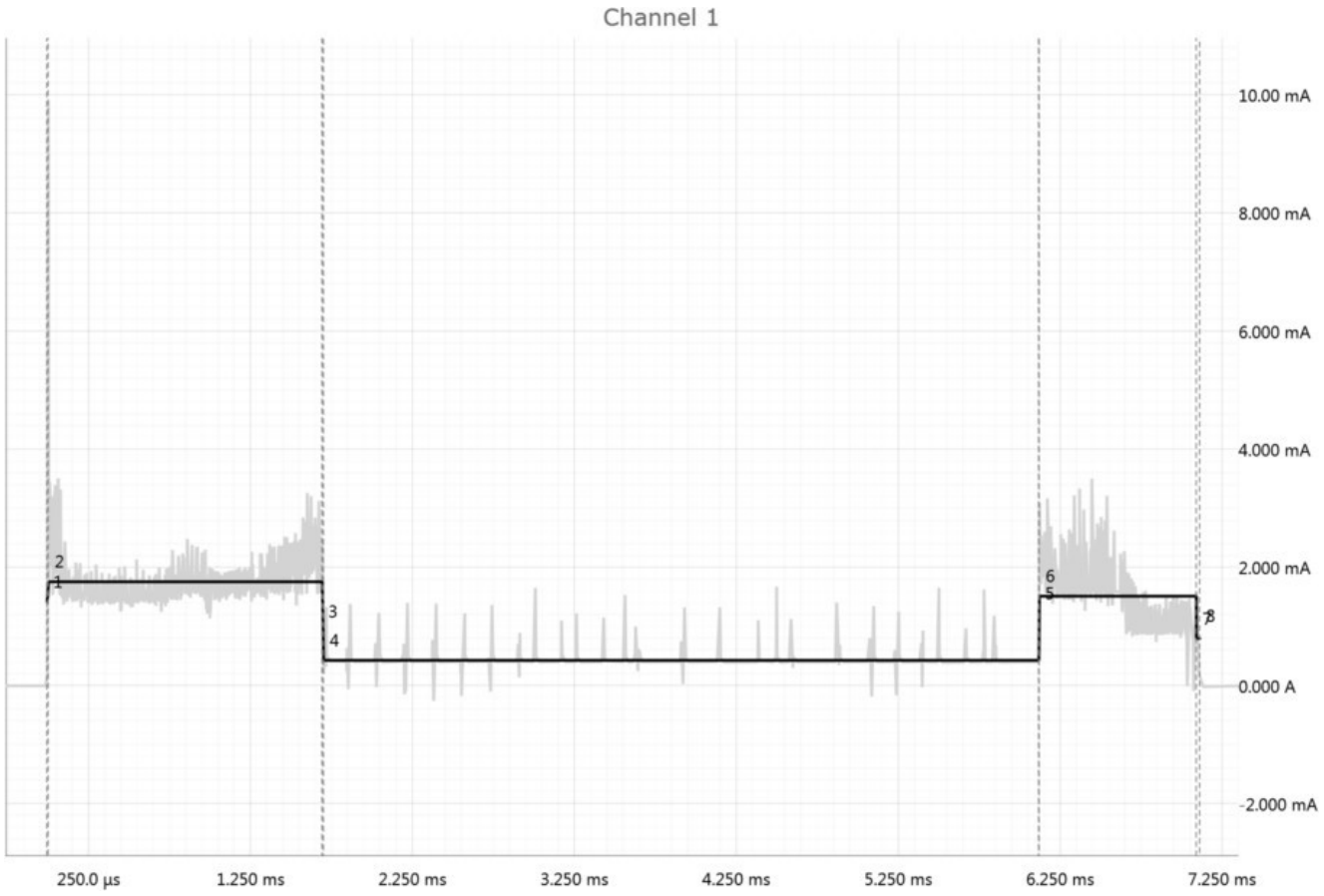

Figure 52. MCU profile in Buck mode, VLLS2 (MCU Stop, Flash Doze)

Table 46. MCU current consumption in Buck mode, VLLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-6.621 µs	8.747 µs	1.413 mA	9.942 mA	-28.55 µA	3.433 pAh	0.19
2	—	2.126 µs	1.690 ms	1.754 mA	3.574 mA	1.095 mA	823.3 pAh	46.76
3	—	1.692 ms	8.747 µs	916.9 µA	2.545 mA	123.6 µA	2.228 pAh	0.12
4	—	1.701 ms	4.417 ms	423.4 µA	1.792 mA	-353.9 µA	519.5 pAh	29.50
5	—	6.118 ms	3.007 µs	1.218 mA	3.011 mA	353.6 µA	1.018 pAh	0.05
6	—	6.121 ms	969.7 µs	1.509 mA	3.567 mA	-150.9 µA	406.6 pAh	23.09
7	—	7.091 ms	21.05 µs	792.8 µA	1.490 mA	-61.77 µA	4.635 pAh	0.26
8	Summary	7.112 ms	7.119 ms	890.4 µA	9.942 mA	-353.9 µA	1.761 nAh	100

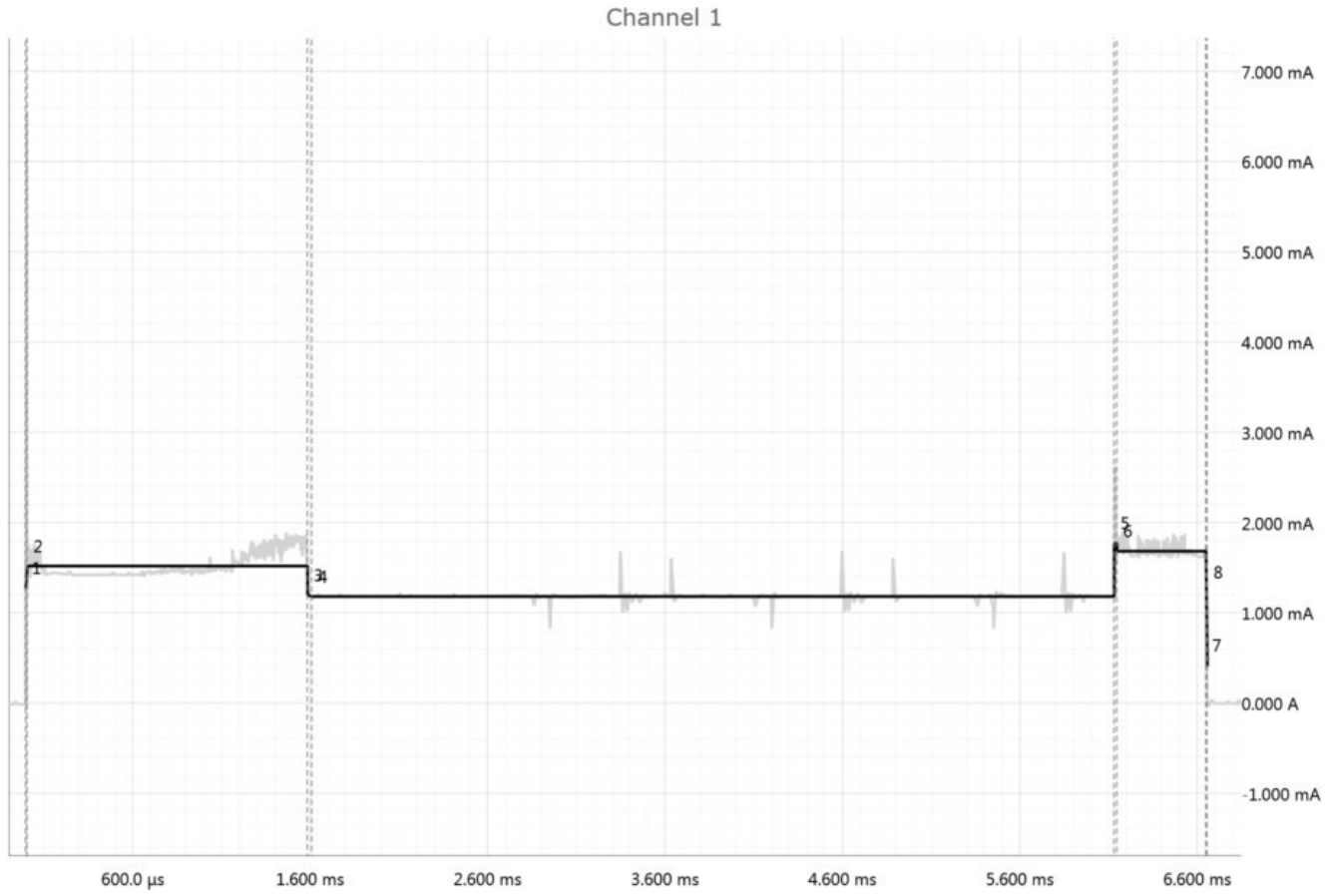

Figure 53. MCU profile in Bypass mode, VLLS2 (MCU Stop, Flash Doze)

Table 47. MCU current consumption in Bypass mode, VLLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-2.448 µs	7.887 µs	1.273 mA	6.561 mA	-93.11 µA	2.789 pAh	0.11
2	—	5.439 µs	1.580 ms	1.519 mA	1.937 mA	1.351 mA	666.6 pAh	27.73
3	—	1.586 ms	24.60 µs	1.196 mA	1.715 mA	1.126 mA	8.169 pAh	0.33
4	—	1.610 ms	4.521 ms	1.181 mA	1.736 mA	782.0 µA	1.483 pAh	61.70
5	—	6.132 ms	15.32 µs	1.770 mA	2.663 mA	1.167 mA	7.532 pAh	0.31
6	—	6.147 ms	502.3 µs	1.682 mA	1.948 mA	1.563 mA	234.6 pAh	9.76
7	—	6.649 ms	7.260 µs	415.9 µA	1.684 mA	-6.912 µA	838.7 fAh	0.03
8	Summry	6.656 ms	6.659 ms	1.299 mA	6.561 mA	-93.11 µA	2.404 nAh	100

4.2.2.13.3 Summary

Table 48. Current profile during advertising event, +5 dBm, FEE 48 MHz, Flash doze, MCU Stop

MCU stop consumption	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
Timing period (ms)	6.327	7.12	5.87	6.66
Consumption (mA)	0.777	0.89	1.344	1.299
MCU stop consumption (nAh)	1.367	1.761	2.19	2.404

Table 49. MCU current consumption event

Vdcdc_in = 3.6 V		LLS2 (ms)	LLS2 (mA)	LLS2 (nAh)	VLLS2 (ms)	VLLS2 (mA)	VLLS2 (nAh)
MCU	buck	6.33	0.78	1.37	7.12	0.89	1.76
	bypass	5.87	1.34	2.19	6.66	1.30	2.40

4.2.2.14 Connection mode

NXP android app has been used to perform connection.

Figure 54. IoT toolbox

On the Central side (in this case a mobile phone or a tablet with Bluetooth LE 5.x available) the following application needs to be installed: IoT Toolbox available on Google® Play as well as on Apple® iTunes (IoT toolbox version 5.0.9 minimum). .

The Thermometer application should be used. For measuring advertising events there is no need for a connecting device, but for measuring connection events it is mandatory. To connect to the FRDM-KW38 board the procedure is simple and straight forward:

1. Open the IoT Toolbox.
2. Press SW3 ON.
3. Power-up FRDM-KW38 board and press SW3 to start advertising.

4. On Android application the `FSL_Thermo` will be reported at scan phase.
5. Connect to `FSL_Thermo` peripheral.
6. Wait for measurements.

Both the following use cases are used:

- LLS2 mode is activated between the connection events.
- VLLS2 mode is activated between the connection events.

Figure 55 shows the current consumption during the connection events.

The binary file settings used are: FEE 48 MHz clock, Advertising with 37 bytes payload and connectable, RF output +5 dBm

- **Buck mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2
- **Bypass mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2

The mobile phone is the master which defines the data rate during the connection. Four data rates are concidered: 1 Mbps, 2 Mbps, 500 kbps (LR S=2), and 125 kbps (LR S=8).

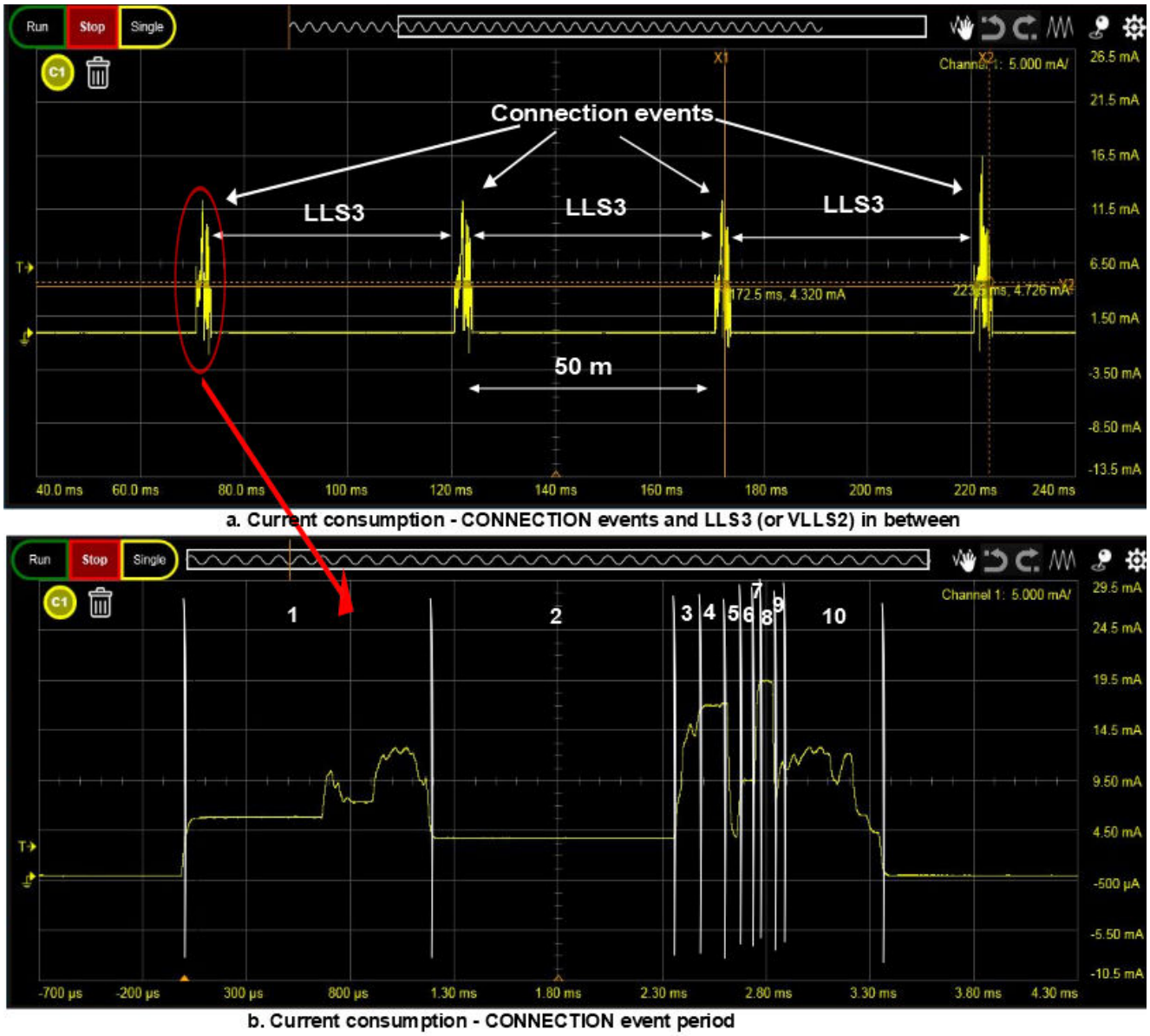

Figure 55. Current consumption - CONNECTION events period

Table 50. Connection events

Phase	Connection event timing
1	Pre-processing
2	MCU stop
3	Rx warmup
4	Active Rx
5	Rx warm-down
6	Rx to Tx transition

Table continues on the next page...

Table 50. Connection events (continued)

Phase	Connection event timing
7	Tx warm-up
8	Active Tx
9	Tx warm-down
10	Post-processing

4.2.2.14.1 Test environment: Connect 1 Mbps, LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
RAM size	16 k	
Data rate	1 Mbps	
Payload	31 bytes	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Connection Interval = 50 ms Advertise from low power LLS2 Slave to Master	
Software	Low Power (PRC3 release)	

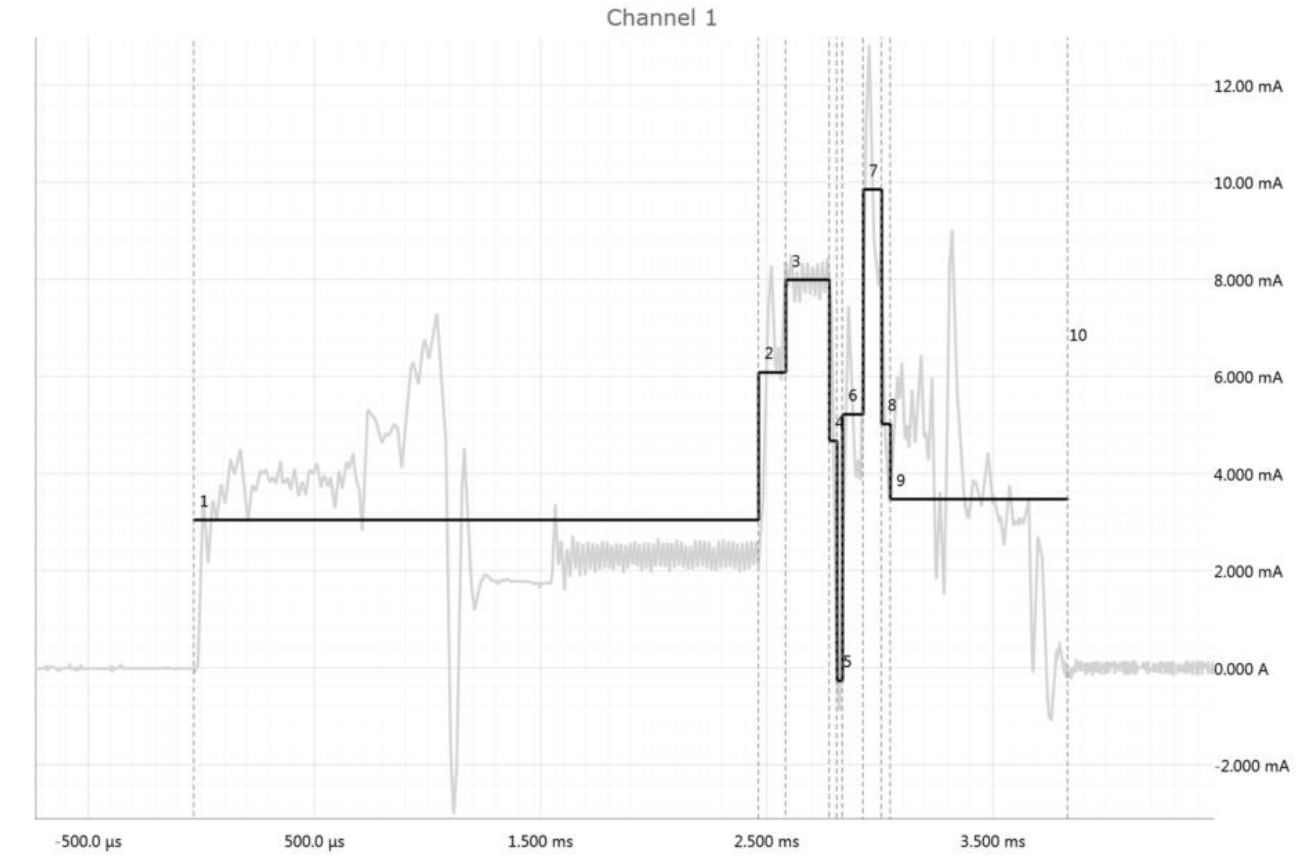

Figure 56. Connect profile in Buck mode, LLS2 (MCU Stop, Flash Doze), 1 Mbps

Table 51. Connect current consumption in Buck mode, LLS2 (MCU Stop, Flash Doze), 1 Mbps

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-32.35 µs	2.496 ms	3.043 mA	7.366 mA	-3.077 mA	2.111 nAh	53.42
2	—	2.464 ms	124.0 µs	6.082 mA	8.430 mA	2.018 mA	203.5 pAh	5.15
3	—	2.585 ms	192.7 µs	7.989 mA	8.611 mA	7.448 mA	427.7 pAh	10.82
4	—	2.777 ms	33.72 µs	4.671 mA	7.862 mA	-129.7 µA	43.76 pAh	1.10
5	—	2.811 ms	24.09 µs	-268.2 µA	2.219 mA	-960.2 µA	-1.795 pAh	-0.04
6	—	2.835 ms	91.53 µs	5.216 mA	7.524 mA	2.053 mA	132.6 pAh	3.35
7	—	2.927 ms	81.90 µs	9.850 mA	12.82 mA	6.918 mA	224.1 pAh	5.67
8	—	3.008 ms	38.54 µs	5.019 mA	8.302 mA	3.373 mA	53.73 pAh	1.36
9	—	3.047 ms	783.9 µs	3.473 mA	9.080 mA	-1.216 mA	756.2 pAh	19.14
10	Summary	3.831 ms	3.863 ms	3.681 mA	12.82 mA	-3.077 mA	3.950 nAh	100

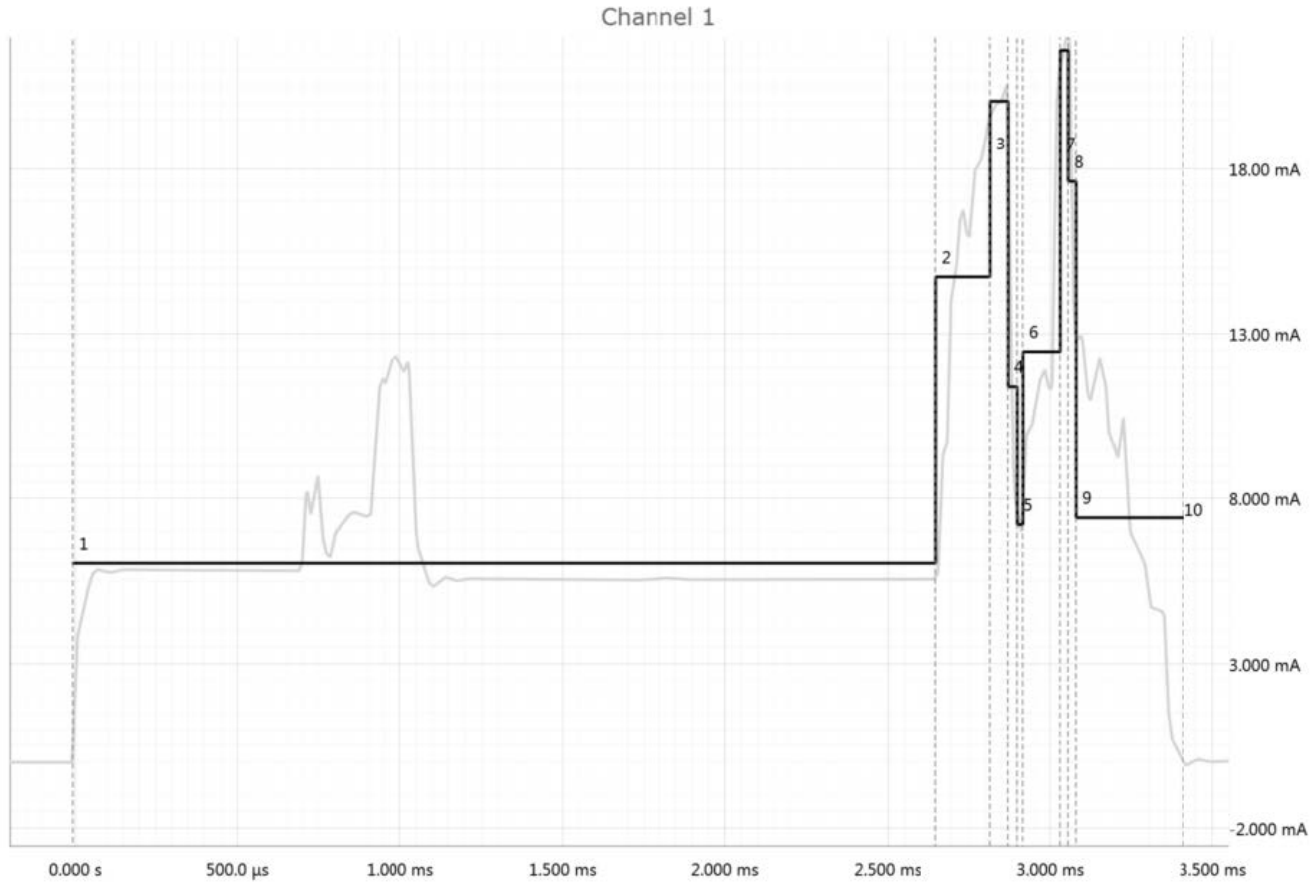

Figure 57. Connect profile in Bypass mode, LLS2 (MCU Stop, Flash Doze), 1 Mbps

Table 52. Connect current consumption in Bypass mode, LLS2 (MCU Stop, Flash Doze), 1 Mbps

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-32.35 µs	2.496 ms	3.043 mA	7.366 mA	-3.077 mA	2.111 nAh	53.42
2	—	2.464 ms	120.4 µs	6.082 mA	8.430 mA	2.018 mA	203.5 pAh	5.15
3	—	2.585 ms	192.7 µs	7.989 mA	8.611 mA	7.448 mA	427.7 pAh	10.82
4	—	2.777 ms	33.72 µs	4.671 mA	7.862 mA	-129.7 µA	43.76 pAh	1.10
5	—	2.811 ms	24.09 µs	-268.2 µA	2.129 mA	-960.2 µA	-1.795 pAh	-0.04
6	—	2.835 ms	91.53 µs	5.216 mA	7.524 mA	2.053 mA	132.6 pAh	3.35
7	—	2.927 ms	81.90 µs	9.850 mA	12.82 mA	6.918 mA	224.1 pAh	5.67
8	—	3.008 ms	38.54 µs	5.019 mA	8.302 mA	3.373 mA	53.73 pAh	1.36
9	—	3.047 ms	783.9 µs	3.473 mA	9.080 mA	-1.216 mA	756.2 pAh	19.14
10	Summary	3.831 ms	3.863 ms	3.681 mA	12.82 mA	-3.077 mA	3.950 nAh	100

4.2.2.14.2 Test environment: Connect 1 Mbps, VLLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
RAM size	16 k	
Data rate	1 Mbps	
Payload	31 bytes	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Connection Interval = 50 ms Advertise from low power VLLS2 Slave to Master	
Software	Low Power (PRC3 release)	

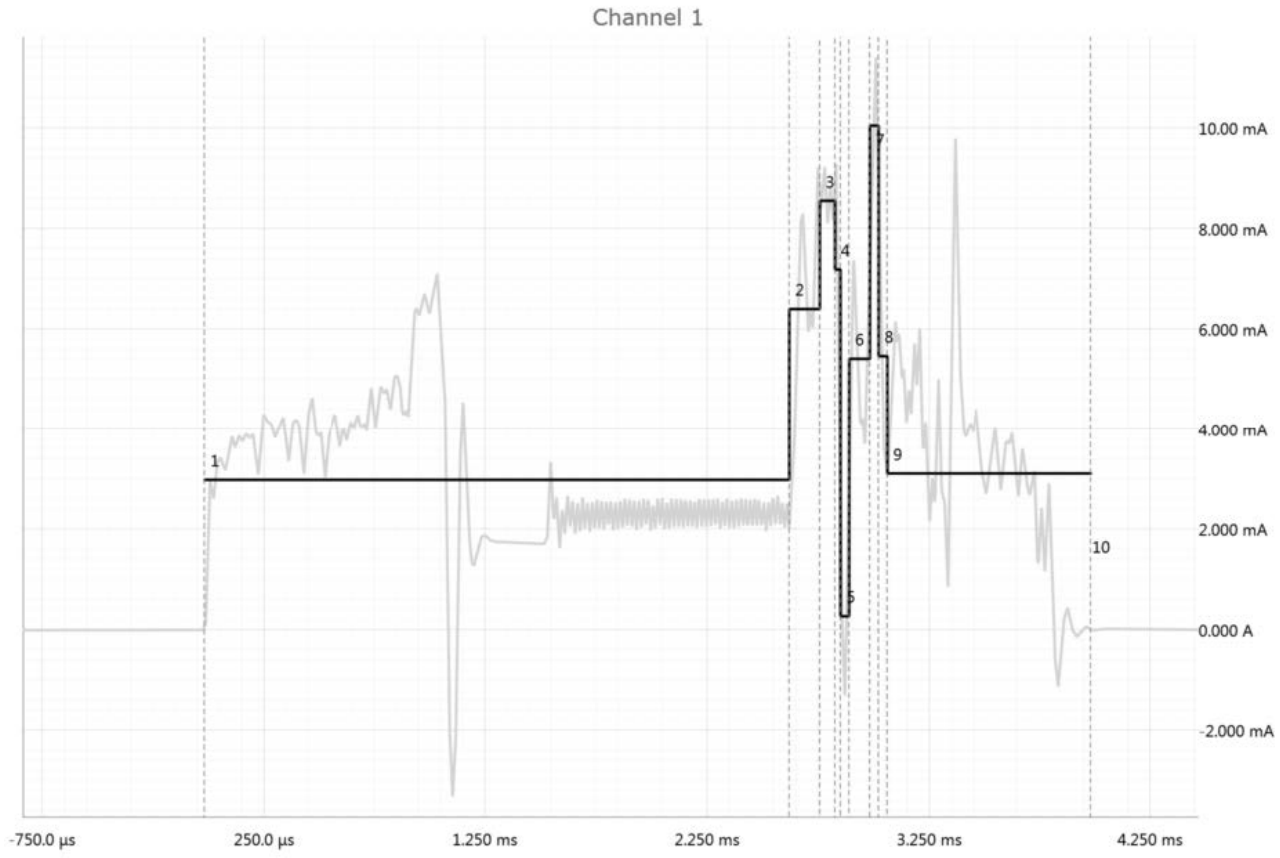

Figure 58. Connect profile in Buck mode, VLLS2 (MCU Stop, Flash Doze)

Table 53. Connect current consumption in Buck mode, VLLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-18.08 µs	2.638 ms	2.973 mA	7.167 mA	-3.402 mA	2.179 nAh	58.24
2	—	2.620 ms	137.3 µs	6.397 mA	9.305 mA	1.933 mA	243.9 pAh	6.52
3	—	2.757 ms	68.64 µs	8.549 mA	9.296 mA	8.027 mA	163.0 pAh	4.35
4	—	2.826 ms	24.51 µs	7.182 mA	9.364 mA	2.632 mA	48.91 pAh	1.30
5	—	2.850 ms	39.22 µs	261.6 µA	3.814 mA	-1.376 mA	2.850 pAh	0.07
6	—	2.889 ms	93.16 µs	5.408 mA	7.455 mA	3.623 mA	139.9 pAh	3.74
7	—	2.983 ms	39.22 µs	10.04 mA	11.46 mA	7.422 mA	109.4 pAh	2.92
8	—	3.022 ms	39.22 µs	5.459 mA	9.433 mA	3.053 mA	59.48 pAh	1.59
9	—	3.061 ms	921.8 µs	3.101 mA	9.858 mA	-1.218 mA	794.1 pAh	21.23
10	Summary	3.983 ms	4.001 ms	3.366 mA	11.46 mA	-3.402 mA	3.740 nAh	100

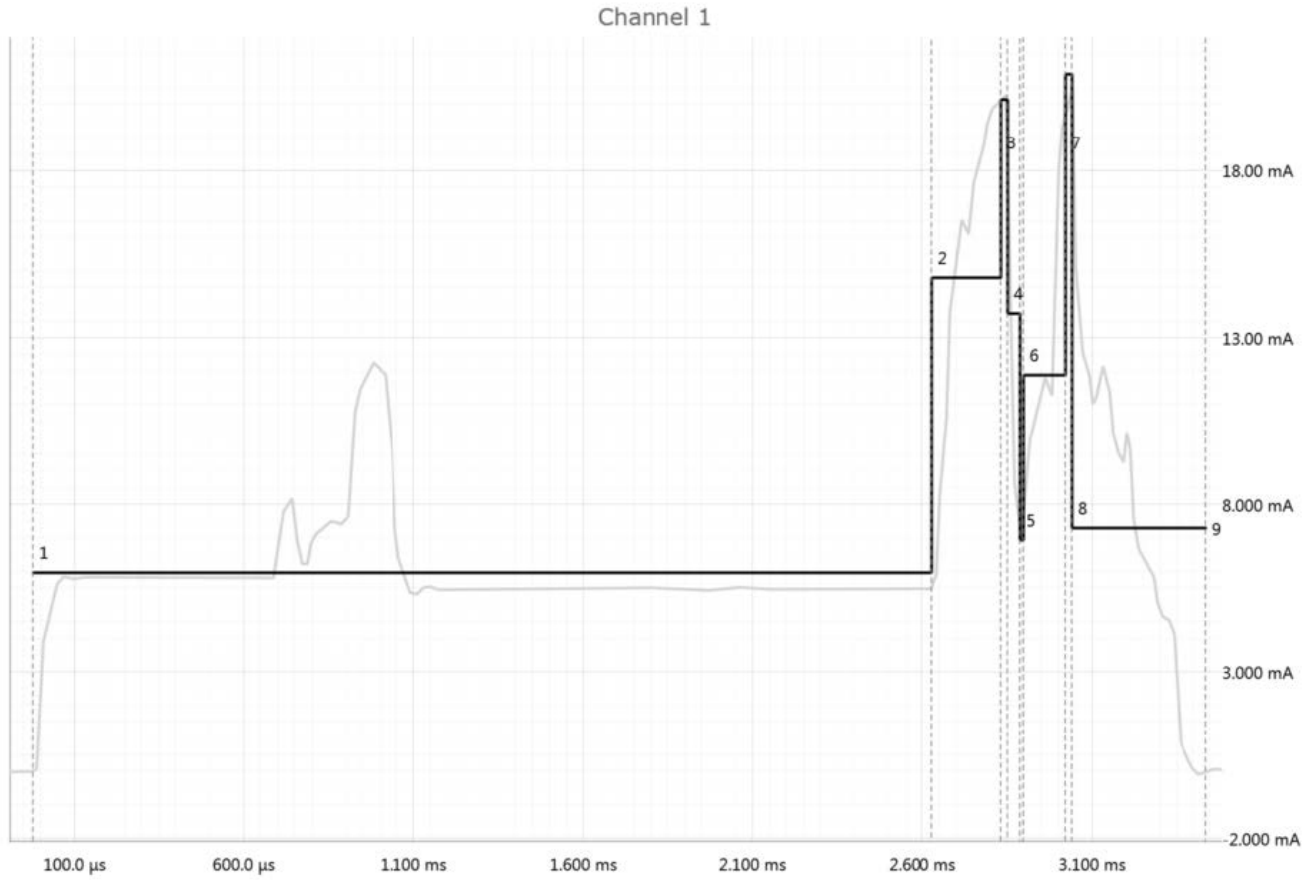

Figure 59. Connect profile in Bypass mode, VLLS2 (MCU Stop, Flash Doze), 1 Mbps

Table 54. Connect current consumption in Bypass mode, VLLS2 (MCU Stop, Flash Doze), 1 Mbps

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-22.00 µs	2.651 ms	5.956 mA	12.27 mA	-6.394 µA	4.386 nAh	64.41
2	—	2.629 ms	203.1 µs	14.79 mA	20.06 mA	5.484 mA	834.4 pAh	12.25
3	—	2.832 ms	20.00 µs	20.14 mA	20.32 mA	20.05 mA	111.9 pAh	1.64
4	—	2.852 ms	36.19 µs	13.72 mA	20.23 mA	7.465 mA	138.0 pAh	2.02
5	—	2.888 ms	10.03 µs	6.932 mA	6.968 mA	6.968 mA	19.32 pAh	0.28
6	—	2.899 ms	123.3 µs	11.89 mA	19.30 mA	8.383 mA	407.2 pAh	5.97
7	—	3.022 ms	19.05 µs	20.90 mA	20.20 mA	19.69 mA	110.6 pAh	1.62
8	—	3.041 ms	396.2 µs	7.287 mA	20.45 mA	-98.10 µA	802.0 pAh	11.77
9	Summary	3.437 ms	3.459 ms	7.087 mA	20.45 mA	-98.10 µA	6.810 nAh	100

4.2.2.14.3 Test environment: Connect 2 Mbps, LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
RAM size	16 k	
Data rate	2 Mbps	
Payload	31 bytes	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Connection Interval = 50 ms Advertise from low power LLS2 Slave to Master	
Software	Low Power (PRC3 release)	

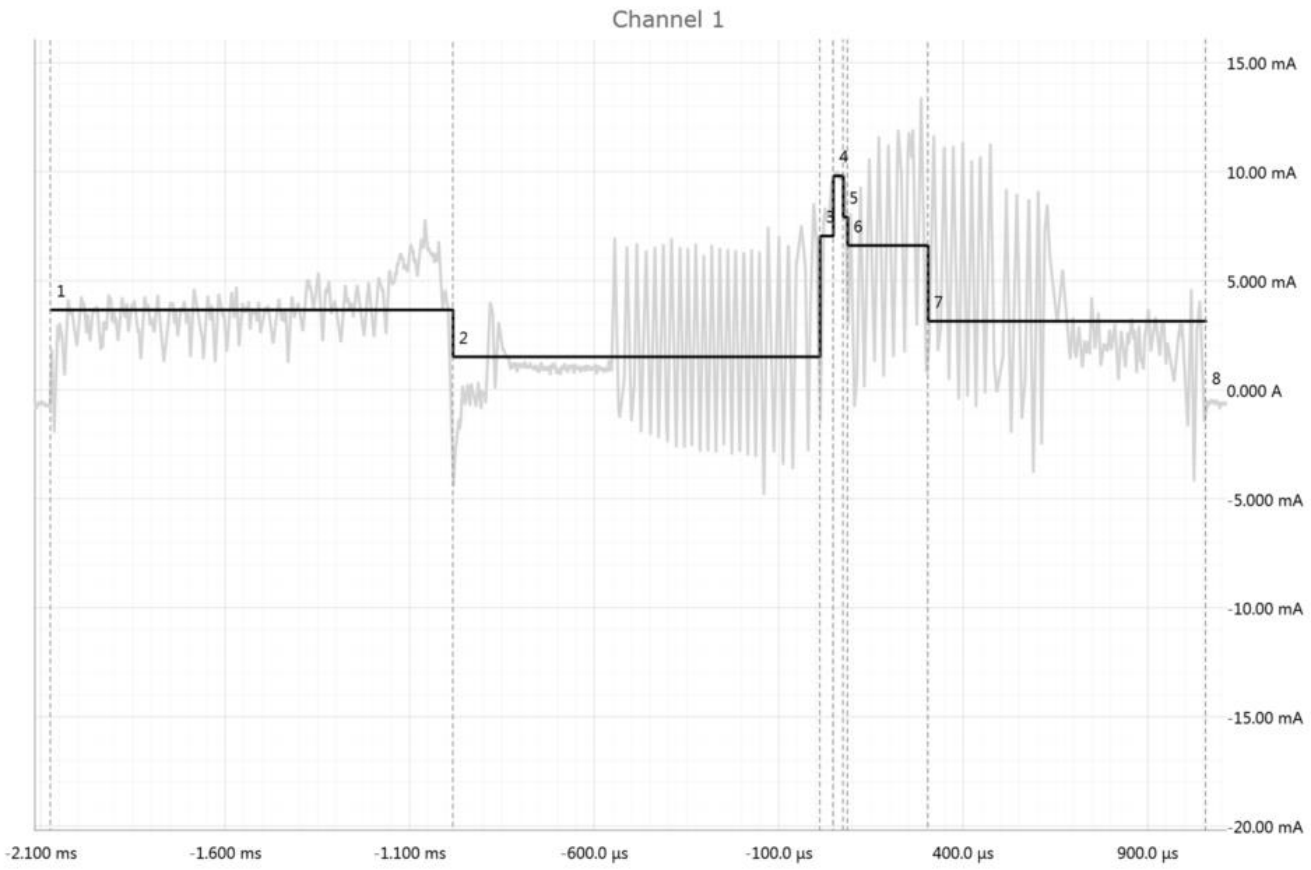

Figure 60. Connect profile in buck mode, LLS2 (MCU Stop, Flash Doze), 2 Mbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-2.073 ms	1.090 ms	3.664 mA	8.116 mA	-4.245 mA	1.110 nAh	40.2688892933618
2		-982.8 µs	994.7 µs	1.512 mA	8.664 mA	-4.886 mA	417.9 pAh	15.1638896963812
3		11.96 µs	35.85 µs	7.052 mA	10.00 mA	-1.549 mA	70.22 pAh	2.54831032931004
4		47.80 µs	26.89 µs	9.807 mA	10.18 mA	9.414 mA	73.24 pAh	2.6578142731632
5		74.69 µs	11.95 µs	7.918 mA	10.05 mA	3.027 mA	26.28 pAh	0.953681056098702
6		86.64 µs	218.1 µs	6.618 mA	13.65 mA	-900.1 µA	400.9 pAh	14.5474370077815
7		304.7 µs	752.8 µs	3.144 mA	11.84 mA	-4.422 mA	657.5 pAh	23.8599783439037
8	Summary	1.057 ms	3.131 ms	3.169 mA	13.65 mA	-4.886 mA	2.756 nAh	100

Figure 61. Connect current consumption in buck mode, LLS2 (MCU Stop, Flash Doze), 2 Mbps

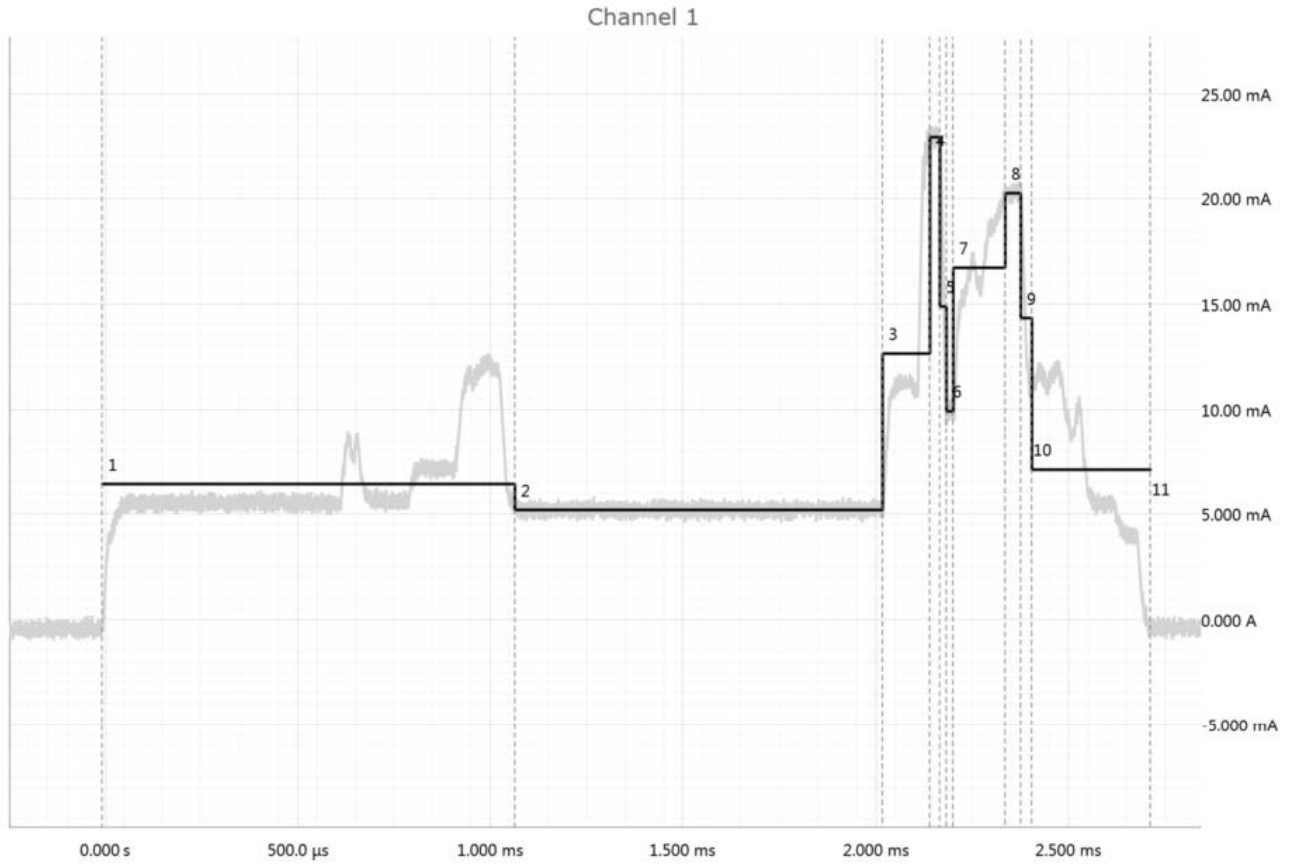

Figure 62. Connect profile in bypass mode, LLS2 (MCU Stop, Flash Doze), 2 Mbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-9.174 µs	1.073 ms	6.410 mA	12.78 mA	-813.3 µA	1.911 nAh	34.2703012197438
2		1.064 ms	952.9 µs	5.187 mA	5.833 mA	4.535 mA	1.373 nAh	24.6267789061916
3		2.017 ms	125.9 µs	12.65 mA	23.37 mA	4.793 mA	442.5 pAh	7.937233514986
4		2.143 ms	25.75 µs	22.96 mA	23.51 mA	22.33 mA	164.3 pAh	2.94617378924744
5		2.168 ms	17.17 µs	14.88 mA	23.27 mA	9.212 mA	70.96 pAh	1.27269592377741
6		2.186 ms	17.17 µs	9.916 mA	10.56 mA	9.284 mA	47.29 pAh	0.848178366708746
7		2.203 ms	134.5 µs	16.71 mA	20.43 mA	9.434 mA	624.2 pAh	11.1965816242649
8		2.337 ms	40.06 µs	20.24 mA	20.80 mA	19.71 mA	225.3 pAh	4.04036253162198
9		2.377 ms	28.61 µs	14.33 mA	20.81 mA	10.48 mA	113.9 pAh	2.04319187551179
10		2.406 ms	306.2 µs	7.092 mA	12.41 mA	-846.0 µA	603.2 pAh	10.8185022479463
11	Summary	2.712 ms	2.721 ms	7.376 mA	23.51 mA	-846.0 µA	5.575 nAh	100

Figure 63. Connect current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 2 Mbps

4.2.2.14.4 Test environment: Connect 2 Mbps, VLLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V

Table continues on the next page...

Table continued from the previous page...

RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	2 Mbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Connection Interval = 50 ms Advertise from low power VLLS2 Slave to Master
Software	Low Power (PRC3 release)

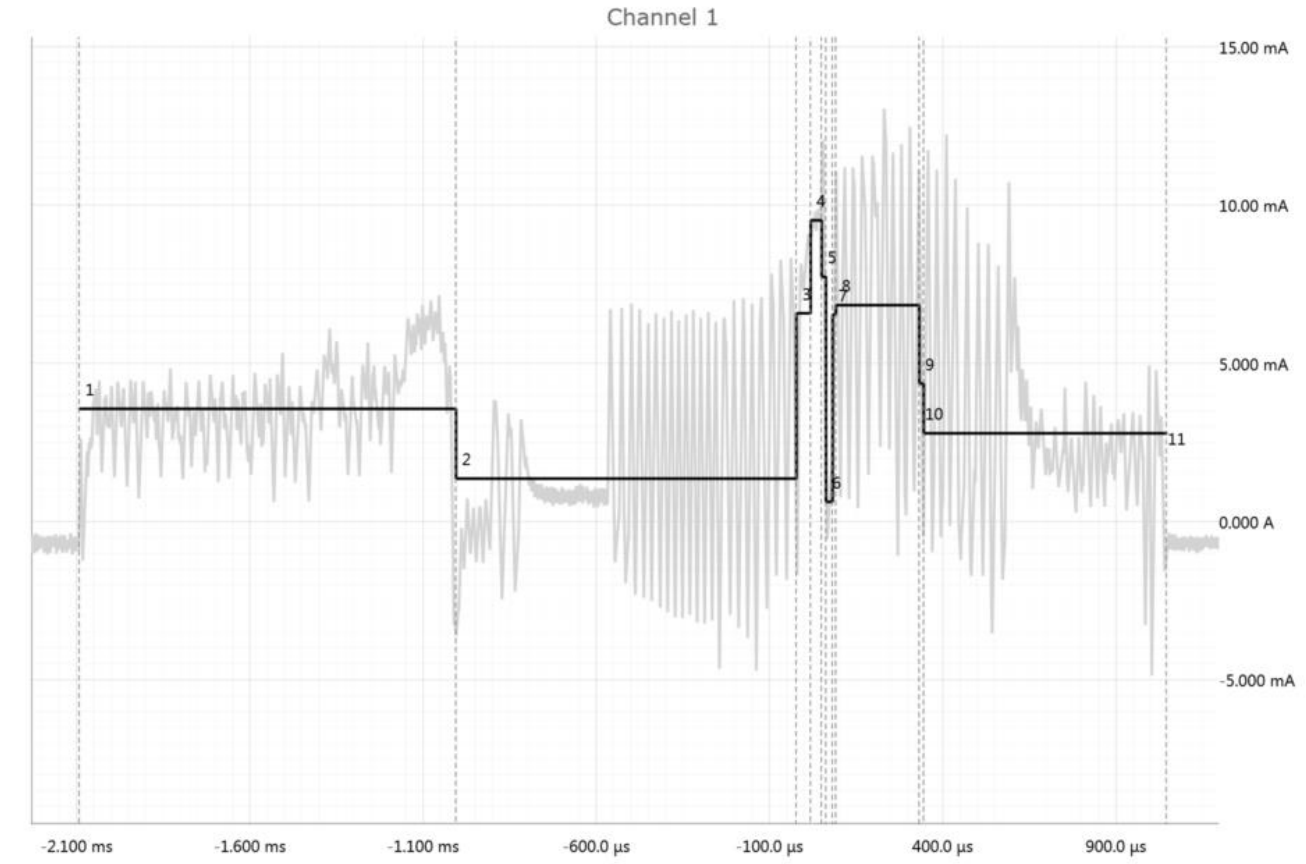

Figure 64. Connect profile in buck mode, VLLS2 (MCU Stop, Flash Doze), 2 Mbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-2.092 ms	1.087 ms	3.561 mA	7.223 mA	-3.512 mA	1.075 nAh	40.3291083158517
2		-1.005 ms	982.4 µs	1.355 mA	8.479 mA	-4.844 mA	369.7 pAh	13.8648480396751
3		-22.46 µs	41.20 µs	6.578 mA	9.245 mA	-1.785 mA	75.28 pAh	2.82328397370347
4		18.74 µs	31.69 µs	9.516 mA	11.21 mA	8.917 mA	83.77 pAh	3.14155077157581
5		50.43 µs	12.68 µs	7.731 mA	12.10 mA	347.1 µA	27.22 pAh	1.02087137753753
6		63.10 µs	19.01 µs	621.9 µA	2.117 mA	-630.4 µA	3.285 pAh	0.123185503340508
7		82.12 µs	9.507 µs	6.539 mA	10.75 mA	1.670 mA	17.27 pAh	0.64760891607505
8		91.62 µs	240.8 µs	6.834 mA	13.10 mA	-1.220 mA	457.2 pAh	17.1461169176159
9		332.5 µs	12.68 µs	4.362 mA	11.02 mA	-647.3 µA	15.36 pAh	0.576001328170638
10		345.1 µs	700.3 µs	2.786 mA	12.32 mA	-5.021 mA	542.0 pAh	20.3274248564543
11	Summary	1.045 ms	3.137 ms	3.060 mA	13.10 mA	-5.021 mA	2.666 nAh	100

Figure 65. Connect current consumption in buck mode, VLLS2 (MCU Stop, Flash Doze), 2 Mbps

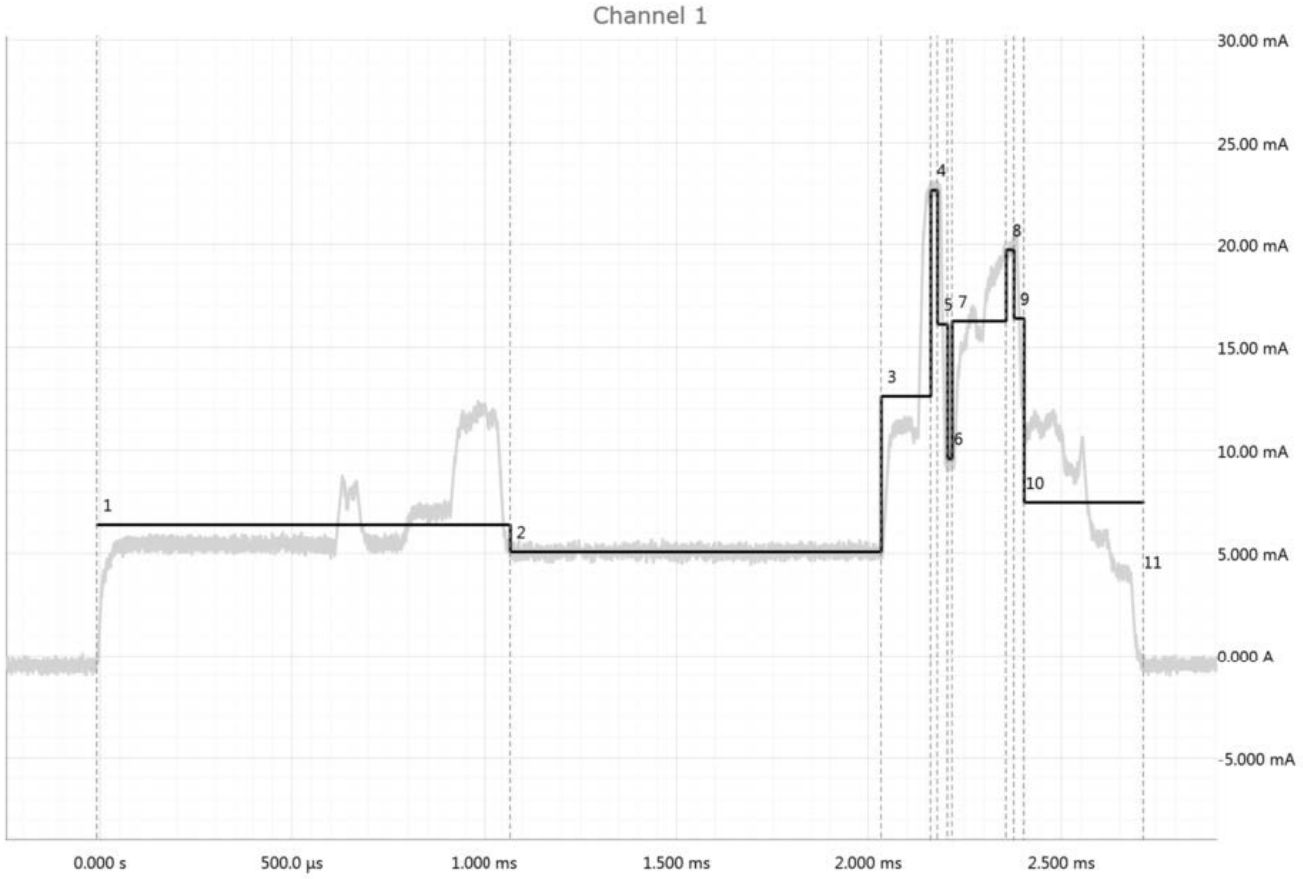

Figure 66. Connect profile in bypass mode, VLLS2 (MCU Stop, Flash Doze), 2 Mbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-8.062 µs	1.078 ms	6.386 mA	12.55 mA	-640.0 µA	1.912 nAh	34.8733826706996
2		1.070 ms	964.1 µs	5.072 mA	5.742 mA	4.417 mA	1.358 nAh	24.7793580300497
3		2.034 ms	128.2 µs	12.62 mA	23.05 mA	4.718 mA	449.4 pAh	8.19722092901836
4		2.162 ms	17.48 µs	22.69 mA	23.21 mA	22.16 mA	110.2 pAh	2.00969520579199
5		2.179 ms	26.21 µs	16.12 mA	23.06 mA	8.911 mA	117.4 pAh	2.14074723360407
6		2.206 ms	11.65 µs	9.588 mA	10.20 mA	8.911 mA	31.03 pAh	0.566055301086768
7		2.217 ms	139.8 µs	16.27 mA	19.98 mA	9.075 mA	632.0 pAh	11.5279383812105
8		2.357 ms	20.39 µs	19.73 mA	20.62 mA	19.16 mA	111.8 pAh	2.03863524719996
9		2.377 ms	26.21 µs	16.40 mA	21.02 mA	10.66 mA	119.4 pAh	2.17861365184372
10		2.404 ms	308.7 µs	7.471 mA	12.06 mA	-1.003 mA	640.7 pAh	11.6883533494954
11	Summary	2.712 ms	2.720 ms	7.254 mA	23.21 mA	-1.003 mA	5.482 nAh	100

Figure 67. Connect current consumption in bypass mode, VLLS2 (MCU Stop, Flash Doze), 2 Mbps

4.2.2.14.5 Test environment: Connect 500 kbps, LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
RAM size	16 k	
Data rate	500 kbps	
Payload	31 bytes	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Connection Interval = 50 ms Advertise from low power LLS2 Slave to Master	
Software	Low Power (PRC3 release)	

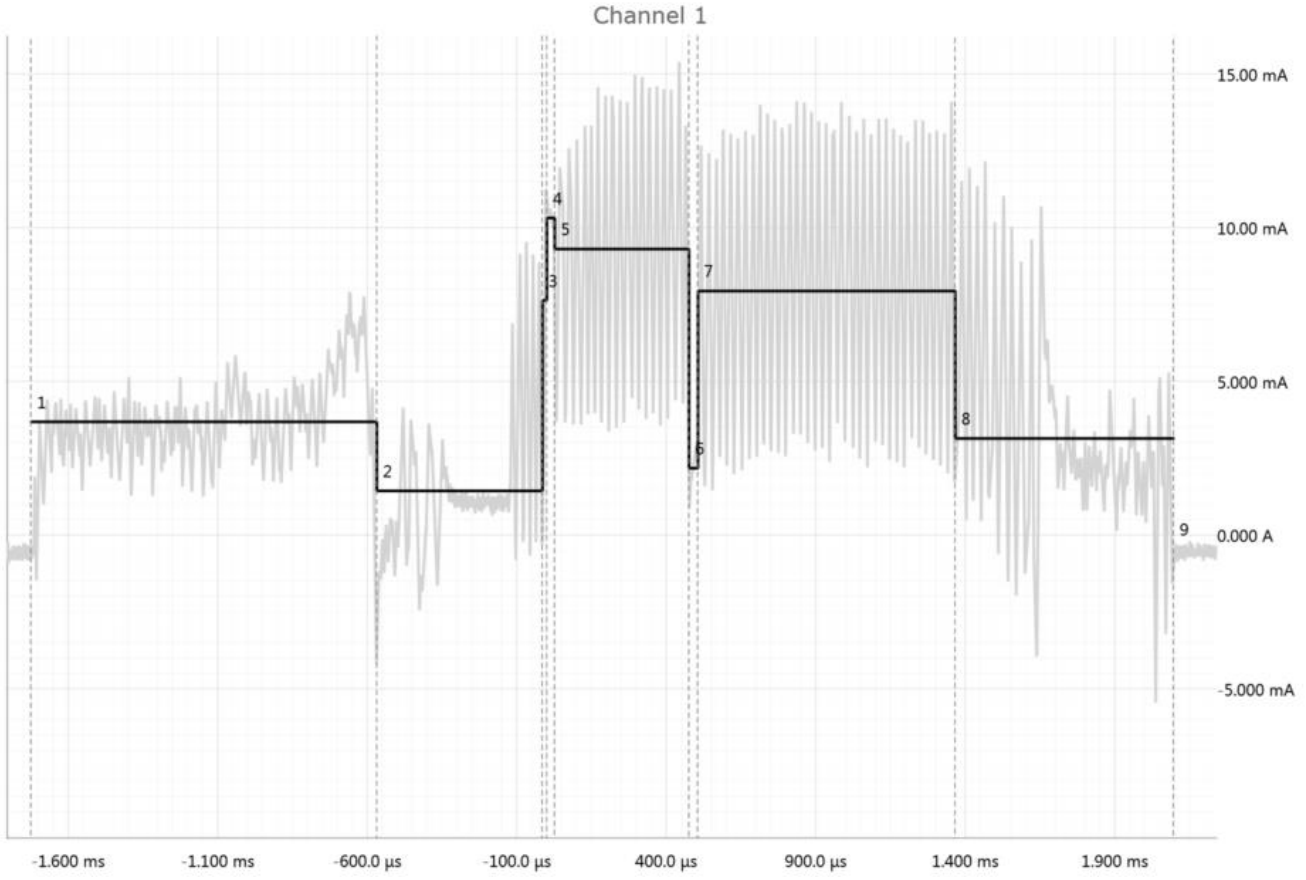

Figure 68. Connect profile in buck mode, LLS2 (MCU Stop, Flash Doze), 500 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-1.724 ms	1.156 ms	3.681 mA	8.150 mA	-4.288 mA	1.182 nAh	22.6423024905239
2		-567.7 µs	553.7 µs	1.436 mA	9.650 mA	-3.967 mA	220.9 pAh	4.23099421189037
3		-14.03 µs	14.97 µs	7.635 mA	11.40 mA	-217.5 µA	31.74 pAh	0.607909104214523
4		935.8 ns	26.19 µs	10.31 mA	11.21 mA	8.142 mA	75.01 pAh	1.43674960298836
5		27.12 µs	449.0 µs	9.302 mA	15.46 mA	1.198 mA	1.160 nAh	22.2191945403193
6		476.1 µs	29.93 µs	2.170 mA	3.440 mA	802.1 µA	18.04 pAh	0.345608452065994
7		506.0 µs	860.5 µs	7.936 mA	14.32 mA	1.367 mA	1.897 nAh	36.3355305427333
8		1.367 ms	729.5 µs	3.138 mA	12.27 mA	-5.501 mA	636.0 pAh	12.1817110552643
9	Summary	2.096 ms	3.820 ms	4.920 mA	15.46 mA	-5.501 mA	5.221 nAh	100

Figure 69. Connect current consumption in buck mode, LLS2 (MCU Stop, Flash Doze), 500 kbps

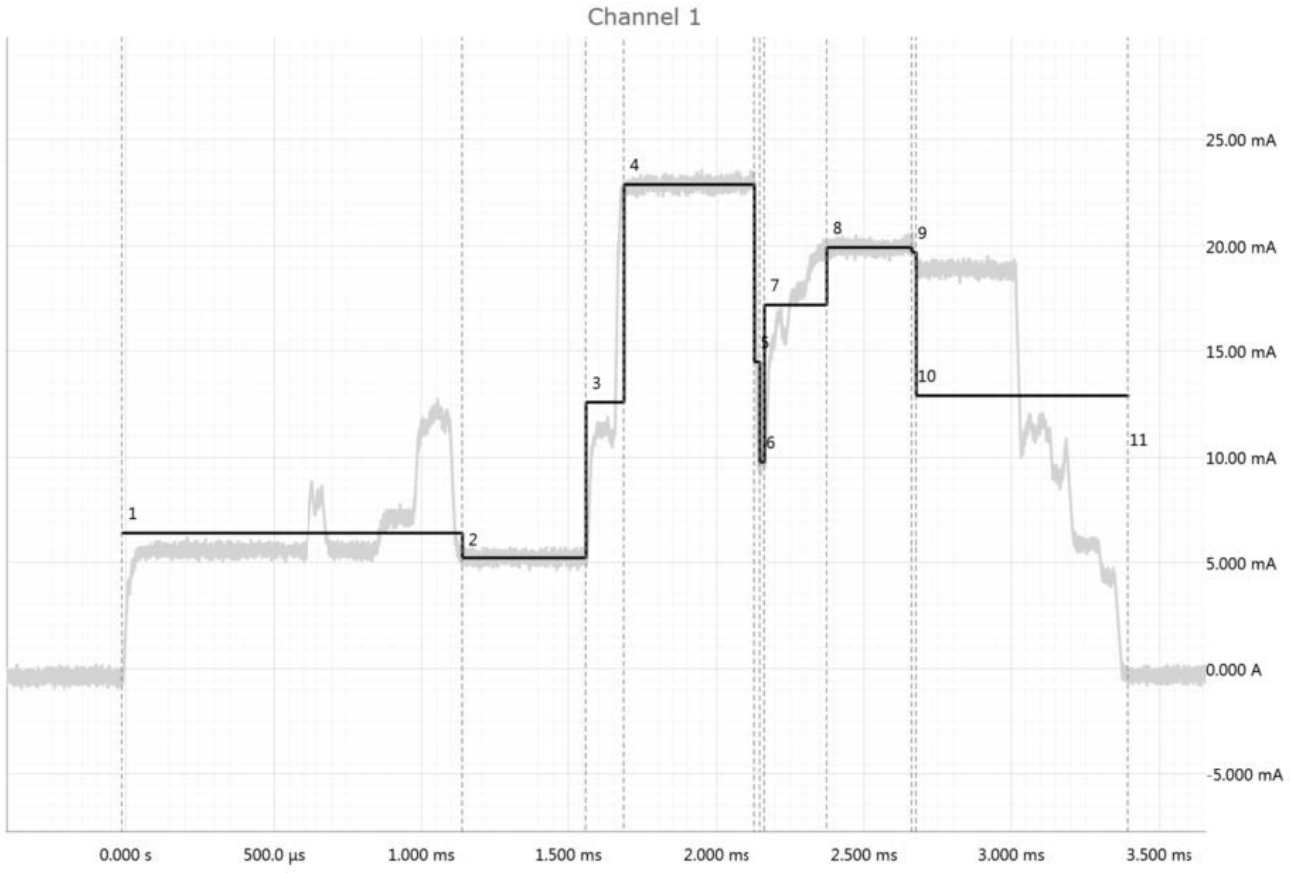

Figure 70. Connect profile in bypass mode, LLS2 (MCU Stop, Flash Doze), 500 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-12.03 µs	1.150 ms	6.439 mA	12.77 mA	-767.5 µA	2.057 nAh	18.2213316604361
2		1.138 ms	420.9 µs	5.207 mA	5.781 mA	4.587 mA	608.8 pAh	5.39300182681246
3		1.559 ms	127.8 µs	12.59 mA	23.04 mA	4.793 mA	446.7 pAh	3.95758303454134
4		1.687 ms	443.5 µs	22.88 mA	23.61 mA	22.12 mA	2.819 nAh	24.9706642216978
5		2.130 ms	18.79 µs	14.48 mA	23.22 mA	9.189 mA	75.58 pAh	0.669539970951743
6		2.149 ms	15.03 µs	9.768 mA	10.37 mA	9.084 mA	40.79 pAh	0.361366077203889
7		2.164 ms	210.5 µs	17.22 mA	20.34 mA	9.392 mA	1.007 nAh	8.91967060978596
8		2.375 ms	285.6 µs	19.92 mA	20.66 mA	19.24 mA	1.581 nAh	14.0021134308231
9		2.660 ms	15.03 µs	19.70 mA	20.67 mA	18.69 mA	82.27 pAh	0.728815754562097
10		2.675 ms	717.8 µs	12.89 mA	19.57 mA	-695.6 µA	2.571 nAh	22.7759134131856
11	Summary	3.393 ms	3.405 ms	11.93 mA	23.61 mA	-767.5 µA	11.29 nAh	100

Figure 71. Connect current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 500 kbps

4.2.2.14.6 Test environment: Connect 500 kbps, VLLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V

Table continues on the next page...

Table continued from the previous page...

RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	500 kbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Connection Interval = 50 ms Advertise from low power VLLS2 Slave to Master
Software	Low Power (PRC3 release)

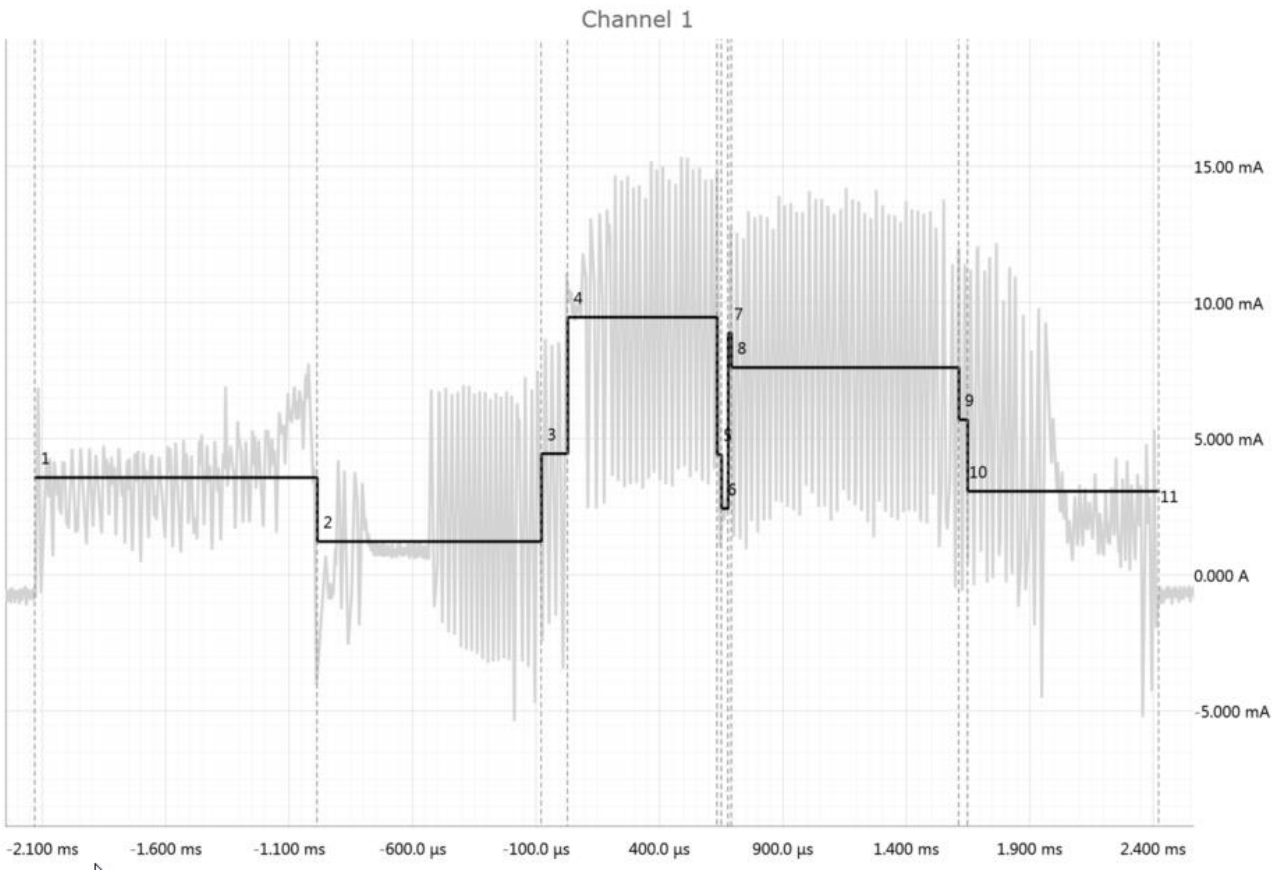

Figure 72. Connect profile in buck mode, VLLS2 (MCU Stop, Flash Doze), 500 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-2.130 ms	1.144 ms	3.568 mA	7.981 mA	-4.094 mA	1.133 nAh	19.2254419271875
2		-985.9 µs	907.8 µs	1.218 mA	7.712 mA	-5.535 mA	307.1 pAh	5.20841999932432
3		-78.01 µs	106.8 µs	4.446 mA	11.18 mA	-3.605 mA	131.9 pAh	2.2376039248336
4		28.80 µs	605.2 µs	9.454 mA	15.56 mA	2.260 mA	1.589 nAh	26.9592736746693
5		634.0 µs	17.80 µs	4.411 mA	14.08 mA	962.2 µA	21.81 pAh	0.369977683605458
6		651.8 µs	26.70 µs	2.432 mA	3.633 mA	1.552 mA	18.04 pAh	0.306009917224586
7		678.5 µs	13.35 µs	8.879 mA	12.94 mA	3.313 mA	32.93 pAh	0.558546996979562
8		691.9 µs	921.2 µs	7.605 mA	14.27 mA	-588.3 µA	1.946 nAh	33.0094270888485
9		1.613 ms	35.60 µs	5.691 mA	12.19 mA	-681.0 µA	56.28 pAh	0.954701608651408
10		1.649 ms	774.3 µs	3.062 mA	12.29 mA	-5.442 mA	658.6 pAh	11.1705971786758
11	Summary	2.423 ms	4.553 ms	4.662 mA	15.56 mA	-5.535 mA	5.896 nAh	100

Figure 73. Connect current consumption in buck mode, VLLS2 (MCU Stop, Flash Doze), 500 kbps

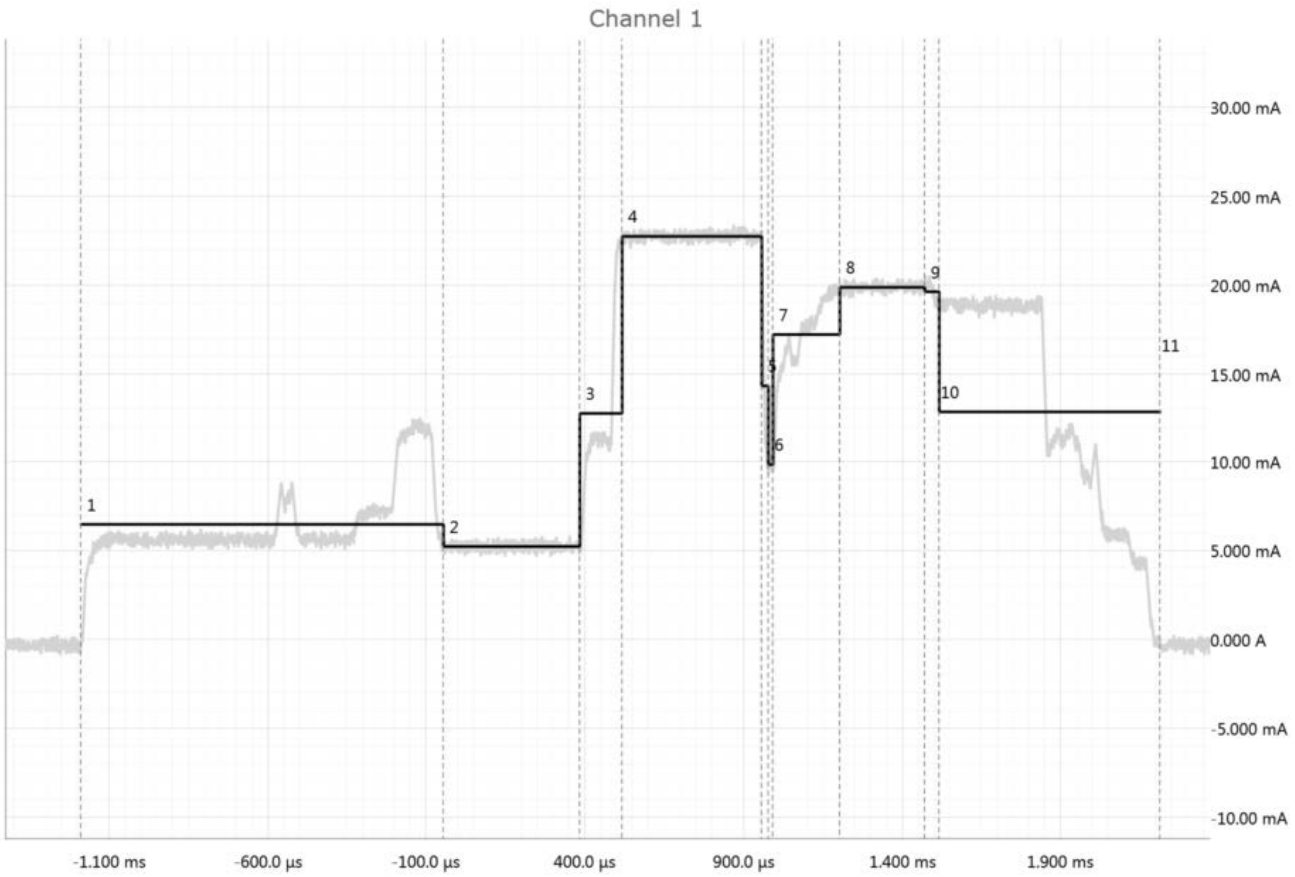

Figure 74. Connect profile in bypass mode, VLLS2 (MCU Stop, Flash Doze), 500 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-1.188 ms	1.144 ms	6.467 mA	12.68 mA	-711.9 µA	2.056 nAh	18.2379109056305
2		-43.98 µs	428.3 µs	5.224 mA	5.843 mA	4.613 mA	621.5 pAh	5.51308695760017
3		384.3 µs	133.4 µs	12.78 mA	22.94 mA	4.829 mA	473.7 pAh	4.20244298991691
4		517.7 µs	438.8 µs	22.74 mA	23.39 mA	22.05 mA	2.772 nAh	24.5901922656958
5		956.6 µs	21.06 µs	14.33 mA	23.35 mA	9.189 mA	83.85 pAh	0.743825292058328
6		977.6 µs	14.04 µs	9.826 mA	10.40 mA	9.333 mA	38.33 pAh	0.340037433599807
7		991.7 µs	210.6 µs	17.22 mA	20.18 mA	9.277 mA	1.008 nAh	8.93791574077364
8		1.202 ms	266.8 µs	19.88 mA	20.50 mA	19.26 mA	1.473 nAh	13.0690696438077
9		1.469 ms	45.64 µs	19.63 mA	20.55 mA	18.43 mA	248.8 pAh	2.20727210758548
10		1.515 ms	698.6 µs	12.87 mA	19.45 mA	-630.1 µA	2.498 nAh	22.1582466633317
11	Summary	2.213 ms	3.402 ms	11.93 mA	23.39 mA	-711.9 µA	11.27 nAh	100

Figure 75. Connect current consumption in bypass mode, VLLS2 (MCU Stop, Flash Doze), 500 kbps

4.2.2.14.7 Test environment: Connect 125 kbps, LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
RAM size	16 k	
Data rate	125 kbps	
Payload	31 bytes	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Connection Interval = 50 ms Advertise from low power LLS2 Slave to Master	
Software	Low Power (PRC3 release)	

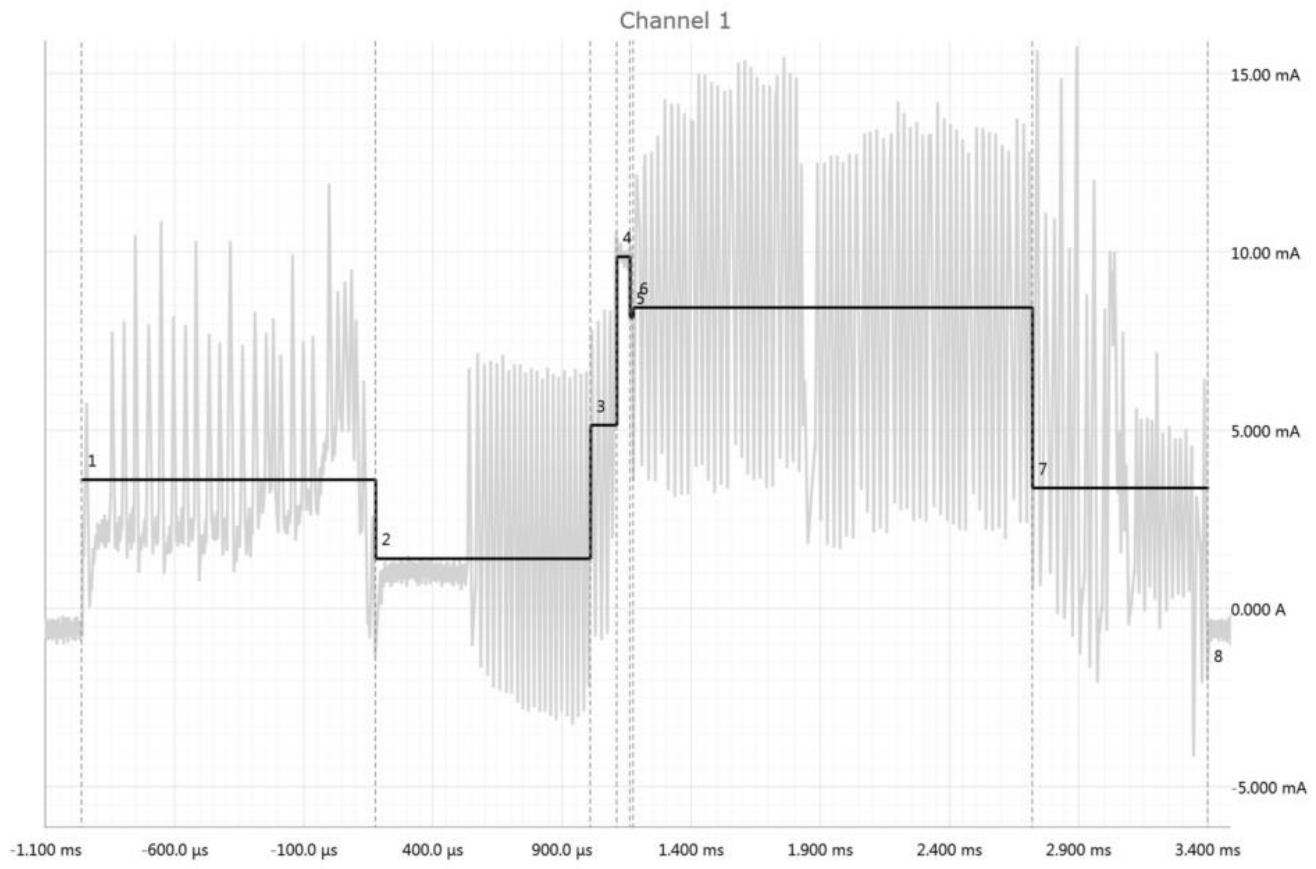

Figure 76. Connect profile in buck mode, LLS2 (MCU Stop, Flash Doze), 125 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-959.4 µs	1.138 ms	3.611 mA	12.03 mA	-1.431 mA	1.141 nAh	18.9012654263683
2		178.4 µs	832.1 µs	1.397 mA	7.215 mA	-3.310 mA	322.9 pAh	5.34824873806179
3		1.010 ms	101.9 µs	5.141 mA	10.67 mA	-1.094 mA	145.5 pAh	2.41015844036445
4		1.112 ms	50.94 µs	9.865 mA	10.40 mA	9.406 mA	139.6 pAh	2.31225047763682
5		1.163 ms	12.74 µs	8.163 mA	10.23 mA	3.423 mA	28.88 pAh	0.478359929431896
6		1.176 ms	1.545 ms	8.437 mA	15.55 mA	532.4 µA	3.621 nAh	59.9855128422622
7		2.721 ms	679.2 µs	3.380 mA	15.84 mA	-4.304 mA	637.8 pAh	10.5642041458745
8	Summary	3.400 ms	4.360 ms	4.985 mA	15.84 mA	-4.304 mA	6.037 nAh	100

Figure 77. Connect current consumption in buck mode, LLS2 (MCU Stop, Flash Doze), 125 kbps

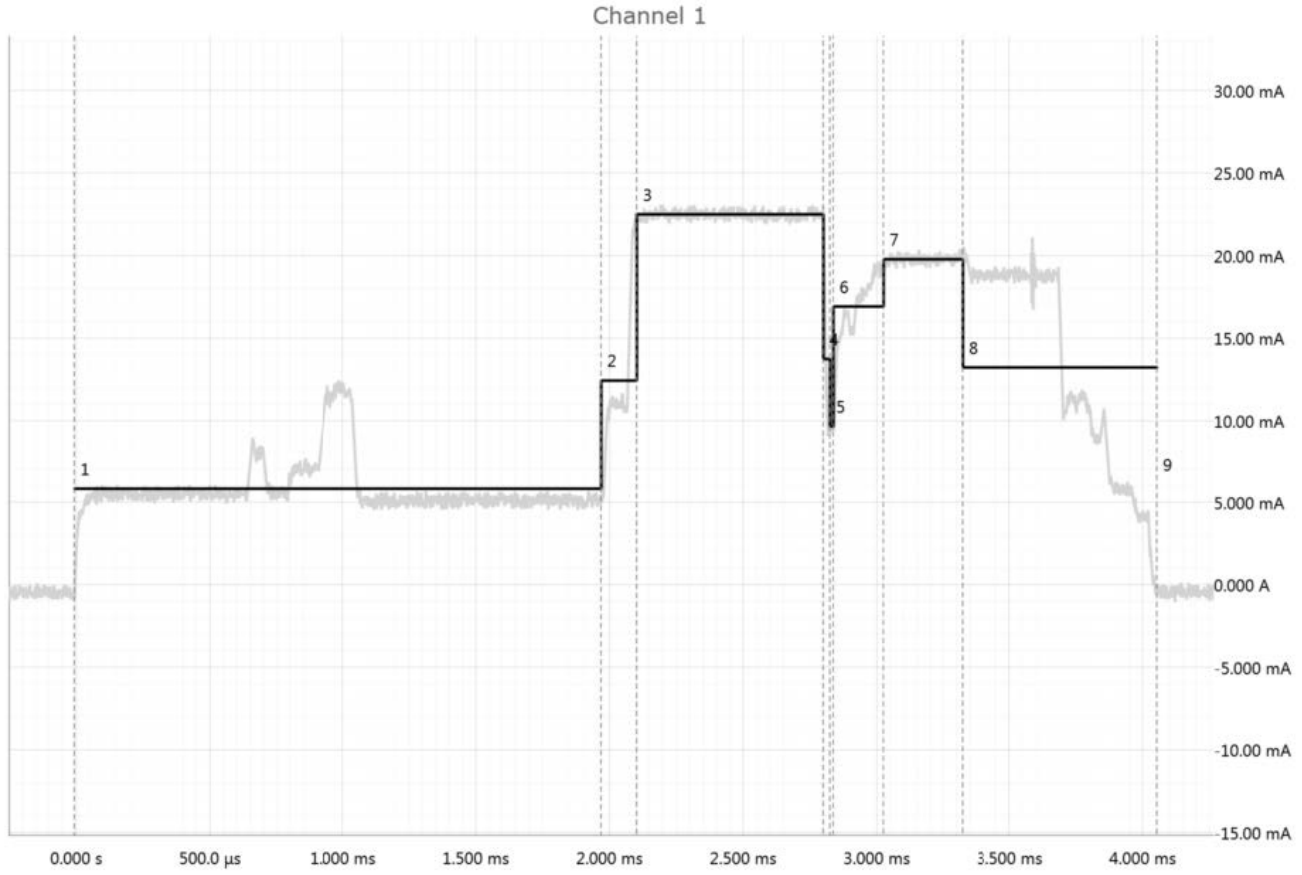

Figure 78. Connect profile in bypass mode, LLS2 (MCU Stop, Flash Doze), 125 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-6.798 µs	1.976 ms	5.807 mA	12.45 mA	-679.2 µA	3.187 nAh	23.8993002228897
2		1.969 ms	133.7 µs	12.44 mA	22.68 mA	4.610 mA	461.7 pAh	3.46219352900664
3		2.103 ms	697.5 µs	22.50 mA	23.19 mA	21.81 mA	4.359 nAh	32.6895112045076
4		2.800 ms	25.06 µs	13.74 mA	23.07 mA	8.780 mA	95.67 pAh	0.717436464341293
5		2.825 ms	12.53 µs	9.657 mA	10.19 mA	9.183 mA	33.61 pAh	0.252066717865841
6		2.838 ms	188.0 µs	16.92 mA	19.84 mA	9.186 mA	883.3 pAh	6.62402330460243
7		3.026 ms	296.6 µs	19.78 mA	20.47 mA	18.93 mA	1.629 nAh	12.2160805978851
8		3.322 ms	731.0 µs	13.23 mA	21.37 mA	-643.2 µA	2.686 nAh	20.1393879589014
9	Summary	4.053 ms	4.060 ms	11.82 mA	23.19 mA	-679.2 µA	13.34 nAh	100

Figure 79. Connect current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 125 kbps

4.2.2.14.8 Test environment: Connect 125 kbps, VLLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	

Table continues on the next page...

Table continued from the previous page...

MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	125 kbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Connection Interval = 50 ms Advertise from low power VLLS2 Slave to Master
Software	Low Power (PRC3 release)

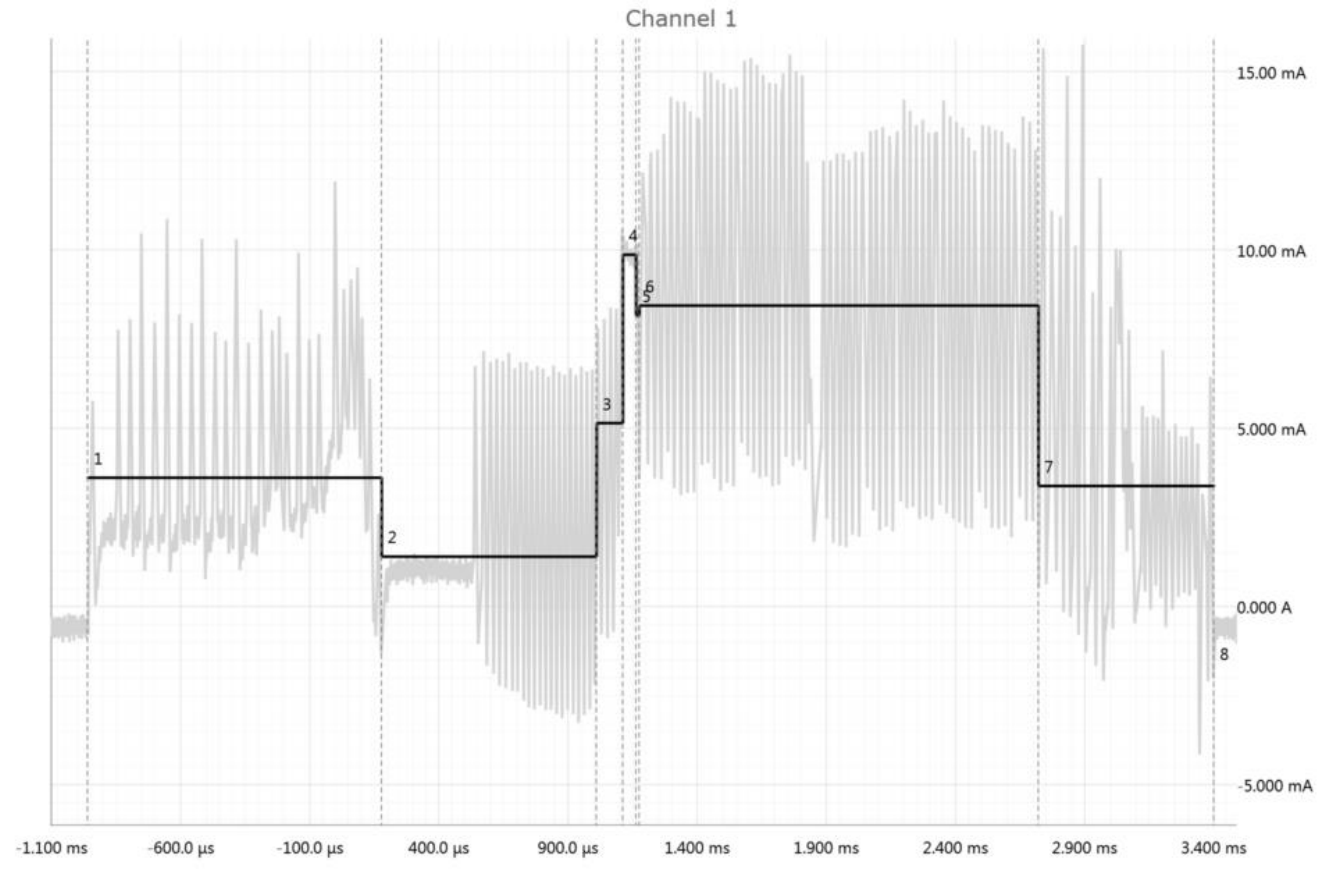

Figure 80. Connect profile in buck mode, VLLS2 (MCU Stop, Flash Doze), 125 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-959.4 µs	1.138 ms	3.611 mA	12.03 mA	-1.431 mA	1.141 nAh	18.9012654263683
2		178.4 µs	832.1 µs	1.397 mA	7.215 mA	-3.310 mA	322.9 pAh	5.34824873806179
3		1.010 ms	101.9 µs	5.141 mA	10.67 mA	-1.094 mA	145.5 pAh	2.41015844036445
4		1.112 ms	50.94 µs	9.865 mA	10.40 mA	9.406 mA	139.6 pAh	2.31225047763682
5		1.163 ms	12.74 µs	8.163 mA	10.23 mA	3.423 mA	28.88 pAh	0.478359929431896
6		1.176 ms	1.545 ms	8.437 mA	15.55 mA	532.4 µA	3.621 nAh	59.9855128422622
7		2.721 ms	679.2 µs	3.380 mA	15.84 mA	-4.304 mA	637.8 pAh	10.5642041458745
8	Summary	3.400 ms	4.360 ms	4.985 mA	15.84 mA	-4.304 mA	6.037 nAh	100

Figure 81. Connect current consumption in buck mode, VLLS2 (MCU Stop, Flash Doze), 125 kbps

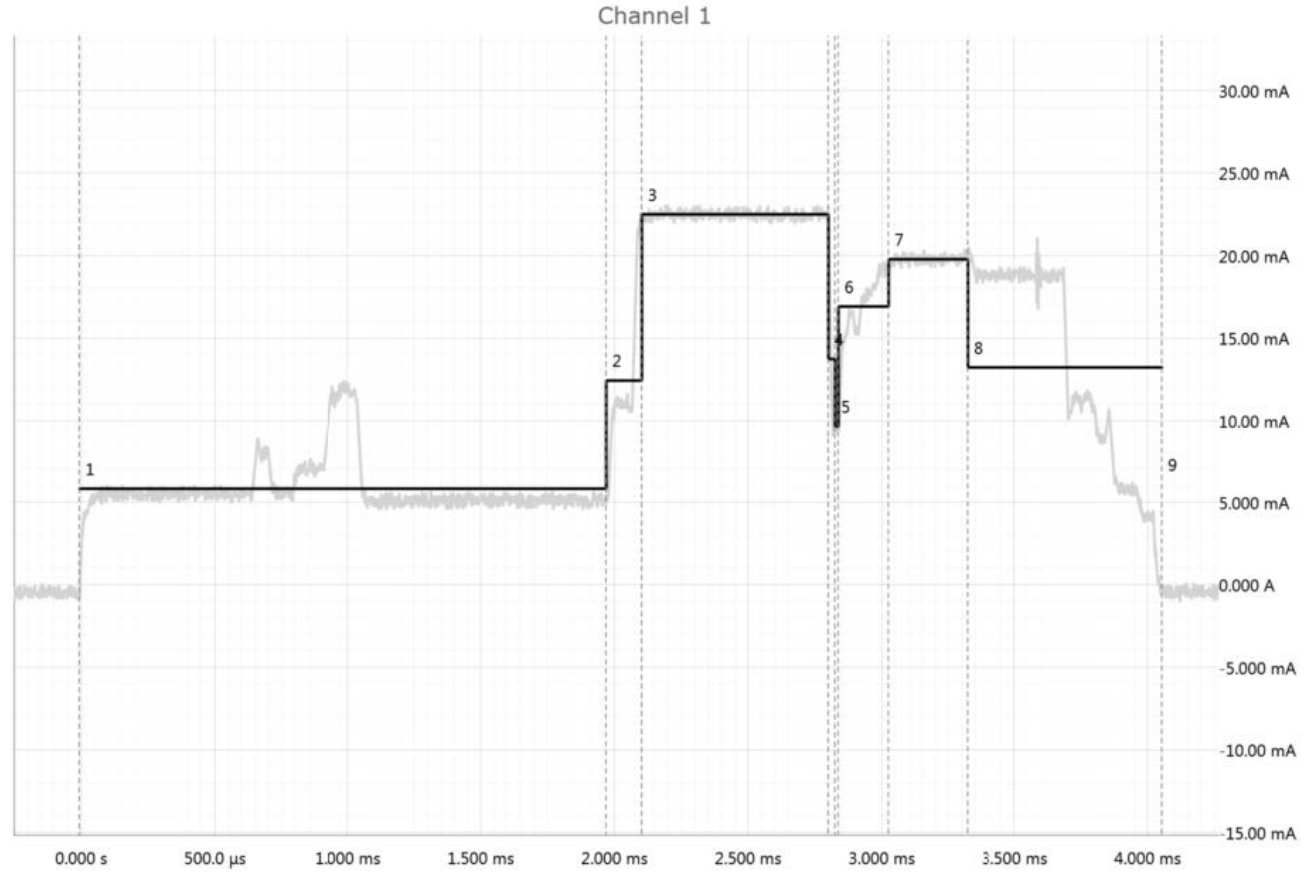

Figure 82. Connect profile in bypass mode, VLLS2 (MCU Stop, Flash Doze), 125 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-6.798 µs	1.976 ms	5.807 mA	12.45 mA	-679.2 µA	3.187 nAh	23.8993002228897
2		1.969 ms	133.7 µs	12.44 mA	22.68 mA	4.610 mA	461.7 pAh	3.46219352900664
3		2.103 ms	697.5 µs	22.50 mA	23.19 mA	21.81 mA	4.359 nAh	32.6895112045076
4		2.800 ms	25.06 µs	13.74 mA	23.07 mA	8.780 mA	95.67 pAh	0.717436464341293
5		2.825 ms	12.53 µs	9.657 mA	10.19 mA	9.183 mA	33.61 pAh	0.252066717865841
6		2.838 ms	188.0 µs	16.92 mA	19.84 mA	9.186 mA	883.3 pAh	6.62402330460243
7		3.026 ms	296.6 µs	19.78 mA	20.47 mA	18.93 mA	1.629 nAh	12.2160805978851
8		3.322 ms	731.0 µs	13.23 mA	21.37 mA	-643.2 µA	2.686 nAh	20.1393879589014
9	Summary	4.053 ms	4.060 ms	11.82 mA	23.19 mA	-679.2 µA	13.34 nAh	100

Figure 83. Connect current consumption in bypass mode, VLLS2 (MCU Stop, Flash Doze), 125 kbps

4.2.2.14.9 Connect no payload vs payload

DCDC: mode	BUCK
Supply	VDCDC IN = 3.6 V
RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	1 Mbps
Payload	0 byte vs 31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Connection Interval = 50 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC3 release)

Connection power consumption found in the previous results (payload 37 bytes) shows a result of 3.68 mA (3.95 nAh).

Performing the same power consumption event with 0 byte shows a result of 3.37 mA (3.75 nAh).

Table 55. Connect current consumption Payload vs no Payload

Payload	Power consumption (mA)	Power consumption (nAh)
0 byte	3.37	3.75
27 bytes	3.68	3.95

4.2.2.14.10 Summary

Table 56. Connect current consumption (MCU Stop, Flash Doze)

48 MHz FEE mode using 32 KHz crystal	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
CONN pre-processing 1 Mbps(mA)	3.03	3.22	6.03	5.91
CONN pre-processing 2 Mbps (mA)	3.03	2.98	6.02	5.97
CONN pre-processing 500 kbps (mA)	3.17	3.15	6.02	6.03
CONN pre-processing 125 kbps (mA)	3.09	3.06	5.98	5.88

Table 57. Connect timing (MCU Stop, Flash Doze)

Radio/Profile timing parameters (ms)	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
48 MHz FEE mode using 32 KHz crystal	T = 25 °C			
Conn pre-processing time - 1 Mbps (ms)	2.5	2.64	2.66	2.65
Conn post-processing time- 1 Mbps (µs)	693	722	329	396
Conn pre-processing time - 2 Mbps (ms)	2.08	2.07	2.02	2.04
Conn pre-processing time - 2 Mbps (µs)	753	700	306	309
Conn pre-processing time - 500 kbps (ms)	1.71	2.05	1.57	1.57
Conn pre-processing time - 500 kbps (µs)	730	774	717	700
Conn pre-processing time - 125 kbps (ms)	1.97	2.04	1.97	1.97
Conn pre-processing time - 125 kbps (µs)	679	755	731	664

Table 58. Connect current consumption event

Connect	`Vdcdc_in` = 3.6 V	LLS2 (ms)	LLS2 (mA)	LLS2 (nAh)	VLLS2 (ms)	VLLS2 (mA)	VLLS2 (nAh)
1 Mbps	buck	3.80	3.54	3.74	4.00	3.36	3.73
	bypass	3.40	7.28	6.88	3.50	7.00	6.81
2 Mbps	buck	3.15	3.54	3.10	3.15	3.10	2.72
	bypass	2.73	7.38	5.59	3.00	7.25	6.05
500 kbps	buck	3.81	5.25	5.56	3.83	3.83	4.82
	bypass	3.40	11.93	11.27	3.40	3.40	11.93
125 kbps	buck	4.39	5.22	6.36	5.86	5.86	5.86
	bypass	4.10	11.82	13.46	13.37	13.37	13.37

4.2.2.15 Scan mode

The following use case is used:

- LLS2 Mode is activated between the scan events.

The binary file settings used are: FEE 48 MHz clock, Scanning

- **Buck mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2
- **Bypass mode**
  - Wakeup from low power mode LLS2
  - Wakeup from low power mode VLLS2

Figure 84 shows the current consumption during the scan events.

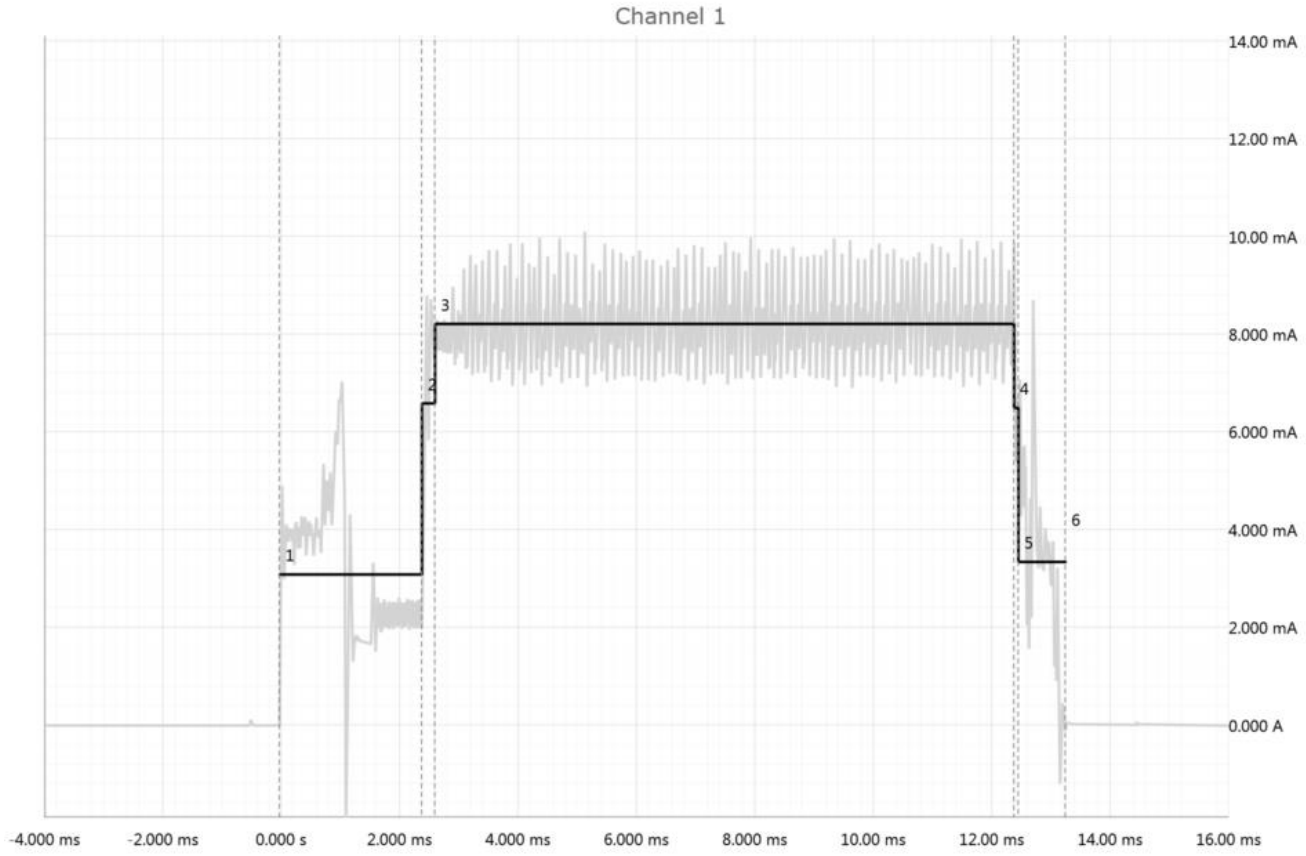

Figure 84. Current consumption - SCAN event period

Table 59. Scan events

Phase	Scan event timing
1	Pre-processing
2	Rx warmup
3	Active Rx
4	Rx warm-down
5	Post-processing

4.2.2.15.1 Test environment: Scan LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF = 3.6 V VDDMCU = 3.6 V
MCU clock mode	FEE 48 MHz	
RAM size	16 k	

Table continues on the next page...

Table continued from the previous page...

Data rate	1 Mbps
Payload	31 bytes
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Scanning Interval = 100 ms Active Scan Duration = 10 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC2 release)

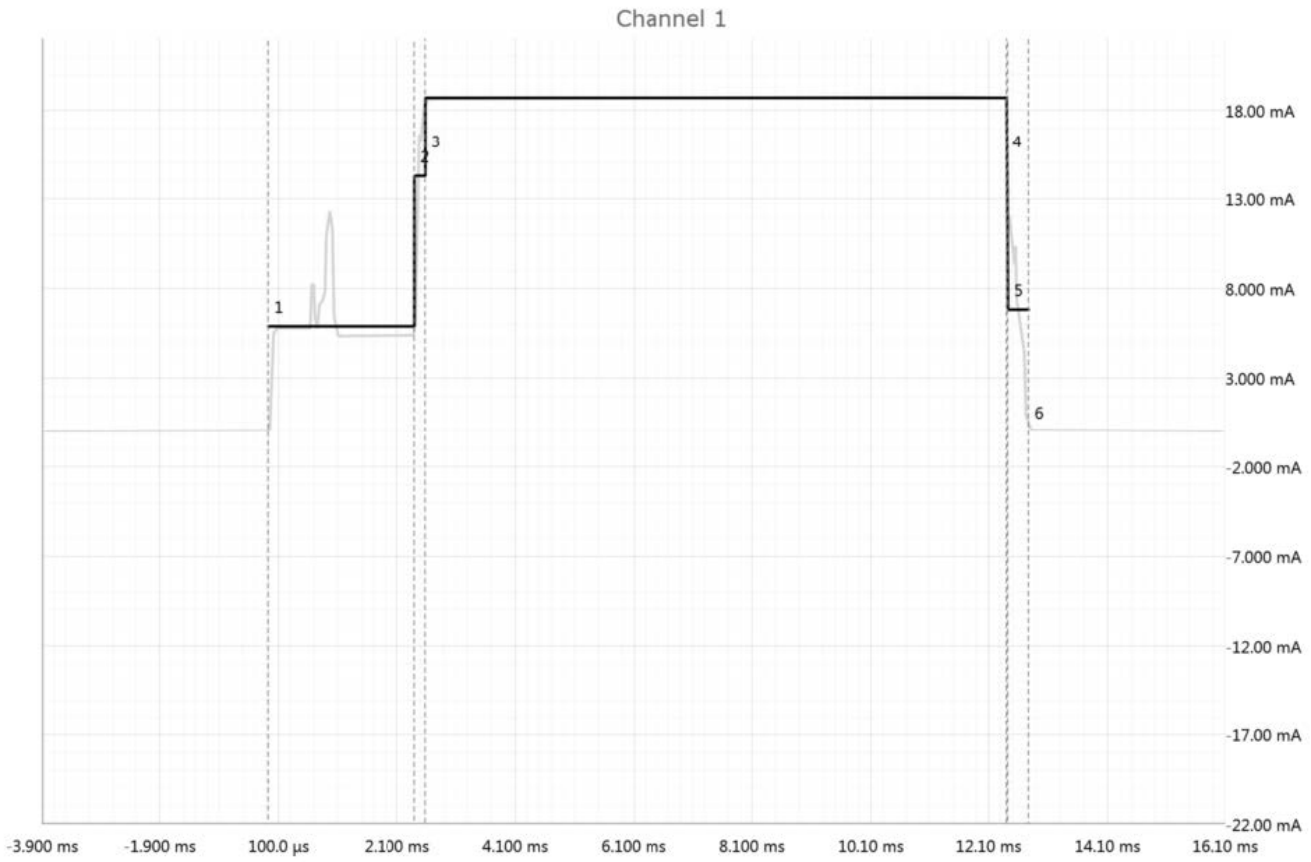

Figure 85. Scan profile in buck mode, LLS2 (MCU Stop, Flash Doze)

Table 60. Scan current consumption in buck mode, LLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-25.88 µs	2.403 ms	3.075 mA	7.084 mA	-2.927 µA	2.053 nAh	8.01
2	—	2.377 ms	221.8 µs	6.577 mA	8.860 mA	1.880 mA	405.2 pAh	1.58
3	—	2.599 ms	9.778 ms	8.204 mA	10.15 mA	6.817 mA	22.28 nAh	87.00
4	—	12.38 ms	73.94 µs	6.485 mA	9.934 mA	5.165 mA	133.2 pAh	0.52
5	—	12.45 ms	794.8 µs	3.333 mA	8.754 mA	-1.287 mA	735.8 pAh	2.87
6	Summary	13.25 ms	13.27 ms	6.947 mA	10.15 mA	-2.927 mA	25.61 nAh	100

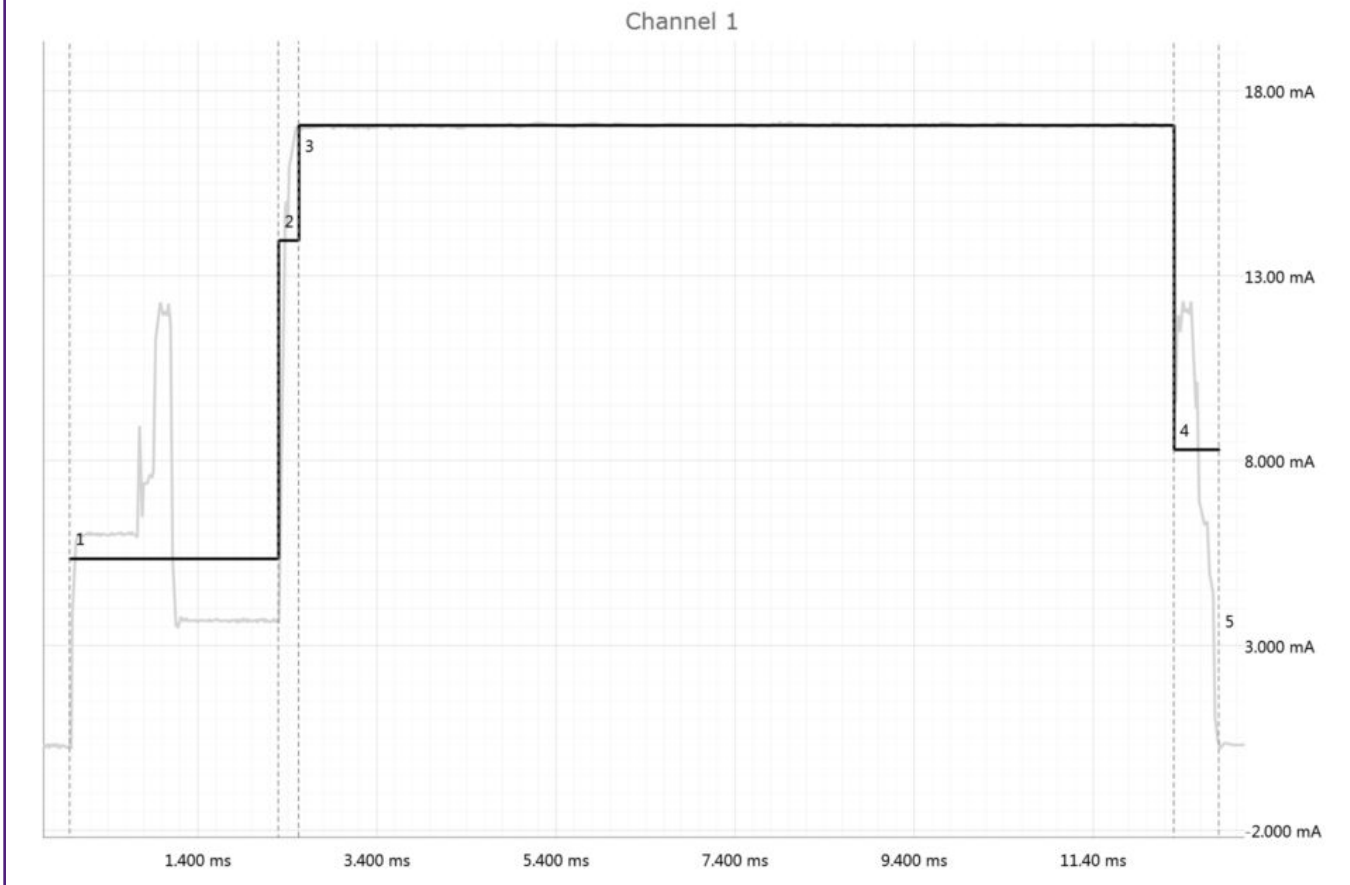

Figure 86. Scan profile in bypass mode, LLS2 (MCU Stop, Flash Doze)

Table 61. Scan current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-73.75 µs	2.477 ms	5.890 mA	12.40 mA	-1.768 µA	4.053 nAh	7.17
2	—	2.403 ms	184.8 µs	14.28 mA	18.51 mA	5.381 mA	733.2 pAh	1.29

Table continues on the next page...

Table 61. Scan current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze) (continued)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
3	—	2.588 ms	9.815 ms	18.69 mA	18.82 mA	18.53 mA	50.96 nAh	90.18
4	—	12.40 ms	23.18 µs	16.07 mA	18.67 mA	11.14 mA	103.5 pAh	0.18
5	—	12.43 ms	346.5 µs	6.819 mA	12.23 mA	48.58 µA	656.4 pAh	1.16
6	Summary	12.77 ms	12.85 ms	15.84 mA	18.82 mA	-1.768 µA	56.51 nAh	100

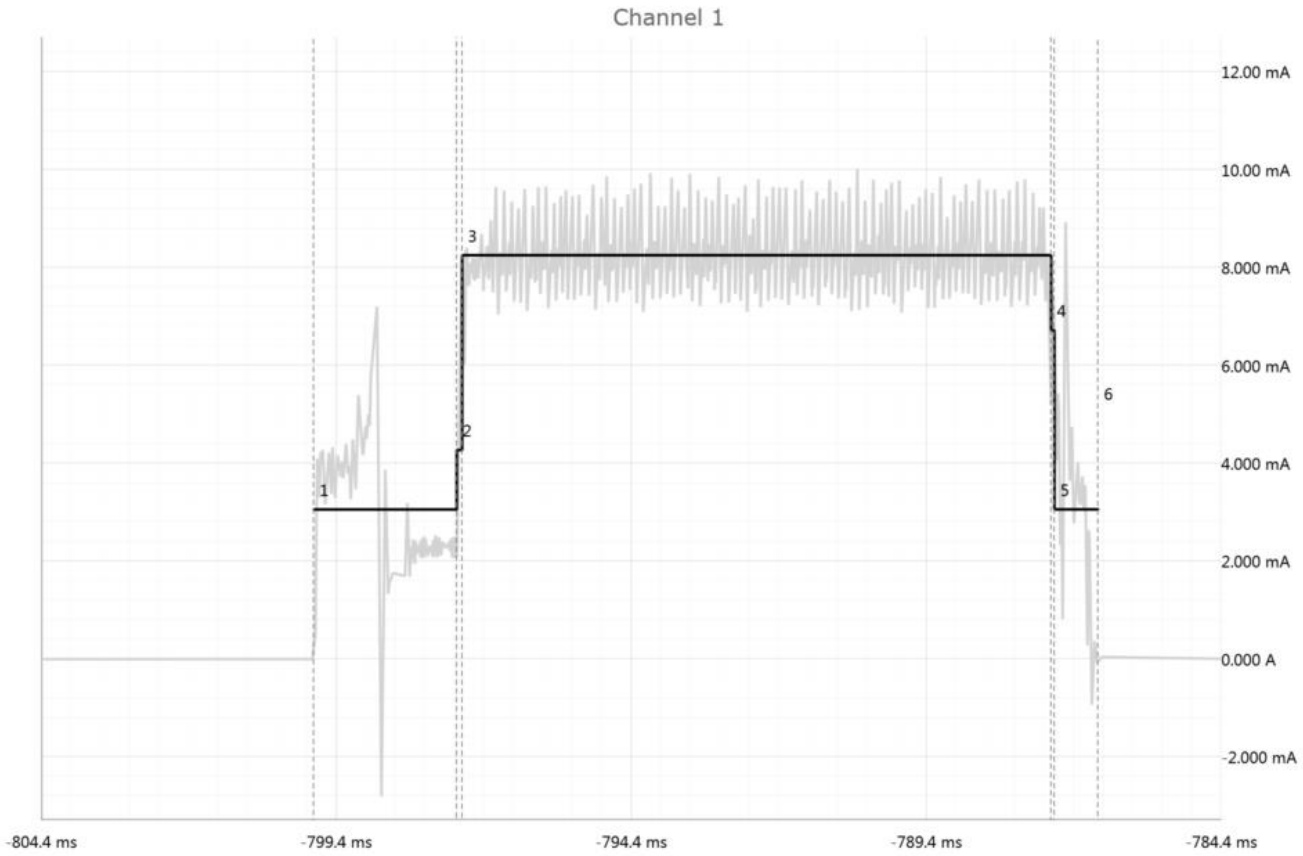

Figure 87. Scan profile in buck mode, VLLS2 (MCU Stop, Flash Doze)

Table 62. Scan current consumption in buck mode, VLLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-799.8 ms	2.421 ms	3.049 mA	7.203 mA	-2.812 mA	2.051 nAh	7.96
2	—	-797.4 ms	92.42 µs	4.264 mA	8.262 mA	2.082 mA	109.5 pAh	0.42
3	—	-797.3 ms	9.982 ms	8.244 mA	10.01 mA	5.203 mA	22.86 nAh	88.77
4	—	-787.3 ms	55.45 µs	6.709 mA	7.448 mA	5.222 mA	103.4 pAh	0.40

Table continues on the next page...

Table 62. Scan current consumption in buck mode, VLLS2 (MCU Stop, Flash Doze) (continued)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
5	—	-787.2 ms	739.4 µs	3.050 mA	8.916 mA	-974.8 µA	626.5 pAh	2.43
6	Summary	-786.5 ms	13.29 ms	6.975 mA	10.01 mA	-2.812 mA	25.75 nAh	100

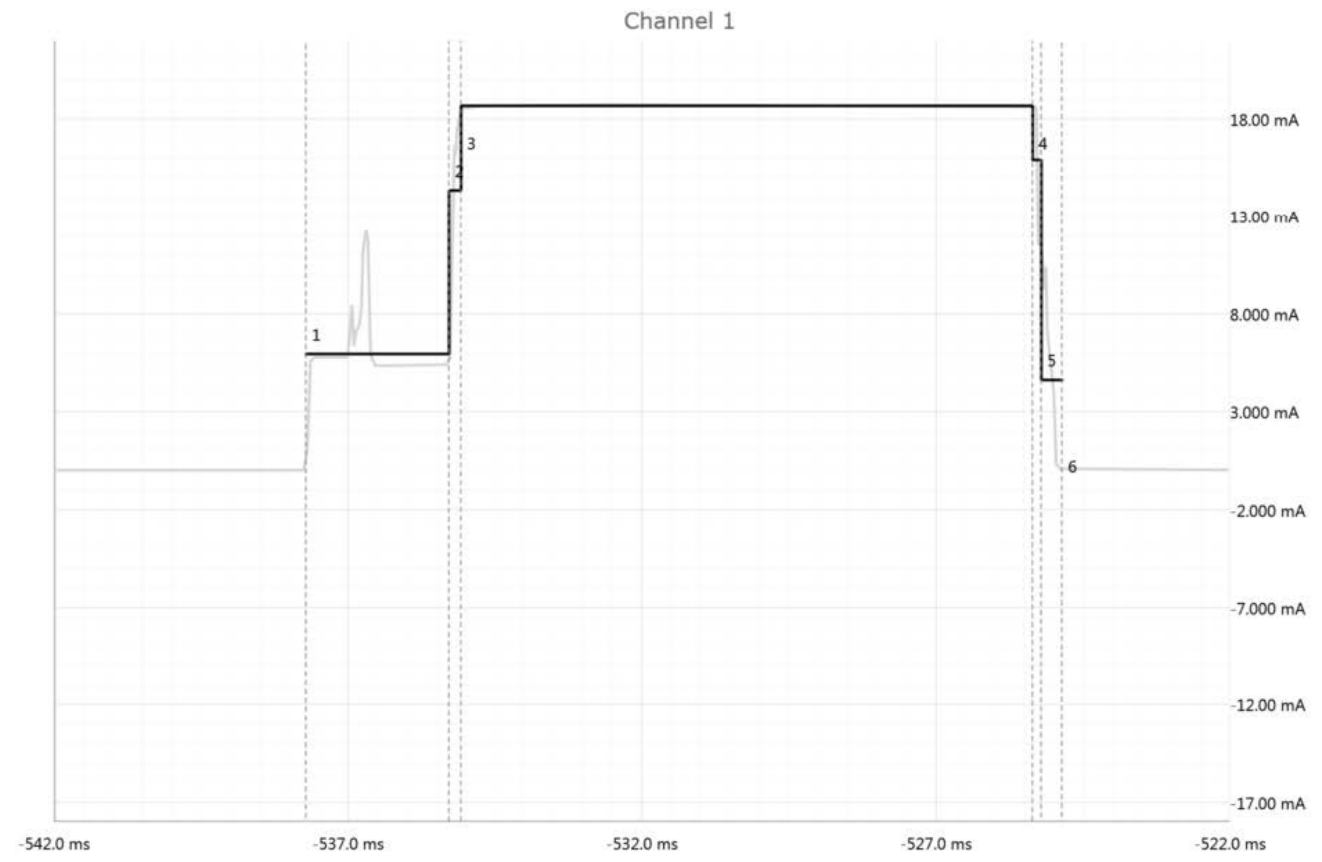

Figure 88. Scan profile in bypass mode, VLLS2 (MCU Stop, Flash Doze)

Table 63. Scan current consumption in bypass mode, VLLS2 (MCU Stop, Flash Doze)

Channel 1 indices								
Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-537.7 ms	2.421 ms	5.945 mA	12.40 mA	23.62 µA	3.998 nAh	7.09
2	—	-535.3 ms	203.3 µs	14.35 mA	18.56 mA	5.384 mA	810.6 pAh	1.43
3	—	-535.1 ms	9.723 ms	18.67 mA	18.76 mA	18.55 mA	50.43 nAh	89.50
4	—	-525.4 ms	147.9 µs	15.91 mA	18.66 mA	11.35 mA	653.6 pAh	1.16
5	—	-525.2 ms	351.2 µs	4.618 mA	11.44 mA	-21.91 µA	450.5 pAh	0.79
6	Summary	-524.9 ms	12.85 ms	15.79 mA	18.76 mA	-21.91 µA	56.34 nAh	100

4.2.2.15.2 Summary

Table 64. Scan current timing (MCU Stop, Flash Doze)

Radio/Profile timing parameters (ms)	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
48 MHz FEE mode using 32 KHz crystal	T = 25 °C			
SCAN pre-processing time (ms)	2.403	2.421	2.477	2.421
SCAN post-processing time (ms)	0.795	0.795	0.346	0.351

Table 65. Scan current consumption event

Vdcdc_in = 3.6 V		LLS2 (ms)	LLS2 (mA)	LLS2 (nAh)	VLLS2 (ms)	VLLS2 (mA)	VLLS2 (nAh)
Scan	buck	13.30	7.09	26.19	13.30	6.98	25.77
	bypass	12.85	15.54	55.47	12.85	15.79	56.36

4.3 Advertising extension

Bluetooth 5.x allows advert packets to be transmitted in the data channels (although the specification prefers to label them as **secondary advert channels**.)

- Increases advertising data length.
- Allows advertising on data channels.
- Enables long range connection establishment.
- Enables chaining and periodic advertising.

In this case the new primary advert points to an auxiliary packet which in turn specifies a **connectionless** train of packets which hop at a known cadence.

The cadence information and the access address code is provided by that auxiliary packet.

The next three figures capture the current consumption during the advertising extension event using data rate at 1 Mbps, 2 Mbps and 500 kbps. Bypass mode graphs are provided as example.

The binary file settings used are:

- FEE 48MHz clock
- Advertising Extension with PDU 8-byte for Channel 37/38/39 and PDU 42-byte (31bytes payload) and connectable
- RF output +5 dBm

Buck mode:

- Wakeup from low power mode LLS2
- Wakeup from low power mode VLLS2

Bypass mode:

- Wakeup from low power mode LLS2
- Wakeup from low power mode VLLS2

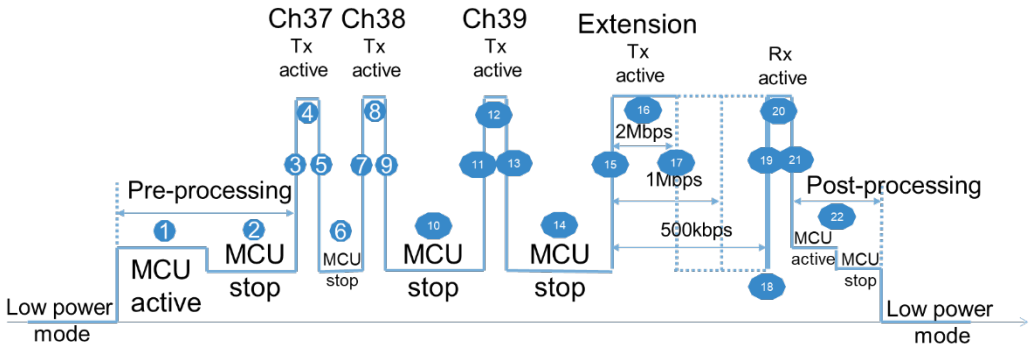

Figure 89. Current consumption - Advertising event period

Table 66. Advertising extension event

Phase	Scan event timing
1	Pre-processing/MCU active
2	Pre-processing/MCU stop
3	Tx warm-up
4	Tx active
5	Tx warm-down
6	MCU stop
7	Tx warm-up
8	Tx active
9	Tx warm-down
10	MCU stop
11	Tx warm-up
12	Tx active
13	Tx warm-down
14	MCU stop
15	Tx warm-up
16	Tx active
17	Tx warm-down
18	Tx to Rx
19	Rx warm-up
20	Rx active
21	Rx warm-down
22	Post-processing

4.3.1 Test environment: Advertising extension 1 Mbps, LLS2

DCDC: mode	BYPASS
Supply	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	1 Mbps
Payload	For CH 37/38/39: PDU size 8 bytes For Secondary CH: PDU size 42, payload size 31
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Adverting Interval = 500 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC3 release)

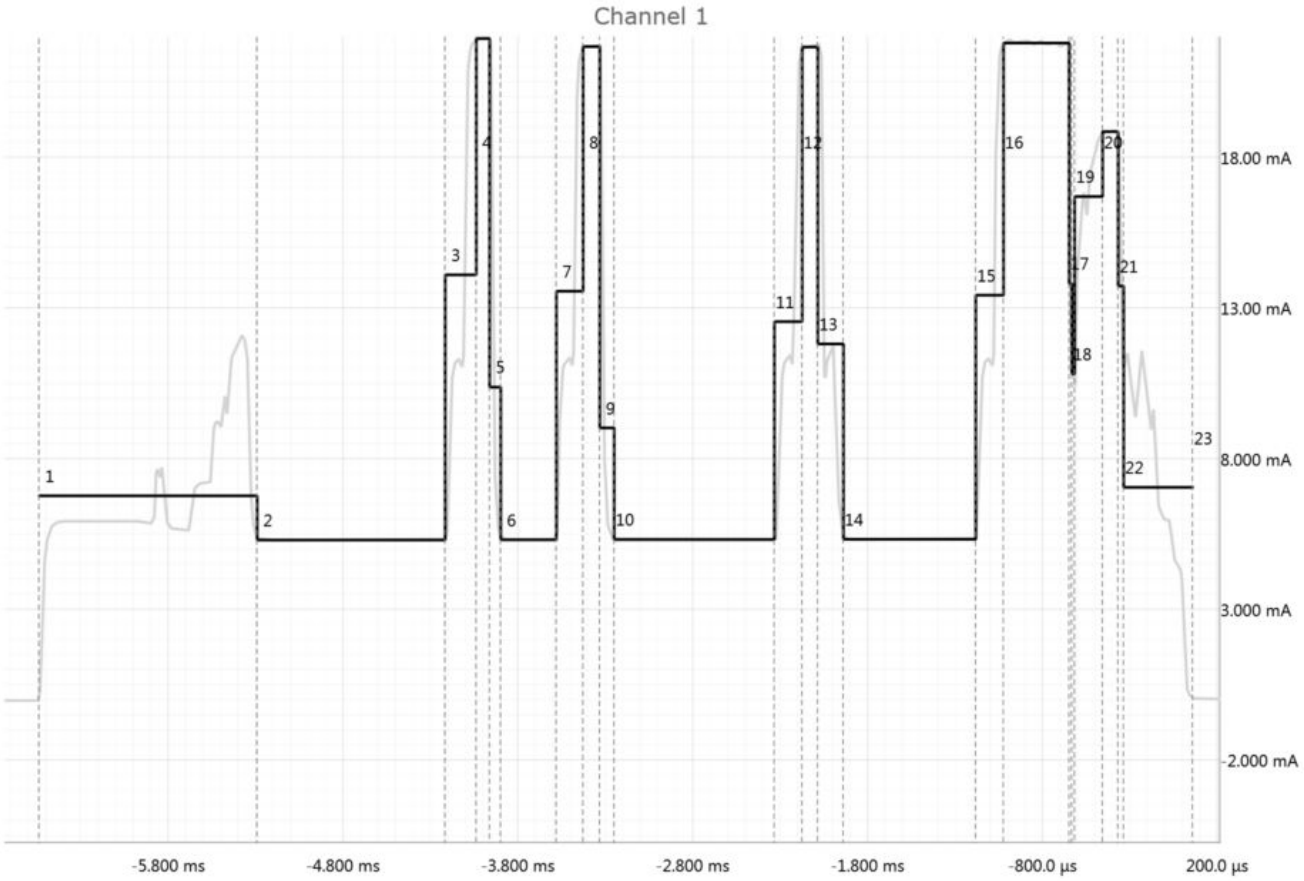

Figure 90. Advertising Extension current profile event after LLS2 mode, bypass mode, 1 Mbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-6.537 ms	1.247 ms	6.764 mA	12.20 mA	-68.27 µA	2.343 nAh	14.4554981028226
2		-5.291 ms	1.075 ms	5.297 mA	5.395 mA	5.199 mA	1.582 nAh	9.76117221697056
3		-4.215 ms	178.1 µs	14.10 mA	22.01 mA	5.262 mA	697.4 pAh	4.30339635129518
4		-4.037 ms	76.34 µs	21.94 mA	22.05 mA	21.82 mA	465.1 pAh	2.87014238664062
5		-3.961 ms	63.61 µs	10.37 mA	22.00 mA	5.379 mA	183.2 pAh	1.13068429842861
6		-3.897 ms	318.1 µs	5.307 mA	5.419 mA	5.204 mA	468.9 pAh	2.89311959138842
7		-3.579 ms	152.7 µs	13.55 mA	21.73 mA	5.291 mA	574.7 pAh	3.54597744857985
8		-3.427 ms	95.42 µs	21.67 mA	21.81 mA	21.54 mA	574.3 pAh	3.54381717208778
9		-3.331 ms	82.70 µs	9.017 mA	21.79 mA	5.259 mA	207.1 pAh	1.27811300813946
10		-3.248 ms	916.0 µs	5.313 mA	5.415 mA	5.197 mA	1.352 nAh	8.34199671665576
11		-2.332 ms	159.0 µs	12.54 mA	21.61 mA	5.250 mA	554.1 pAh	3.41906502203154
12		-2.173 ms	89.06 µs	21.65 mA	21.77 mA	21.50 mA	535.6 pAh	3.3051296719325
13		-2.084 ms	146.3 µs	11.80 mA	21.82 mA	5.381 mA	479.7 pAh	2.95990033887108
14		-1.938 ms	757.0 µs	5.323 mA	5.480 mA	5.211 mA	1.119 nAh	6.9063262943366
15		-1.181 ms	159.0 µs	13.42 mA	21.82 mA	5.315 mA	592.8 pAh	3.65804144165251
16		-1.022 ms	375.3 µs	21.79 mA	22.02 mA	19.53 mA	2.271 nAh	14.0158278921864
17		-646.6 µs	14.95 µs	13.80 mA	19.52 mA	11.12 mA	57.32 pAh	0.353717284125572
18		-631.7 µs	16.22 µs	10.81 mA	11.14 mA	10.35 mA	48.72 pAh	0.300601862433539
19		-615.5 µs	159.7 µs	16.69 mA	18.85 mA	10.32 mA	740.4 pAh	4.56883898479575
20		-455.8 µs	89.06 µs	18.85 mA	18.95 mA	18.73 mA	466.2 pAh	2.87679075334807
21		-366.7 µs	31.81 µs	13.72 mA	18.92 mA	10.94 mA	121.3 pAh	0.748253588071564
22		-334.9 µs	394.4 µs	7.046 mA	11.68 mA	-5.032 µA	772.0 pAh	4.76358957320594
23	Summary	59.48 µs	6.597 ms	8.844 mA	22.05 mA	-68.27 µA	16.21 nAh	100

Figure 91. Advertising Extension current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 1 Mbps

4.3.2 Test environment: Advertising extension 2 Mbps, LLS2

DCDC: mode	BYPASS
Supply	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	2 Mbps
Payload	For CH 37/38/39: PDU size 8 bytes For Secondary CH: PDU size 42, payload size 31
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Adverting Interval = 500 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC3 release)

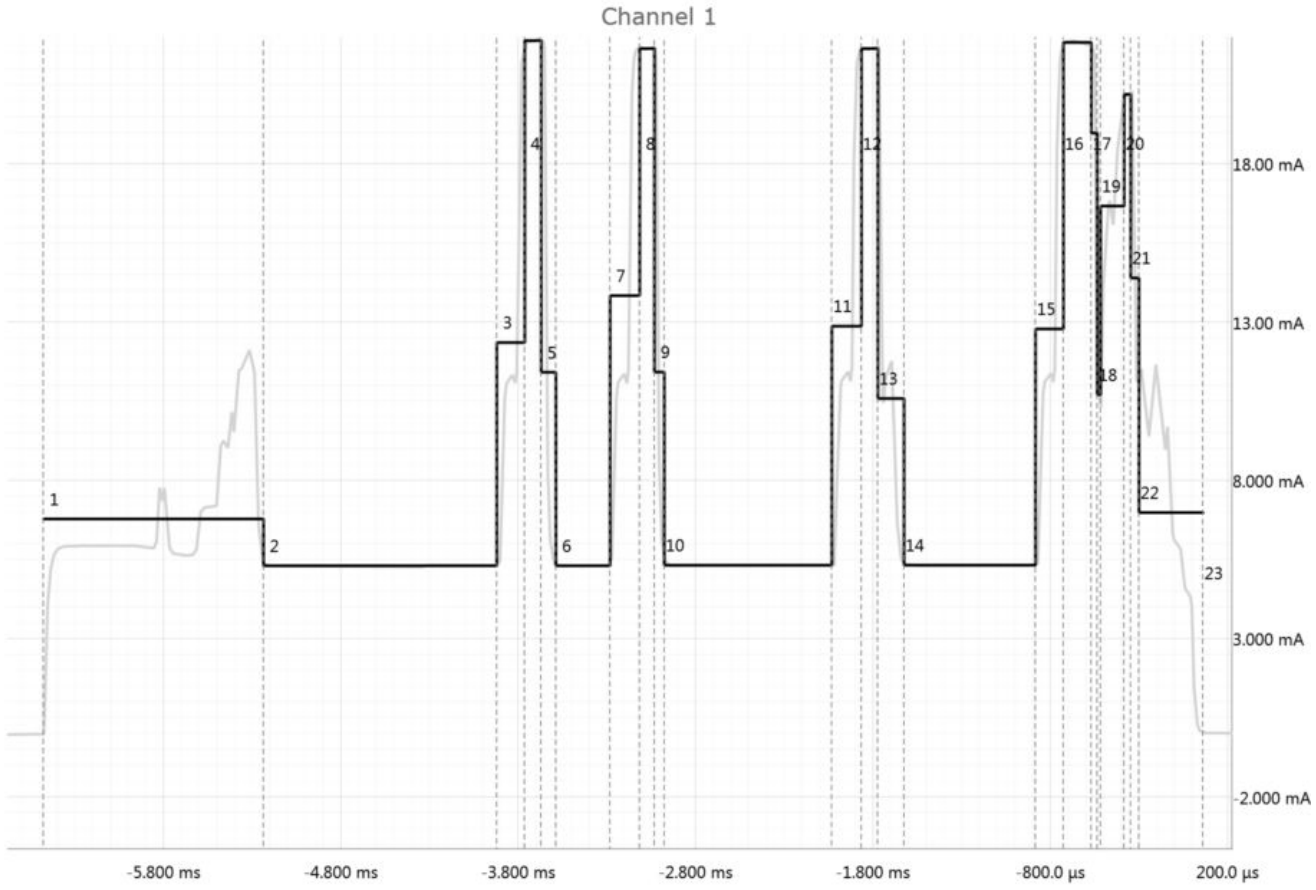

Figure 92. Advertising Extension current profile event after LLS2 mode, bypass mode, 2 Mbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-6.476 ms	1.241 ms	6.777 mA	12.19 mA	-107.8 µA	2.336 nAh	15.6421882372223
2		-5.235 ms	1.315 ms	5.298 mA	5.387 mA	5.191 mA	1.935 nAh	12.9579188567973
3		-3.920 ms	157.4 µs	12.35 mA	21.76 mA	5.243 mA	539.8 pAh	3.61492706476587
4		-3.763 ms	92.59 µs	21.89 mA	22.04 mA	21.72 mA	562.9 pAh	3.76971460529404
5		-3.670 ms	83.33 µs	11.41 mA	22.02 mA	5.308 mA	264.1 pAh	1.76876273055552
6		-3.587 ms	305.6 µs	5.299 mA	5.384 mA	5.220 mA	449.8 pAh	3.01185341802591
7		-3.281 ms	166.7 µs	13.83 mA	21.78 mA	5.295 mA	640.3 pAh	4.28759070470083
8		-3.115 ms	83.33 µs	21.64 mA	21.79 mA	21.51 mA	500.8 pAh	3.3539767771455
9		-3.031 ms	55.56 µs	11.42 mA	21.76 mA	5.495 mA	176.2 pAh	1.18000470009193
10		-2.976 ms	944.4 µs	5.314 mA	5.534 mA	5.214 mA	1.394 nAh	9.33560425592415
11		-2.031 ms	166.7 µs	12.87 mA	21.69 mA	5.237 mA	595.7 pAh	3.98931198408969
12		-1.865 ms	92.59 µs	21.63 mA	21.78 mA	21.52 mA	556.4 pAh	3.72627399464318
13		-1.772 ms	148.1 µs	10.58 mA	21.75 mA	5.331 mA	435.4 pAh	2.91602156427841
14		-1.624 ms	740.7 µs	5.317 mA	5.415 mA	5.227 mA	1.094 nAh	7.3262799085096
15		-883.3 µs	157.4 µs	12.78 mA	21.87 mA	5.263 mA	558.8 pAh	3.74193706401439
16		-725.9 µs	157.4 µs	21.83 mA	21.99 mA	21.63 mA	954.4 pAh	6.39150815618585
17		-568.5 µs	33.20 µs	18.97 mA	21.84 mA	11.24 mA	174.9 pAh	1.17145833958034
18		-535.3 µs	19.14 µs	10.70 mA	11.24 mA	10.26 mA	56.89 pAh	0.380952922958175
19		-516.2 µs	132.8 µs	16.66 mA	19.99 mA	10.21 mA	614.8 pAh	4.1169562969384
20		-383.3 µs	37.04 µs	20.19 mA	20.34 mA	19.98 mA	207.7 pAh	1.39084627299787
21		-346.3 µs	46.30 µs	14.39 mA	20.36 mA	11.02 mA	185.0 pAh	1.23915665746803
22		-300.0 µs	361.1 µs	6.977 mA	11.74 mA	-16.45 µA	699.9 pAh	4.68675548781266
23	Summary	61.11 µs	6.537 ms	8.224 mA	22.04 mA	-107.8 µA	14.93 nAh	100

Figure 93. Advertising Extension current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 2 Mbps

4.3.3 Test environment: Advertising extension 500 kbps, LLS2

DCDC: mode	BYPASS
Supply	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	500 kbps
Payload	For CH 37/38/39: PDU size 8 bytes For Secondary CH: PDU size 42, payload size 31
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Adverting Interval = 500 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC3 release)

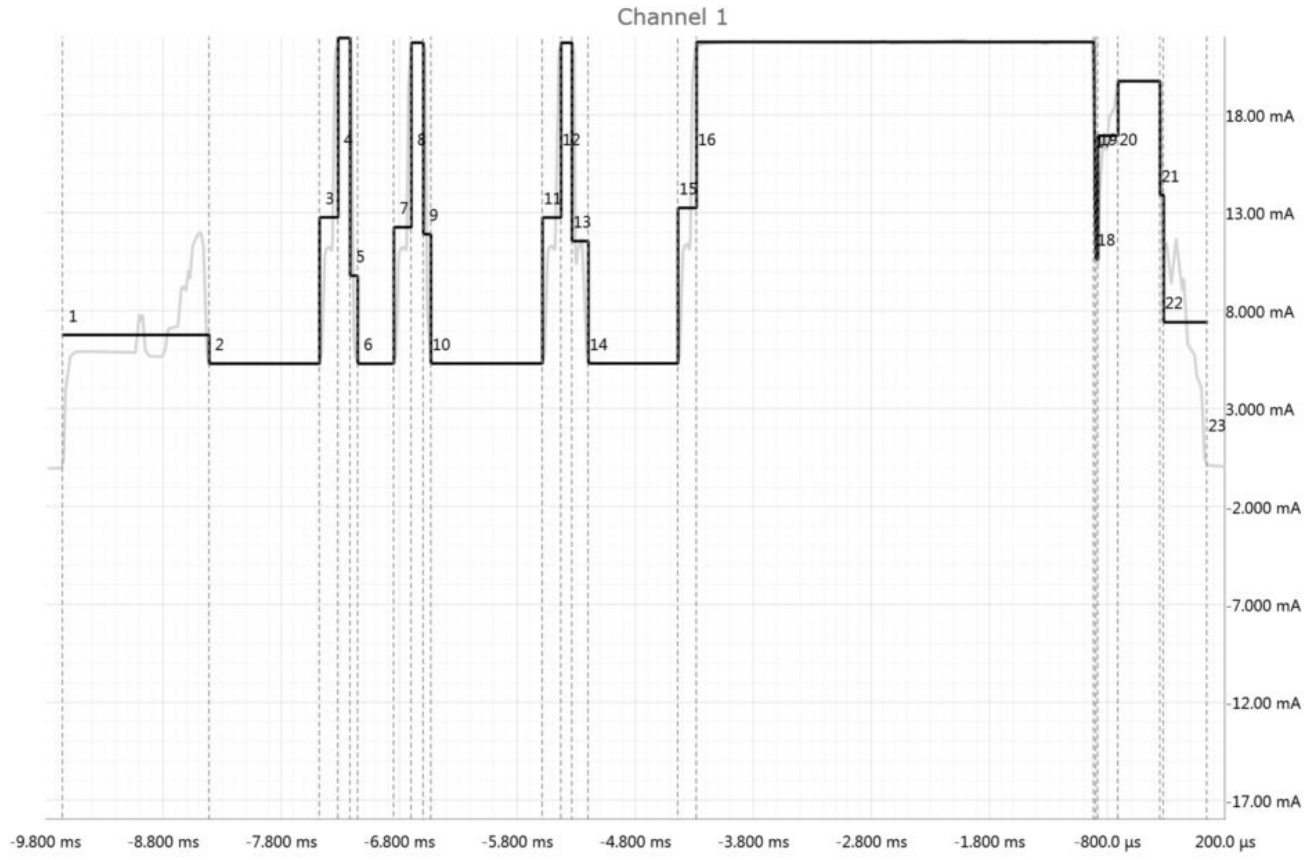

Figure 94. Advertising Extension current profile event after LLS2 mode, bypass mode, 500 kbps

Channel 1 Indices

Num.	Label	Time	Duration	Mean	Max	Min	Integral	Ratio
1		-9.652 ms	1.241 ms	6.763 mA	12.21 mA	-135.9 µA	2.331 nAh	6.55552166783311
2		-8.411 ms	935.2 µs	5.293 mA	5.450 mA	5.173 mA	1.375 nAh	3.86729576522941
3		-7.476 ms	157.4 µs	12.76 mA	21.84 mA	5.244 mA	558.1 pAh	1.56980640050924
4		-7.319 ms	101.9 µs	21.93 mA	22.06 mA	21.76 mA	620.4 pAh	1.74504876524947
5		-7.217 ms	64.81 µs	9.784 mA	21.95 mA	5.294 mA	176.2 pAh	0.495471414989844
6		-7.152 ms	305.6 µs	5.295 mA	5.396 mA	5.204 mA	449.4 pAh	1.26397015836921
7		-6.846 ms	148.1 µs	12.26 mA	21.63 mA	5.234 mA	504.6 pAh	1.41923556026051
8		-6.698 ms	101.9 µs	21.69 mA	21.85 mA	21.52 mA	613.6 pAh	1.72572367113559
9		-6.596 ms	64.81 µs	11.91 mA	21.78 mA	5.381 mA	214.3 pAh	0.602884929913844
10		-6.531 ms	944.4 µs	5.304 mA	5.431 mA	5.197 mA	1.391 nAh	3.91368484287538
11		-5.587 ms	157.4 µs	12.76 mA	21.73 mA	5.206 mA	557.7 pAh	1.56869952358727
12		-5.430 ms	92.59 µs	21.68 mA	21.82 mA	21.52 mA	557.7 pAh	1.56870901413811
13		-5.337 ms	138.9 µs	11.55 mA	21.73 mA	5.367 mA	445.7 pAh	1.25371046061536
14		-5.198 ms	759.3 µs	5.308 mA	5.453 mA	5.198 mA	1.120 nAh	3.14899244768933
15		-4.439 ms	157.4 µs	13.25 mA	21.53 mA	5.287 mA	579.3 pAh	1.62936958726596
16		-4.281 ms	3.365 ms	21.72 mA	21.91 mA	21.46 mA	20.31 nAh	57.1146418732938
17		-916.3 µs	18.72 µs	15.65 mA	21.80 mA	10.87 mA	81.42 pAh	0.229011465876565
18		-897.5 µs	17.28 µs	10.63 mA	10.89 mA	10.26 mA	51.02 pAh	0.143490430199347
19		-880.2 µs	170.0 µs	16.94 mA	19.61 mA	10.24 mA	799.6 pAh	2.2488586923565
20		-710.3 µs	355.8 µs	19.73 mA	19.87 mA	19.52 mA	1.949 nAh	5.48299082145133
21		-354.5 µs	30.25 µs	13.90 mA	19.75 mA	10.89 mA	116.8 pAh	0.328533715676258
22		-324.3 µs	366.9 µs	7.411 mA	11.81 mA	32.73 µA	755.3 pAh	2.12434879148454
23	Summary	42.59 µs	9.694 ms	13.20 mA	22.06 mA	-135.9 µA	35.55 nAh	100

Figure 95. Advertising Extension current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 500 kbps

4.3.4 Timing data

Table 67. Advertising extension timing table

Phase	Scan event timing	Timing (µs)											
		Buck						Bypass					
		LLS2			VLLS2			LLS2			VLLS2		
		1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded
1	Pre-processing MCU active	1250	1250	1250	1650	1650	1650	1250	1250	1250	1700	1700	1700
2	Pre-processing MCU stop	1200	1500	1100	1250	900	1100	1050	1350	950	1150	800	1000
3	Tx warm-up	15	15	15	15	15	15	150	150	150	150	150	150
4	TX active	100	100	100	100	100	100	100	100	100	100	100	100
5	TX warm-down	20	20	20	20	20	20	65	65	65	65	65	65
6	MCU stop	450	450	450	450	450	450	300	300	300	300	300	300
7	Tx warm-up	20	20	20	20	20	20	150	150	150	150	150	150
8	TX active	100	100	100	100	100	100	100	100	100	100	100	100
9	TX warm-down	20	20	20	20	20	20	70	70	70	70	70	70
10	MCU stop	1050	1050	1050	1050	1050	1050	950	950	950	950	950	950
11	Tx warm-up	20	20	20	20	20	20	150	150	150	150	150	150
12	TX active	100	100	100	100	100	100	100	100	100	100	100	100

Table continues on the next page...

Table 67. Advertising extension timing table (continued)

Phase	Scan event timing	Timing (µs)											
		Buck						Bypass					
		LLS2			VLLS2			LLS2			VLLS2		
		1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded
13	TX warm-down	20	20	20	20	20	20	150	150	150	150	150	150
14	MCU stop	850	850	850	850	850	850	750	750	750	750	750	750
15	TX warm-up	20	20	20	20	20	20	150	150	150	150	150	150
16	TX active	400	150	3400	400	150	3400	400	150	3400	400	150	3400
17	Tx warm-down	20	20	20	20	20	20	25	25	25	25	25	25
18	Tx to RX	20	20	20	20	20	20	20	20	20	20	20	20
19	Rx warm-up	20	20	20	20	20	20	150	150	150	150	150	150
20	Rx active	350	250	550	350	250	550	90	45	350	90	45	350
21	Rx warm-down	30	30	30	30	30	30	30	30	30	30	30	30
22	Post-processing	900	900	900	1200	1200	1200	350	350	350	600	600	600
23	Total	6975	6925	10075	7725	7025	10775	6550	6555	9710	7350	6705	10460

Table 68. Advertising Extension consumption table

Phase	Scan event timing	Consumption (mA)											
		Buck						Bypass					
		LLS2			VLLS2			LLS2			VLLS2		
		1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded
1	Pre-processing MCU active	3.49	3.53	3.41	3.69	3.73	3.71	6.764	6.777	6.763	6.602	6.604	6.56
2	Pre-processing MCU stop	2.59	2.53	2.56	2.53	2.59	2.52	5.297	5.298	5.293	5.26	5.23	5.23
3	Tx warm-up	9.04	5.1	7.28	5.63	6.98	7.1	14.1	12.35	12.76	12.04	20.02	11.88
4	TX active	9.93	10.37	9.79	8.78	8.75	8.54	21.94	21.89	21.93	20.13	20.21	20.07
5	TX warm-down	8.65	8.29	3.58	4.12	2.98	5.19	10.37	11.41	9.784	9.54	20.08	10.81
6	MCU stop	2.75	2.78	2.84	2.68	2.81	2.83	5.307	5.299	5.295	5.26	5.33	5.24
7	Tx warm-up	7.7	7.45	7.83	6.53	5.2	6.89	13.55	13.83	12.26	10.78	19.8	12.05
8	TX active	10.32	9.8	9.73	8.7	8.9	8.73	21.67	21.64	21.69	19.89	19.97	19.86
9	TX warm-down	7.57	6.29	5.28	5.75	5.1	4.62	9.017	11.42	11.91	8.84	19.94	8.54
10	MCU stop	2.57	2.54	2.58	2.48	2.59	2.49	5.313	5.314	5.3	5.27	5.36	5.24
11	Tx warm-up	8.55	6.39	4.97	5.76	7.39	5.06	12.54	12.87	12.76	12.97	19.9	11.45
12	TX active	10.82	10.06	8.16	7.84	7.64	7.73	21.65	21.63	21.68	19.88	19.9	19.8
13	TX warm-down	7.5	6.64	4.65	5.66	3.93	2.29	11.8	10.58	11.55	10.33	20	10.4

Table continues on the next page...

Table 68. Advertising Extension consumption table (continued)

Phase	Scan event timing	Consumption (mA)											
		Buck						Bypass					
		LLS2			VLLS2			LLS2			VLLS2		
		1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded	1M1M	1M2M	1MCoded
14	MCU stop	2.59	2.5	2.63	2.6	2.6	2.59	5.323	5.317	5.308	5.25	5.44	5.24
15	TX warm-up	8.78	7.99	5.05	4.89	7.65	5.54	13.42	12.78	13.25	12.09	20.1	13.4
16	TX active	9.34	9.71	9.35	8.72	8.93	8.66	21.79	21.83	21.72	19.93	20.2	19.8
17	Tx warm-down	—	—	—	6.83	5.23	6.86	13.8	18.97	15.65	13.75	20.1	14.77
18	Tx to RX	6.4	5.65	4.76	—	2.27	4.05	10.81	10.7	10.63	10.4	10.69	10.32
19	Rx warm-up	—	—	—	—	5.7	—	16.69	16.66	16.94	16.63	19.8	17.23
20	Rx active	7.84	8.056	8.28	—	7.99	8.29	18.85	20.19	19.73	18.86	20.2	19.66
21	Rx warm-down	—	5.058	—	—	7.2	7.89	13.72	14.39	13.9	13.91	20.2	14.28
22	Post-processing	3.62	3.52	3.61	4.6	3.89	3.86	7.046	6.977	7.411	7.86	7.87	7.87
23	Total	**4.002**	**3.752**	**5.725**	**3.918**	**3.834**	**5.362**	**8.844**	**8.224**	**13.2**	**8.407**	**8.113**	**12.01**

4.3.5 Summary data

Table 69. Advertising extension consumption summary table

Advertising Extension	Unit: nAh	Vdcdc_in (V) power supply (Ambiant, 25°C)					
		2.1	2.4	2.7	3	3.3	3.6
1 Mbps, LLS2	Buck	11.511	10.480	9.530	8.808	8.228	7.772
	Bypass	15.861	15.928	16.008	15.970	16.006	16.086
2 Mbps, LLS2	Buck	10.754	9.635	8.788	8.157	7.671	7.222
	Bypass	14.719	14.770	14.841	14.784	14.944	14.933

Table continues on the next page...

Table 69. Advertising extension consumption summary table (continued)

Advertising Extension	Unit: nAh	Vdcdc_in (V) power supply (Ambiant, 25°C)					
		2.1	2.4	2.7	3	3.3	3.6
Coded 500 kbps, LLS2	Buck	25.012	22.295	20.261	18.551	17.181	16.095
	Bypass	35.048	35.150	35.296	35.302	35.454	35.545
1 Mbps, VLLS2	Buck	12.671	11.276	10.354	9.673	8.984	8.414
	Bypass	16.968	16.900	17.080	17.091	17.074	17.104
2 Mbps, VLLS2	Buck	11.256	10.025	9.263	8.615	8.035	7.573
	Bypass	14.944	14.985	15.015	14.980	15.041	15.108
coded 500 kbps, VLLS2	Buck	25.026	22.349	20.318	18.674	17.339	16.160
	Bypass	34.489	34.716	34.684	34.862	34.833	34.829

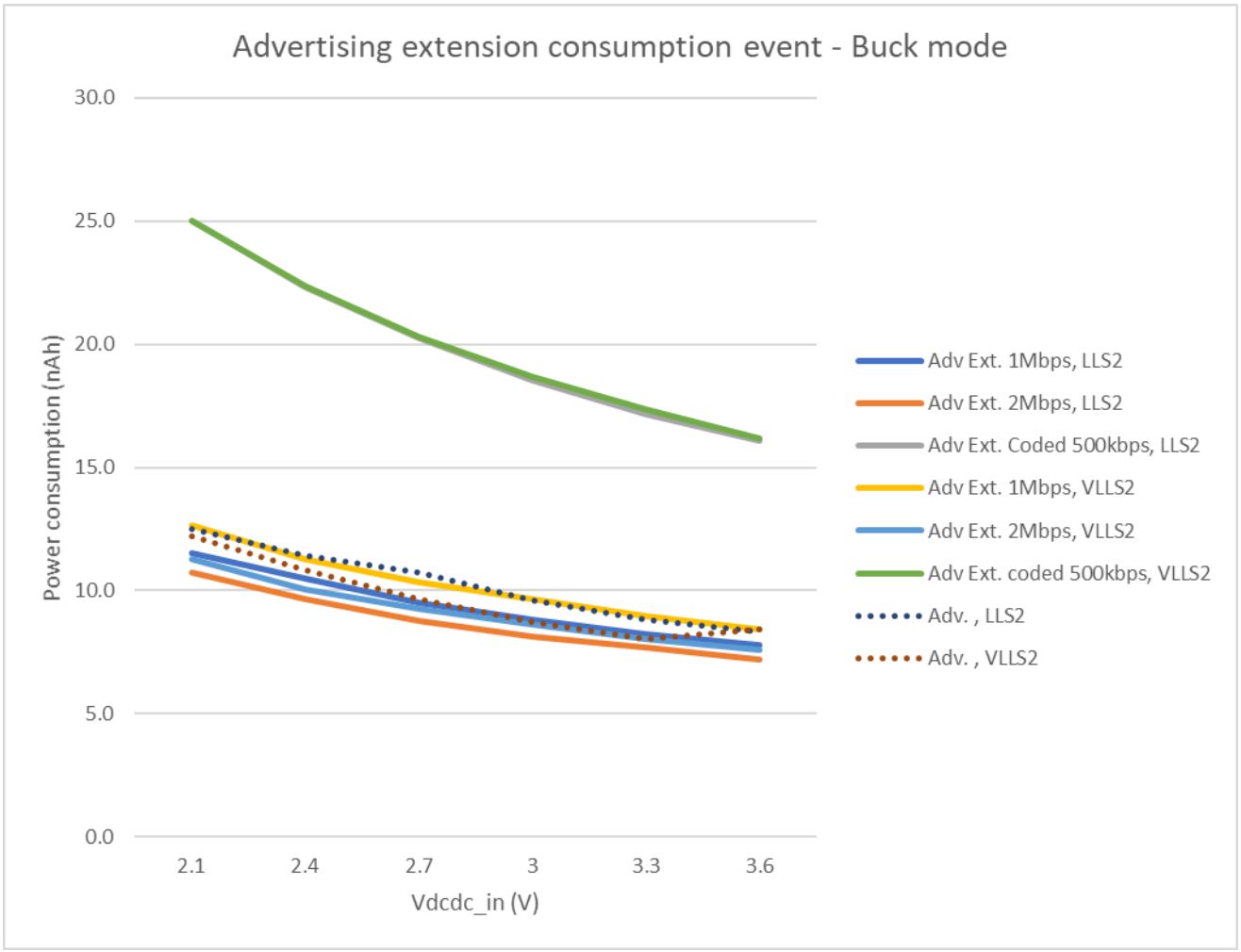

Figure 96. Advertising Extension consumption event, buck mode

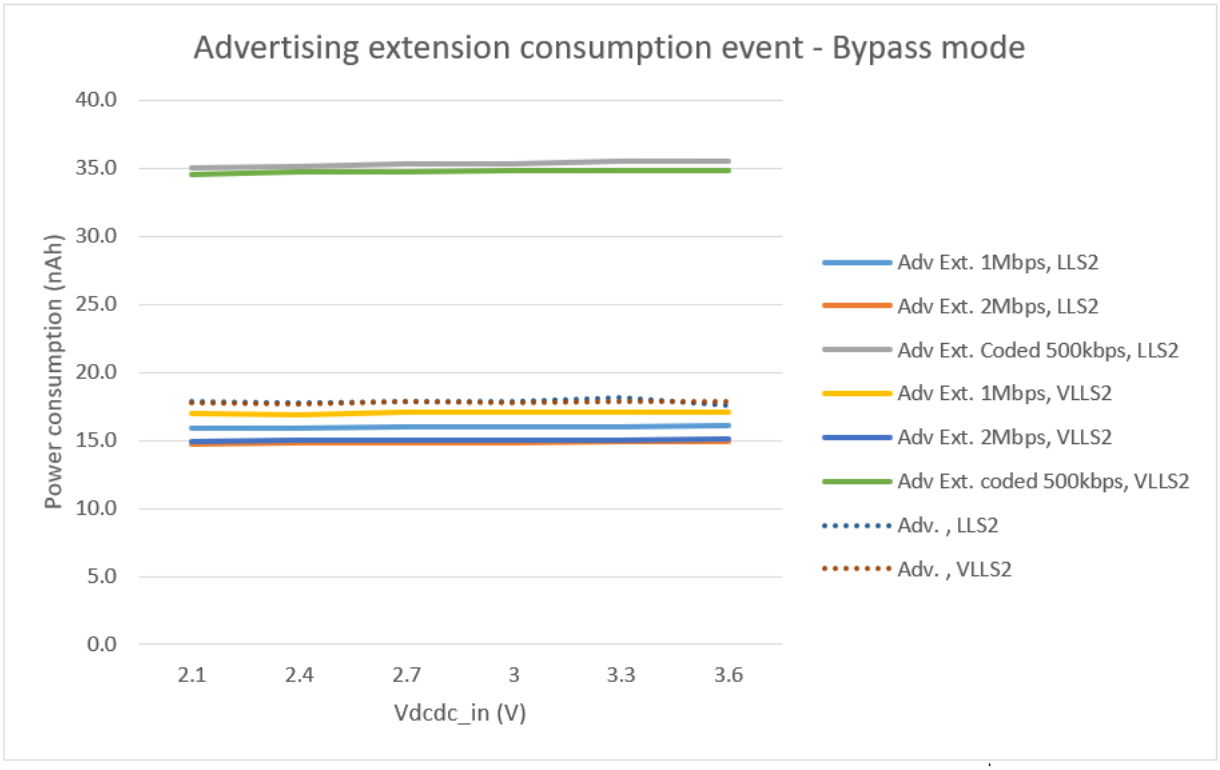

Figure 97. Advertising Extension consumption event, bypass mode

4.4 Scan extension

Using the steps provided in Software configuration for low-power operation, partial Bluetooth LE scenario (Low power application) was captured and can be observed in Figure 98. The main events and phases are documented within the capture. All the plots that follows depicts current.

Both use cases are used:

- LLS2 Mode is activated between the Scan events.

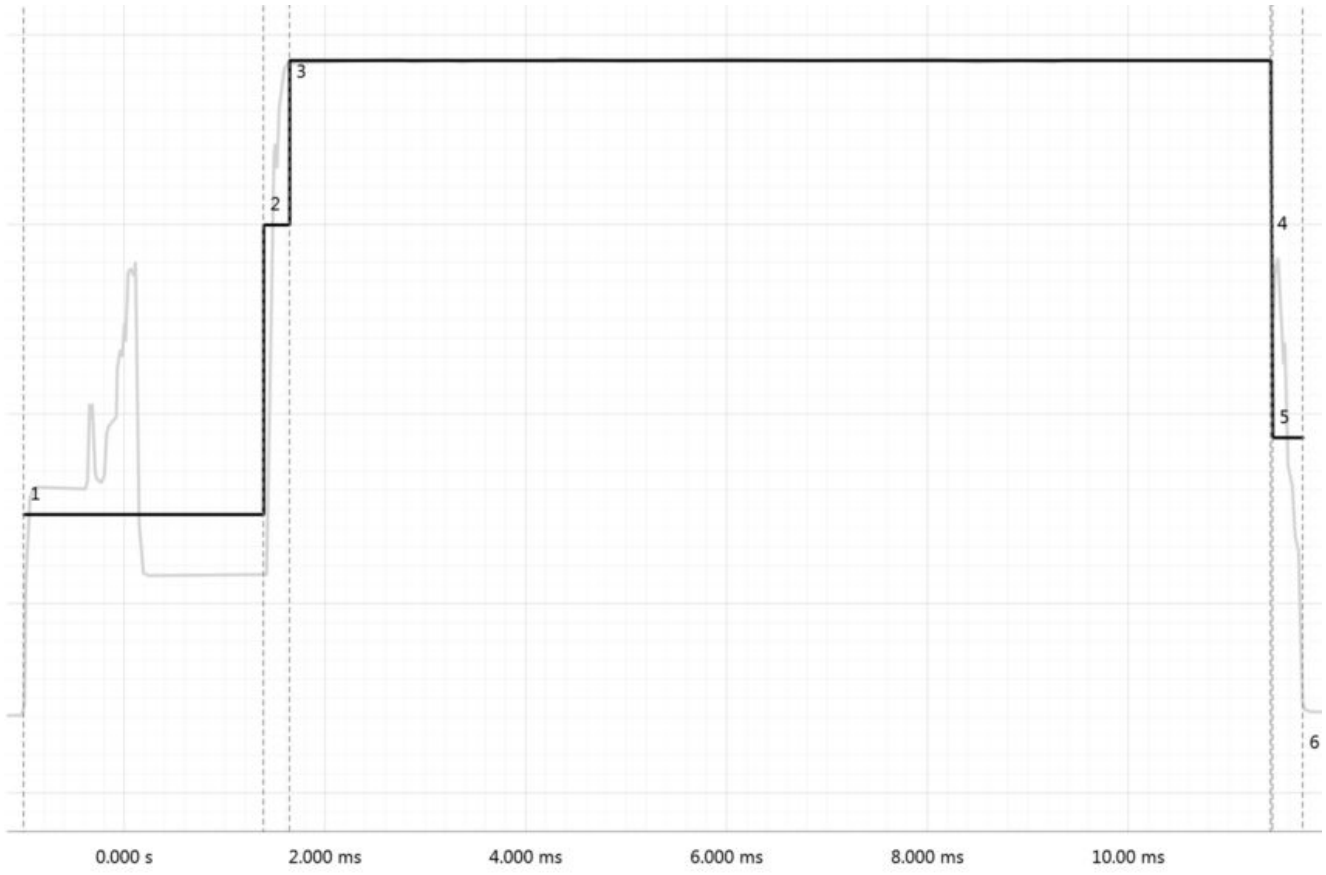

Figure 98. Current consumption - SCAN extension event period

Table 70. SCAN extension events

Phase	Scan event timing
1	Pre-processing
2	Rx warm-up
3	Active Rx
4	Active Rx warm-down
5	Post-processing

The next four figures capture the current consumption during the Scan extension event using data rate at 1 Mbps and 500 kbps. Buck and bypass mode graphs are provided as example.

The binary file settings used are:

- FEE 48 MHz clock
- Scan Extension
- Connectable

Buck mode:

- Wakeup from low power mode LLS2

Bypass mode:

- Wakeup from low power mode LLS2

4.4.1 Test environment: Scan extension 1 Mbps, LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF=3.6 V VDDMCU=3.6 V
RF output power	+5 dBm	
MCU clock mode	FEE 48 MHz	
RAM size	16 k	
Data rate	1 Mbps	
Payload	31 bytes	
Connectable	Yes	
Flash	Doze	
MCU	Stop	
Setting	Scanning Interval = 480 ms Active Scan Duration = 10 ms Advertise from low power LLS2 Slave to Master	
Software	Low Power (PRC3 release)	

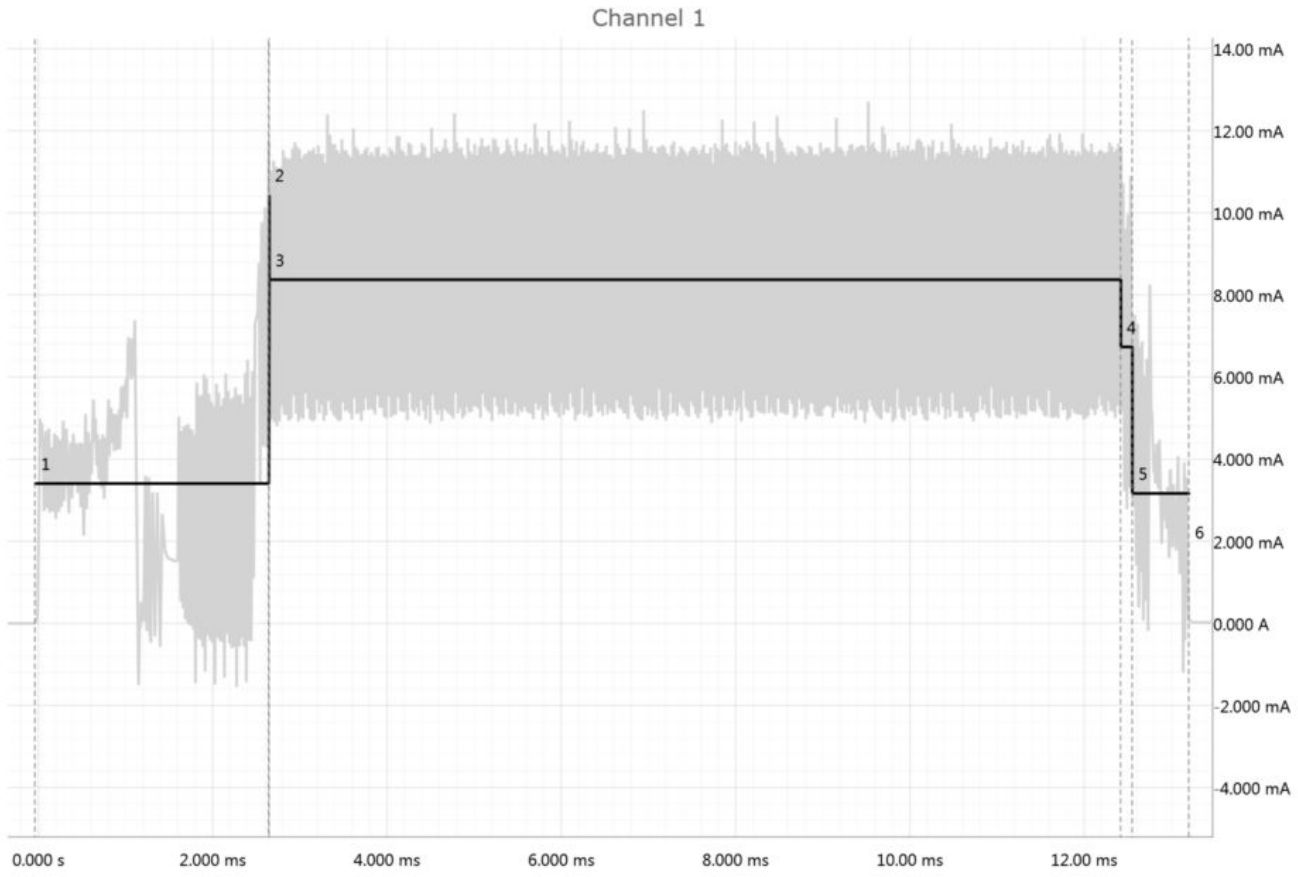

Figure 99. Scan Extension current profile event after LLS2 mode, buck mode, 1 Mbps

Table 71. Scan Extension current consumption in buck mode, LLS2 (MCU Stop, Flash Doze), 1 Mbps

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-38.00 µs	2.682 ms	3.404 mA	11.85 mA	-1.628 mA	2.536 nAh	9.72
2	—	2.644 ms	5.609 µs	10.42 mA	11.82 mA	8.280 mA	16.24 pAh	0.06
3	—	2.650 ms	9.771 ms	8.370 mA	12.83 mA	4.728 mA	22.72 nAh	87.08
4	—	12.42 ms	131.9 µs	6.730 mA	11.67 mA	2.682 mA	246.5 pAh	0.94
5	—	12.55 ms	649.5 µs	3.162 mA	8.332 mA	-1.306 mA	570.5 pAh	2.18
6	Summary	13.20 ms	13.24 ms	7.093 mA	12.83 mA	-1.628 mA	26.09 nAh	100

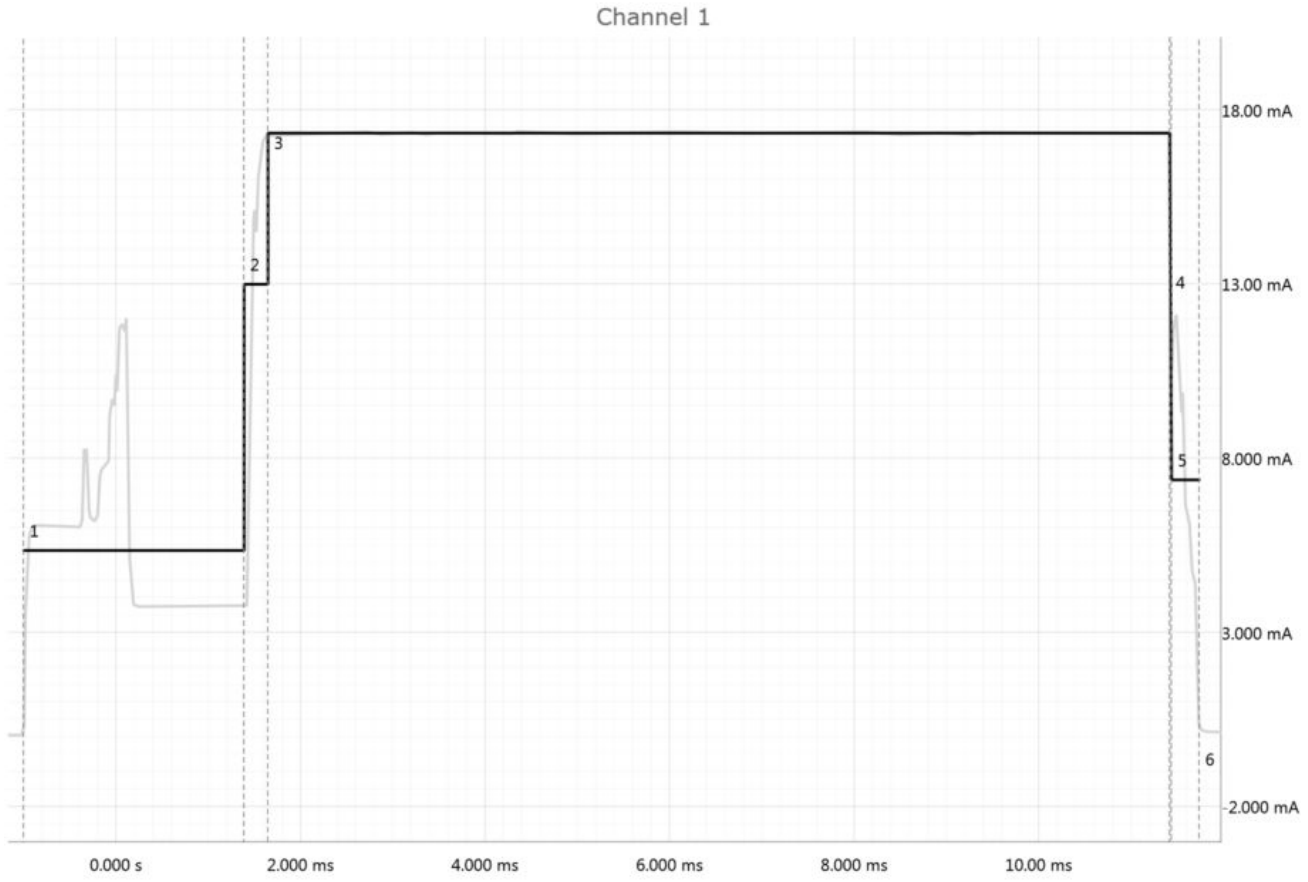

Figure 100. Scan Extension current profile event after LLS2 mode, bypass mode, 1Mbps

Table 72. Scan Extension current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 1 Mbps

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-1.000 ms	2.389 ms	5.346 mA	12.09 mA	14.04 µA	3.547 nAh	6.79
2	—	1.389 ms	259.3 µs	12.99 mA	17.33 mA	3.650 mA	935.2 pAh	1.79
3	—	1.648 ms	9.773 ms	17.33 mA	17.46 mA	17.18 mA	47.04 nAh	90.11
4	—	11.42 ms	18.52 µs	12.47 mA	17.17 mA	10.45 mA	64.17 pAh	0.12
5	—	11.44 ms	299.7 µs	7.371 mA	12.22 mA	293.8 µA	613.7 pAh	1.17
6	Summary	11.74 ms	12.74 ms	14.75 mA	17.46 mA	14.04 µA	52.20 nAh	100

4.4.2 Test environment: Scan extension 500 kbps, LLS2

DCDC: mode	BUCK	BYPASS
Supply	VDCDC_IN = 3.6 V	VDDRF = 3.6 V VDDMCU = 3.6 V

Table continues on the next page...

Table continued from the previous page...

RF output power	+5 dBm
MCU clock mode	FEE 48 MHz
RAM size	16 k
Data rate	500 kbps
Payload	31 byte
Connectable	Yes
Flash	Doze
MCU	Stop
Setting	Scanning Interval = 480 ms Active Scan Duration = 10 ms Advertise from low power LLS2 Slave to Master
Software	Low Power (PRC3 release)

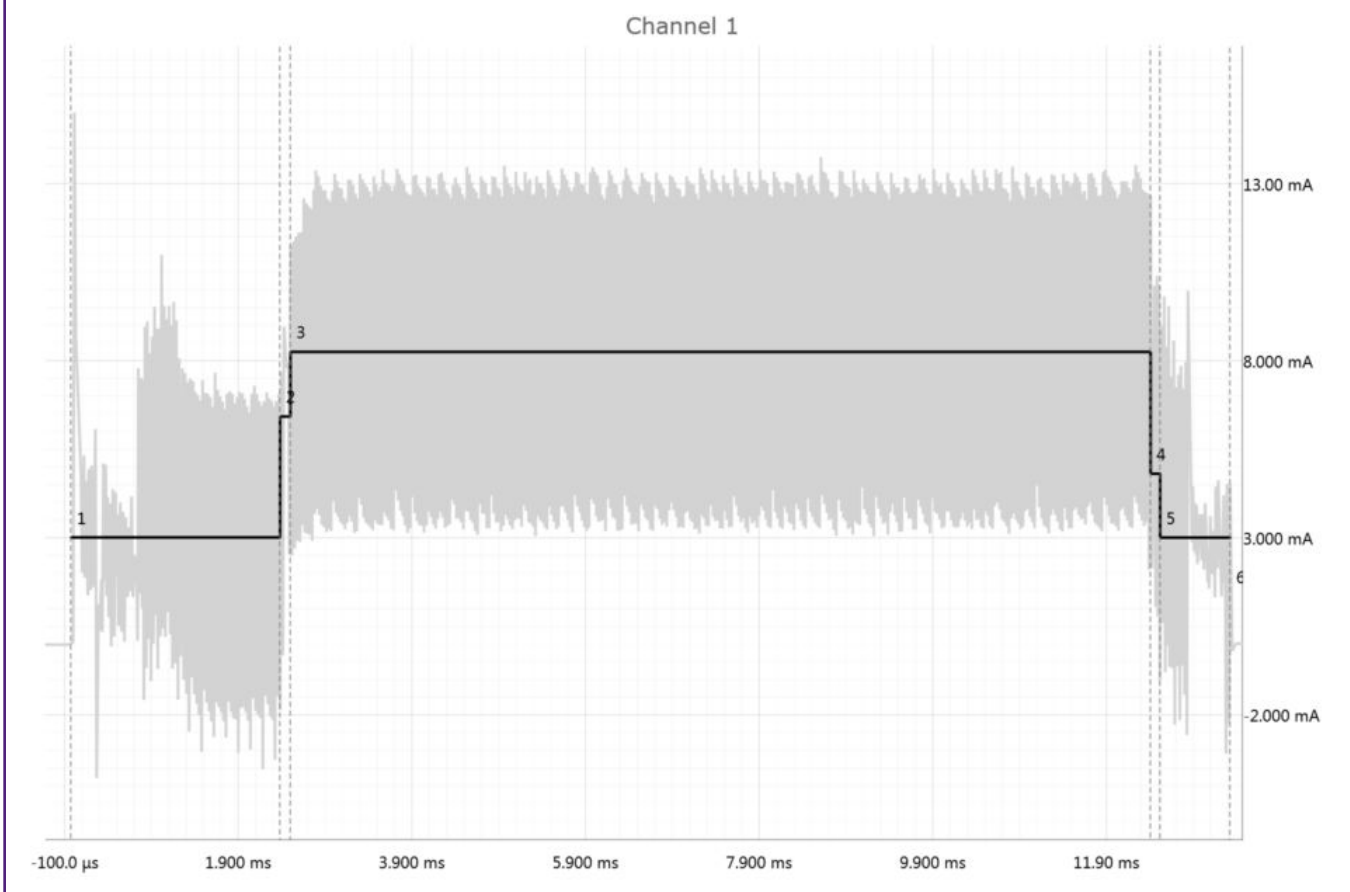

Figure 101. Scan Extension current profile event after LLS2 mode, buck mode, 500 kbps

Table 73. Scan Extension current consumption in buck mode, LLS2 (MCU Stop, Flash Doze), 500 kbps

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-25.93 µs	2.408 ms	3.009 mA	15.10 mA	-3.839 mA	2.013 nAh	7.81
2	—	2.382 ms	119.6 µs	6.423 mA	11.26 mA	1.955 mA	213.4 pAh	0.82
3	—	2.502 ms	9.907 ms	8.248 mA	13.85 mA	1.975 mA	22.70 nAh	88.16
4	—	12.41 ms	110.2 µs	4.809 mA	12.70 mA	-1.108 mA	147.2 pAh	0.57
5	—	12.52 ms	806.5 µs	3.006 mA	10.04 mA	-3.196 mA	673.3 pAh	2.61
6	Summary	13.33 ms	13.35 ms	6.942 mA	15.10 mA	-3.839 mA	25.75 nAh	100

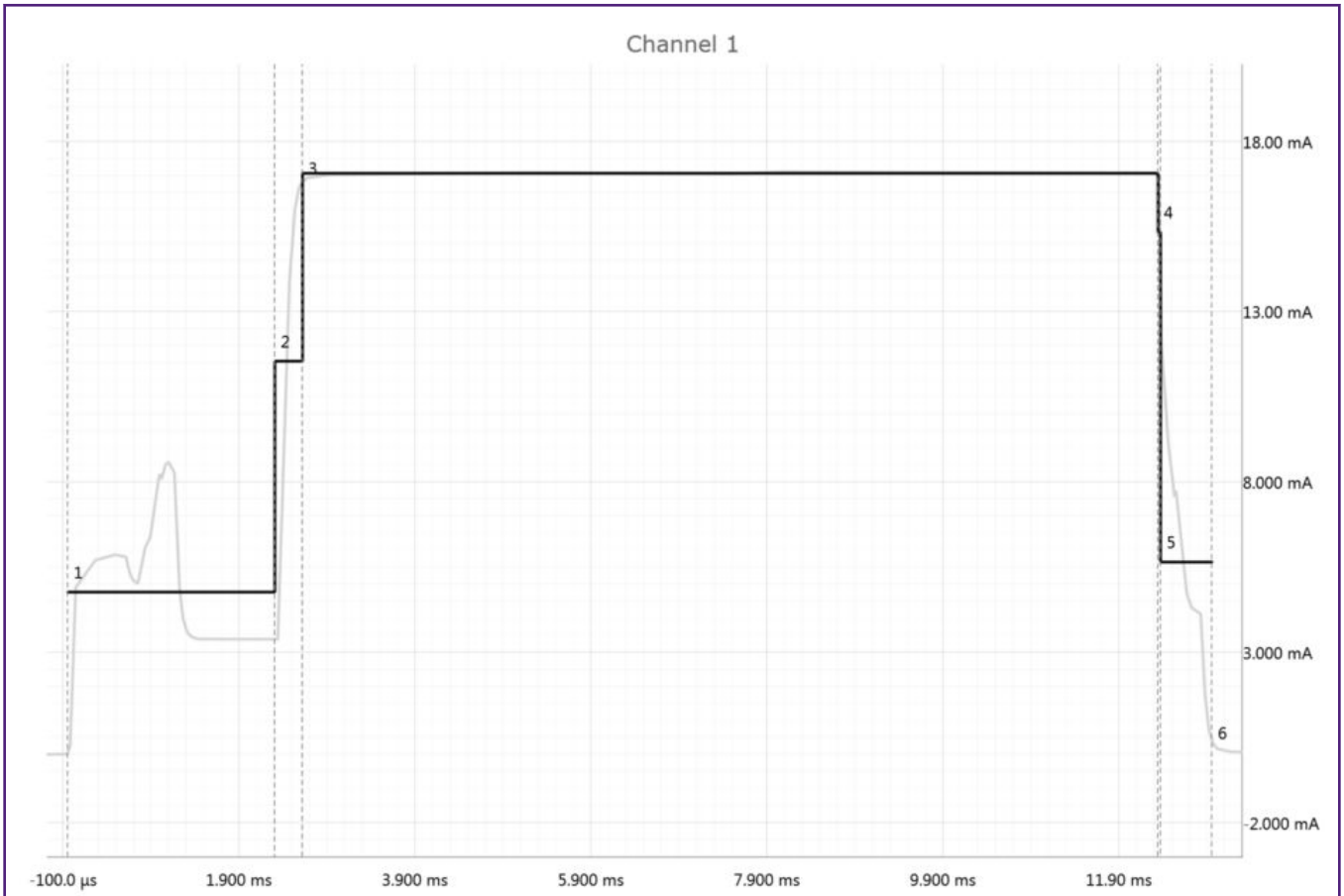

Figure 102. Scan Extension current profile event after LLS2 mode, bypass mode, 500 kbps

Table 74. Scan Extension current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 500 kbps

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
1	—	-44.44 µs	2.352 ms	4.764 mA	12.09 mA	-42.01 µA	3.112 nAh	6.07
2	—	2.307 ms	314.8 µs	11.54 mA	17.33 mA	3.314 mA	1.009 nAh	1.96
3	—	2.622 ms	9.722 ms	17.06 mA	17.46 mA	16.80 mA	46.06 nAh	89.92
4	—	12.34 ms	29.32 µs	12.47 mA	15.33 mA	12.93 mA	124.8 pAh	0.24

Table continues on the next page...

Table 74. Scan Extension current consumption in bypass mode, LLS2 (MCU Stop, Flash Doze), 500 kbps (continued)

Num.	Label	Time	Duration	Mean	Max.	Min.	Integral	Ratio
5	—	12.37 ms	583.3 µs	7.371 mA	5.644 mA	362.8 µA	914.5 pAh	1.78
6	Summary	12.96 ms	13.00 ms	14.75 mA	14.18 mA	-42.01 µA	51.22 nAh	100

4.4.3 Timing data

Table 75. Scanning Extension timing table

		Timing (ms)			
		Buck		Bypass	
		LLS2		LLS2	
		1M1M	1MCoded	1M1M	1MCoded
1	Pre processing	**2.682**	**2.408**	**2.389**	**2.352**
2	Rx warm up	0.0056	0.119	0.259	0.315
3	Rx active	**9.771**	**9.907**	**9.773**	**9.722**
4	Rx warm down	0.132	0.11	0.0018	0.029
5	Post-processing	**0.65**	**0.806**	**0.3**	**0.583**
6	Total	**13.24**	**13.35**	**12.72**	**13.00**

Table 76. Scanning Extension consumption table

		Consumption (mA)			
		Buck		Bypass	
		LLS2		LLS2	
		1M1M	1MCoded	1M1M	1MCoded
1	Pre processing	3.404	3.009	5.346	4.764
2	Rx warm up	10.42	6.423	12.99	11.54
3	Rx active	8.37	8.248	17.33	17.06
4	Rx warm down	6.73	4.809	12.47	15.33
5	Post-processing	3.162	3.006	7.371	5.644
6	Total	**7.09**	**6.94**	**14.75**	**14.18**

4.4.4 Summary data

Table 77. Scanning Extension consumption summary table

		Vdcdc_in power supply (Volt)					
Scan Extension	Unit: nAh	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**

Table continues on the next page...

Table 77. Scanning Extension consumption summary table (continued)

		Vdcdc_in power supply (Volt)					
Scan Ext. 1Mbps, LLS2	Buck	41.390	36.850	33.240	30.330	27.940	26.09
	Bypass	55.400	55.540	55.660	55.980	56.190	56.200
Scan Ext. Coded 500kbps, LLS2	Buck	40.750	36.230	32.830	30.330	27.800	25.750
	Bypass	54.840	54.900	54.830	54.740	54.980	55.220

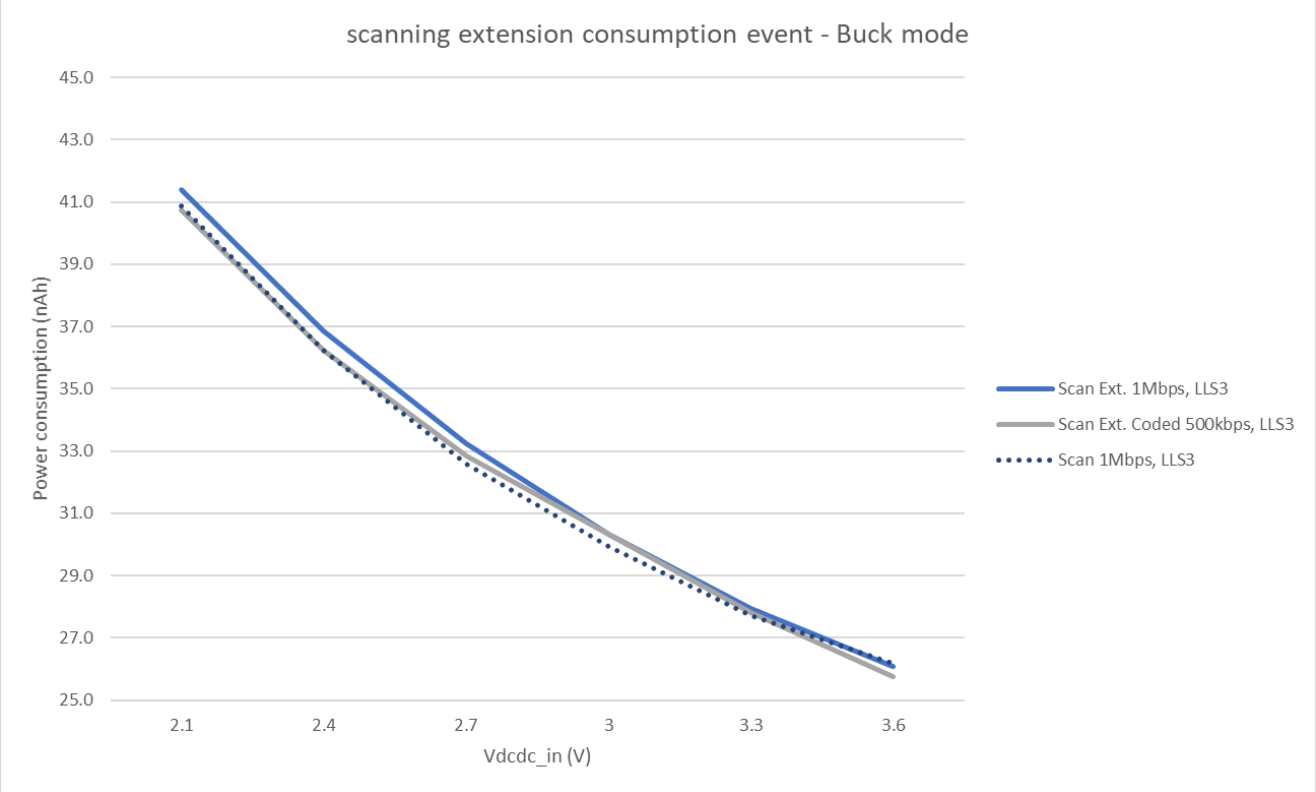

Figure 103. Scanning Extension consumption event, buck mode

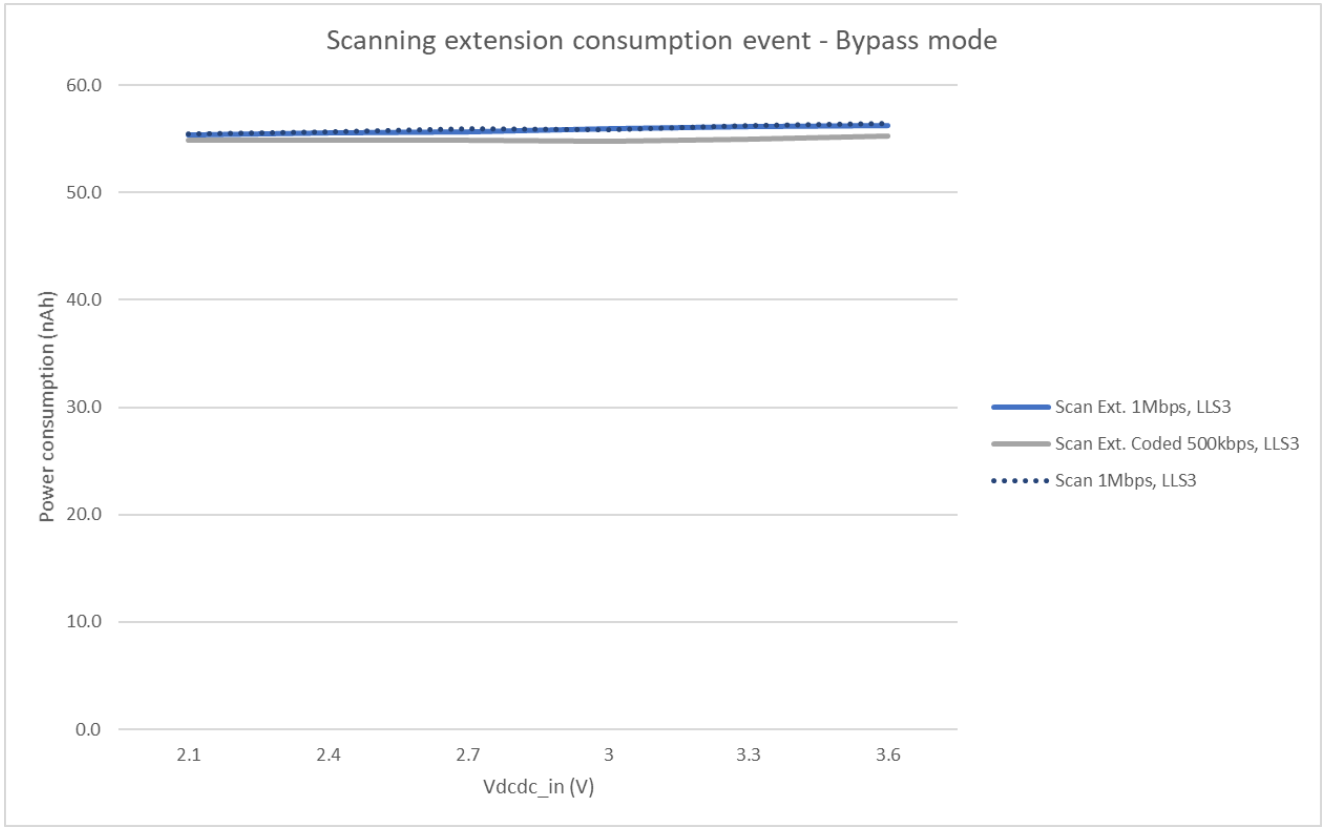

Figure 104. Scanning Extension consumption event, bypass mode

4.5 Channel Selection Algorithm #1 and #2

Channel Selection Algorithm #1 is the legacy method that only supports channel selection for connection events. **Channel Selection Algorithm #1** consists of two stages: calculation of the unmapped channel index followed by mapping this index to a data channel index from the set of usedchannels.

Channel Selection Algorithm #2 supports channel selection for both connection events and periodic advertising packets. At the start of an event, which can be a connection event or a periodic advertising packet, the algorithm described here generates an event channel index (which is a data channel index or secondary advertising channel index, as appropriate). Some of the CSA #2 claims are

- Channel Selection Algorithm #2 (CSA #2) is a more complex and harder to track algorithmfor obtaining the channel index for the nextevent.
- It is more effective at avoiding interference and multi-path fading effects than Channel Selection Algorithm #1, especially in high-throughput usecases.

4.6 High Duty Cycle Advertising

High Duty Cycle advertising able faster connection setup possible.

No specific power consumption are done for this mode.

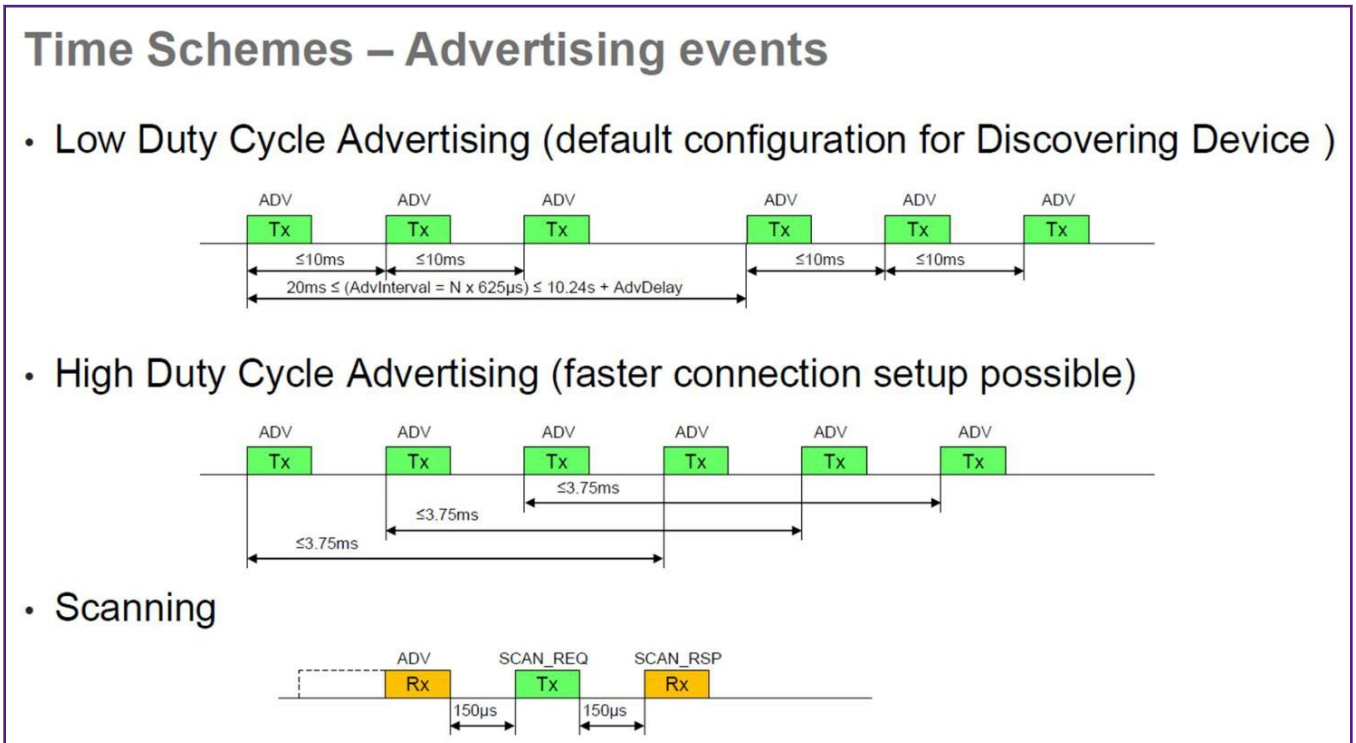

Figure 105. Low and high duty cycle advertising

4.7 Reports

Table 78 and Table 79 provide power consumption at 3.6 V in the Buck and Bypass modes, at ambient temperature (+25 °C).

Table 78. SoC measurements summary table (ambient temperature)

Deep Sleep Mode (as defined in connectivity framework)	MCU state	BLE LL state	BLE_LL reference CLK source	Typical use case	KW38 current consumption @ 3 V
Mode 6	STOP	Active[1]	32 MHz	Only MCU in STOP	2.25 mA
Mode 1	VLLS2 Buck VLLS2 Bypass	DSM2 (STOP)	32 kHz oscillator	VLLS2 between RF activities	2.12 µA 2.35 µA
Mode 1	LLS2 Buck LLS2 Bypass	DSM2 (STOP)	32 kHz oscillator	LLS2 between RF activities	2.71 µA 3.7 µA
Mode 9	VLLS2/3	OFF	NA	Advertising period larger than 10.24 sec	2.05 µA
RAM OFF	VLLS1	OFF	NA	VLLS1 when DCDC buck	1.65 µA
RAM OFF	Pswitch	OFF	NA	Pswitch to ground	20 nA

Table continues on the next page...

Table 78. SoC measurements summary table (ambient temperature) (continued)

Deep Sleep Mode (as defined in connectivity framework)	MCU state	BLE LL state	BLE_LL reference CLK source	Typical use case	KW38 current consumption @ 3 V
Mode 4	VLLS1	OFF	—	VLLS1 when DCDC Buck	0.88 µA (POR 319 ms) 1.31 µA (POR 36 ms)
Mode 4	VLLS0 (POR=0)	OFF	—	VLLS0 when DCDC Bypass	391 nA
Mode 4	VLLS0 (POR=1)	OFF	—	VLLS0 when DCDC Bypass	200 nA
DSM 9	VLLS2/3	Idle	NA	Advertising interval larger than 10.24 sec	2.05 µA
RAM OFF (during Advertising)	VLLS1	Idle	NA	Ultra fast wake-up,VLLS1	1.65 µA
RAM OFF (during Advertising)	VLLS1	Idle	NA	Ultra fast, wake-up, Pswitch	20 nA
Mode 4	Pswitch	OFF	—	Pswitch to ground	20 nA
• Active mode: Buck mode (Vdcdc_in = 3 V, 1P8 = 1.8 V, 1P5 = 1.5 V), FEE 48 MHz, MCU STOP, Flash dozed Condition of measurement: Vdcdc_in = 3 V, 25°C (Ambient)					

Table 79. Wakeup timing summary table

Type of wakeup	Timing (ms)
VLLS1	319/36[1]
VLLS0 (POR=0)	36
VLLS0 (POR=1)	37
Pswitch	37
POR	34
• 319 ms default SW setting consume less current than 36 ms setting but 1st Tx is longer after the wake up. Setting for 36 ms, the current consumption is 1.31 µA.	

4.7.1 Power consumption summary tables

Table 80. Event power consumption summary table

1 event, vdcdc_in = 3.6 V, 25 °C		LLS2 (ms)	LLS2 (mA)	LLS2 (nAh)	VLLS2 (ms)	VLLS2 (mA)	VLLS2 (nAh)
Advertising	buck	6.46	4.63	8.31	7.30	4.65	9.44
	bypass	5.90	10.74	17.60	6.75	10.04	18.83
MCU	buck	6.33	0.78	1.37	7.12	0.89	1.76
	bypass	5.87	1.34	2.19	6.66	1.30	2.40
Connect- 1 Mbps	buck	3.80	3.54	3.74	4.00	3.36	3.73
	bypass	3.40	7.28	6.88	3.50	7.00	6.81
Connect- 2 Mbps	buck	3.15	3.54	3.10	3.15	3.10	2.72
	bypass	2.73	7.38	5.59	2.72	7.25	5.48
Connect- 500 kbps	buck	3.81	5.25	5.56	3.83	3.83	4.82
	bypass	3.40	11.93	11.27	3.40	3.40	11.93
Connect- 125 kbps	buck	4.39	5.22	6.36	5.86	5.86	5.86
	bypass	4.10	11.82	13.46	13.37	13.37	13.37
Scan	buck	13.30	7.09	26.19	13.30	6.98	25.77
	bypass	12.85	15.54	55.47	12.85	15.79	56.36

Table 81. Advertising Power consumption summary table

48 MHz FEE mode using 32 KHz crystal	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
Advertising consumption on 1 event @+5 dBm	6.46 ms	7 ms	5.9 ms	6.75 ms
	4.63 mA	4.54 mA	10.74 mA	10.04 mA
	8.3 nAh	**8.08 nAh**	**17.6 nAh**	**18.81 nAh**
Advertising consumption details				
TX Active (+5dBm, PA_POWER = 0x62) + MCU STOP	**8.12**	**8.14**	**21.87**	**21.66**
RX Active + MCU STOP	**9.33**	**9.37**	**25.36**	**25.16**
TX Warm-up + MCU STOP	**10.25**	**10.27**	**27.04**	**26.39**
TX Warm-down + MCU STOP	**8.73**	**8.64**	**22.81**	**22.67**
RX warm-up + MCU STOP	7.26	4.82	15.19	14.37
Rx warm-down + MCU STOP	6.50	7.85	19.21	19.48
Tx to Rx transition + MCU STOP	6.28	7.28	16.46	16.75

Table continues on the next page...

Table 81. Advertising Power consumption summary table (continued)

48 MHz FEE mode using 32 KHz crystal	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
(Advertising event)				
Rx to Tx transition + MCU STOP (Connect event)	3.90	4.07	14.31	13.48
Scanning + MCU STOP	4.79	4.50	16.23	16.14

Table 82. Pre-Post processing, MCU consumption summary table

48 MHz FEE mode using 32 KHz crystal	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
ADV pre-processing (mA)	3.01	3.31	6.01	5.66
CONN pre-processing - 1 Mbps (mA)	3.03	3.22	6.03	5.91
CONN pre-processing - 2 Mbps (mA)	3.03	2.98	6.02	5.97
CONN pre-processing - LRS2 (mA)	3.17	3.15	6.02	6.03
CONN pre-processing - LRS8 (mA)	3.09	3.06	5.98	5.88
Radio Post-processing (mA)	3.1	3.44	5.86	6.9
MCU STOP (mA)	2.39	2.42	5.52	5.25

Table 83. MCU power consumption summary table

MCU STOP consumption	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
	T = 25 °C			
Timing period (ms)	6.327	7.12	5.87	6.66
Consumption (mA)	0.777	0.89	1.344	1.299
MCU stop consumption (nAh)	1.367	1.561	2.19	2.404

4.7.2 Timing summary table

Table 84. Advertising and connection timing summary table

Radio/Profile timing parameters (ms)	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
48 MHz FEE mode using 32 KHz crystal	T = 25 °C		T = 25 °C	
ADV Pre-processing Time	2.36 ms	2.86 ms	2.27 ms	2.87 ms

Table continues on the next page...

Table 84. Advertising and connection timing summary table (continued)

Radio/Profile timing parameters (ms)	Buck mode consumption (3.6 V)		Bypass mode consumption (3.6 V)	
	DSM = LLS2	DSM = VLLS2	DSM = LLS2	DSM = VLLS2
48 MHz FEE mode using 32 KHz crystal	T = 25 °C		T = 25 °C	
ADV Post-porcessing Time	865 us	922 us	339 us	578 us
Conn Pre-processing Time-1Mbps	2.5 ms	2.64 ms	2.66 ms	2.65 ms
Conn Post-processing Time-1 Mbps	693 us	722 us	329 us	396 us
Conn Pre-processing Time-2 Mbps	2.08 ms	2.07 ms	2.02 ms	2.04 ms
Conn Post-processing Time-2 Mbps	753 us	700 us	306 us	309 us
Conn Pre-processing Time-500 kbps	1.71 ms	2.05 ms	1.57 ms	1.57 ms
Conn Post-processing Time-500 kbps	730 us	774 us	717 us	700 us
Conn Pre-processing Time-125 kbps	1.97 ms	2.04 ms	1.97 ms	1.97 ms
Conn Post-processing Time-125 kbps	679 us	755 ms	731 us	664 us
SCAN Pre-processing Time	2.403 ms	2.421 ms	2.477 ms	2.421 ms
SCAN Post-porcessing Time	0.795 ms	0.795 ms	0.346 ms	0.351 ms

5 Acronyms and Abbreviations

Table 85. Acronyms and abbreviations

Acronym/Abbreviation	Description
ADC	Analog to Digital Converter
Arm	Advanced RISC Machine (RISC – Reduced Instruction Set Computer)
Bluetooth LE	Bluetooth Low-Energy aka Bluetooth Smart
BPSK	Binary Phase Shift Keying
BTLL	Bluetooth Link Layer
CMP	Comparator module
DAC	Digital to Analog Converter
DC	Direct Current
DSM	Deep Sleep Mode
DUT	Device Under Test
ESR	Equivalent Series Resistance
FRDM	Freedom board
GAP	Generic Access Profile
GFSK	Gaussian Frequency Shift Keying
GPIO	General Purpose Input/Output

Table continues on the next page...

Table 85. Acronyms and abbreviations (continued)

Acronym/Abbreviation	Description
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet Of Things
ISM	Industrial, Scientific and Medical bands
LE	Low Energy
LL	Link Layer
LLS	Low-Leakage Stop
LLWU	Low-Leakage Wake-up Unit
LPTMR	Low-power Timer
LPUART	Low-power UART
MBAN	Medical Body Area Network
MCU	Microcontroller Unit
O-QPSK	Offset Quadrature Phase Shift Keying
PC	Personal Computer
PDU	Protocol Data Unit
PMC	Power Management Controller
RX	Reception
SAR	Successive Approximation Register ADC
SCGC	System Clock Gating Control register
SIM	System Integration Module
SMPS	Switched Mode Power Supply
SRAM	Static Random Access Memory
TMR	Timer
TSM	Transceiver Sequence Manager
TX	Transmission
UART	Universal Asynchronous Receiver Transmitter
USB	Universal Serial Bus
VLLS	Very Low Leakage Stop
XCVR	Transceiver

How To Reach Us

Home Page:

nxp.com

Web Support:

nxp.com/support

Information in this document is provided solely to enable system and software implementers to use NXP products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits based on the information in this document. NXP reserves the right to make changes without further notice to any products herein.

NXP makes no warranty, representation, or guarantee regarding the suitability of its products for any particular purpose, nor does NXP assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. “Typical” parameters that may be provided in NXP data sheets and/or specifications can and do vary in different applications, and actual performance may vary over time. All operating parameters, including “typicals,” must be validated for each customer application by customer's technical experts. NXP does not convey any license under its patent rights nor the rights of others. NXP sells products pursuant to standard terms and conditions of sale, which can be found at the following address: nxp.com/SalesTermsandConditions.

While NXP has implemented advanced security features, all products may be subject to unidentified vulnerabilities. Customers are responsible for the design and operation of their applications and products to reduce the effect of these vulnerabilities on customer’s applications and products, and NXP accepts no liability for any vulnerability that is discovered. Customers should implement appropriate design and operating safeguards to minimize the risks associated with their applications and products.

For more information, please visit: http://www.nxp.com

For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: April 2020

Document identifier: AN12459

arm