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Laird
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Datasheet

BL652-SA and BL652-SC

Version 2.2

Revision History

Version	Date	Notes	Approver
1.0	20 July 2016	Initial Release	Jonathan Kaye
1.1	30 Aug 2016	Corrected Operating Temperature voltage to read VCC 1.8 V-3.6 V rather than 1.7 V-3.6V Corrected minor formatting issues and typo Changed the SIO_02 pin # (OTA mode table) to 23 vs. 21	Raj Khatri
1.2	02 Sept 2016	Added missing BT SIG info Updated Declaration of Conformity Added text to Note 1 of Pin Definition Notes Fixed error in Note 13 of Pin Definition Notes	Jonathan Kaye/ Raj Khatri
1.3	14 Sept 2016	Updated BT SIG section	Jonathan Kaye
1.4	14 Oct 2016	Updates to JTAG Signals and wiring	Raj Khatri
1.5	15 Nov 2016	Fix SIO_12 reference to SIO_02 in vSP Command Mode	Raj Khatri
1.6	14 Feb 2017	Fixed UART Interface pins in Table 20	Mark Duncombe
1.7	06 Mar 2017	Updated Standby Doze references from 1.2 uA to 2.0 uA	Raj Khatri
1.8	29 June 2017	Added X-Y-Z indication to Updated DoC with new RED standards	Raj Khatri
1.9	28 July 2017	Updated Ble_avg calculation in section 4.2 Measured Current Waveforms during Advertising and Connection	Raj Khatri
2.0	18 Sept 2017	Updated tables 21, 22, and 23 to include SIO pins	Raj Khatri
2.1	10 Oct 2017	Added the mFlexPIFA antenna information	Bill Steinike
2.2	23 Oct 2017	Changed all BT4.2 references to BTv5.0 Updated the BT SIG section	Jonathan Kaye

CONTENTS

1 Overview and Key Features

Every BL652 Series module is designed to enable OEMs to add single-mode Bluetooth Low Energy (BLE) v5.0 to small, portable, power-conscious devices. The BL652 modules are supported with Laird's *smart*BASIC, an event-driven programming language that enables OEMs to make their BLE product development quicker and simpler, significantly reducing time to market. *smart*BASIC enables customers to develop a complete embedded application inside the compact BL652 hardware, connecting to a wide array of external sensors via its I2C, SPI, UART, ADC or GPIO interfaces. The BL652 also provides flexibility in the OEM's application development choice with full support for using Nordic's SDK and firmware tools.

Based on the world-leading Nordic Semiconductor nRF52832 chipset, the BL652 modules provide ultra-low power consumption with outstanding wireless range via 4 dBm of transmit power. A broad range of BLE profiles including Temperature and Heart Rate are available, and *smart*BASIC provides the ideal mechanism to support any BLE profile development of your choice. This document should be read in conjunction with the *smart*BASIC user manual.

Note: BL652 hardware is functionally capable as the nRF52832 chipset used in the module design. Not all features are currently exposed within Laird's *smart*BASIC firmware implementation.

1.1 Features and Benefits

- Bluetooth v5.0 - Single mode
- NFC-A Listen mode compliant
- External or internal antennas
- *smart*BASIC programming language or Nordic SDK
- Compact footprint
- Programmable Tx power +4 dBm to -20 dBm
- Tx whisper mode (-40 dBm)
- Rx sensitivity: -96 dBm
- Ultra-low power consumption
- Tx: 5.3 mA peak (at 0 dBm, DCDC on) – See *Power Consumption* section Note 1
- Rx: 5.4 mA peak (DCDC on) – See *Power Consumption* section Note 1
- Standby Doze: 2.0 uA typical
- Deep Sleep: 0.4 uA – See *Power Consumption* section Note 4
- UART, GPIO, ADC, PWM, FREQ output, timers, I2C, and SPI interfaces
- Fast time-to-market
- FCC, CE, IC, and Japan certified; Full Bluetooth Declaration ID
- Other regulatory certifications on request (all certifications are in process)
- No external components required
- Industrial temperature range (-40 to + 85)

1.2 Application Areas

- Medical devices
- Wellness devices
- iOS "appcessories"
- Fitness sensors
- Location awareness
- Home automation

Note: Figures on this page are gathered from the nRF52 datasheet provided by Nordic.

2 SPECIFICATION

2.1 Specification Summary

Table 1: BL652 Specifications

Categories	Feature	Implementation
Wireless Specification	Bluetooth®	V5.0 – Single mode Concurrent master and slave Diffie-Hellman based pairing
	Frequency	2.402 - 2.480 GHz
	Maximum Transmit Power Setting	+4 dBm Conducted BL652-SA +4 dBm Conducted BL652-SC
	Minimum Transmit Power Setting	-20 dBm (in 4 dB steps) with *smart*BASIC command -16 dBm, -12 dBm, - 8 dBm, - 4 dBm, 0 dBm
	Tx Whisper Mode 1 Transmit Power	-40 dBm (min.) with *smart*BASIC command
	Receive Sensitivity (0.1% BER)	-96 dBm typical
	Link Budget	100 dB (@ 1 Mbps)
	Range	Up to 100 meters in free space
	Tx Whisper Modes	Range reduction feature with Tx Whisper modes via *smart*BASIC command
	Range (Tx Whisper Mode 1)	<~100 cm
	Raw Data Rates	1 Mbps (over-the-air)
NFC	NFC-A Listen mode compliant	Based on NFC forum specification ▪ 13.56 MHz ▪ Date rate 106 kbps ▪ NFC-A tag – Can only be a target/tag; cannot be an initiator **Modes of Operation:** ▪ Disable ▪ Sense ▪ Activated **Use Cases:** ▪ Touch-to-Pair with NFC ▪ NFC enabled Out-of-Band Pairing
	System Wake-On-Field function	Proximity Detection
Host Interface and Peripherals	Total	32 x Multifunction I/O lines
	UART	Tx, Rx, CTS, RTS DCD, RI, DTR, DSR (See Note 1) Default 115200,n,8,1 From 1,200bps to 1Mbps

Categories	Feature	Implementation
	GPIO	Up to 32, with configurable: I/O direction, O/P drive strength (standard 0.5 mA or high 3mA/5 mA), Pull-up /pull-down
	ADC	Eight 8/10/12-bit channels 0.6 V internal reference Configurable 4, 2, 1, 1/2, 1/3, 1/4, 1/5 1/6(default) pre-scaling Configurable acquisition time 3uS, 5uS, 10uS(default), 15uS, 20uS, 40uS. One-shot mode
	PWM output	PWM outputs on 12 GPIO output pins. PWM output duty cycle: 0%-100% PWM output frequency: Up to 500kHz (See Note 7)
	FREQ output	FREQ outputs on 2 GPIO output pins. FREQ output frequency: 0 MHz-4MHz (50% duty cycle)
	I2C	One I2C interface (up to 400 kbps) (See Note 2)
	SPI	One SPI Master interface (up to 4 Mbps) (See Note 3)
Optional *External to the BL652 module*	External 32.768kHz crystal	For customer use, connect +/-20ppm accuracy crystal for more accurate protocol timing.
	External SPI serial flash	For customer use e.g. data-logging
Profiles	Services supported (See Note 4)	Laird's *smart*BASIC firmware supports the following:: ▪ Central Mode ▪ Peripheral Mode ▪ Custom Series
	Nordic SDK v3x0	Any exposed within the related Nordic softdevice (application development to be done by OEM)
FW upgrade	*smart*BASIC runtime engine FW upgrade (See Note 4)	Via JTAG or UART
Programmability	*smart*BASIC	On-board programming language similar to BASIC.
	*smart*BASIC application download	Via UART Via Over-the-Air (if SIO_02 pin is pulled high externally)
	Nordic SDK	Via JTAG
Control Protocols	Any	User defined via *smart*BASIC

Categories	Feature	Implementation	
Operating Modes	Self-contained Run mode	Selected by nAutoRun pin status: LOW (0V). Then runs $autorun$ (*smart*BASIC application script) if it exists.	
	Interactive/Development mode	HIGH (VCC). Then runs via at+run (and *file name* of *smart*BASIC application script).	
Supply Voltage	Supply (VCC)	1.8- 3.6 V – Internal DCDC converter or LDO (See Note 5)	
Power Consumption (See Note 5)	Active Modes Peak Current (for maximum Tx power +4 dBm) – Radio only	Advertising mode	7.5 mA peak Tx (with DCDC)
		Connecting mode	5.4 mA peak Tx (with DCDC)
	Active Modes Peak Current (for Tx Whisper mode2 power -40 dBm) – Radio only	Advertising mode	2.7 mA peak Tx (with DCDC)
		Connecting mode	5.4 mA peak Tx (with DCDC)
	Active Modes Average Current	Depends on many factors, see *Power Consumption*.	
	Ultra Low Power Modes	Standby Doze Deep Sleep	2.0 uA typical (Note 6) 400 nA (Note 6)
Antenna Options	Internal	Ceramic chip monopole antenna – on-board **BL652-SA variant**	
	External	Dipole antenna (with IPEX connector) Dipole PCB antenna (with IPEX connector) Connection via IPEX MH4 – **BL652-SC variant** See the Antenna Information sections for FCC and IC, MIC, and CE.	
Physical	Dimensions	14 mm x 10 mm x 2.1 (TBC) mm Pad Pitch: 0.75 mm Pad Type: Plated half-moon edge pads (easy to hand solder)	
	Weight	<1 gram	
Environmental	Operating	-40 ˚C to +85 ˚C (VCC 1.8V-3.6V)	
	Storage	-40 ˚C to +85 ˚C	
Miscellaneous	Lead Free	Lead-free and RoHS compliant	
	Warranty	1-Year Warranty	
Development Tools	Development Kit	Development kit (DVK-BL652-xx) and free software tools	
Approvals	Bluetooth®	Full Bluetooth SIG Declaration ID	
	FCC / IC / CE / MIC	All BL652 Series	

Module Specification Notes:

Note 1	DSR, DTR, RI, and DCD can be implemented in the *smart*BASIC application.

Module Specification Notes:

Note 2	With I2C interface selected, pull-up resistors on I2C SDA and I2C SCL ***must*** be connected externally as per I2C standard.
Note 3	SPI interface (master) consists of SPI MOSI, SPI MISO, and SPI CLK. SPI CS is created by using any spare SIO pin within the *smart*BASIC application script allowing multi-dropping.
Note 4	The BL652 module comes loaded with *smart*BASIC runtime engine firmware but does not come loaded with any *smart*BASIC application script (as that is dependent on customer-end application or use). Laird provides many sample *smart*BASIC application scripts covering the services listed. Additional BLE services are being added every quarter.
Note 5	Use of the internal DCDC convertor or LDO is decided by the underlying BLE stack.
Note 6	These figures are measured on the BL652-Sx-xx. ▪ Deep Sleep current for BL652-Sx-xx ~400nA (typical) ▪ Standby Doze current for BL652-xx-A1 2.0 uA (typical)
Note 7	PWM output signal has a frequency and duty cycle property. PWM output is generated using dedicated hardware in the chipset. There is a trade-off between PWM output frequency and resolution. For example: ▪ PWM output frequency of 500 kHz (2 uS) results in resolution of 1:2. ▪ PWM output frequency of 100 kHz (10 uS) results in resolution of 1:10. ▪ PWM output frequency of 10 kHz (100 uS) results in resolution of 1:100. ▪ PWM output frequency of 1 kHz (1000 uS) results in resolution of 1:1000. Refer to the *smart*BASIC user guide for details. It's available from the Laird BL652 product page.

3 HARDWARE SPECIFICATIONS

3.1 Block Diagram and Pin-out

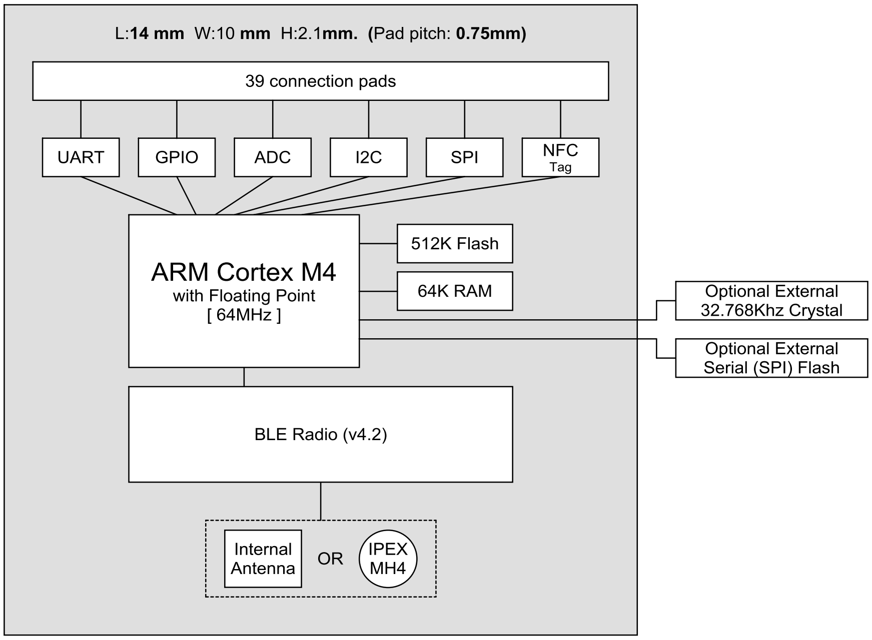

Figure 1: BL652 Block diagram

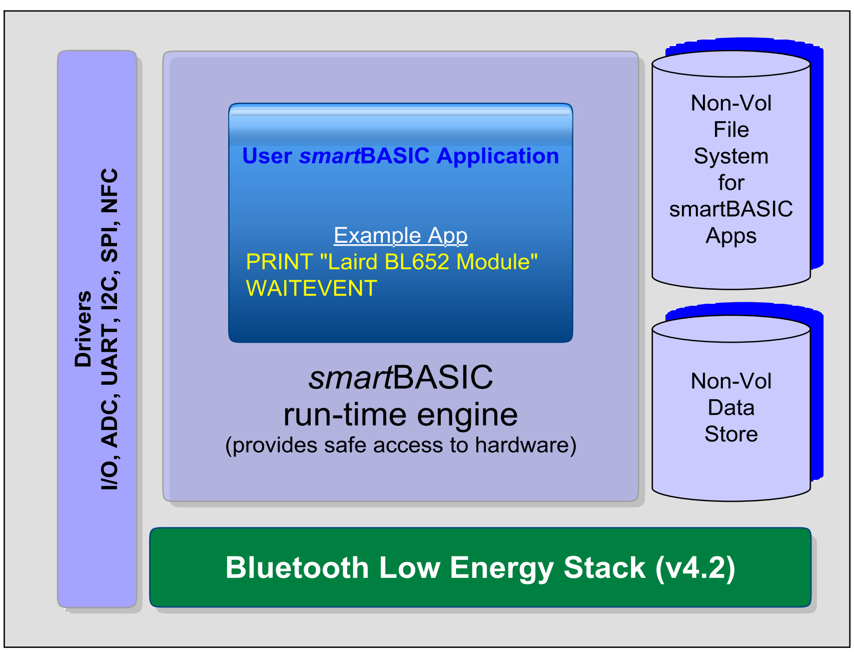

Figure 2: Functional HW and SW block diagram for BL652 series BLE smartBASIC module

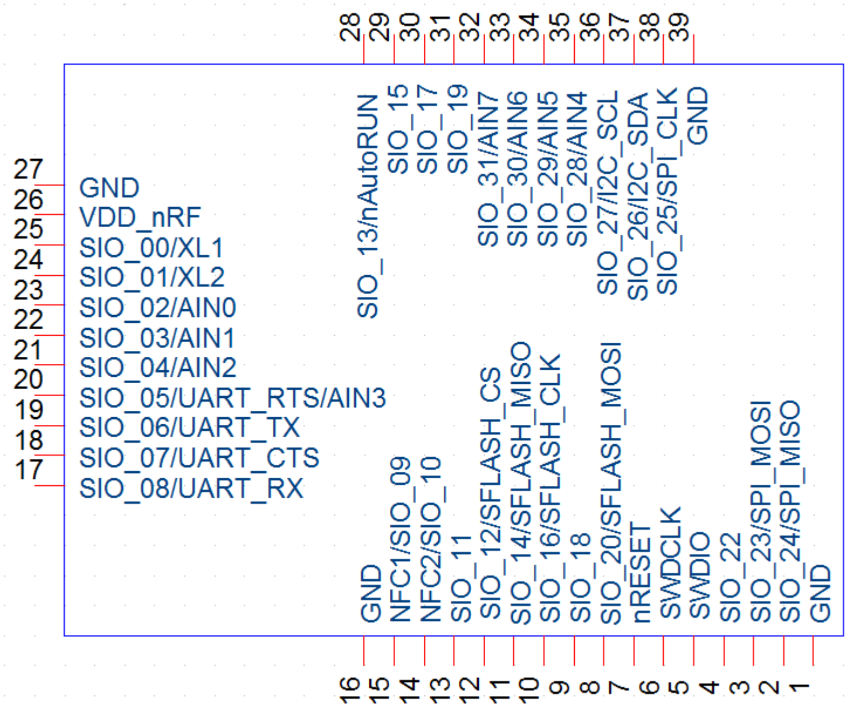

Figure 3: BL652-Sx module pin-out (top view)

3.2 Pin Definitions

Table 2: Pin definitions

Pin #	Pin Name	Default Function	Alternate Function	In/ Out	Pull Up/ Down	nRF52832 QFN Pin	nRF52832 QFN Name	Comment
1	GND	-	-	-	-	-	-	-
2	SIO_24/ SPI_MISO	SIO_24	SPI_MISO	IN	PULL-UP	29	PO.24	**Laird Devkit:** SPI EEPROM. SPI_Eeprom_MISO, Input. SPIOPEN() in *smart*BASIC selects SPI function; MOSI and CLK are outputs when in SPI master mode.
3	SIO_23/ SPI_MOSI	SIO_23	SPI_MOSI	IN	PULL-UP	28	PO.23	**Laird Devkit:** SPI EEPROM. SPI_Eeprom_MOSI, Output SPIOPEN() in *smart*BASIC selects SPI function, MOSI and CLK are outputs in SPI master.
4	SIO_22	SIO_22		IN	PULL-UP	27	PO.22	**Laird Devkit:** SPI EEPROM. SPI_Eeprom_CS, Input
5	SWDIO	SWDIO	-	-	PULL-UP	26	SWDIO	-

Pin #	Pin Name	Default Function	Alternate Function	In/ Out	Pull Up/ Down	nRF52832 QFN Pin	nRF52832 QFN Name	Comment
6	SWDCLK	SWDCLK	-	-	PULL-DOWN	25	SWDCLK	-
7	nRESET	nRESET	-	IN	PULL-UP	24	PO.21/ nRESET	System Reset (Active Low)
8	SIO_20/ SFLASH_MOSI	SIO_20	SFLASH_MOSI	IN	PULL-UP	23	PO.20	**Laird Devkit:** Optional External serial SPI flash for data logging purpose. High level API in *smart*BASIC can be used for fast access using open/close/read/write API functions.
9	SIO_18	SIO_18	-	IN	PULL-UP	21	PO.18	-
10	SIO_16/ SFLASH_CLK	SIO_16	SFLASH_CLK	IN	PULL-UP	19	PO.16	**Laird Devkit:** Optional External serial SPI flash for data logging purpose. High level API in *smart*BASIC can be used for fast access using open/close/read/write API functions.
11	SIO_14/ SFLASH_MISO	SIO_14	SFLASH_MISO	IN	PULL-UP	17	PO.14	
12	SIO_12/ SFLASH_CS	SIO_12	SFLASH_CS	IN	PULL-UP	15	PO.12	
13	SIO_11	SIO_11	-	IN	PULL-UP	14	PO.11	**Laird Devkit:** BUTTON1
14	NFC2/ SIO_10	NFC2	SIO_10	IN	-	12	PO.10/NFC2	-
15	NFC1/ SIO_09	NFC1	SIO_09	IN	-	11	PO.09/NFC1	-
16	GND	-	-	-	-	-	-	-
17	SIO_08/ UART_RX	SIO_08	UART_RX	IN	PULL-UP	10	PO.08	UARTCLOSE() selects DIO functionality UARTOPEN() selects UART COMMS behaviour
18	SIO_07/ UART_CTS	SIO_07	UART_CTS	IN	PULL-DOWN	9	PO.07	
19	SIO_06/ UART_TX	SIO_06	UART_TX	OUT	Set High in FW	8	PO.06	
20	SIO_05/ UART_RTS/ AIN3	SIO_05	UART_RTS/ AIN3	OUT	Set Low in FW	7	PO.05/AIN3	
21	SIO_04/ AIN2	SIO_04	AIN2	IN	PULL-UP	6	PO.04/AIN2	Internal pull-down
22	SIO_03/ AIN1	SIO_03	AIN1	IN	PULL-UP	5	PO.03/AIN1	**Laird Devkit:** Temp Sens Analog or Arduino Analog

Pin #	Pin Name	Default Function	Alternate Function	In/ Out	Pull Up/ Down	nRF52832 QFN Pin	nRF52832 QFN Name	Comment
23	SIO_02/ AIN0	SIO_02	AIN0	IN	PULL-DOWN	4	PO.02/AIN0	Internal pull-down
24	SIO_01/ XL2	SIO_01	XL2	IN	PULL-UP	3	PO.01/XL2	**Laird Devkit:** Optional 32.768kHz crystal pad XL2
25	SIO_00/ XL1	SIO_00	XL1	IN	PULL-UP	2	PO.00/XL1	**Laird Devkit:** Optional 32.768kHz crystal pad XL1
26	VDD_nRF	-	-	-	-	-	-	1.7V to 3.6V
27	GND	-	-	-	-	-	-	-
28	SIO_13/ nAutoRUN	nAutoRUN	SIO_13	IN	PULL-DOWN	16	PO.13	**Laird Devkit:** FTDI USB_DTR via jumper on J12pin1-2.
29	SIO_15	SIO_15	-	IN	PULL-UP	18	PO.15	**Laird Devkit:** BUTTON2
30	SIO_17	SIO_17	-	IN	PULL-UP	20	PO.17	**Laird Devkit:** LED1
31	SIO_19	SIO_19	-	IN	PULL-UP	22	PO.19	**Laird Devkit:** LED2
32	SIO_31/ AIN7	SIO_31	AIN7	IN	PULL-UP	43	PO.31/AIN7	-
33	SIO_30/ AIN6	SIO_30	AIN6	IN	PULL-UP	42	PO.30/AIN6	-
34	SIO_29/ AIN5	SIO_29	AIN5	IN	PULL-UP	41	PO.29/AIN5	-
35	SIO_28/ AIN4	SIO_28	AIN4	IN	PULL-UP	40	PO.28/AIN4	-
36	SIO_27/ I2C_SCL	SIO_27	I2C_SCL	IN	PULL-UP	39	PO.27	**Laird Devkit:** I2C RTC chip. I2C clock line.
37	SIO_26/ I2C_SDA	SIO_26	I2C_SDA	IN	PULL-UP	38	PO.26	**Laird Devkit:** I2C RTC chip. I2C data line.
38	SIO_25/ SPI_CLK	SIO_25	SPI_CLK	IN	PULL-UP	37	PO.25	**Laird Devkit:** SPI EEPROM. SPI_Eeprom_CLK, Output SPIOPEN() in *smart*BASIC selects SPI function, MOSI and CLK are outputs when in SPI master mode.
39	GND	-	-	-	-	-	-	-

Pin Definition Notes:

Note 1	SIO = Signal Input or Output. Secondary function is selectable in *smart*BASIC application.

Pin Definition Notes:

Note 2	DIO = Digital Input or Output. I/O voltage level tracks VCC.
Note 3	AIN = Analog Input
Note 4	DIO or AIN functionality is selected using the GpioSetFunc() function in *smart*BASIC.
Note 5	AIN configuration selected using GpioSetFunc() function.
Note 6	I2C, UART, SPI controlled by xxxOPEN() functions in *smart*BASIC.
Note 7	SIO_5 to SIO_8 are DIO by default when $autorun$ app runs on power-up.
Note 8	JTAG (two-wire SWD interface), pin 5 (SWDIO) and pin 6 (SWDCLK). Laird recommends you use JTAG (2-wire interface) to handle future BL652 module firmware upgrades. You MUST wire out the JTAG (2-wire interface) on your host design (see Figure 8, where four lines should be wired out, namely SWDIO, SWDCLK, GND and VCC). Firmware upgrades can still be performed over the BL652 UART interface, but this is slower (60 seconds using UART vs. 10 seconds when using JTAG) than using the BL652 JTAG (2-wire interface). Upgrading *smart*BASIC runtime engine firmware or loading the *smart*BASIC applications is done using the UART interface.
Note 9	Pull the nRESET pin (pin 7) low for minimum 100 milliseconds to reset the BL652.
Note 10	SPI CS is created by using any spare SIO pin within their *smart*BASIC application script allowing multi-dropping.
Note 11	The SIO_02 pin must be pulled high externally to enable an OTA (over-the-air) *smart*BASIC application download. Refer to the latest firmware release documentation for details.
Note 12	Ensure that SIO_02 (pin 23) and AutoRUN (pin 28) are ***not both high*** (externally), in that state, the UART is bridged to Virtual Serial Port service; the BL652 module does not respond to AT commands and cannot load *smart*BASIC application scripts.
Note 13	The *smartBASIC* runtime engine has DIO (Default Function) INPUT pins, which are set PULL-UP by default. This avoids floating inputs (which can cause current consumption to drive with time in low power modes (such as Standby Doze). You can disable the PULL-UP through your *smart*BASIC application. All of the SIO pins (with a default function of DIO) are inputs (apart from SIO_05 and SIO_06, which are outputs): ▪ SIO_06 (alternative function UART_TX) is an output, set High (in the firmware). ▪ SIO_05 (alternative function UART_RTS) is an output, set Low (in the firmware).

Pin Definition Notes:

- SIO_08 (alternative function UART_RX) is an input, set with internal pull-up (in the firmware).
- SIO_07 (alternative function UART_CTS) is an input, set with internal pull-down (in the firmware).
- SIO_02 is an input set with internal pull-down (in the firmware). It is used for OTA downloading of *smart*BASIC applications. Refer to the latest firmware release documentation for details.

Note 14 Not required for BL652 module normal operation. If you fit an external serial (SPI) flash for data logging purposes, then that external serial (SPI) flash must connect to BL652 module pins SIO_12 (SFLASH_CS), SIO_14 (SFLASH_MISO), SIO_16 (SFLASH_CLK), and SIO_20 (SFLASH_MOSI); in that case, a high level API in *smart*BASIC can be used for fast access using open/close/read/write API functions.

By default, these are GPIO pins. Only when in their FlashOpen() *smart*BASIC app are these lines dedicated to SPI and for talking to the off-board flash.

If you decide to use an external serial (SPI) flash with BL652-SX-xx, then **ONLY** the manufacturer part numbers below **MUST** be used:

- 4 Mbit Macronix MX25R4035F
  http://www.macronix.com/Lists/DataSheet/Attachments/3288/MX25R4035F,%20Wide%20Range,%204Mb,%20v1.2.pdf
- 8 Mbit Macronix MX25R8035F
  http://www.macronix.com/Lists/DataSheet/Attachments/3532/MX25R8035F,%20Wide%20Range,%208Mb,%20v1.2.pdf

*smart*BASIC does not provide access to any external serial (SPI) flash other than these part numbers.

Note 15 Not required for BL652 module normal operation. The on-chip 32.768kHz RC oscillator provides the standard accuracy of ±250 ppm, with calibration required every 8seconds (default) to stay within ±250 ppm.

BL652 also allows as an option to connect an external higher accuracy (±20 ppm) 32.768 kHz crystal to the BL652-SX-xx pins SIO_01/XL2 (pin 24) and SIO_00/XL1 (pin 25). This provides higher accuracy protocol timing and helps with radio power consumption in the system standby doze/deep sleep modes by reducing the time that the Rx window must be open.

The BL652 module is delivered with the integrated *smart*BASIC runtime engine firmware loaded (but no onboard *smart*BASIC application script). Therefore it boots into AT command mode by default.

At reset, all SIO lines are configured as the defaults shown above.

SIO lines can be configured through the *smart*BASIC application script to be either inputs or outputs with pull-ups or pull-downs. When an alternative SIO function is selected (such as I2C or SPI), the firmware does not allow the setup of internal pull-up/pull-down. Therefore, when I2C interface is selected, pull-up resistors on I2C SDA and I2C SCL ***must*** be connected externally as per I2C standard.

UART_RX, UART_TX, and UART_CTS are 3.3 V level logic (if VCC is 3.3 V; such as SIO pin I/O levels track VCC). For example, when Rx and Tx are idle, they sit at 3.3 V (if VCC is 3.3 V). Conversely, handshaking pins CTS and RTS at 0V are treated as assertions.

Pin 28 (nAutoRUN) is an input, with active low logic. In the development kit (DVK-BL652-xx) it is connected so that the state is driven by the host's DTR output line. The nAutoRUN pin must be externally held high or low to select between the following two BL652 operating modes:

- Self-contained Run mode (nAutoRUN pin held at 0V –this is the default (internal pull-down enabled))
- Interactive/Development mode (nAutoRUN pin held at VCC)

The *smart*BASIC runtime engine firmware checks for the status of nAutoRUN during power-up or reset. If it is low and if there is a *smart*BASIC application script named **$autorun$**, then the *smart*BASIC runtime engine firmware executes the application script automatically; hence the name S*elf-contained Run Mode*.

3.3 Electrical Specifications

3.3.1 Absolute Maximum Ratings

Absolute maximum ratings for supply voltage and voltages on digital and analogue pins of the module are listed below; exceeding these values causes permanent damage.

Table 3: Maximum current ratings

Parameter	Min	Max	Unit
Voltage at VDD_nRF pin	-0.3	+3.9 (Note 1)	V
Voltage at GND pin		0	V
Voltage at SIO pin (at VDD_nRF≤3.6V)	-0.3	VDD_nRF +0.3	V
Voltage at SIO pin (at VDD_nRF≥3.6V)	-0.3	3.9	V
NFC antenna pin current (NFC1/2)	-	80	mA
Radio RF input level	-	10	dBm
Environmental			
Storage temperature	-40	+85	ºC
MSL (Moisture Sensitivity Level)	-	3	-
ESD (as per EN301-489) Conductive Air Coupling		 4 8	 KV KV
Flash Memory (Endurance) (Note 2)	-	10000	Write/erase cycles
Flash Memory (Retention)	-	10 years at 40°C	-

Maximum Ratings Notes:

Note 1	The absolute maximum rating for VCC pin (max) is 3.9V for the BL652-Sx-xx.
Note 2	Wear levelling is used in file system.

3.3.2 Recommended Operating Parameters

Table 4: Power supply operating parameters

Parameter	Min	Typ	Max	Unit
VDD_nRF (independent of DCDC)[1]	1.8	3.3	3.6	V
VCC Maximum ripple or noise[2]	-	-	10	mV
VCC rise time (0 to 1.7V)[3]	-	-	60	mS
Operating Temperature Range	-40	-	+85	ºC

Recommended Operating Parameters Notes:

Note 1	4.7 uF internal to module on VCC. In *smart*BASIC runtime engine firmware, use of the internal DCDC convertor or LDO is decided by the underlying BLE stack.
Note 2	This is the maximum VCC ripple or noise (at any frequency) that does not disturb the radio.
Note 3	The on-board power-on reset circuitry may not function properly for rise times outside the noted interval.

Table 5: Signal levels for interface, SIO

Parameter	Min	Typ	Max	Unit
V_{IH} Input high voltage	0.7 VDD_nRF		VDD_nRF	V
V_{IL} Input low voltage	VSS		0.3 x VDD_nRF	V
V_{OH} Output high voltage				
(std. drive, 0.5mA) (Note 1)	VDD_nRF -0.4		VDD_nRF	V
(high-drive, 3mA) (Note 1)	VDD_nRF -0.4		VDD_nRF	V
(high-drive, 5mA) (Note 2)	VDD_nRF -0.4		VDD_nRF	
V_{OL} Output low voltage				
(std. drive, 0.5mA) (Note 1)	VSS		VSS+0.4	V
(high-drive, 3mA) (Note 1)	VSS		VSS+0.4	V
(high-drive, 5mA) (Note 2)	VSS		VSS+0.4	
V_{OL} Current at VSS+0.4V,Output set low				
(std. drive, 0.5mA) (Note 1)	1	2	4	mA
(high-drive, 3mA) (Note 1)	3	-	-	mA
(high-drive, 5mA) (Note 2)	6	10	15	mA
V_{OL} Current at VDD_nRF -0.4, Output set low				
(std. drive, 0.5mA) (Note 1)	1	2	4	mA
(high-drive, 3mA) (Note 1)	3	-	-	mA
(high-drive, 5mA) (Note 2)	6	9	14	mA
Pull up resistance	11	13	16	kΩ
Pull down resistance	11	13	16	kΩ
Pad capacitance		3		pF

Parameter	Min	Typ	Max	Unit
Pad capacitance at NFC pads		4		pF

Signal Levels Notes:

Note 1 For VDD_nRF≥1.7V. The *smart*BASIC firmware supports high drive (3 mA, as well as standard drive).

Note 2 For VDD_nRF≥2.7V. The *smart*BASIC firmware supports high drive (5 mA (since VDD_nRF≥2.7V), as well as standard drive).

Table 6: SIO pin alternative function AIN (ADC) specification

Parameter	Min	Typ	Max	Unit
ADC Internal reference voltage	-1.5%	0.6 V	+1.5%	%
ADC pin input internal selectable scaling		4, 2, 1, 1/2, 1/3, 1/4, 1/5 1/6		scaling
ADC input pin (AIN) voltage maximum without damaging ADC w.r.t[1] VCC Prescaling 0V-VDD_nRF 4, 2, 1, ½, 1/3, ¼, 1/5, 1/6		VDD+0.3		V
Configurable via smartBASIC Resolution	8bit mode	10bit mode	12bit mode	bits
Configurable via smartBASIC[2] Acquisition Time, source resistance ≤10kΩ Acquisition Time, source resistance ≤40kΩ Acquisition Time, source resistance ≤100kΩ Acquisition Time, source resistance ≤200kΩ Acquisition Time, source resistance ≤400kΩ Acquisition Time, source resistance ≤800kΩ		 3 5 10 15 20 40		 uS uS uS uS uS uS
Conversion Time[3]		<2		uS
ADC input impedance (during operation)[3] Input Resistance Sample and hold capacitance at maximum gain		 >1 2.5		 MOhm pF

Recommended Operating Parameters Notes:

Note 1 Stay within internal 0.6 V reference voltage with given pre-scaling on AIN pin and do not violate ADC maximum input voltage (for damage) for a given VCC, e.g. If VCC is 3.6V, you can only expose AIN pin to VDD+0.3 V. Default pre-scaling is 1/6 which configurable via smartBASIC.

Note 2 smartBASIC runtime engine firmware allows configurable resolution (8-bit, 10-bit or 12-bit mode) and acquisition time. The sampling frequency is limited by the sum of sampling time and acquisition time. The maximum sampling time is 2us. For acquisition time of 3us the total conversion time is therefore 5us, which makes maximum sampling frequency of 1/5us = 200kHz. Similarly, if acquisition

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Recommended Operating Parameters Notes:

	time of 40us chosen, then the conversion time is 42us and the maximum sampling frequency is 1/42us = 23.8kHz
Note 3	ADC input impedance is estimated mean impedance of the ADC (AIN) pins.

3.3.3 nAutoRUN Pin and Operating Modes

Operating modes (refer to the *smart*BASIC guide for details):

- Self-contained mode
- Interactive/Development mode

Table 7: nAutoRUN pin

Signal Name	Pin #	I/O	Comments
nAutoRUN /(SIO_13)	28	I	Input with active low logic. Internal pull down (default). Operating mode selected by nAutoRun pin status: ▪ If Low (0V), runs $autorun$ if it exists ▪ If High (VCC), runs via at+run (and file name of application)

Pin 28 (nAutoRUN) is an input, with active low logic. In the development board (DVK-BL652-xx) it is connected so that the state is driven by the host's DTR output line. nAutoRUN pin needs to be externally held high or low to select between the two BL652 operating modes:

- Self-contained Run mode (nAutoRUN pin held at 0V).
- Interactive/Development mode (nAutoRUN pin held at VCC).

*smart*BASIC runtime engine firmware checks for the status of nAutoRUN during power-up or reset. If it is low AND if there is a *smart*BASIC application named $autorun$, the *smart*BASIC runtime engine executes the application automatically; hence the name *self-contained run mode*.

3.3.4 OTA (Over-the-Air) *smart*BASIC Application Download

Refer to latest firmware release documentation (firmware release notes and *smart*BASIC user guide) for details.

Table 8: OTA mode

Signal Name	Pin #	I/O	Comments
SIO_02	23	I	Internal pull down (default). OTA mode selected by externally pulling-up SIO_02 pin: **High (VCC),** then OTA *smart*BASIC application download is possible.

The OTA *smart*BASIC application download feature can be useful for production because it allows the module to be soldered into an end product without pre-configuration; the application can then be downloaded over-the-air once the product has been pre-tested.

Note: It is the *smart*BASIC application that is downloaded over-the-air and NOT the firmware. Since this is principally designed for use in production with multiple programming stations in a locality, the transmit power is limited (to lower Tx power). See the ***smart*****BASIC user guide** for more details.

4 POWER CONSUMPTION

Data taken at VCC_nRF of 3.0 V with internal (to chipset) LDO ON or with internal (to chipset) DCDC ON (see Note 1) and 25°C.

4.1 Power Consumption

Table 9: Power consumption

Parameter	Min	Typ	Max	Unit
Active mode 'peak' current (Note 1) **(Advertising or Connection)**		With DCDC [with LDO]		
Tx only run peak current @ Txpwr = +4 dBm		7.5 [16.6]		mA
Tx only run peak current @ Txpwr = 0 dBm		5.3 [11.6]		mA
Tx only run peak current @ Txpwr = -4 dBm		4.2 [9.3]		mA
Tx only run peak current @ Txpwr = -8 dBm		3.8 [8.4]		mA
Tx only run peak current @ Txpwr = -12 dBm		3.5 [7.7]		mA
Tx only run peak current @ Txpwr = -16 dBm		3.3 [7.3]		mA
Tx only run peak current @ Txpwr = -20 dBm		3.2 [7.0]		mA
Tx Whisper mode 1 (Note 2) Tx only run peak current @ Txpwr = -40 dBm		2.7 [5.9]		mA
Active Mode				
Rx only 'peak' current (Note 2)		5.4 [11.7]		mA
Ultra Low Power Mode 1 (Note 2) Standby Doze, 64k RAM retention		2.0		uA
Ultra Low Power Mode 2 (Note 3) Deep Sleep (no RAM retention)		400		nA
Active Mode Average current (Note 4)				
Advertising Average Current draw				
Max, with advertising interval (min) 20 mS		~511		uA
Min, with advertising interval (max) 10240 mS		~3.2		uA
Connection Average Current draw				
Max, with connection interval (min) 7.5 mS		~513		uA
Min, with connection interval (max) 4000 mS		~2.9		uA

Power Consumption Notes:

Note 1 This is for Peak Radio Current only, but there is additional current due to the MCU, refer to Table 12 and Table 15 for the peak and "Average Advert/connection (burst) current" consumption profile (with DCDC on) during advertising and connection versus TX power. In *smart*BASIC runtime engine firmware, use of the internal DCDC convertor or LDO is decided by the underlying BLE stack.

Note 2 BL652-Sx-xx: Standby Doze is 2.0 uA typical. Standby Doze is entered automatically (when a waitevent

	statement is encountered within a smartBASIC application script). In Standby Doze, all peripherals that are enabled stay on and may re-awaken the chip. Depending on active peripherals, current consumption ranges from ~2.0 µA to 270 uA (when UART is ON). See individual peripherals current consumption data in the Peripheral Block Current Consumption section. smartBASIC runtime engine firmware has added new functionality to detect GPIO change with no current consumption cost, it is possible to close the UART and get to the 2.0uA current consumption regime and still be able to detect for incoming data and be woken up so that the UART can be re-opened at expense of losing that first character. The BL652 Standby Doze current consists of the below nRF52 blocks: ▪ nRF52 System ON IDLE current (no RAM retention) (1.2 uA) – This is the base current of the CPU ▪ LFRC (0.35 uA) and RTC (0.1uA) running as well as 64k RAM retention (0.32 uA) – This adds to the total of 2 uA typical.
Note 3	In Deep Sleep, everything is disabled and the only wake-up sources (including NFC to wakeup) are reset and changes on SIO or NFC pins on which sense is enabled. The current consumption seen is ~400 nA typical in BL652-Sx-xx. ▪ *smart*BASIC runtime engine firmware requires a hardware reset to come out of deep sleep. ▪ *smart*BASIC runtime engine firmware also allows coming out from Deep Sleep to Standby Doze through GPIO signal through the reset vector. Deep Sleep mode is entered with a command in *smart*BASIC application script.
Note 4	Data taken with a transmit power of 4 dBm and all peripherals off (UART OFF after radio event), slave latency of 0 (in a connection). Average current consumption depends on a number of factors (including Tx power, VCC, accuracy of 32MHz and 32.768 kHz). With these factors fixed, the largest variable is the advertising or connection interval set. Advertising Interval range: ▪ 20 milliseconds to 10240 milliseconds in multiples of 0.625 milliseconds for the following Advert type: ADV_IND and ADV_DIRECT_IND ▪ 100 milliseconds to 10240 milliseconds in multiples of 0.625 milliseconds for the following Advert types: ADV_SCAN_IND and ADV_NONCONN_IND For advertising timeout, if the advert type is ADV_DIRECT_IND, then the timeout is limited to 1.28 seconds (1280 milliseconds). For an advertising event: ▪ The minimum average current consumption is when the advertising interval is large 10240 mS (although this may cause long discover times (for the advertising event) by scanners ▪ The maximum average current consumption is when the advertising interval is small 20 mS Other factors that are also related to average current consumption include the advertising payload bytes in each advertising packet and whether it's continuously advertising or periodically advertising. Connection Interval range: ▪ 7.5 milliseconds to 4000 milliseconds in multiples of 1.25 milliseconds. For a connection event:

- The minimum average current consumption is when the connection interval is large 4000 milliseconds
- The maximum average current consumption is with the shortest connection interval of 7.5 ms; no slave latency.

Other factors that are also related to average current consumption include:

- Whether transmitting six packets per connection interval with each packet containing 20 bytes (which is the maximum for each packet)
- An inaccurate 32.768 kHz master clock accuracy would increase the average current consumption.

4.2 Measured Current Waveforms during Advertising and Connection

The following figures illustrate current waveforms observed as the BL652 module performs advertising and connection functionality.

TX power – 4 dBm 29 byte payload
Advert duration ~4.377 ms Advertising interval – 20 ms

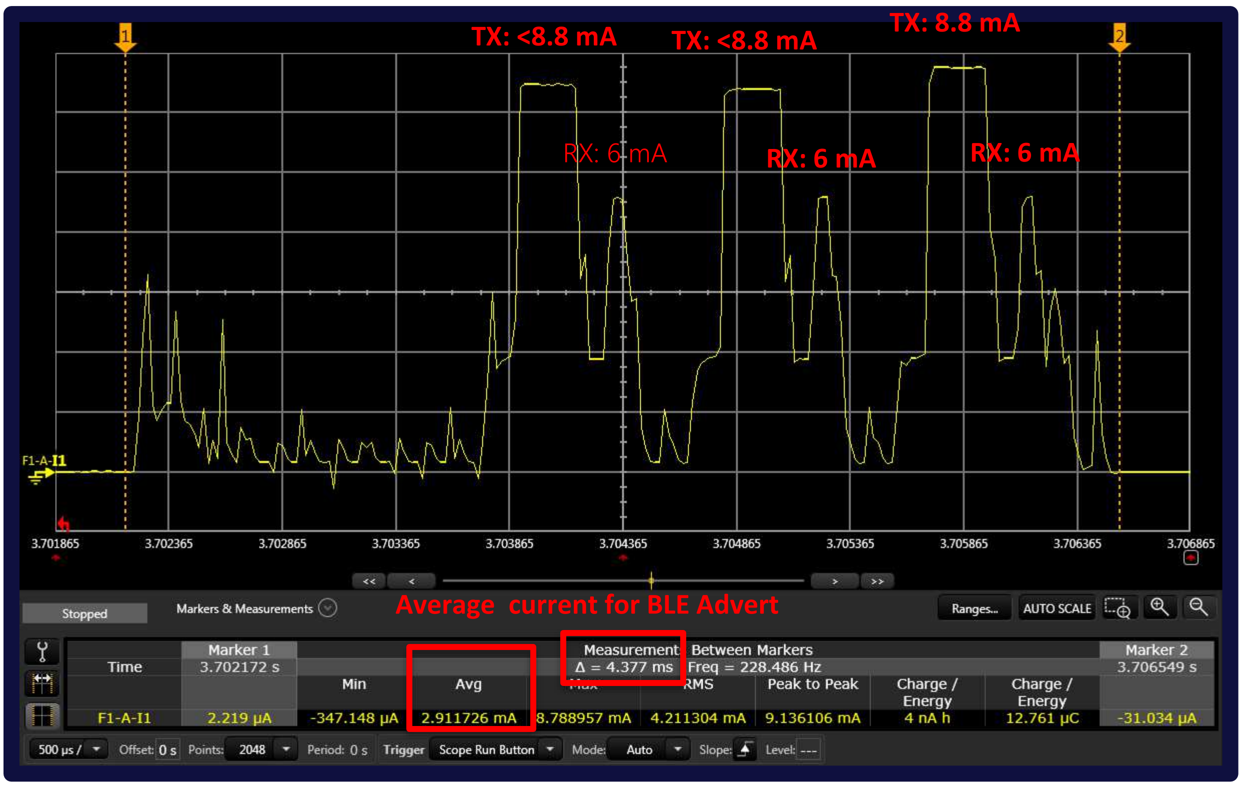


Figure 4: Typical peak current consumption profile (with DCDC ON) during advertising in slave mode @ TX PWR +4 dBm. UART is OFF

TX power – 4 dBm	29 byte payload
Interval – 7.5 ms	Advertising interval – 20 ms

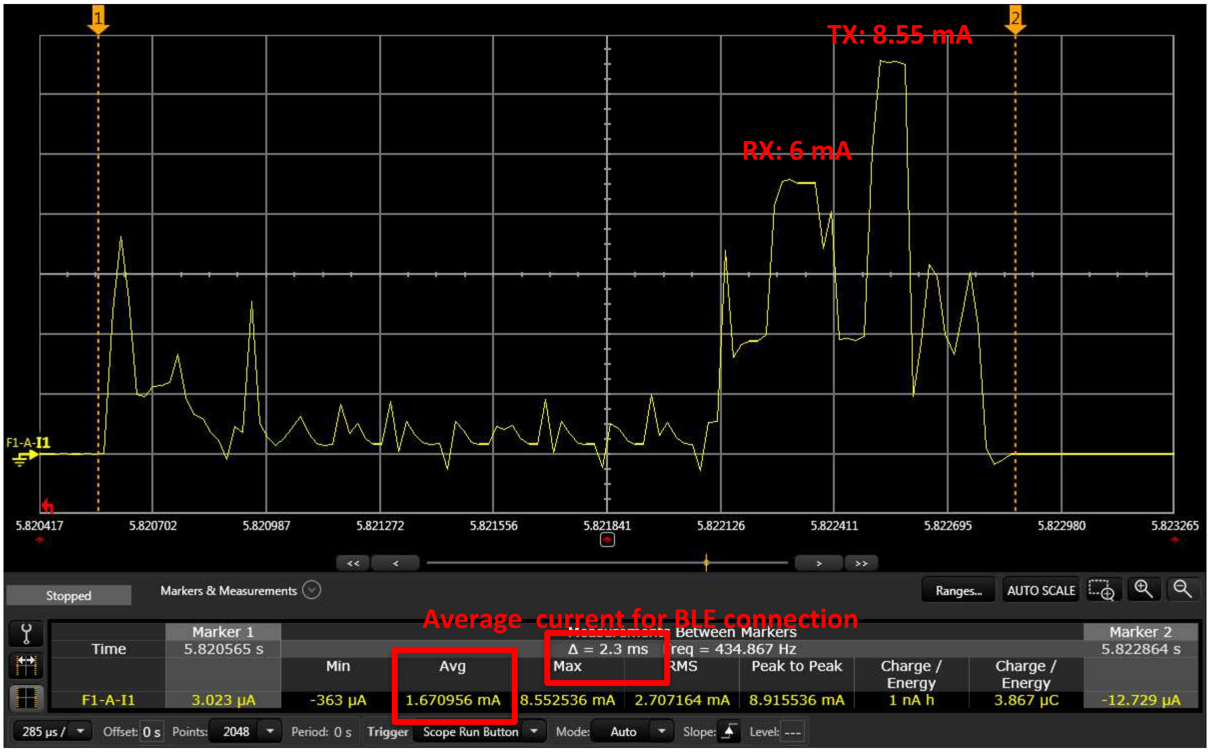


Figure 5: Typical peak current consumption profile (with DCDC ON) during data connection event in slave mode @ TX PWR +4dBm UART is OFF

Note: In the above pictures, UART is OFF. Y-axis current (1.3 mA per square).

To make things easier the average current during the whole BLE event is shown in the plot above, and then the BLE event total charge consumption is found by multiplying the average current over the BLE event with the length of the event. This charge can then be used to extrapolate the average current for **different advertising intervals**, by dividing by the interval. Then the StandbyDoze (IDLE) current must be added to give the total average current. In this example we can calculate the average current to be:

The total charge of the BLE event:

```
BLE_charge = BLE_avg * BLE_length
```

The average current consumed by the BLE event for a specific interval:

```
BLE_avg = BLE_charge / (BLE_interval + perturbation)
```

The perturbation is given as a random number between 0 and 10 milliseconds added to the interval to prevent advertisers to periodically transmit at the exact same time. This averages to 5 milliseconds.

Adding the IDLE current (StandbyDoze mode) to the inactive part of the interval:

TOT_avg = BLE_avg + IDLE * (BLE_interval - BLE_length) / BLE_interval

Performing the calculation with the numbers 25mS advertising internal and TX power for 4dBm for example:

BLE_charge = 4.377 ms * 2.91 mA = 12.74 uC

BLE_avg = 12.74 uC / (20 ms + 5 ms) = 509.78 uA

TOT_avg = 509.78 uA + 2 uA * (25 ms - 4.377 ms)/25 ms = 511.43 uA

Table 10 and Table 11 display the measured "Average Advert (Burst) current" (for a given TX power) which can be used to calculate the Total average current for any advertising interval.

Table 12 and Table 13 display the measured "Average Connection (Burst) current" (for a given TX power) which can be used to calculate the Total average current for any connection interval.

The following table (Table 10) shows the measured total average current consumption profile (with DCDC on) during advertising in slave mode versus TX power for a minimum advertising interval of 25 milliseconds. Note that UART is off.

Table 10: Measured total average current consumption profile – for a minimum advertising interval of 25 ms

TX Power (dBm)	Average Advert (Burst) Current (uA)	Average Advert (Burst) Duration (mS)	BLE Advert Charge (uC)	BLE Advert Interval 20 mS plus 5 mS Perturbation	BLE Advert Average (uA)	Max Standby Doze Current (uA)	BLE Advert Interval 20 mS plus 5 mS Pertubation	Total Average Current (uA)
4	2911.726	4.377	12744.625	25	509.785	2	25	511.435
0	2431.095	4.377	10640.903	25	425.636	2	25	427.286
-4	2163.884	4.377	9471.320	25	378.853	2	25	380.503
-8	2151.602	4.377	9417.562	25	376.702	2	25	378.352
-12	2086.596	4.377	9133.031	25	365.321	2	25	366.971
-16	2052.041	4.377	8981.783	25	359.271	2	25	360.921
-20	2029.615	4.377	8883.625	25	355.345	2	25	356.995
-40	1960.112	4.377	8579.410	25	343.177	2	25	344.826

The following table (Table 11) shows the measured total average current consumption profile (with DCDC on) during advertising in slave mode versus TX power for a maximum advertising interval of 10240 milliseconds. Note that UART is off.

Table 11: Measured total average current consumption profile – for a minimum advertising interval of 10240 ms

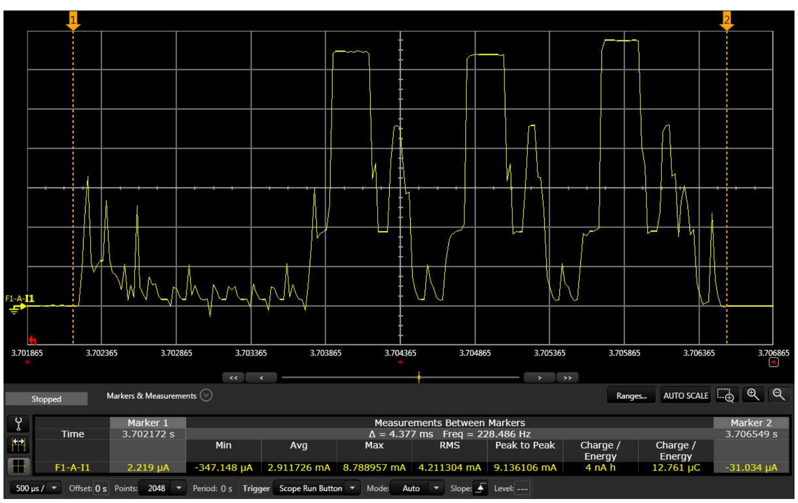
TX Power (dBm)	Average Advert (Burst) Current (uA)	Average Advert (Burst) Duration (mS)	BLE Advert Charge (uC)	BLE Advert Interval 10240 mS plus 5 mS Perturbation	BLE Advert Average (uA)	Max Standby Doze Current (uA)	BLE Advert Interval 10240 mS plus 5 mS Perturbation	Total Average Current (uA)
4	2911.726	4.377	12744.625	10245	1.244	2	10245	3.243
0	2431.095	4.377	10640.903	10245	1.039	2	10245	3.038
-4	2163.884	4.377	9471.320	10245	0.924	2	10245	2.924
-8	2151.602	4.377	9417.562	10245	0.919	2	10245	2.918
-12	2086.596	4.377	9133.031	10245	0.891	2	10245	2.891
-16	2052.041	4.377	8981.783	10245	0.877	2	10245	2.876
-20	2029.615	4.377	8883.625	10245	0.867	2	10245	2.866
-40	1960.112	4.377	8579.410	10245	0.837	2	10245	2.837

Table 12 displays measured peak and "Average Advert (burst) current" consumption profile (with DCDC on) during advertising in slave mode versus TX power. Between Marker 1 and 2 is the average BLE advert current.

Table 12: Measured average advert (burst) current consumption profiles (with DCDC on) during advertising in slave mode vs TX power

TX power: 4 dBm
Advert

29 byte payload
20 ms interval



Average BLE advert current burst
(excluding advertising interval): 2.911 mA

Aside:
Peak TX current: 8.8 mA
Peak RX current: 6 mA