AN1246: EFR32BG SoC *Bluetooth*® Smart Device Power Consumption Measurements

Silicon Labs offers a complete portfolio of fully-certified modules and SoC solutions for Bluetooth Smart connectivity that are known collectively as the EFR32BG family. This application note describes how to measure the power consumption of EFR32BG devices using the setup and procedures recommended in *AN969: Measuring Power Consumption in Wireless Gecko Devices*.

KEY POINTS

- An EFR32BG WSTK is required.
- A test example is available in the Bluetooth SDK.
- Results from that test example are provided for both Series 1 and Series 2 devices.

1. Setup

1. Obtain a Bluetooth Wireless Starter Kit and radio board.
2. Build and install a test application, as described below.
3. Configure the WSTK as described in *AN969: Measuring Power Consumption in Wireless Gecko Devices*.

To observe power consumption, the device must be programmed with a suitable test application. A beaconing application is an excellent reference for power consumption evaluation because it showcases the real-world transmit (TX) and sleep currents of the device by default. With minor modifications to the application code, the receive (RX) current can be verified as well.

If you have not already done so, install Simplicity Studio and the Bluetooth SDK. The Bluetooth SDK includes several software examples to create Bluetooth application projects. Select the **SOC – iBeacon** example. This provides an iBeacon device implementation that sends non-connectible advertisements in iBeacon format. The iBeacon Service gives Bluetooth accessories a simple and convenient way to send iBeacons to iOS devices. This example demonstrates the power consumption at 0 dBm TX power. Follow the directions in the quick-start guide applicable to your version of the SDK to build and flash the example project to the device (*QSG139: Bluetooth® SDK v2.x Quick Start Guide* or *QSG169: Bluetooth® SDK v3.x Quick-Start Guide*).

The SoC-iBeacon application sets the device to broadcast in a non-connectable mode, which means that only TX and sleep events are observed in the current profile. To also observe RX events, edit the application script to make the device broadcast in a connectable mode as follows:

If you use Simplicity Studio 4/Bluetooth SDK 2.x:

1. Open the **main.c** file in the SoC-iBeacon project by double-clicking it.
2. Edit the parameters for **gecko_cmd_le_gap_start_advertising** in the `bcnSetupAdvBeaconing` function.

```
gecko_cmd_le_gap_start_advertising(0, le_gap_user_data, le_gap_undirected_connectable)
```

3. Rebuild the project and program the test device with the new image.

If you use Simplicity Studio 5/Bluetooth SDK 3.x:

1. Open the **app.c** file in the SoC-iBeacon project by double-clicking it.
2. Edit the parameters for **sl_bt_advertiser_start** in the `bcnSetupAdvBeaconing` function.

```
sc = sl_bt_advertiser_start
                advertising_set_handle,
                advertiser_user_data,
                advertiser_connectable_scannable);
```

3. Rebuild the project and program the test device with the new image.

2. Test Example

This section:

- Gives a brief overview of current profiles (for example, magnitude vs. time) commonly observed in Bluetooth Smart devices for reference.
- Provides an example showing the capture of power measurements for an EFR32BG radio board and their interpretation

2.1 Reference Current Profiles

The following figures show the form and breakdown of a typical current consumption profile for a Bluetooth Smart device while in an advertising or connection state.

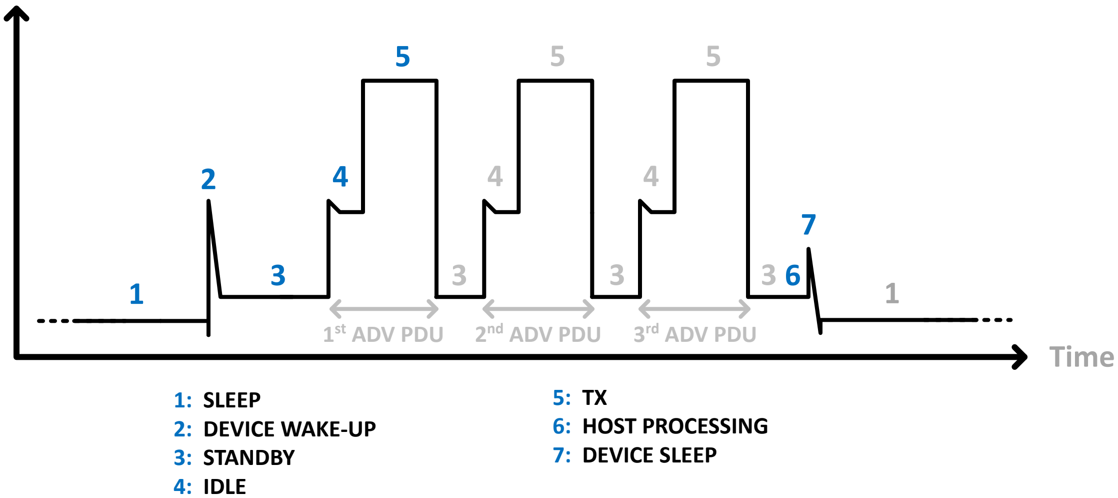


Figure 2.1. General Current Profile for a Non-Connectable Advertising Event

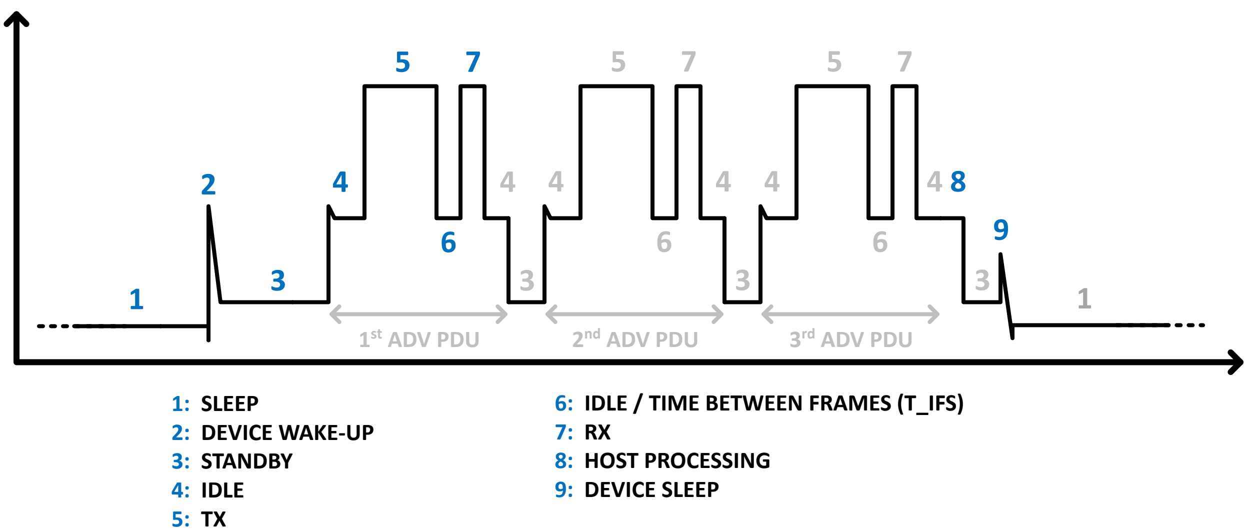


Figure 2.2. General Current Profile for a Connectable Advertising Event

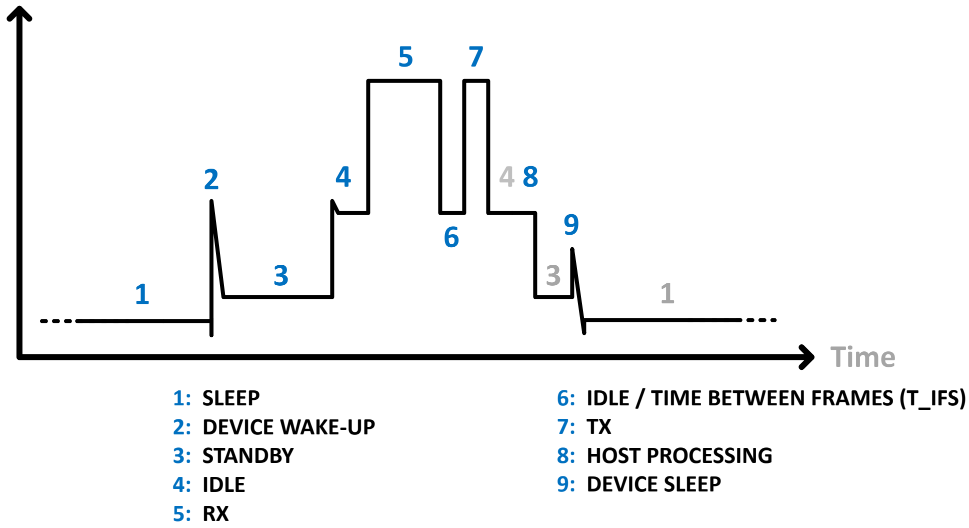


Figure 2.3. General Current Profile for a Connection Event

2.2 Measuring Power Consumption

Once you have gone through the setup and procedure steps outlined in *AN969: Measuring Power Consumption in Wireless Gecko Devices*, measuring the power consumption of an EFR32BG device is straightforward.This section provides an example of how to turn the captured current consumption profile to an actual set of power measurements giving useful information.

After running a test, use the scope cursors in the N6705B to measure every event in the current profile individually. The cursors can be enabled or disabled by pressing the Scope View button under "Measure" in the front panel of the DC analyzer. To scroll the cursors over the waveform, rotate the marker 1 and marker 2 knobs under "Waveform Display." The following figure shows a screenshot of a current profile with the scope cursors enabled. This current profile is a zoomed-in view of a large periodic burst corresponding to the current consumed by the SoC while broadcasting a beacon every 100 ms.

Note: Measurements are enabled by default when the scope cursors are active.

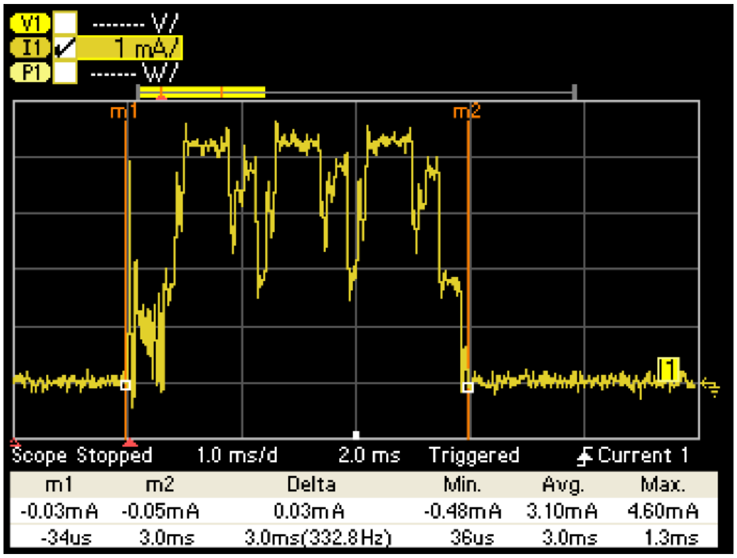


Figure 2.4. Current Profile Segment Measured with Scope Cursors - Device: Series 2 EFR32BG22

2.2.1 Measuring Power Consumption on Series 1 Devices

Per the application's default settings, the Series 1 EFR32BG1 device broadcasts a beacon with a frame of 46 octets every 100 ms, at a 0 dBm TX output power level, running from the DCDC converter. The figure below shows the active portion only of the captured current profile for a beacon broadcast broken into individual events similarly to the reference profiles in 2.1 Reference Current Profiles. The table that follows summarizes the measurements recorded using the scope cursors. Notice that the numbering of events in the upper part of the figure corresponds to the columns in the table.

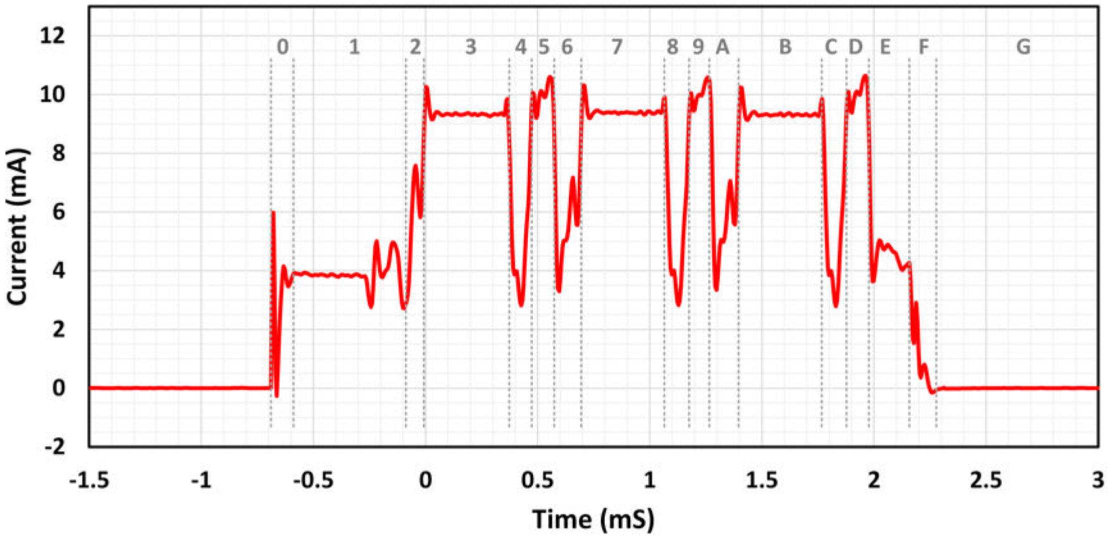


Figure 2.5. Current Profile for Series 1 EFR32BG1 SoC Running SoC-iBeacon Example Application (Active Only)

Table 2.1. Power and Energy Measurements for the Current Profile in the Figure Above

	UNIT	DEV WKUP	STANDBY	IDLE	TX_1	T_IFS	RX_1	STANDBY/IDLE	TX_2	T_IFS	RX_2	STANDBY/IDLE	TX_3	T_IFS	RX_3	POST PROCESS	DEV SLEEP	SLEEP
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G
Average Current	mA	2.9	3.9	6.4	9.4	5.2	10.0	6.0	9.4	5.2	10.0	5.8	9.4	5.2	10.0	4.8	1	0.0018
Time	µs	97	502	67	379	102	92	128	379	102	97	123	379	102	97	174	128	97052
Supply Voltage	V	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Power	mW	9.6	12.9	21.2	30.9	17.2	33.1	19.8	31.1	17.1	33.0	19.2	30.9	17.2	33.1	15.7	3.3	0.006
Energy	µJ	0.9	6.5	1.4	11.7	1.8	3.0	2.5	11.8	1.7	3.2	2.4	11.7	1.7	3.2	2.7	0.4	0.6

The previous table shows the following:

- The captured current profile is divided into events numbered (in hex) 0 through G.
- The first and second rows show the measured average current for each event (in mA) and its duration (in µs).
- The third row shows the nominal supply level for the test device (3.3 V).
- The fourth row shows the average power for each event, calculated by multiplying the first and third rows.
- The fifth row shows the energy consumed by the device in each event, calculated by multiplying the fourth and second rows (and dividing by 1000 for units to match).

The table below gives a summary of the measurements in Table 2.1 Power and Energy Measurements for the Current Profile in the Figure Above on page 5, which leads to some useful observations.

- The TX, RX, and sleep average currents for the Series 1 EFR32BG1 SoC are 9.38 mA, 10.00 mA, and 1.8 µA respectively.
- In terms of energy, the Series 1 EFR32BG1 SoC consumes 67.3 µJ while broadcasting a beacon in connectable mode every 100 ms, out of which 66.7 µJ are used while the device is active and only 0.6 µJ while the device is sleeping.
- The previous observation implies that increasing the broadcast interval and, hence, keeping the device in sleep mode longer helps minimize energy consumption, as should be expected.
- Depending on the broadcasting interval, there is a point at which the sleep mode energy consumption will equal or exceed the energy consumed when the device is active, which can be verified independently.

Table 2.2. Summary of Power Measurements for Series 1 EFR32BG1 SoC

		Time (µs)	Average Current (mA)	Energy (µJ)
Full Event	**0-G**	100000	0.20	67.3
Active Only	**0-F**	2948	6.86	66.7
Sleep	**G**	97052	0.0018	0.6
TX	**3, 7, B**	1137	9.38	35.2
RX	**5, 9, D**	286	10.00	9.4

2.2.2 Measuring Power Consumption on Series 2 Devices

Per the application's default settings, the Series 2 EFR32BG22 device broadcasts a beacon with a frame of 46 octets every 100 ms, at a 0 dBm TX output power level, running from the DCDC converter. The figure below shows the active portion only of the captured current profile for a beacon broadcast broken into individual events similarly to the reference profiles in 2.1 Reference Current Profiles. The table that follows summarizes the measurements recorded using the scope cursors. Notice that the numbering of events in the upper part of the figure corresponds to the columns in the table.

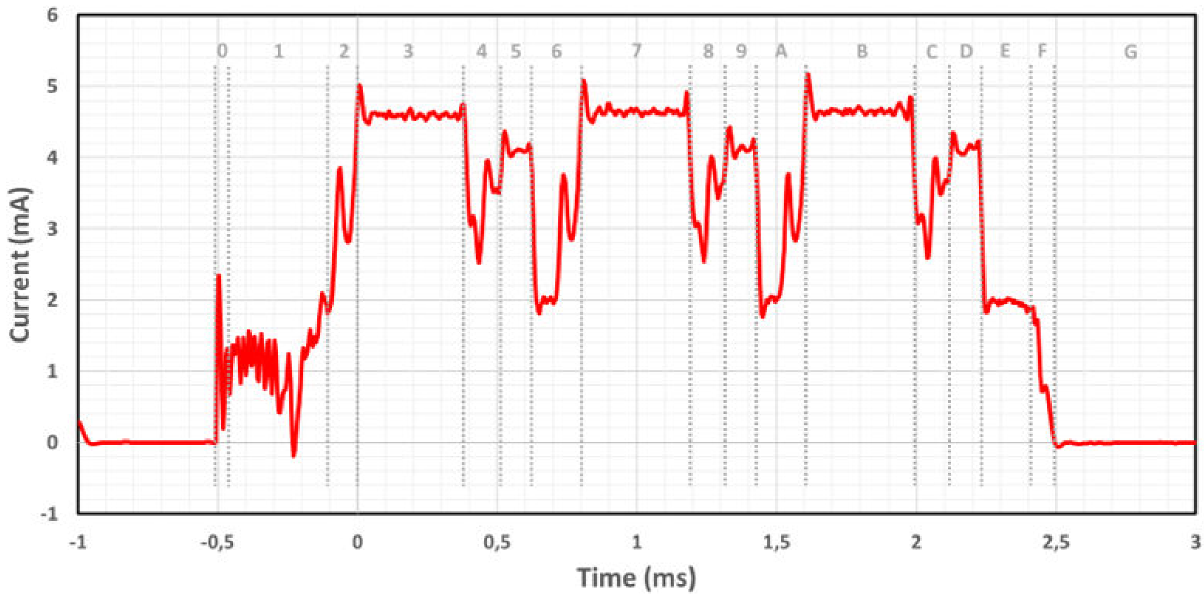


Figure 2.6. Current Profile for Series 2 EFR32BG22 SoC Running SoC-iBeacon Example Application (Active Only)

Table 2.3. Power and Energy Measurements for the Current Profile in the Figure Above (EM2 Debug Disabled)

	UNIT	DEV WKUP	STANDBY	IDLE	TX_1	T_IFS	RX_1	STANDBY/IDLE	TX_2	T_IFS	RX_2	STANDBY/IDLE	TX_3	T_IFS	RX_3	POST PROCESS	DEV SLEEP	SLEEP
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G
Average Current	mA	1.0	1.1	3.1	4.6	3.5	4.1	2.7	4.7	3.5	4.2	2.7	4.7	3.5	4.1	2.1	0.8	0.0013
Time	μs	40	363	109	379	137	106	178	382	136	106	179	379	136	105	205	65	96995
Supply Voltage	V	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Power	mW	2.9	3.4	9.2	13.8	10.5	12.4	8.2	14.0	10.5	12.5	8.2	14.0	10.4	12.4	6.2	2.3	0.004
Energy	μJ	0.1	1.2	1.0	5.2	1.4	1.3	1.5	5.3	1.4	1.3	1.5	5.3	1.4	1.3	1.3	0.2	0.4

The previous table shows the following:

- The captured current profile is divided into events numbered (in hex) 0 through G.
- The first and second rows show the measured average current for each event (in mA) and its duration (in μs).
- The third row shows the nominal supply level for the test device (3.0 V).
- The fourth row shows the average power for each event, calculated by multiplying the first and third rows.
- The fifth row shows the energy consumed by the device in each event, calculated by multiplying the fourth and second rows (and dividing by 1000 for units to match).

The following table gives a summary of the measurements in Table 2.3 Power and Energy Measurements for the Current Profile in the Figure Above (EM2 Debug Disabled) on page 7, which leads to some useful observations.

- The TX, RX, and sleep average currents for the Series 2 EFR32BG22 SoC are 4.65mA, 4.14 mA, and 1.3 µA respectively.
- In terms of energy, the Series 2 EFR32BG22 SoC consumes 31.2 µJ while broadcasting a beacon in connectable mode every 100 ms, out of which 30.8 µJ are used while the device is active and only 0.4 µJ while the device is sleeping.
- The previous observation implies that increasing the broadcast interval and, hence, keeping the device in sleep mode longer helps minimize energy consumption, as should be expected.
- Depending on the broadcasting interval, there is a point at which the sleep mode energy consumption will equal or exceed the energy consumed when the device is active, which can be verified independently.

Table 2.4. Summary of Power Measurements for Series 2 EFR32BG22 SoC

		Time (µs)	Average Current (mA)	Energy (µJ)
Full Event	**0-G**	100000	0.10	31.2
Active Only	**0-F**	3005	3.42	30.8
Sleep	**G**	96995	0.0013	0.4
TX	**3, 7, B**	1140	4.65	15.9
RX	**5, 9, D**	317	4.14	3.9

2.2.3 Sleep Mode Current Profiles When Using a DCDC Converter

Keep in mind that the SoC-iBeacon application runs the EFR32BG device from the DCDC converter in Low Power (LP) mode (see *AN0948: Power Configurations and DC-DC*). As result, a current spike is observed every time the output voltage of the DCDC converter is refreshed while the device is sleeping.

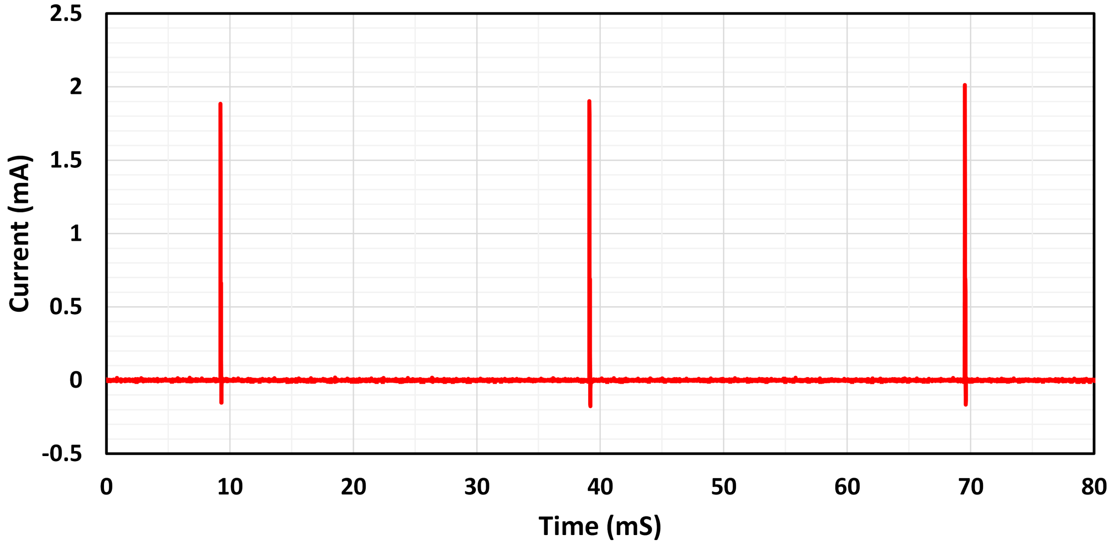


Figure 2.7. Current Profile for Series 1 EFR32BG1 SoC Running SoC-iBeacon Example Application (Sleep)

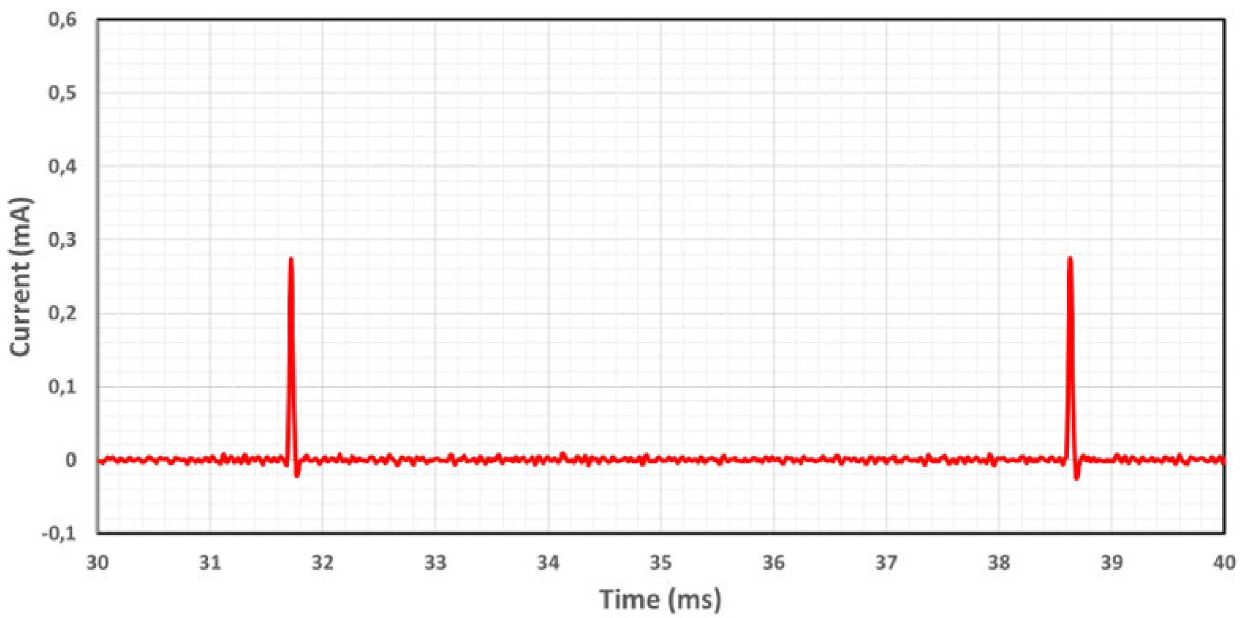


Figure 2.8. Current Profile for Series 2 EFR32BG22 SoC Running SoC-iBeacon Example Application (Sleep)

For beacons with a short broadcast interval (such as 100 ms or less), the measured average sleep current may differ from the datasheet sleep current for the device depending on (A) the number of current spikes observed during sleep and (B) the location of the spikes relative to the time interval used for sleep current averaging. For beacons with a long broadcast interval, however, the measured average sleep current and the datasheet sleep current for the device should be the same.

3. Document Revision History

Revision 0.2

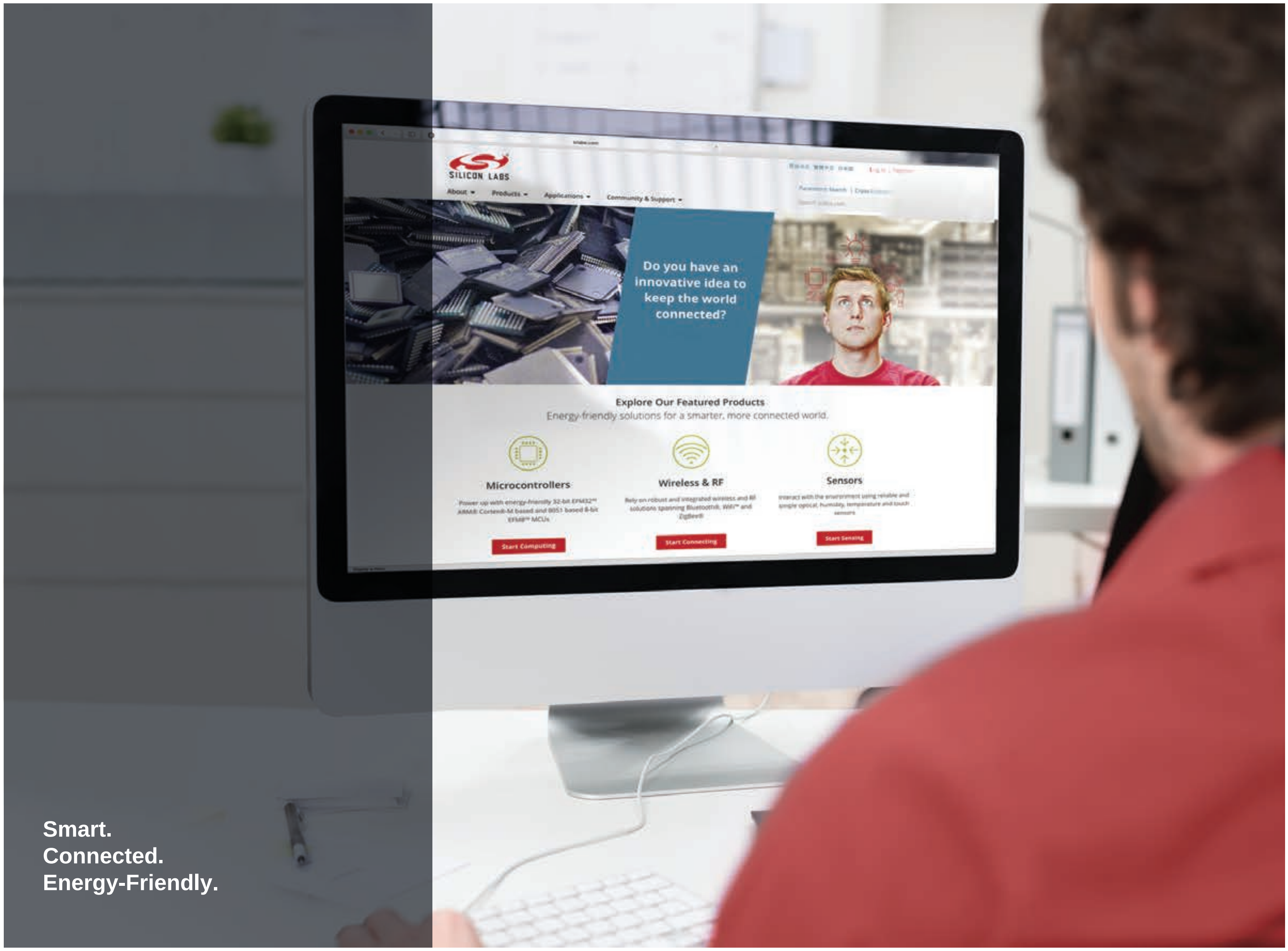
September, 2020

Updated Section 1 for SDK v3.x quick-start guide and API.

Revision 0.1

March, 2020

Initial release.



Products
www.silabs.com/products

Quality
www.silabs.com/quality

Support and Community
community.silabs.com

Silicon Laboratories Inc.
400 West Cesar Chavez
Austin, TX 78701
USA

http://www.silabs.com