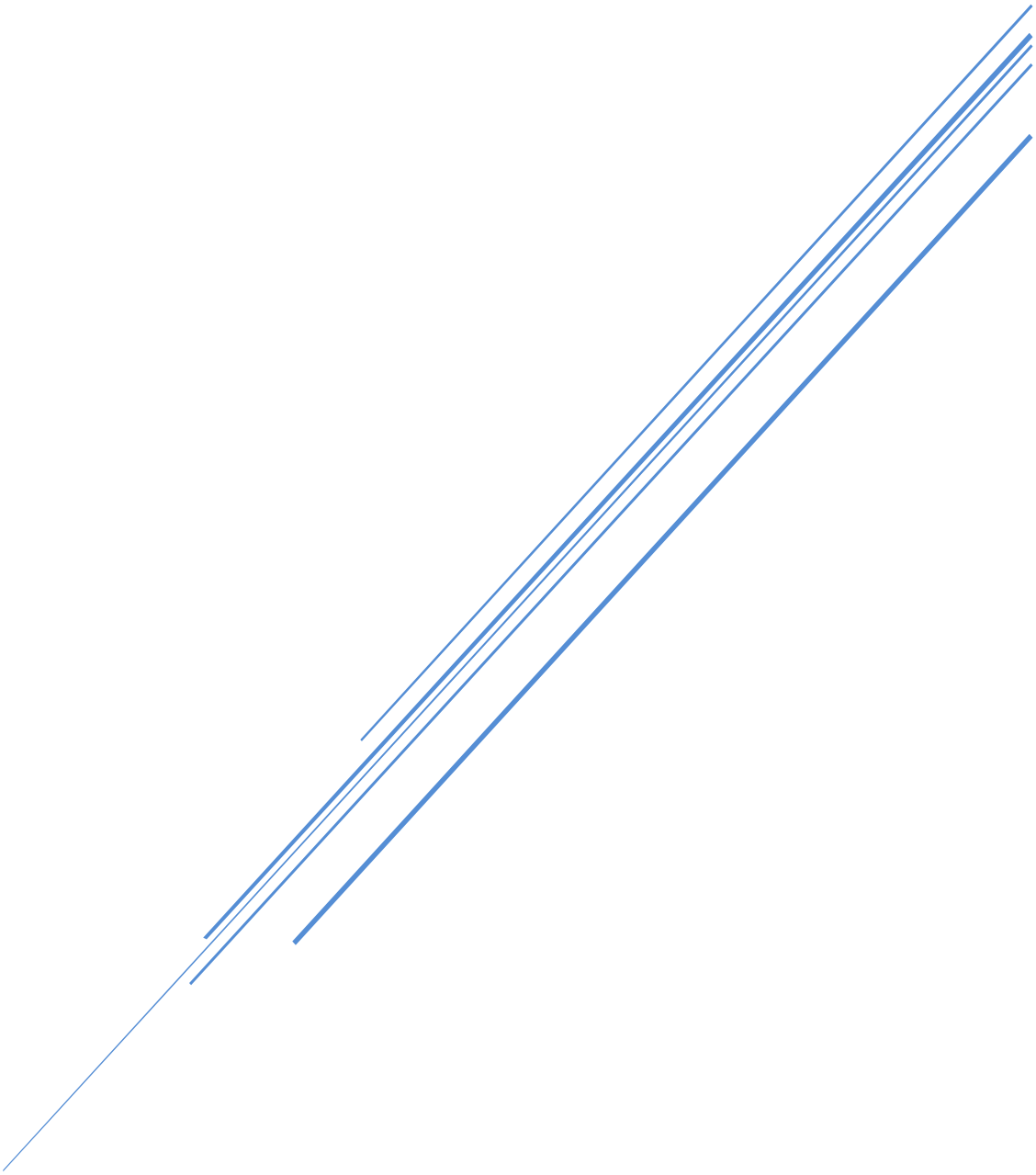
POWER CONSUMPTION

ble_beacon



Schule der ansprechenden Künste

Andreas Erdmann

1 Power Consumption – ble_beacon 3
1.1 Baseline – the starting point 3
1.1.1 Calculation 3
1.1.2 SoftDevice flashed, no app flashed 4
1.1.3 SoftDevice, just go to idle mode 4
1.1.4 SoftDevice, init bsp (led off), and just go to idle mode 4
1.1.5 SoftDevice, init bsp (with one led on), and just go to idle mode 5
1.1.6 SoftDevice, init bsp (led off) + twi_config + (both) sensor_init 5
1.1.7 SoftDevice, init bsp (led off) + twi_config + no sensor_init 5
1.1.8 SoftDevice, init bsp (led off) + twi_config + only kx022 init 5
1.1.9 SoftDevice, init bsp (led off) + twi_config + only SHT3 init 6
1.1.10 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, no sensor data + BLE adv 6
1.1.11 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, no sensor data + BLE adv + SAADC measurement 7
1.1.12 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, no sensor data + without BLE init/adv + SAADC measurement 7
1.1.13 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, SHT3 measurement + without BLE init/adv + SAADC measurement 7
1.1.14 all but KX022 measurement, 1/8 data acquisition for SHT and SAADC 8
1.1.15 on top of 1.1.14 use different parameter 8
1.2 Power Optimization KX022 Accelerometer 9
1.2.1 Baseline, no BLE, no sensor init 9
1.2.2 Change to TWI without transaction manager, SHT3 init and KX022 init to standby 10
1.2.3 With KX022 and SHT3 “one shot” measurement, 1 Hz 10
1.2.4 Overall 11
1.2.5 Cycle 11
1.3 Use RTC INT for while waiting for accel data 11
1.3.1 Baseline 11
1.3.2 Use RTC counter (freq 1/256) for KX022 “put to operation”, “wait for accel data”, and during SHT3 temp/hum measurement (w/max. 15ms time) 12
1.3.3 one minute, analog to 1.2.4 12
1.4 Further optimization 12
1.4.1 Using nested approach: start long running SHT3 first, complete KX022 tasks and read SHT3 values KX022: ODR 1600 -> delay time 3ms 12
1.4.2 one minute, analog to Part 3 overall 12

1.4.3 KX022: ODR 200 -> delay time 7ms 13
1.4.4 one minute, analog to 1.3.3 13
1.5 Longer intervals between adv and samples 14
1.6 Button functionality introduced 14
2 Original Beacon Firmware (for comparison) 15
3 Used configuration 15

1 Power Consumption – ble_beacon

In the first part in chapter 1.1 we measure the power consumption with the current implementation. We'll identify in 1.1.14 and 1.1.15.1 that everything is ok but the accelerometer. Thus, in the following chapter 1.2 we will focus on optimizing the accelerometer usage.

Anyway, the different measurements and information we get from different configurations is interesting, so we will keep this information in the document, too, as a reference and starting point for other interested people during their optimization.

1.1 Baseline – the starting point

The baseline for the device is measured with only the SoftDevice S132 (Bluetooth 5 Central and Peripheral protocol stack) and no app flashed.

1.1.1 Calculation

From the data sheets for the NRF52832, KX022 (accelerometer) and SHT3 (temperature/humidity sensor) we get the following data which leads to a calculated power consumption.

NRF52 device
tbd

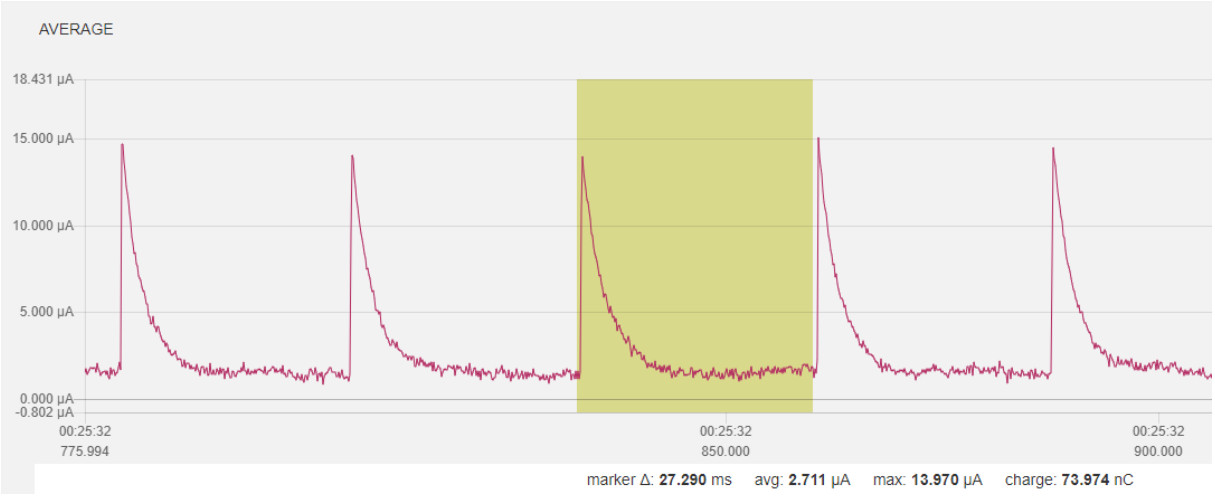
KX022 device	
High power mode	145 µA@2.5 V
Low power mode	10 µA
Standby	0.9 µA

SHT3 device	
Idle state	0.2 µA (max 2 µA)
Average	2 µA while measuring w/lowest repeat.+ single shot

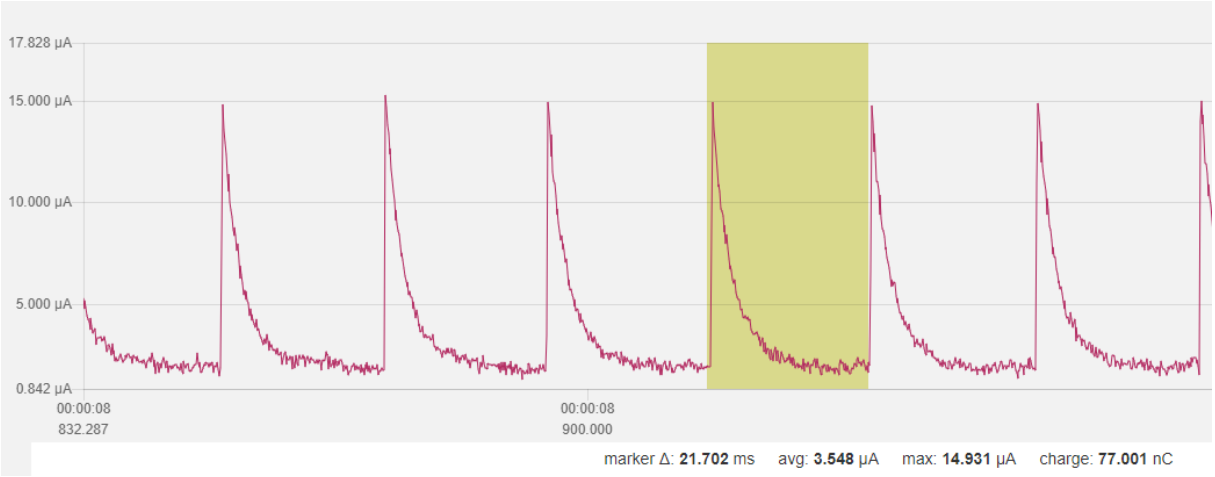
Overall we thus can expect a power consumption as stated in the following table:

Overall
NRF52
KX022
SHT3
SUM

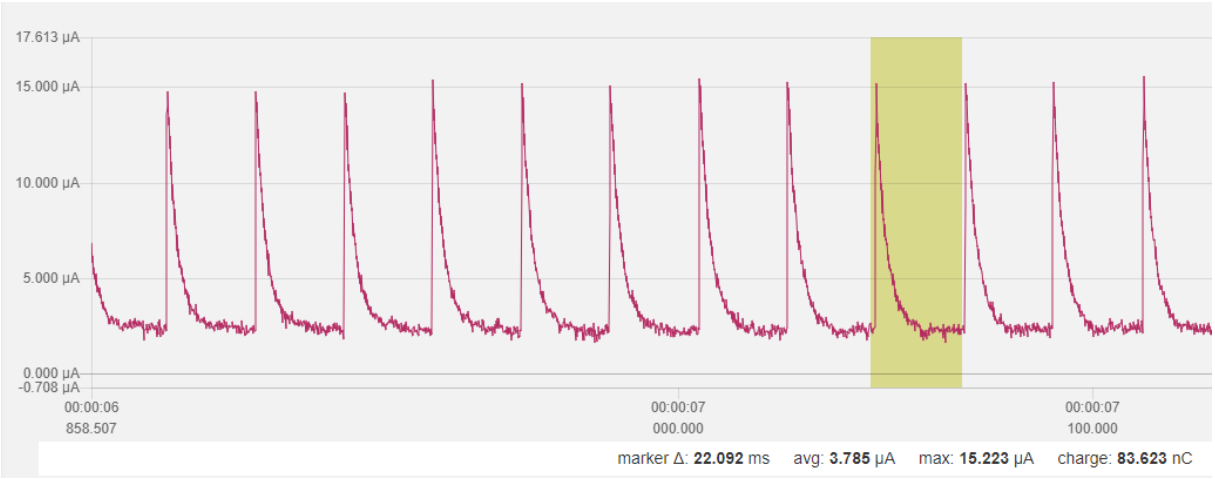
1.1.2 SoftDevice flashed, no app flashed



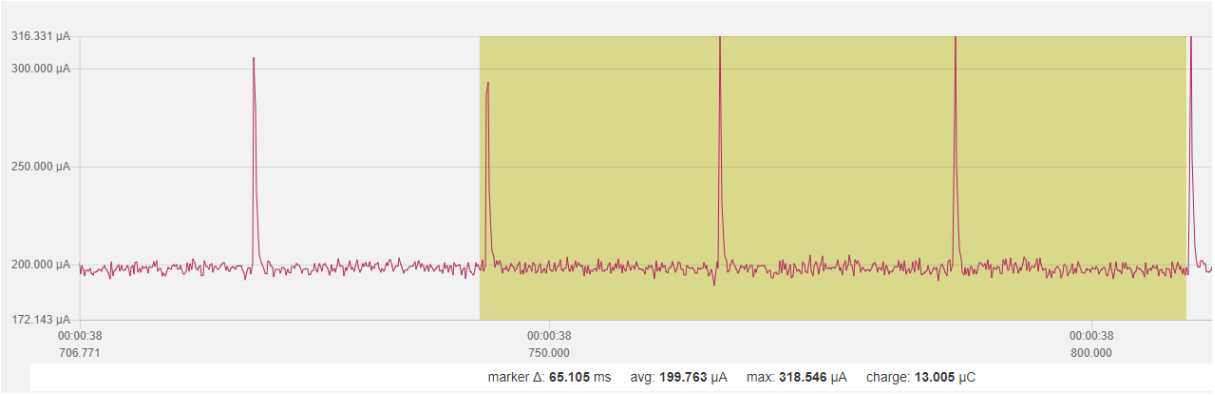
1.1.3 SoftDevice, just go to idle mode



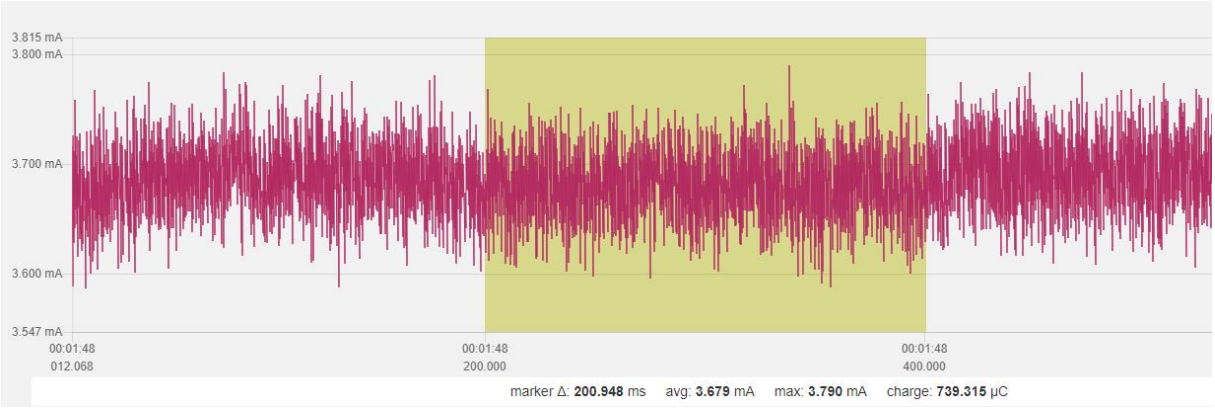
1.1.4 SoftDevice, init bsp (led off), and just go to idle mode



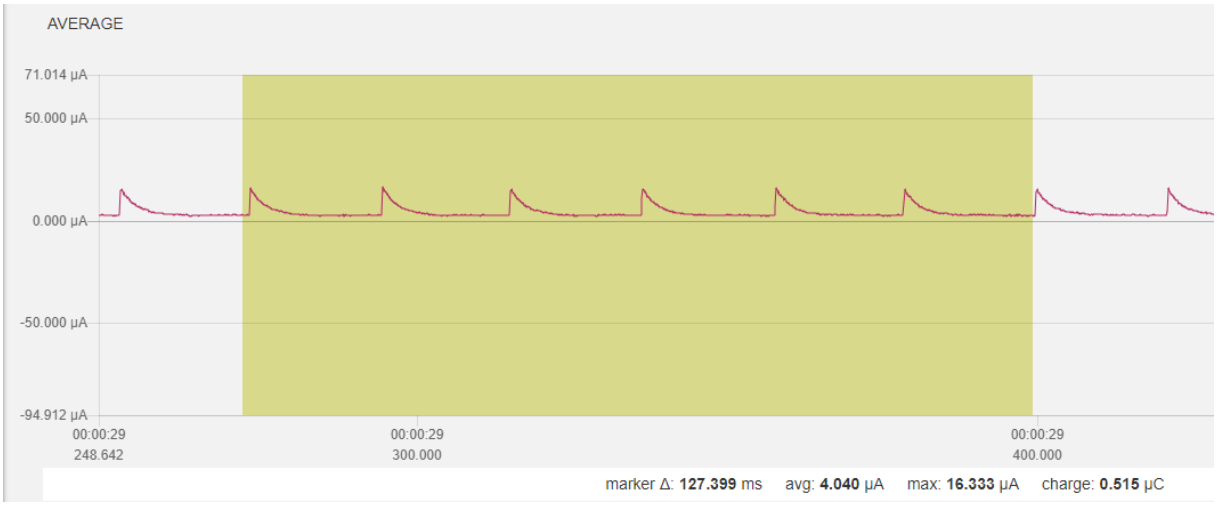
1.1.5 SoftDevice, init bsp (with one led on), and just go to idle mode



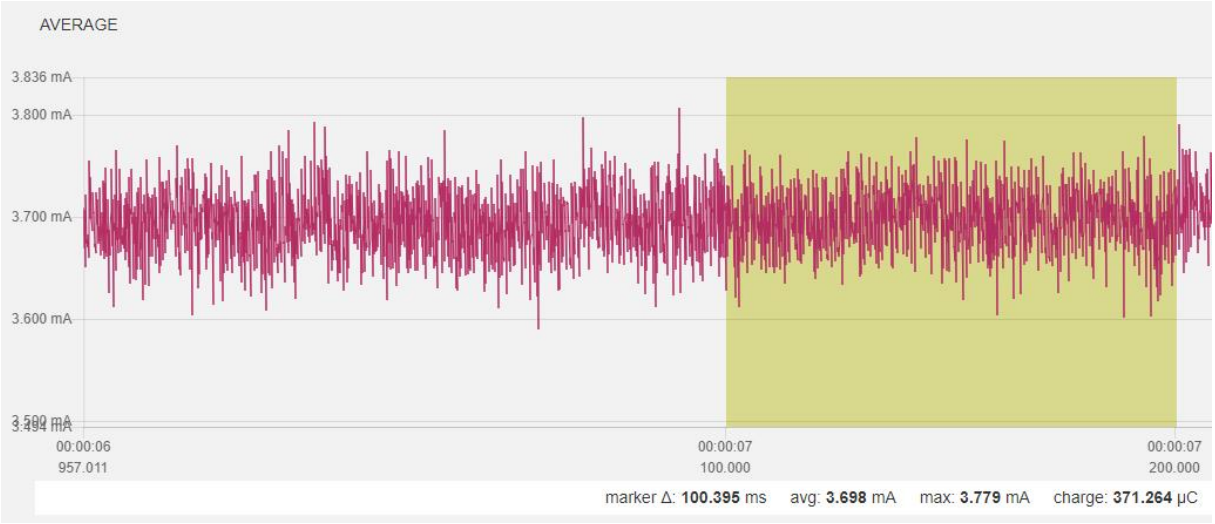
1.1.6 SoftDevice, init bsp (led off) + twi_config + (both) sensor_init



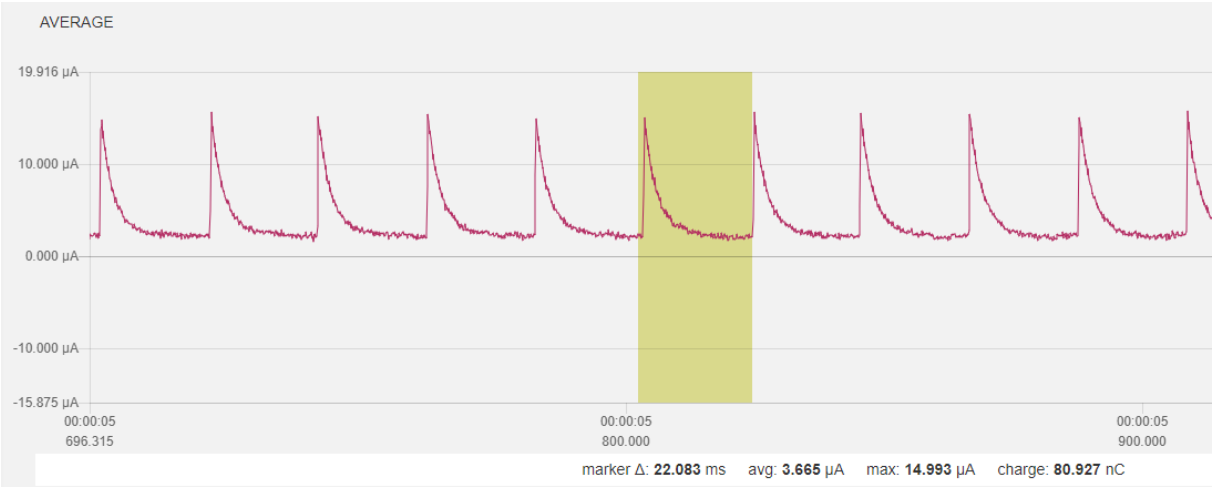
1.1.7 SoftDevice, init bsp (led off) + twi_config + no sensor_init



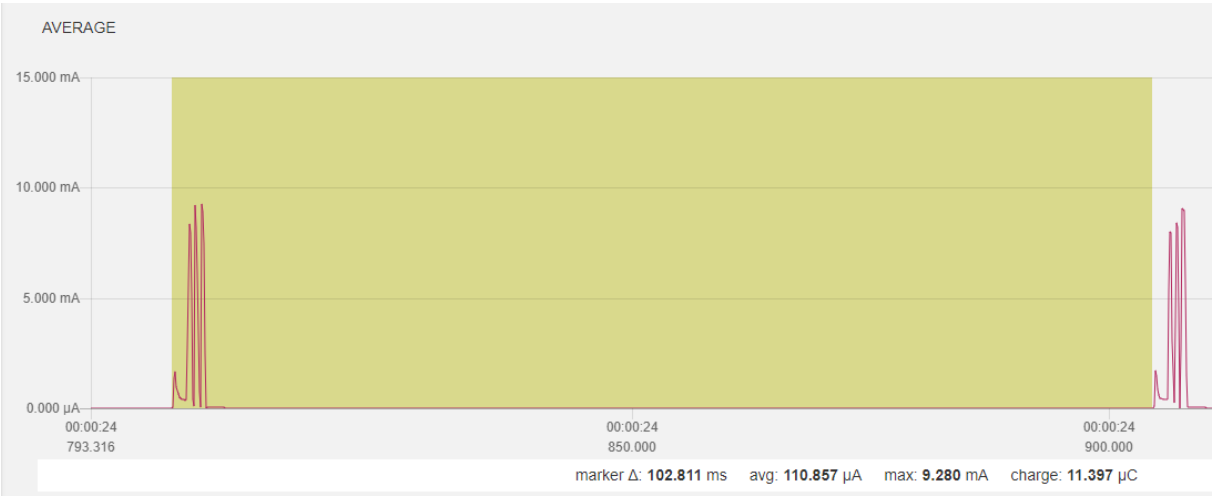
1.1.8 SoftDevice, init bsp (led off) + twi_config + only kx022 init



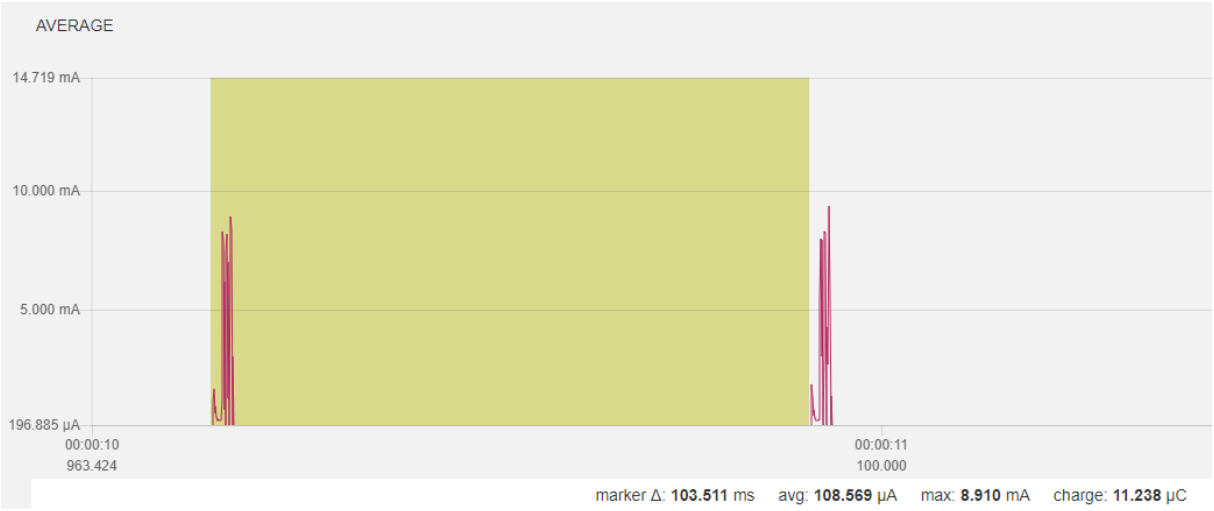
1.1.9 SoftDevice, init bsp (led off) + twi_config + only SHT3 init



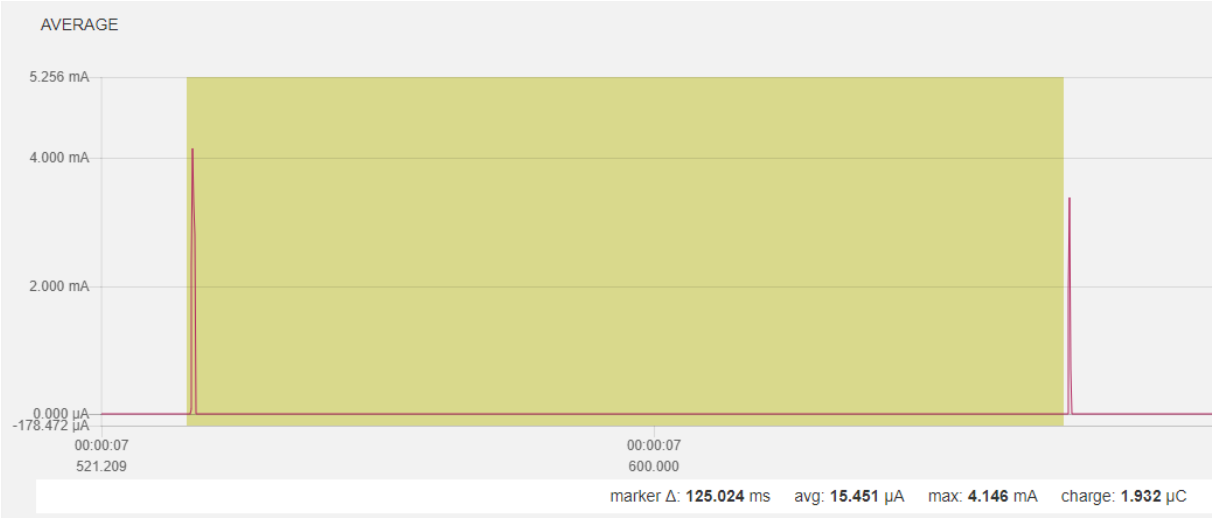
1.1.10 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, no sensor data + BLE adv



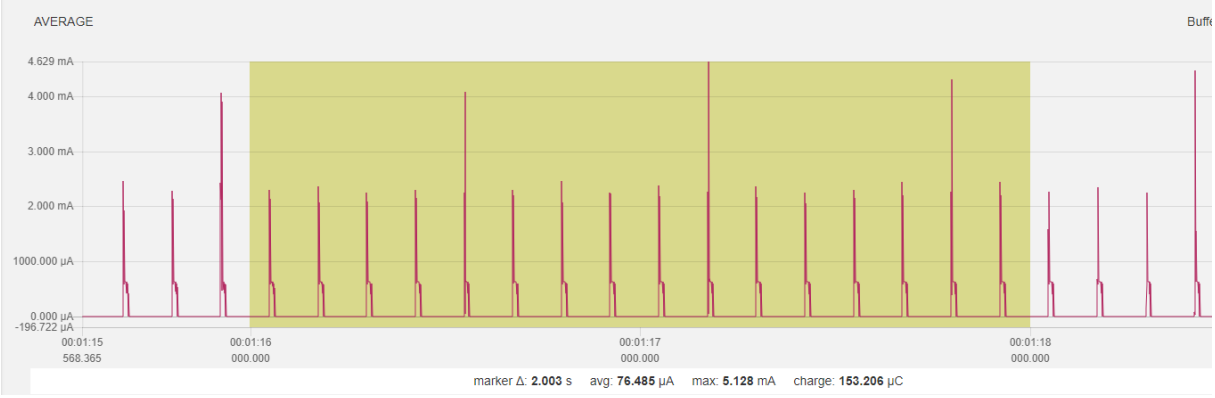
1.1.11 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, no sensor data + BLE adv + SAADC measurement



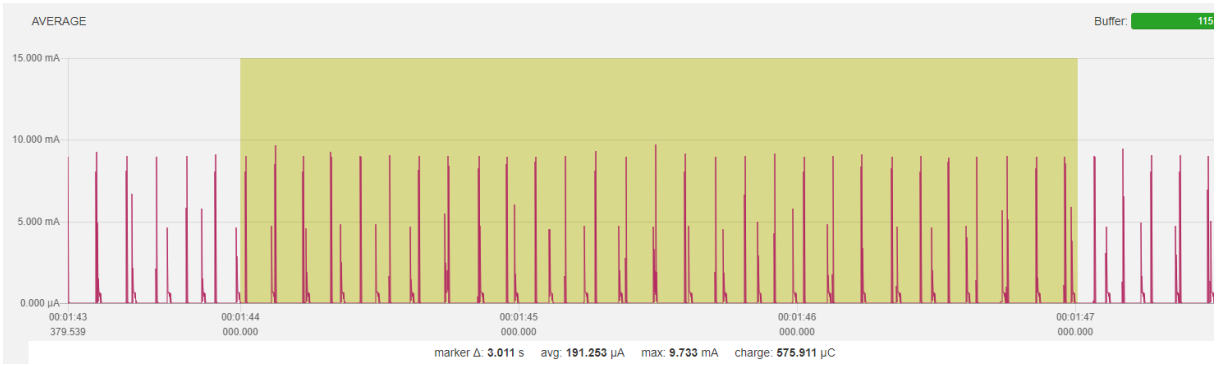
1.1.12 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, no sensor data + without BLE init/adv + SAADC measurement



1.1.13 SoftDevice, init bsp (led off) + twi_config + SHT3 but no KX022, SHT3 measurement + without BLE init/adv + SAADC measurement

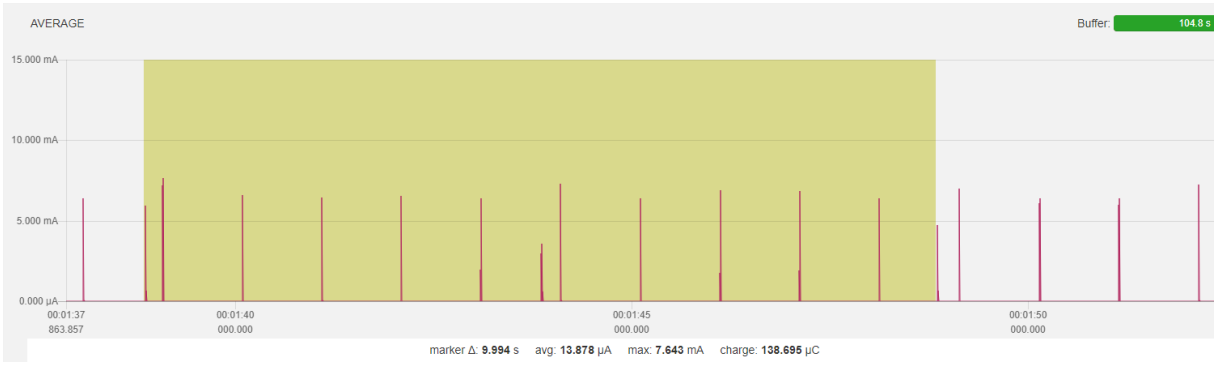


1.1.14 all but KX022 measurement, 1/8 data acquisition for SHT and SAADC

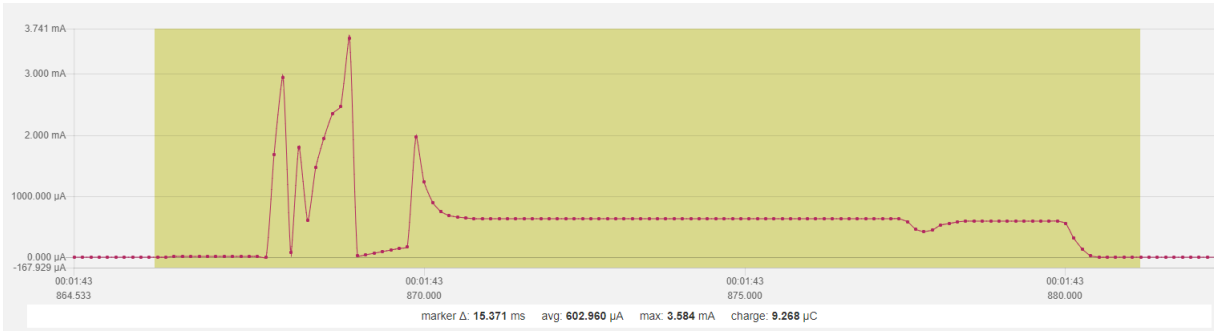


1.1.15 on top of 1.1.14 use different parameter

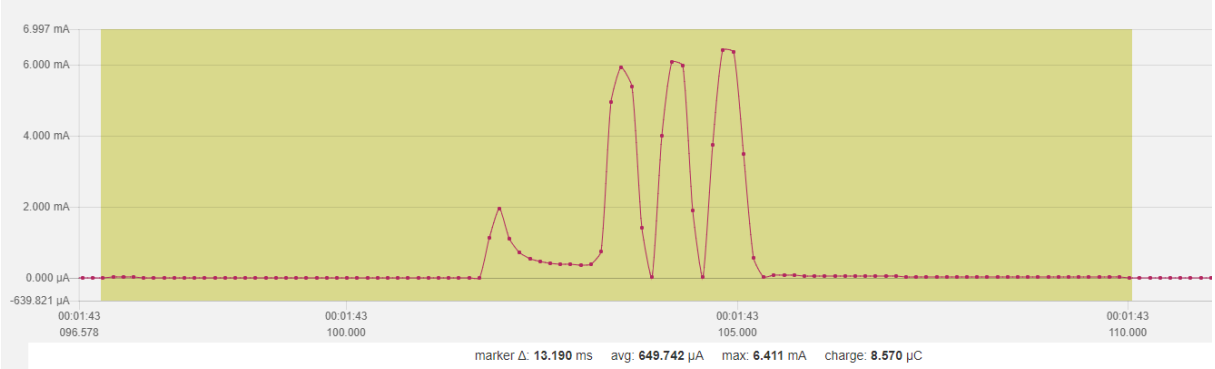
- reduce transmit power to 0dBm from +4dBm
- adv int to 1 sec from 1/10 sec
- SHT update int to 5 sec from 1/8 sec
- SADC update int to 10 sec from 1/8 sec



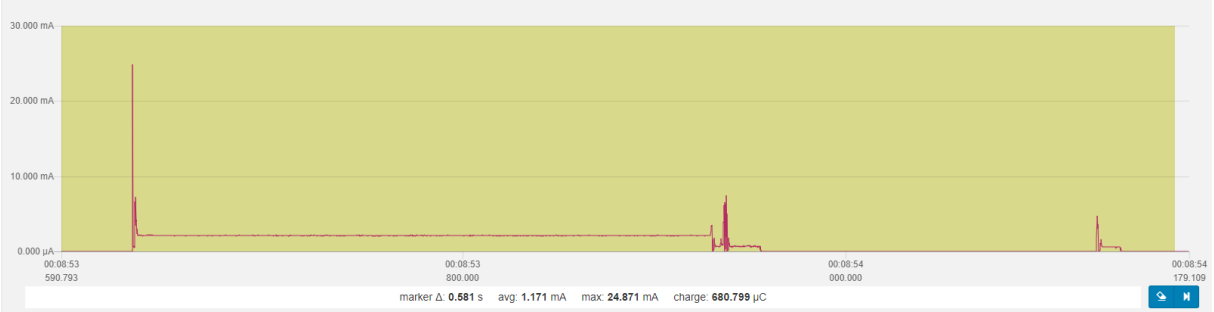
1.1.15.1 Sensor update (all 5 sec)



1.1.15.2 Adv (all 1 sec)



1.1.15.3 Startup

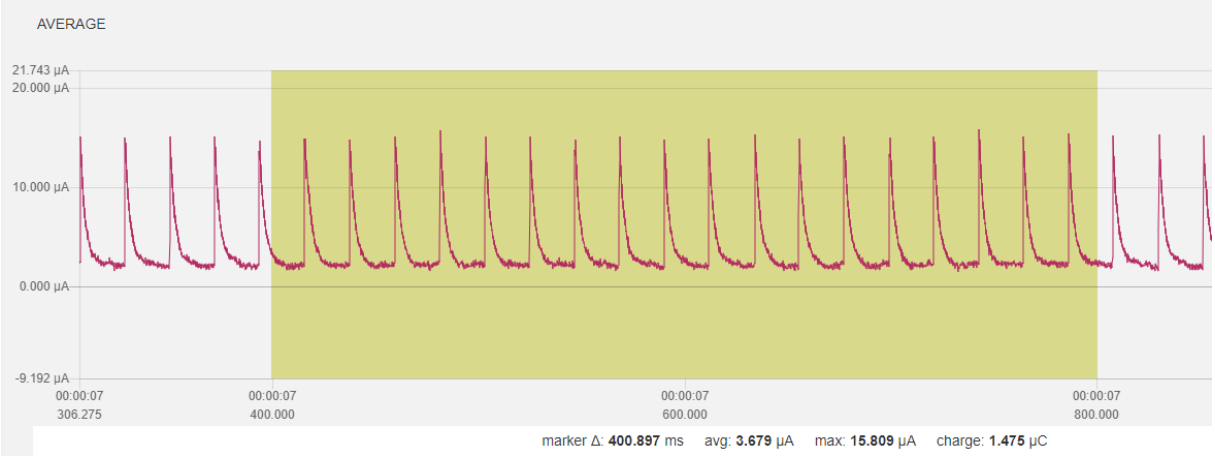


- Peaks
    - Power on peak
    - First adv
    - First sensor acquisition

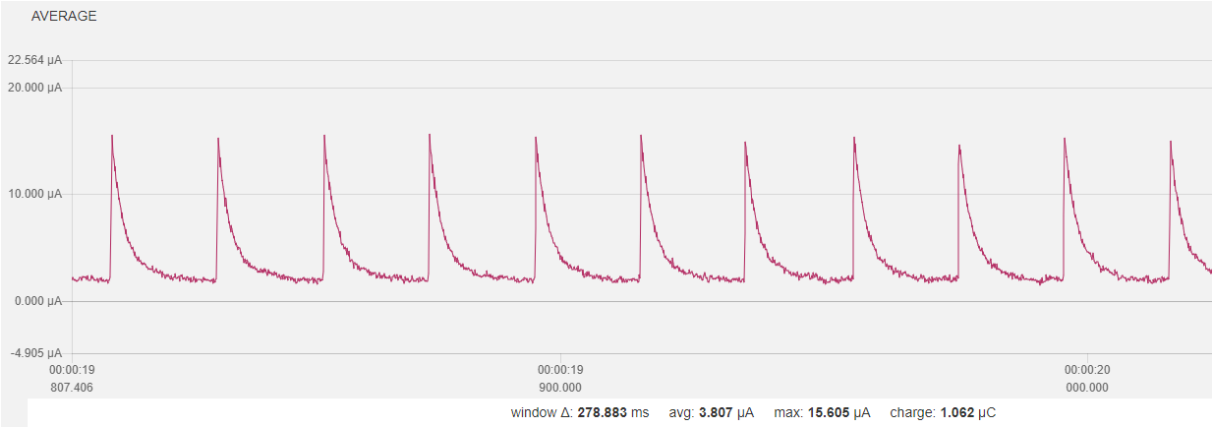
1.2 Power Optimization KX022 Accelerometer

As we saw in the previous chapter, we need to focus on optimizing the KX022 accelerometer power consumption.

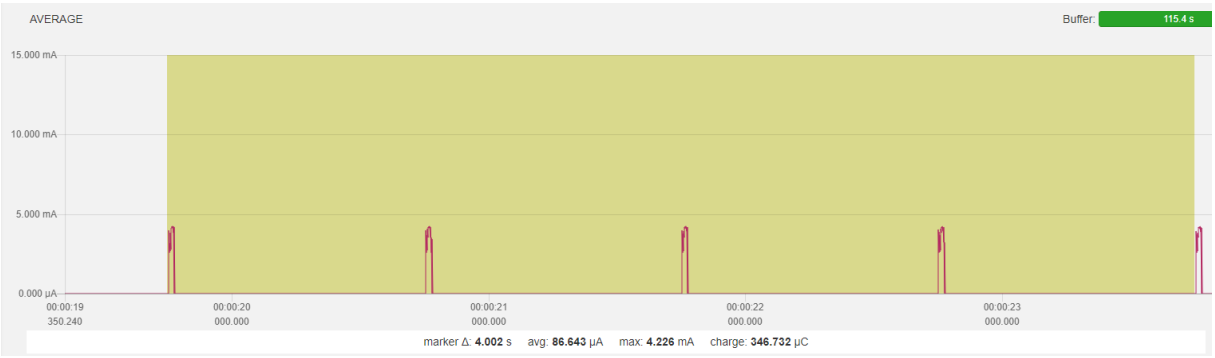
1.2.1 Baseline, no BLE, no sensor init



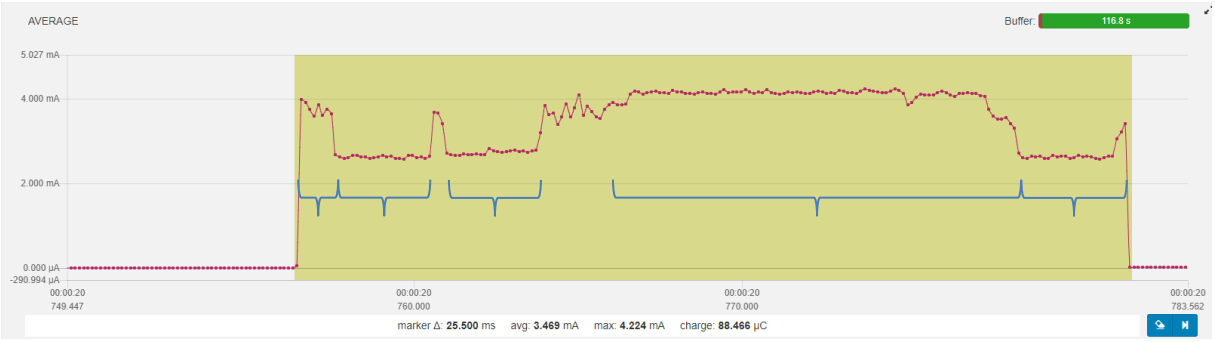
1.2.2 Change to TWI without transaction manager, SHT3 init and KX022 init to standby



1.2.3 With KX022 and SHT3 “one shot” measurement, 1 Hz



1.2.3.1 One measurement

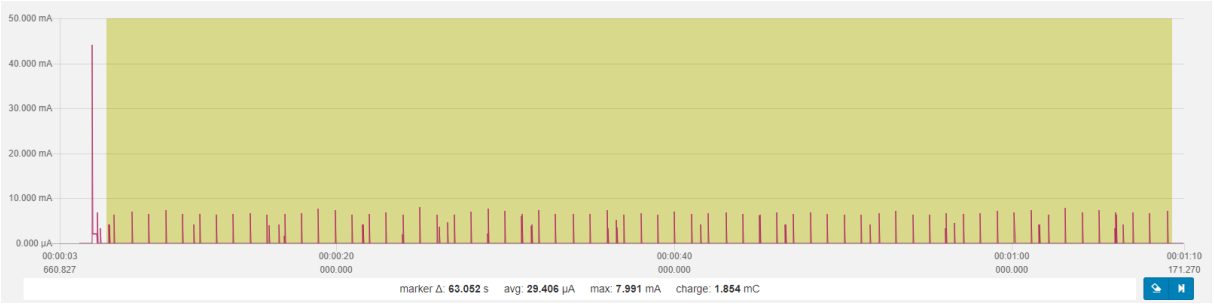


Init KX022, Standby	1,2ms
wait 1.2/ODR	3ms
set to operate	0,5ms
wait 1.2/ODR for value	3ms
read accel values	…
SUM	~8ms
Set SHT3 to SHT3_MEAS_HIGHREP_STRETCH	
wait clock stretch	12,5ms
read temperature and humidity	2,8ms
SUM	~15ms

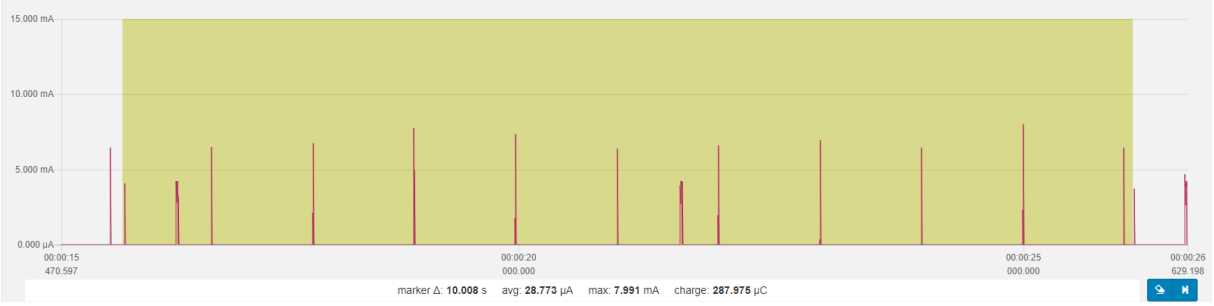
Process data and sleep again…

Overall cycle 25ms, avg. power consumption 3,5mA, idle < 4uA

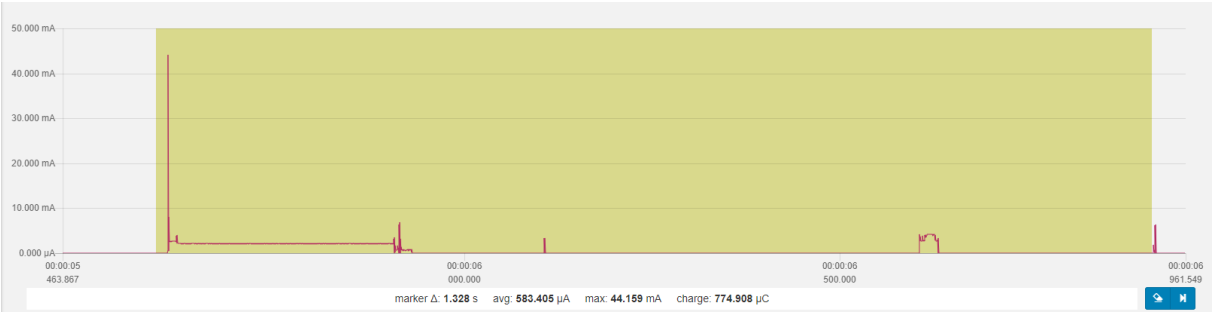
1.2.4 Overall



1.2.4.1 One 10sec cycle



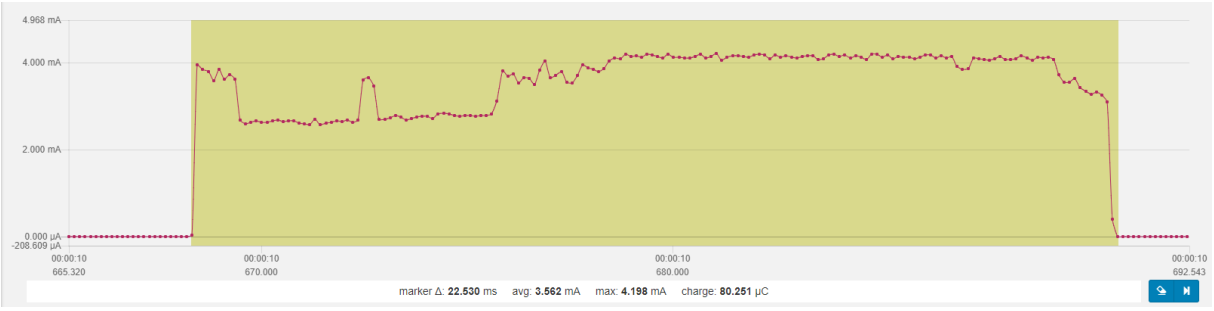
1.2.5 Cycle



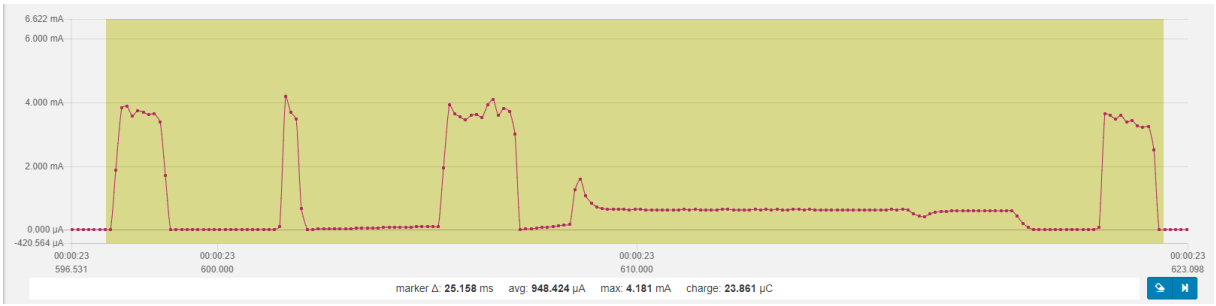
BLE 0 dBm, adv. interval	1s
sensor (SHT3 and KX022) interval	5s
SAADC (battery level) interval	10s
overall power consumption	~30uA (28,77uA)
idle power consumption	3,5uA

1.3 Use RTC INT for while waiting for accel data

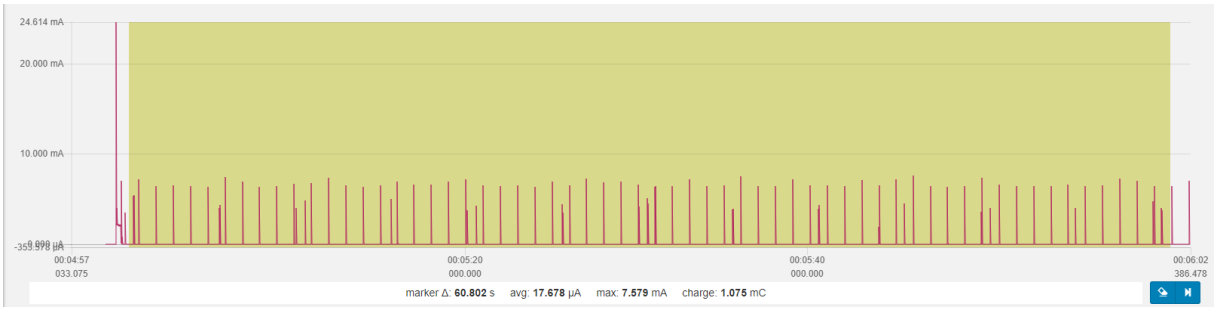
1.3.1 Baseline



1.3.2 Use RTC counter (freq 1/256) for KX022 “put to operation”, “wait for accel data”, and during SHT3 temp/hum measurement (w/max. 15ms time)



1.3.3 one minute, analog to 1.2.4

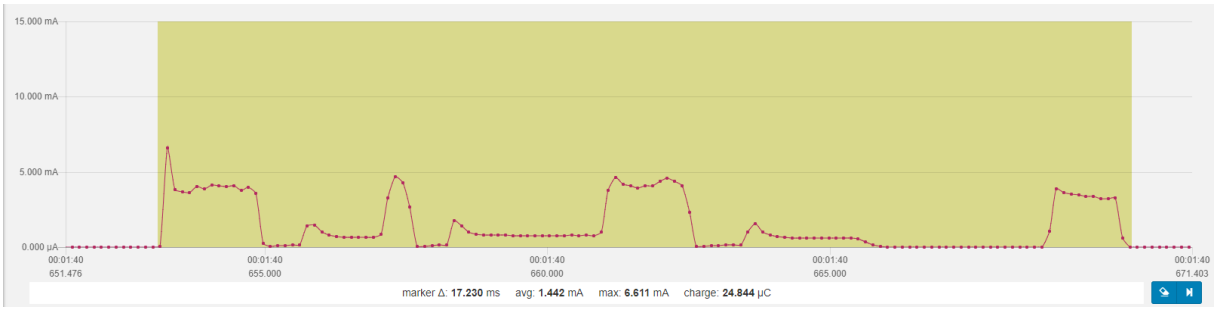


Optimization summary (1.2.4→1.3.3)

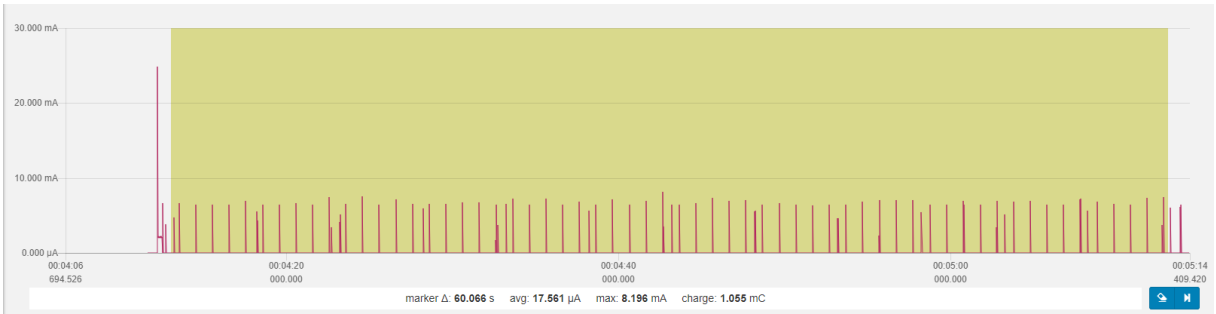
BLE 0 dBm, adv. interval	1s	
sensor (SHT3 and KX022) interval	5s	
SAADC (battery level) interval	10s	
overall power consumption	~30uA (28,77uA)	→ 17,68uA
idle power consumption	3,5uA	→ 3,5 uA

1.4 Further optimization

1.4.1 Using nested approach: start long running SHT3 first, complete KX022 tasks and read SHT3 values
KX022: ODR 1600 -> delay time 3ms

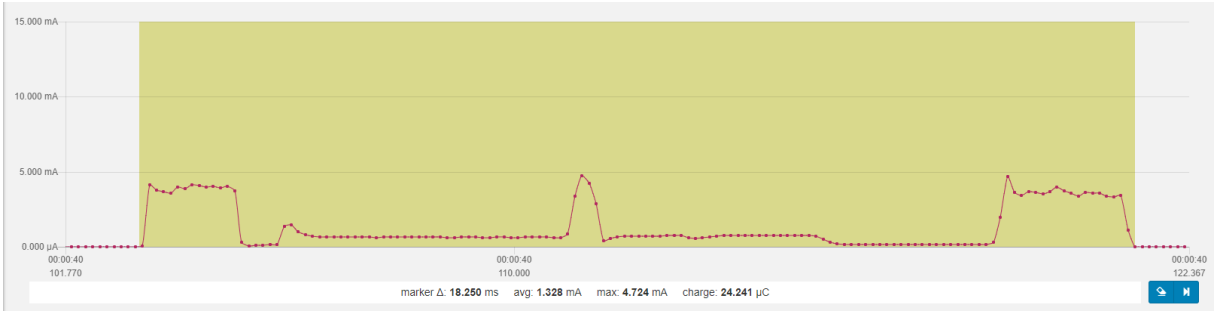


1.4.2 one minute, analog to 1.3.3

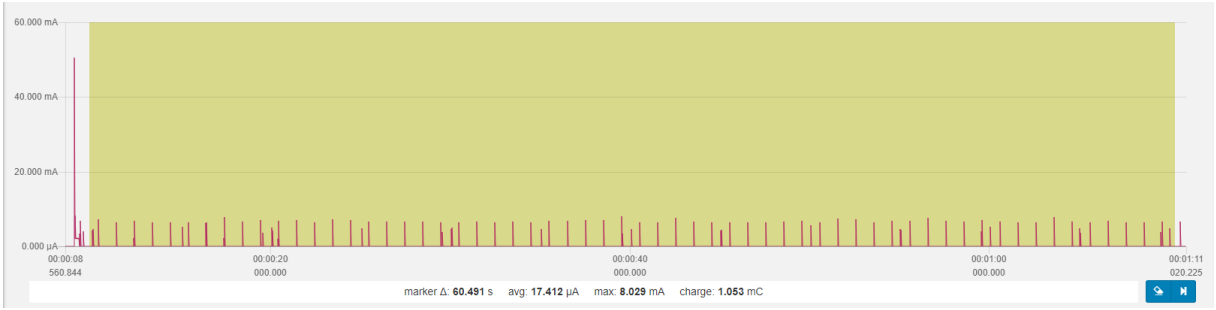


thus, no real further improvement

1.4.3 KX022: ODR 200 -> delay time 7ms

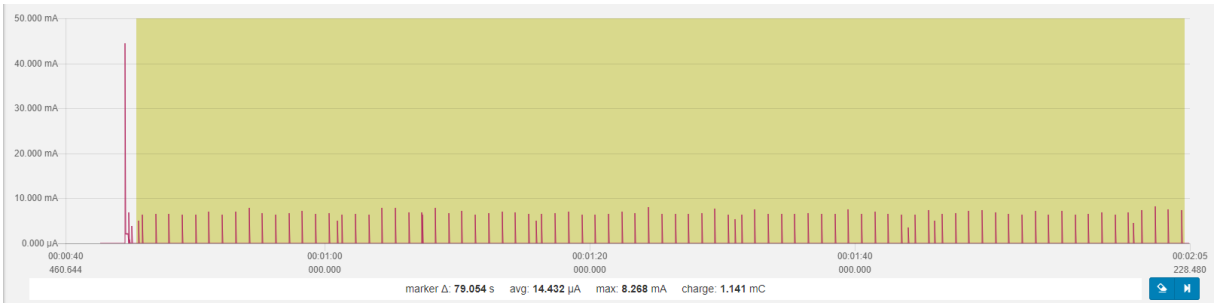


1.4.4 one minute, analog to 1.3.3



thus, no real further improvement

1.5 Longer intervals between adv and samples

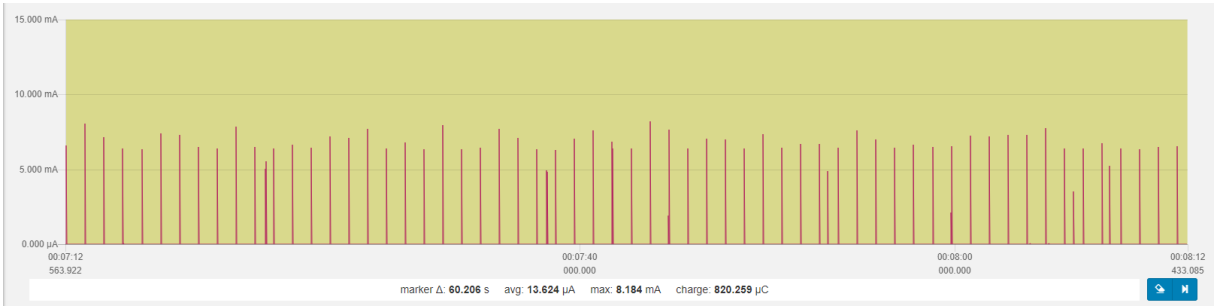


BLE 0 dBm, adv. interval	1s
sensor (SHT3 and KX022) interval	15s
SAADC (battery level) interval	60s
overall power consumption	14,4uA
idle power consumption	3,6 uA

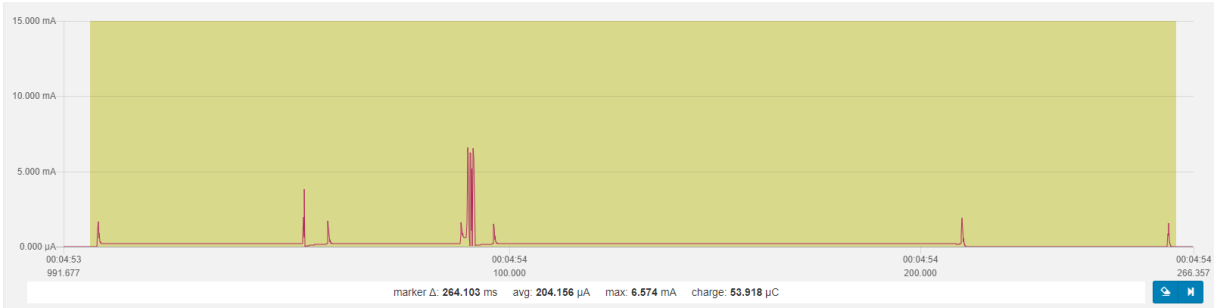
*220mAh / 0,0144mA * 0,7 = 10.694 h = ~1.2 Jahre*

(> 1 Jahr = 365*24h = 8760h; CR2032 = 220 mAh)

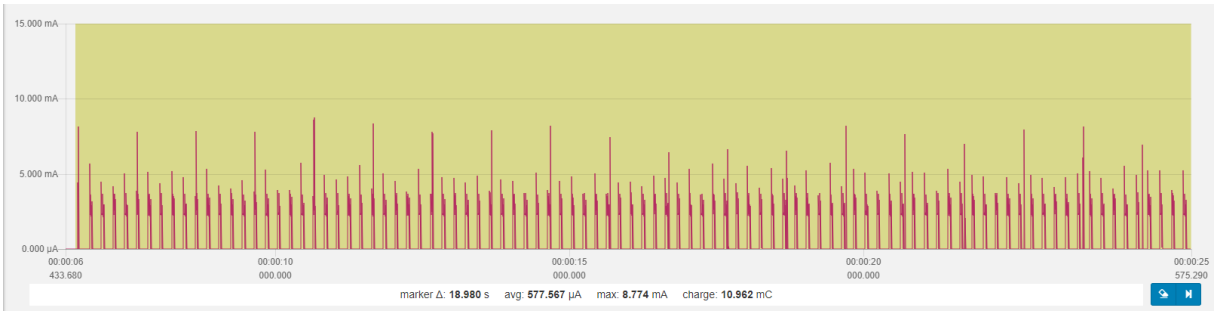
1.6 Button functionality introduced



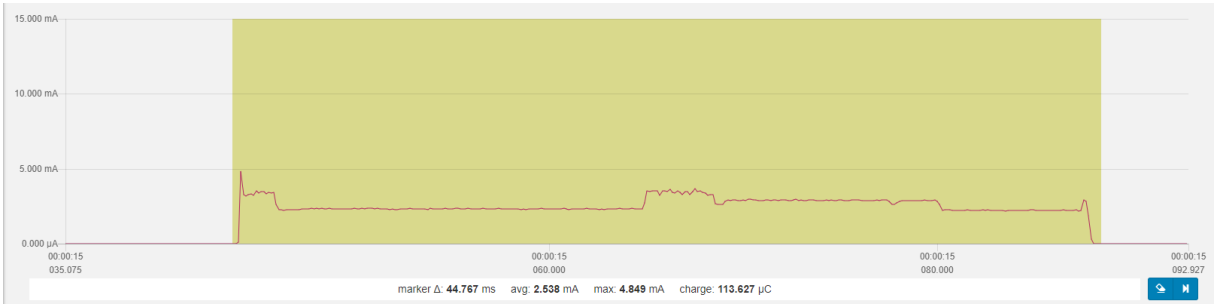
Single button press



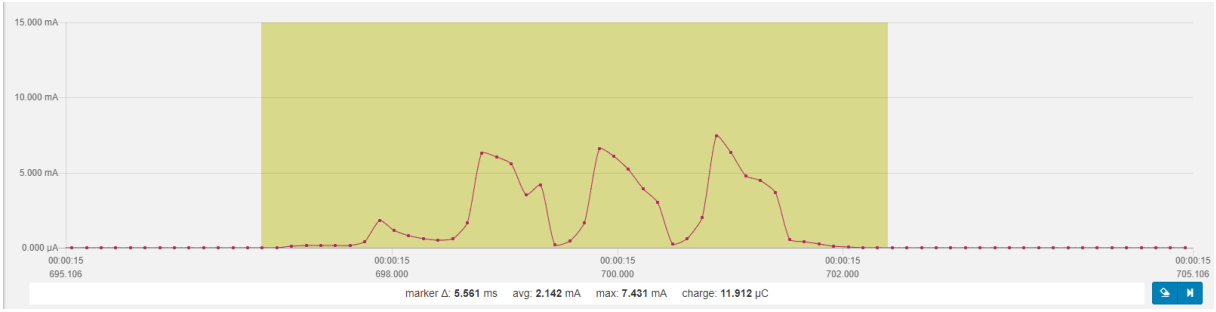
2 Original Beacon Firmware (for comparison)



Frequent spikes (5 Hz)



Larger but rarer spikes (1 Hz)



3 Used configuration

Tbd