Power Consumption

ble\_beacon

Schule der ansprechenden Künste

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[1 Power Consumption – ble\_beacon 3](#_Toc8373928)

[1.1 Baseline – the starting point 3](#_Toc8373929)

[1.1.1 Calculation 3](#_Toc8373930)

[1.1.2 SoftDevice flashed, no app flashed 4](#_Toc8373931)

[1.1.3 SoftDevice, just go to idle mode 4](#_Toc8373932)

[1.1.4 SoftDevice, init bsp (led off), and just go to idle mode 4](#_Toc8373933)

[1.1.5 SoftDevice, init bsp (with one led on), and just go to idle mode 5](#_Toc8373934)

[1.1.6 SoftDevice, init bsp (led off) + twi\_config + (both) sensor\_init 5](#_Toc8373935)

[1.1.7 SoftDevice, init bsp (led off) + twi\_config + no sensor\_init 5](#_Toc8373936)

[1.1.8 SoftDevice, init bsp (led off) + twi\_config + only kx022 init 5](#_Toc8373937)

[1.1.9 SoftDevice, init bsp (led off) + twi\_config + only SHT3 init 6](#_Toc8373938)

[1.1.10 SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, no sensor data + BLE adv 6](#_Toc8373939)

[1.1.11 SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, no sensor data + BLE adv + SAADC measurement 7](#_Toc8373940)

[1.1.12 SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, no sensor data + without BLE init/adv + SAADC measurement 7](#_Toc8373941)

[1.1.13 SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, SHT3 measurement + without BLE init/adv + SAADC measurement 7](#_Toc8373942)

[1.1.14 all but KX022 measurement, 1/8 data acquisition for SHT and SAADC 8](#_Toc8373943)

[1.1.15 on top of 1.1.14 use different parameter 8](#_Toc8373944)

[1.2 Power Optimization KX022 Accelerometer 9](#_Toc8373945)

[1.2.1 Baseline, no BLE, no sensor init 9](#_Toc8373946)

[1.2.2 Change to TWI without transaction manager, SHT3 init and KX022 init to standby 10](#_Toc8373947)

[1.2.3 With KX022 and SHT3 “one shot” measurement, 1 Hz 10](#_Toc8373948)

[1.2.4 Overall 11](#_Toc8373949)

[1.2.5 Cycle 11](#_Toc8373950)

[1.3 Use RTC INT for while waiting for accel data 11](#_Toc8373951)

[1.3.1 Baseline 11](#_Toc8373952)

[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](#_Toc8373953)

[1.3.3 one minute, analog to 1.2.4 12](#_Toc8373954)

[1.4 Further optimization 12](#_Toc8373955)

[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](#_Toc8373956)

[1.4.2 one minute, analog to Part 3 overall 12](#_Toc8373957)

[1.4.3 KX022: ODR 200 -> delay time 7ms 13](#_Toc8373958)

[1.4.4 one minute, analog to 1.3.3 13](#_Toc8373959)

[1.5 Longer intervals between adv and samples 14](#_Toc8373960)

[1.6 Button functionality introduced 14](#_Toc8373961)

[2 Original Beacon Firmware (for comparison) 15](#_Toc8373962)

[3 Used configuration 15](#_Toc8373963)

# 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.

## 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.

### 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 |  |

### SoftDevice flashed, no app flashed



### SoftDevice, just go to idle mode



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



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



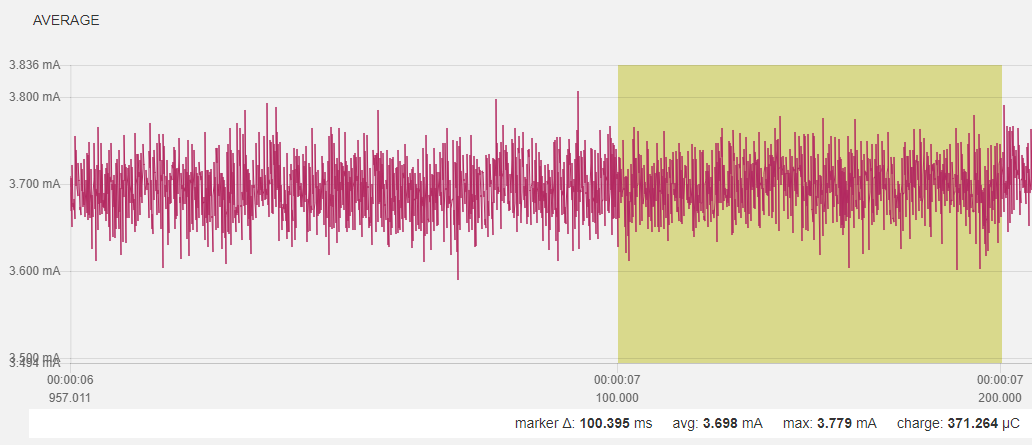
### SoftDevice, init bsp (led off) + twi\_config + (both) sensor\_init



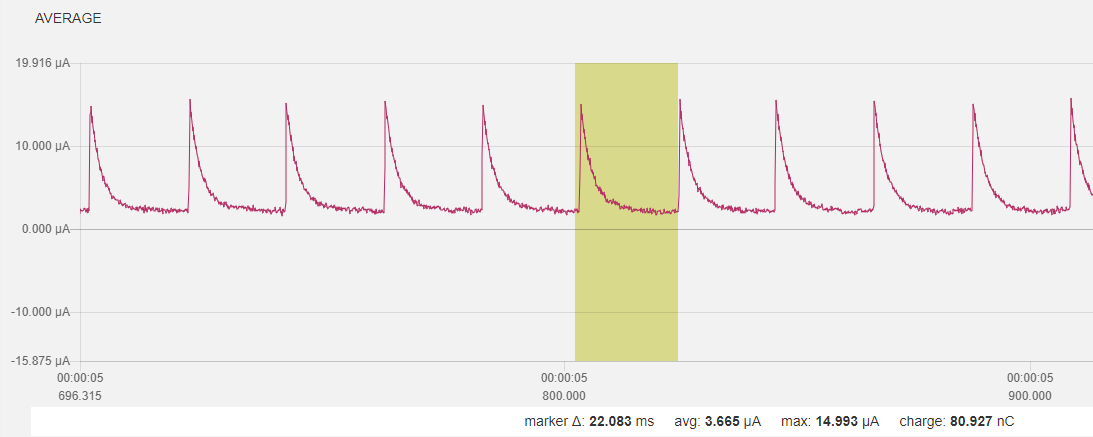
### SoftDevice, init bsp (led off) + twi\_config + no sensor\_init



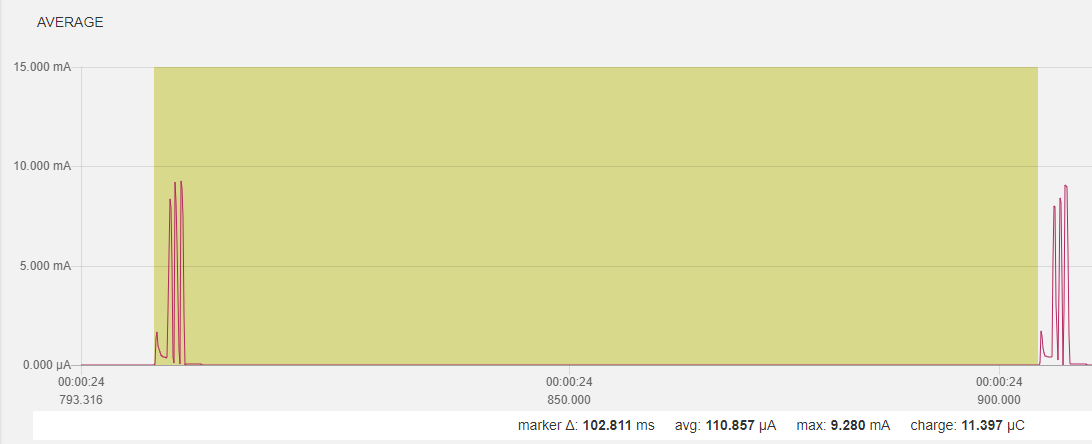
### SoftDevice, init bsp (led off) + twi\_config + only kx022 init



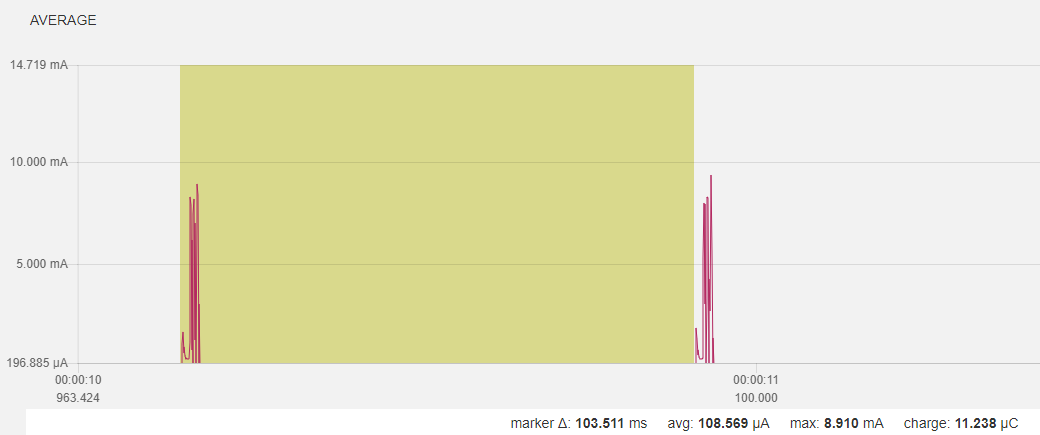
### SoftDevice, init bsp (led off) + twi\_config + only SHT3 init



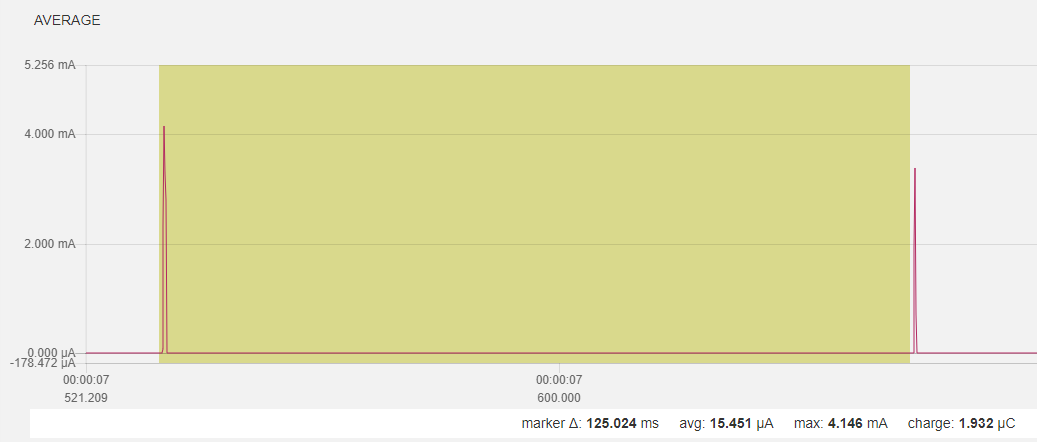
### SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, no sensor data + BLE adv



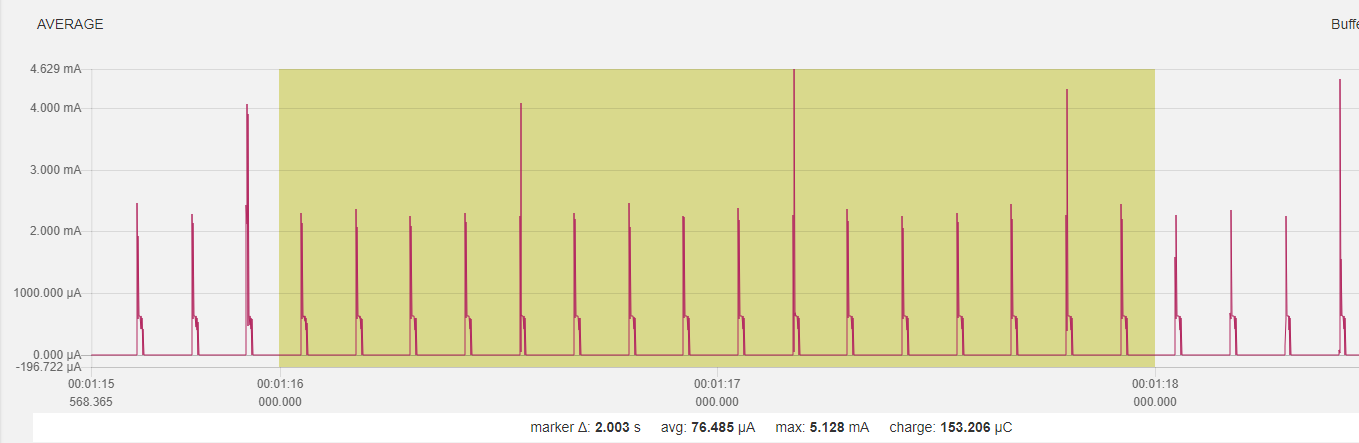
### SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, no sensor data + BLE adv + SAADC measurement



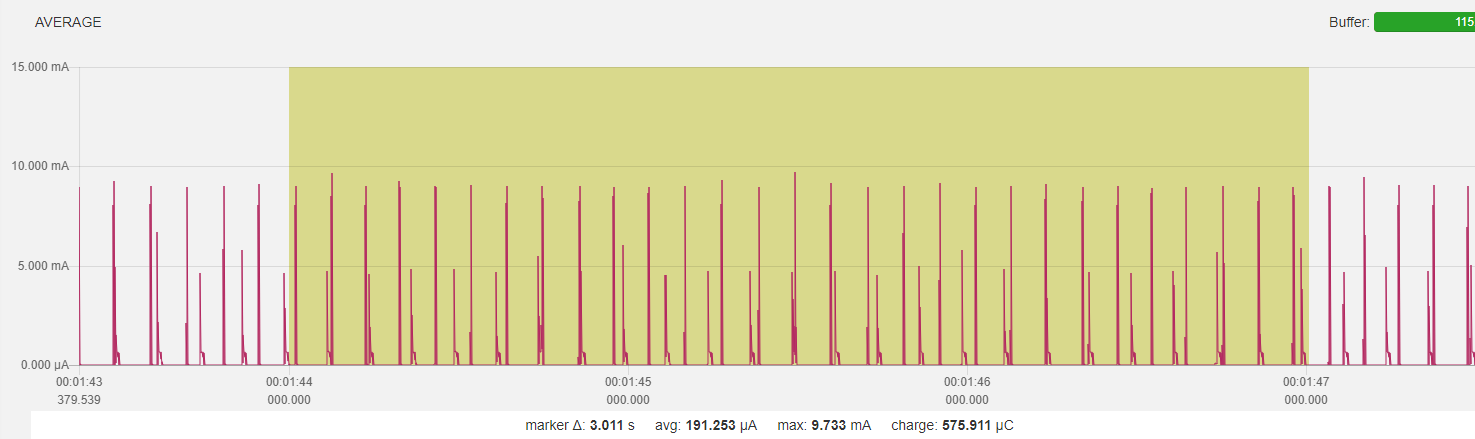
### SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, no sensor data + without BLE init/adv + SAADC measurement



### SoftDevice, init bsp (led off) + twi\_config + SHT3 but no KX022, SHT3 measurement + without BLE init/adv + SAADC measurement



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

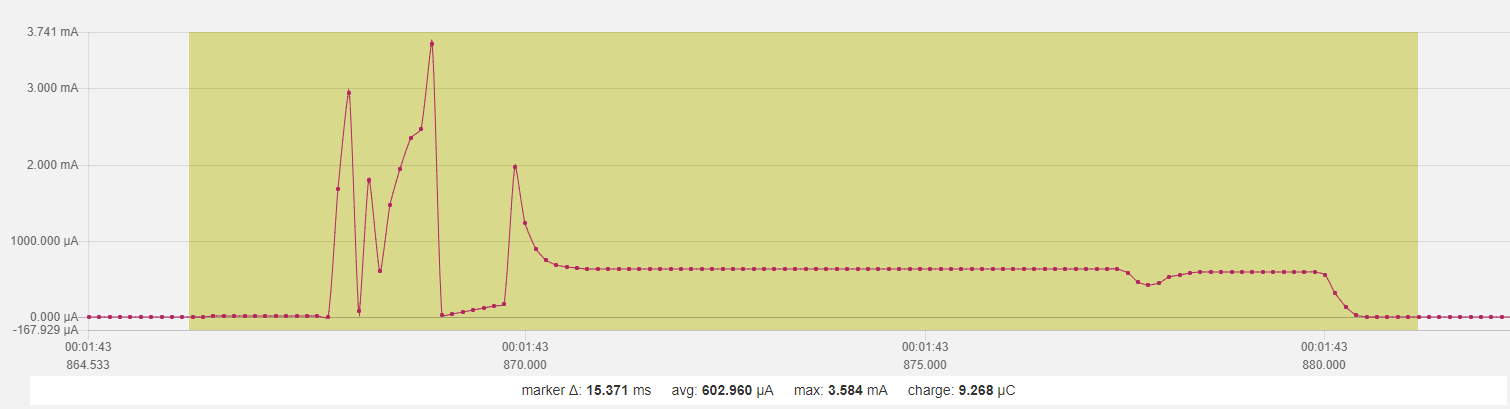


### on top of 1.1.14 use different parameter

* 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



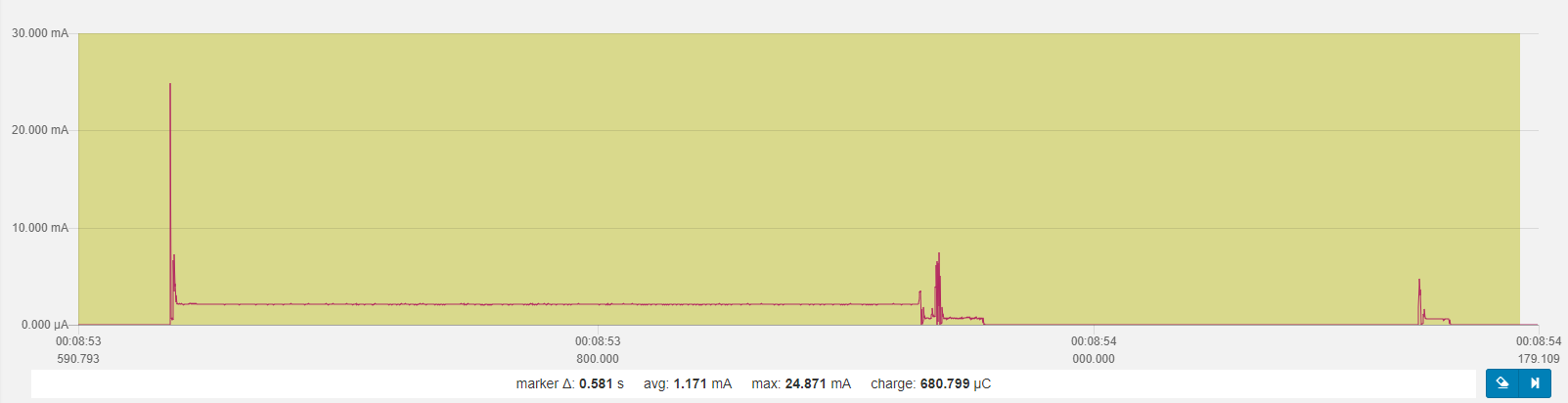
#### Sensor update (all 5 sec)



#### Adv (all 1 sec)

#### 

#### Startup

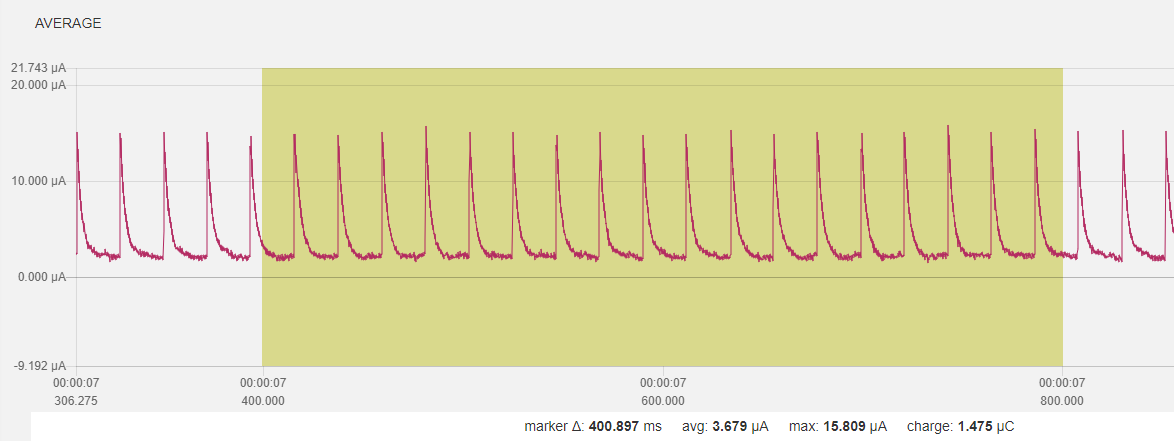


* Peaks
  + Power on peak
  + First adv
  + First sensor acquisition

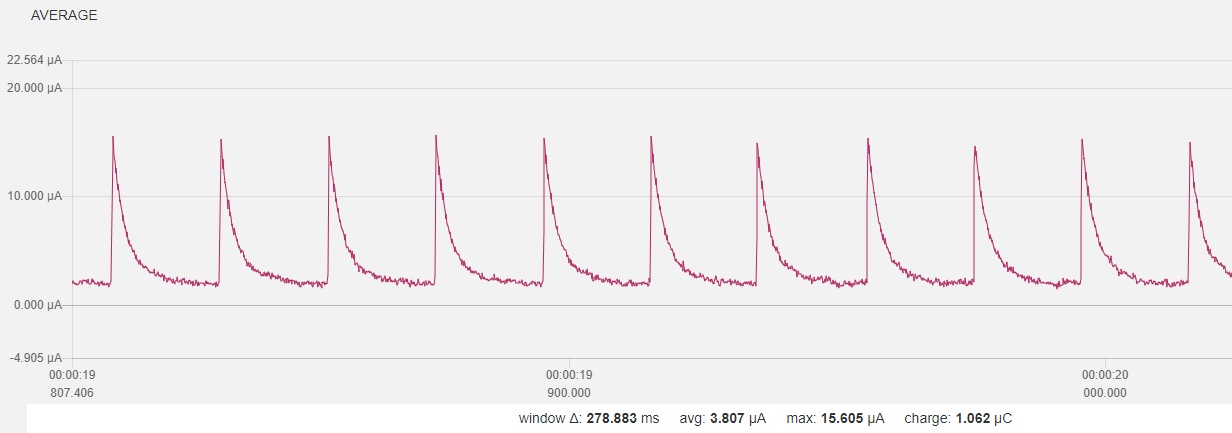
## Power Optimization KX022 Accelerometer

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

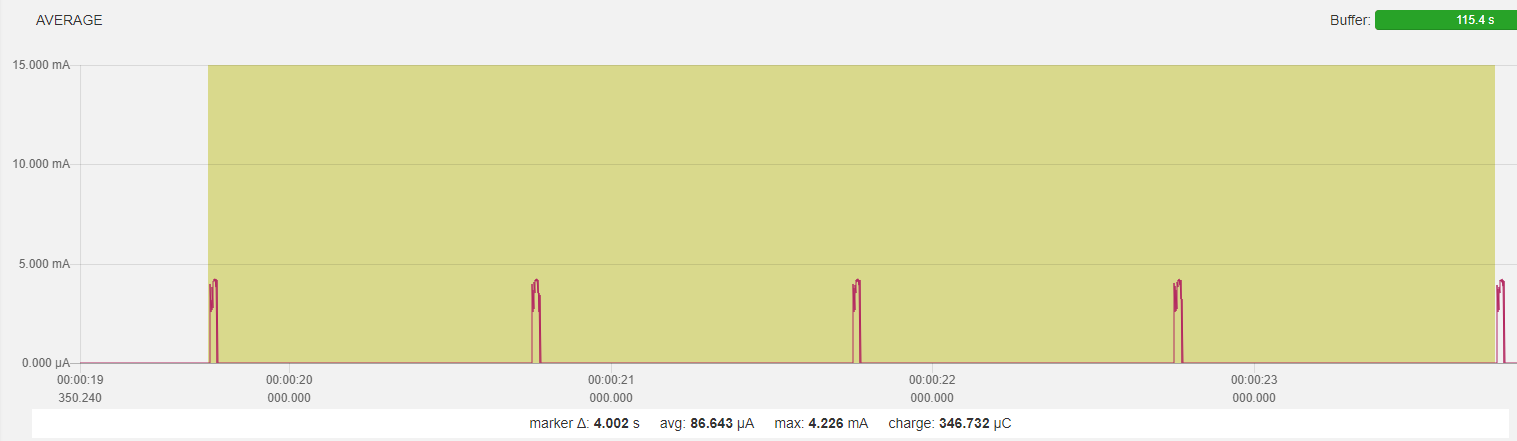
### Baseline, no BLE, no sensor init



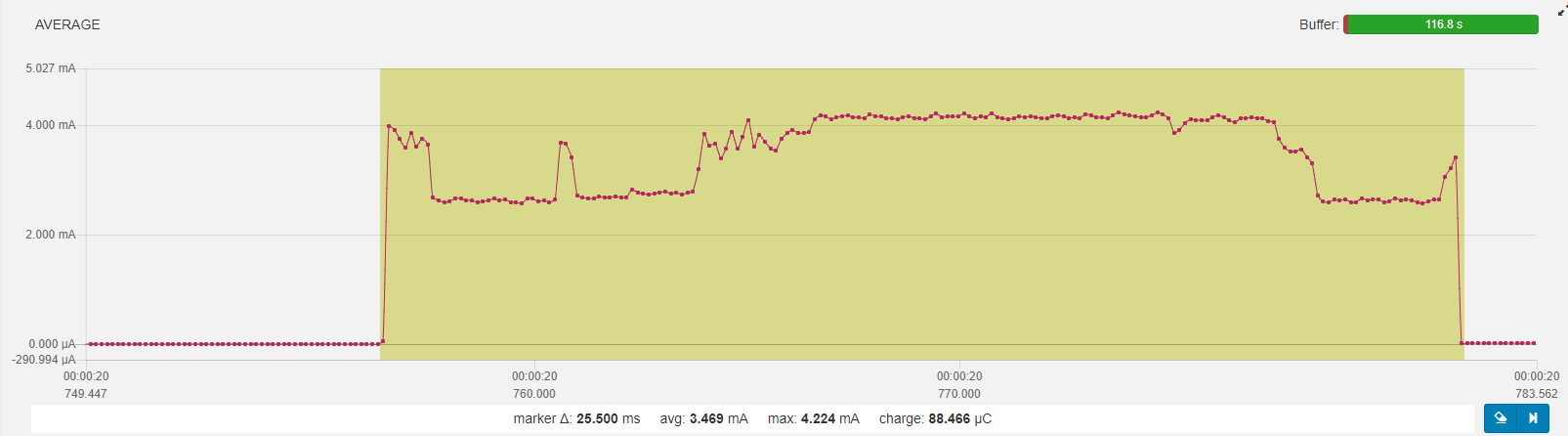
### Change to TWI without transaction manager, SHT3 init and KX022 init to standby



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



#### One measurement

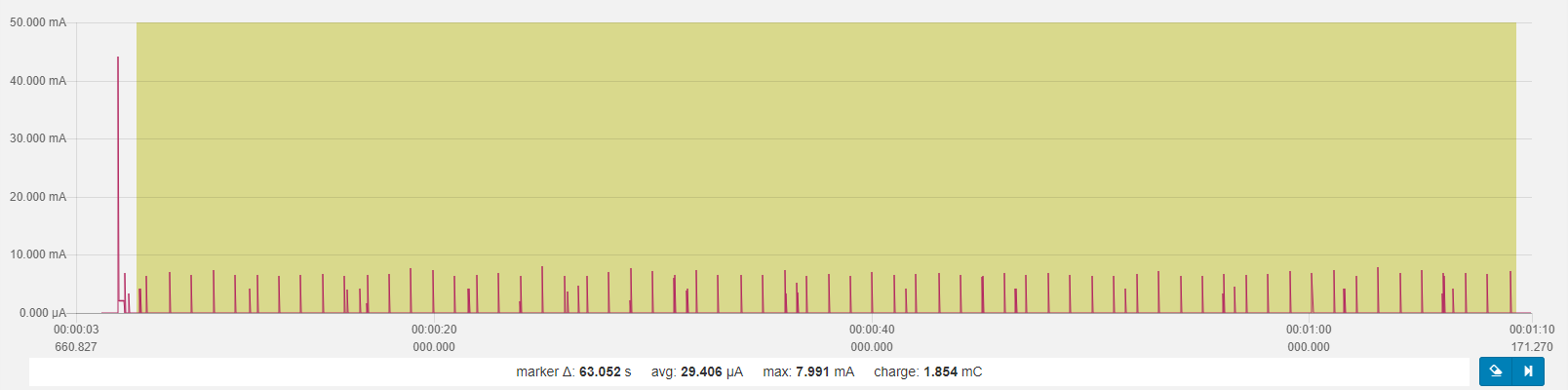


Init KX022, Standby 1,2ms  
wait 1.2/ODR 3ms  
set to operate 0,5ms  
wait 1.2/ODR for value 3ms  
read accel values …  
SUM ~8ms

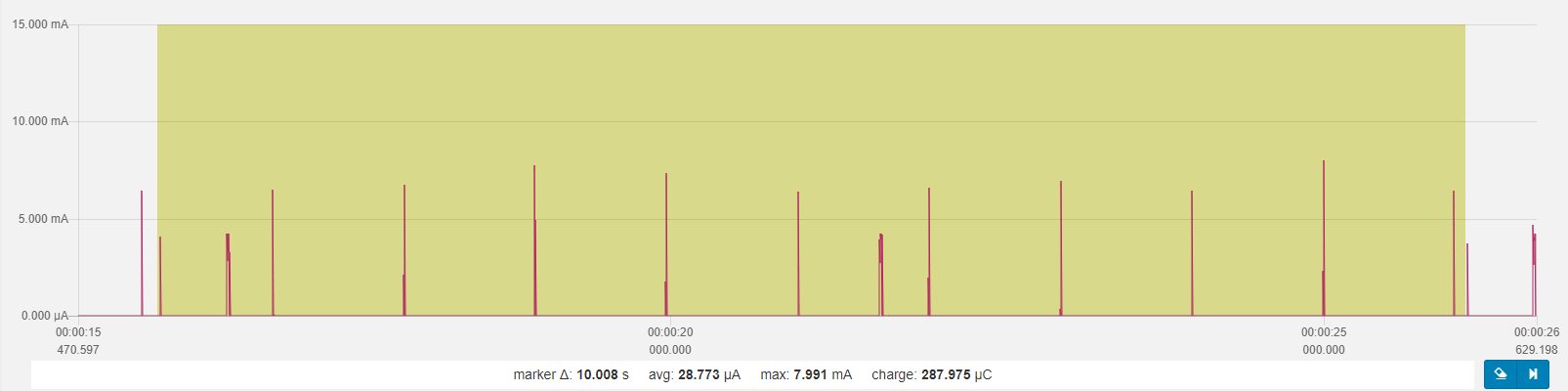
Set SHT3 to SHT3\_MEAS\_HIGHREP\_STRETCH  
wait clock stretch 12,5ms  
read temperature and humidity 2,8ms  
SUM ~15ms

Process data and sleep again…  
Overall cycle 25ms, avg. power consumption 3,5mA, idle < 4uA

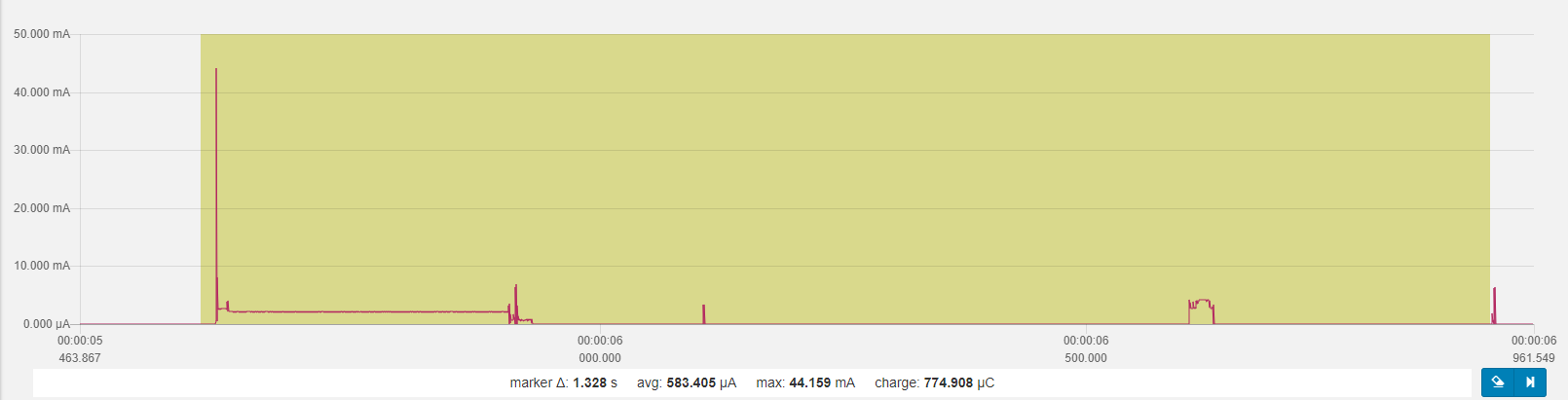
### Overall



#### One 10sec cycle



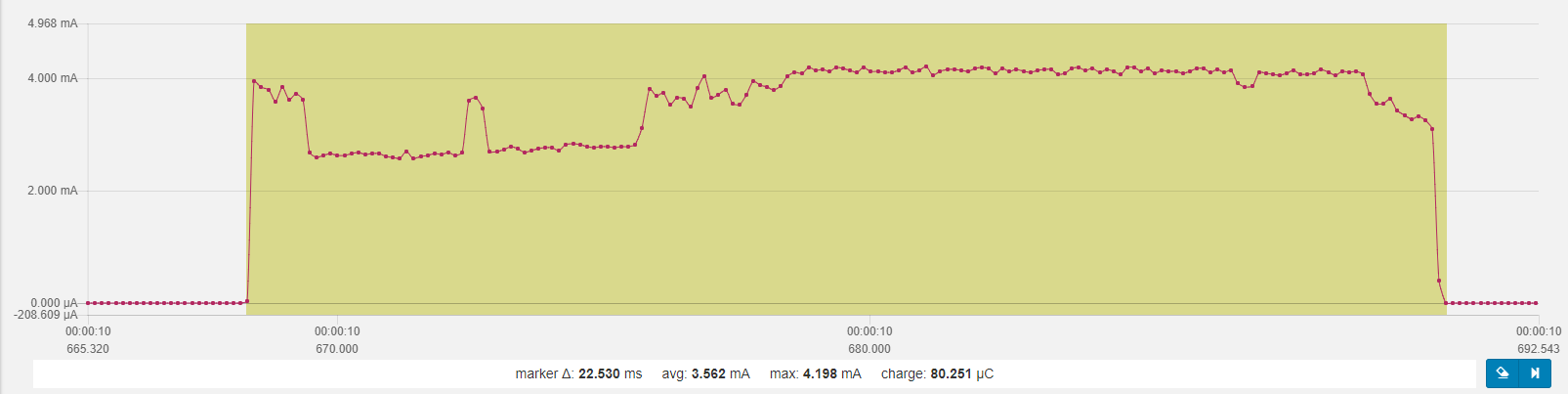
### Cycle



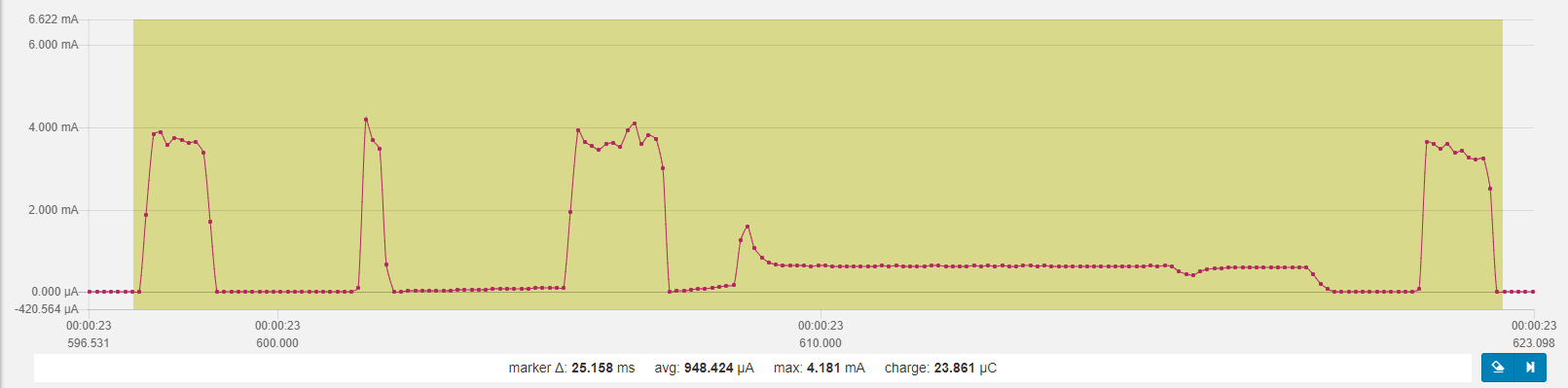
BLE 0 dBm, adv. interval 1s  
sensor (SHT3 and KX022) interval 5s  
SAADC (battery level) interval 10s  
overall power consumption ~30uA (28,77uA)  
idle power consumption 3,5uA

## Use RTC INT for while waiting for accel data

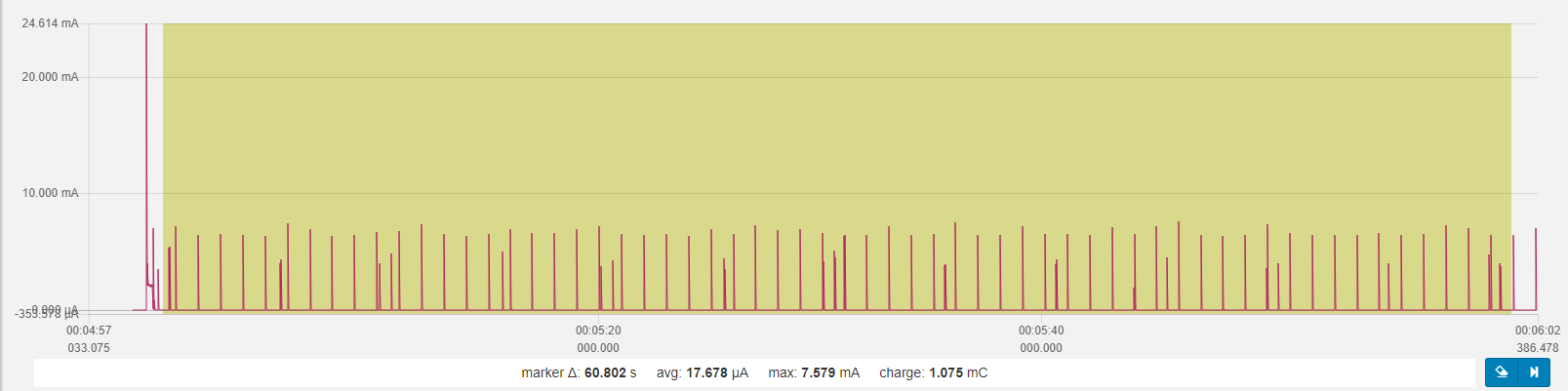
### Baseline



### 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)



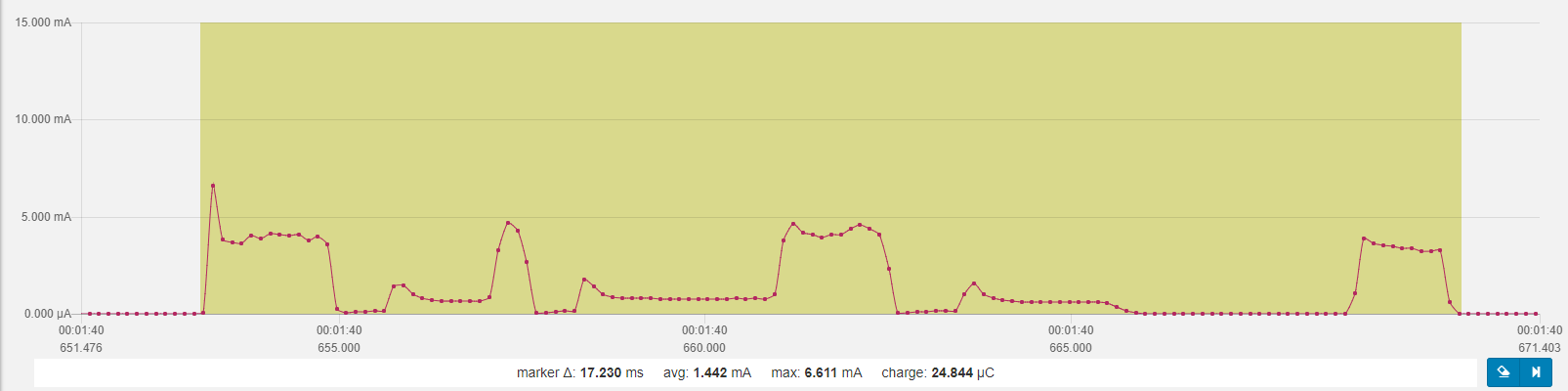
### one minute, analog to 1.2.4



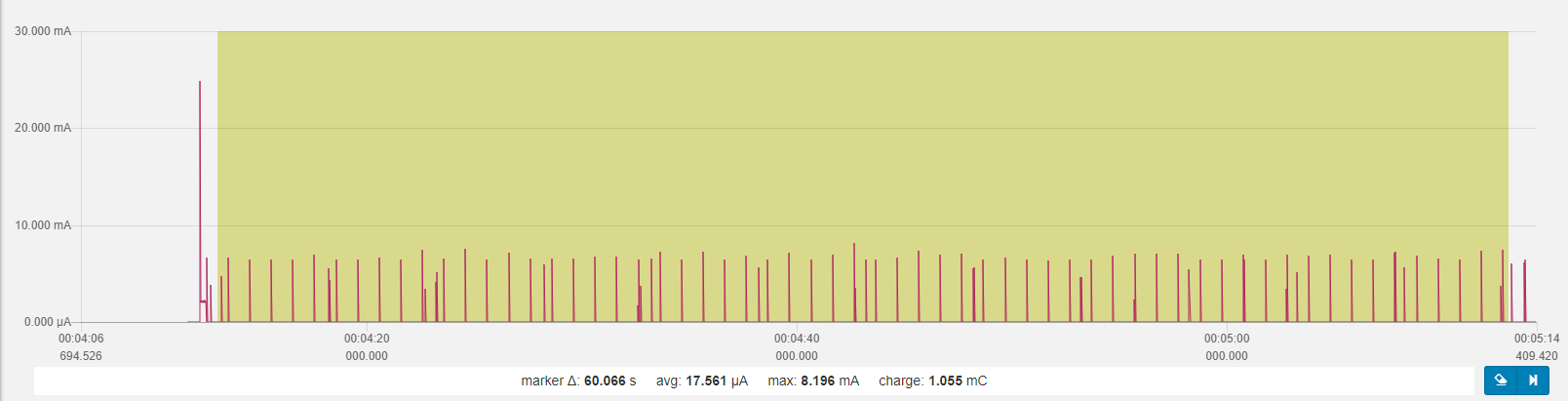
Optimization summary (1.2.4🡪1.3.3)  
BLE 0 dBm, adv. interval 1s  
sensor (SHT3 and KX022) interval 5s  
SAADC (battery level) interval 10s  
overall power consumption ~30uA (28,77uA) 🡪 17,68uA   
idle power consumption 3,5uA 🡪 3,5 uA

## Further optimization

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

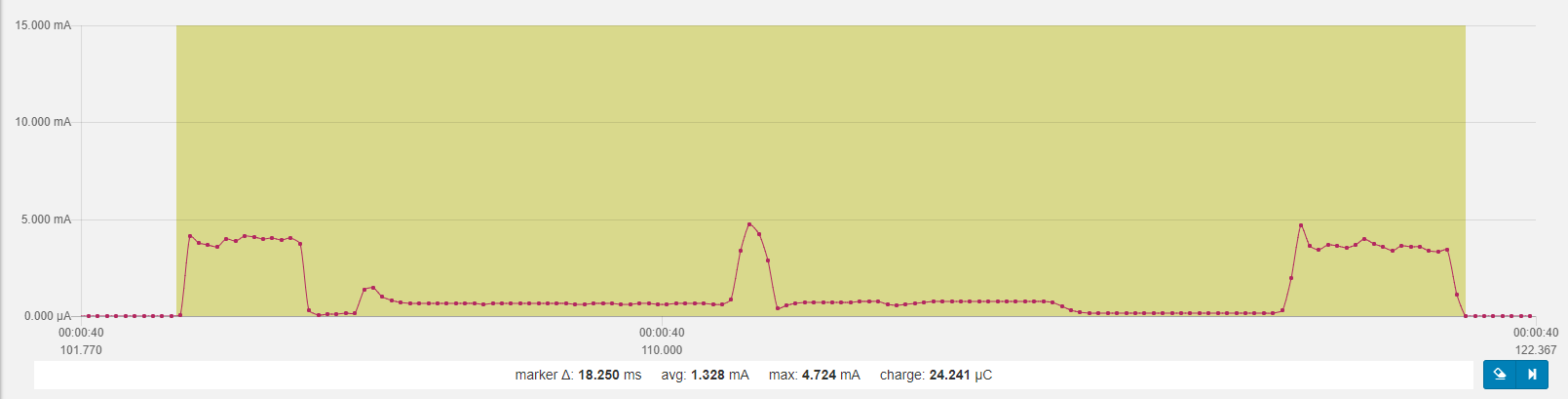


### one minute, analog to 1.3.3

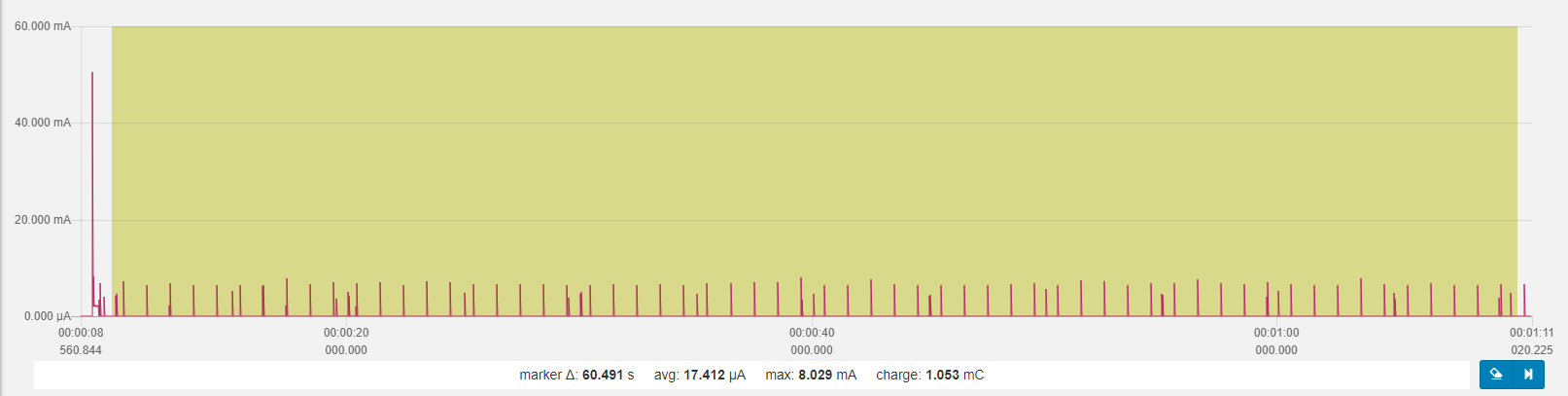


thus, no real further improvement

### KX022: ODR 200 -> delay time 7ms

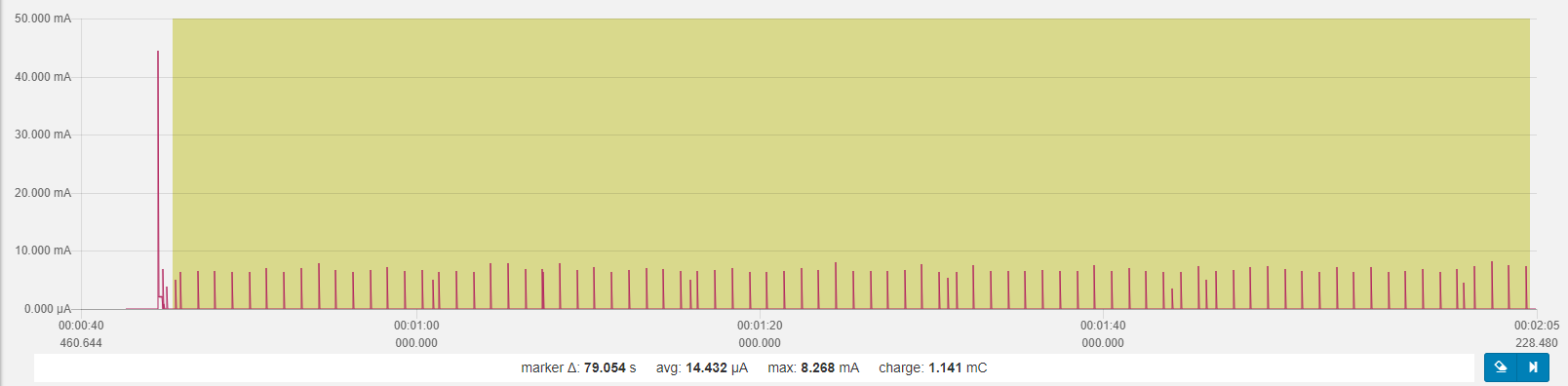


### one minute, analog to 1.3.3



thus, no real further improvement

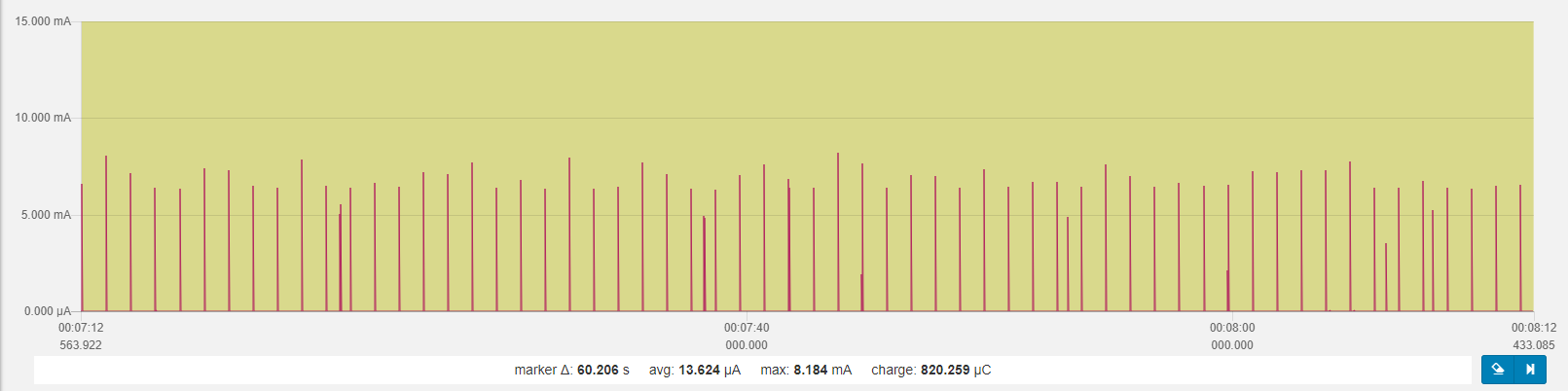
## Longer intervals between adv and samples

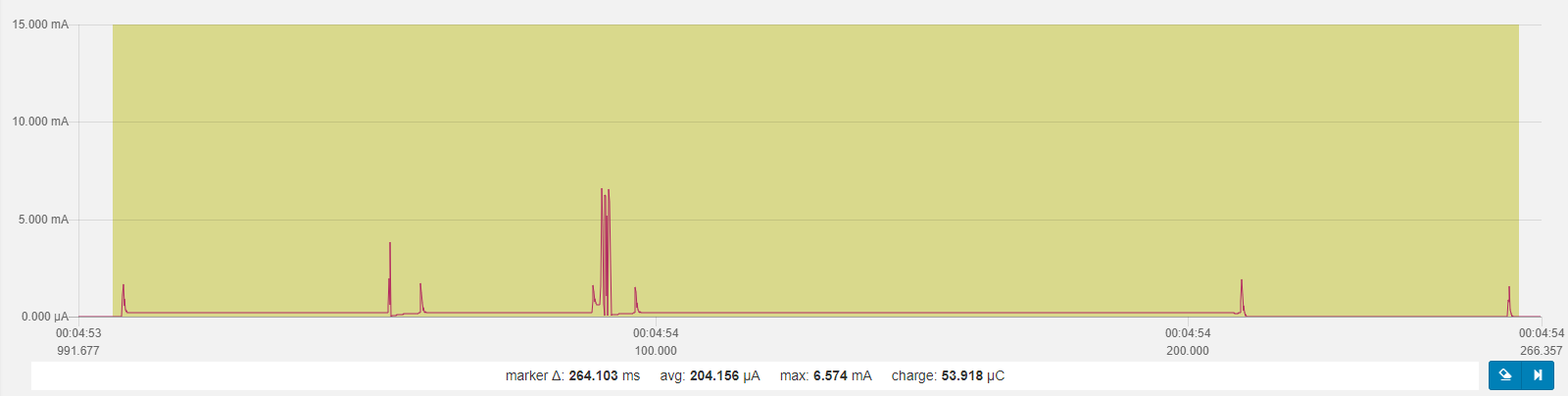
BLE 0 dBm, adv. interval 1s  
sensor (SHT3 and KX022) interval 15s  
SAADC (battery level) interval 60s  
overall power consumption 14,4uA   
idle power consumption 3,6 uA

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

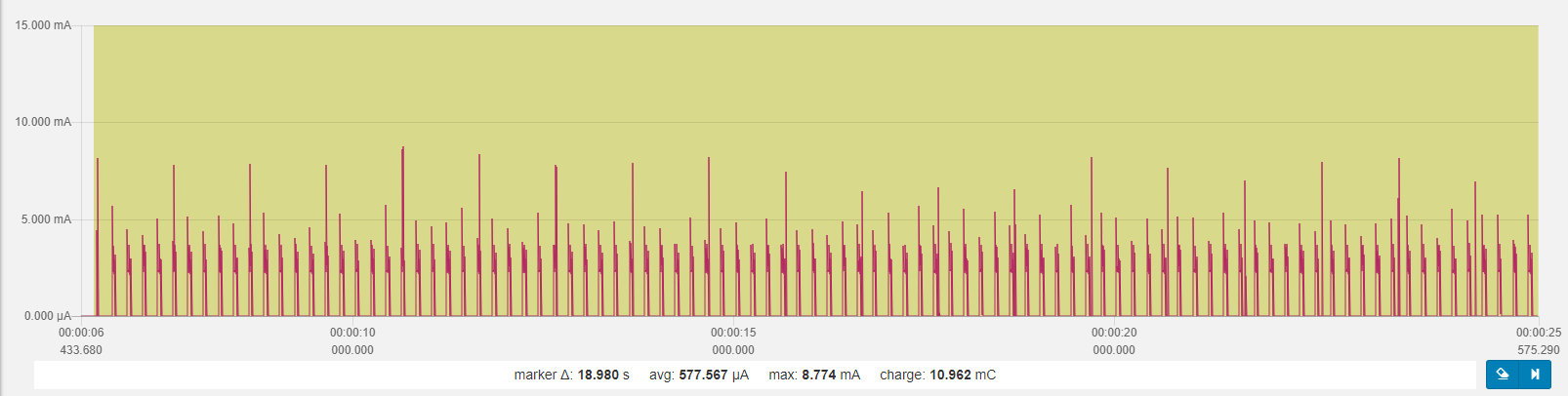
(> 1 Jahr = 365\*24h = 8760h; CR2032 = 220 mAh)

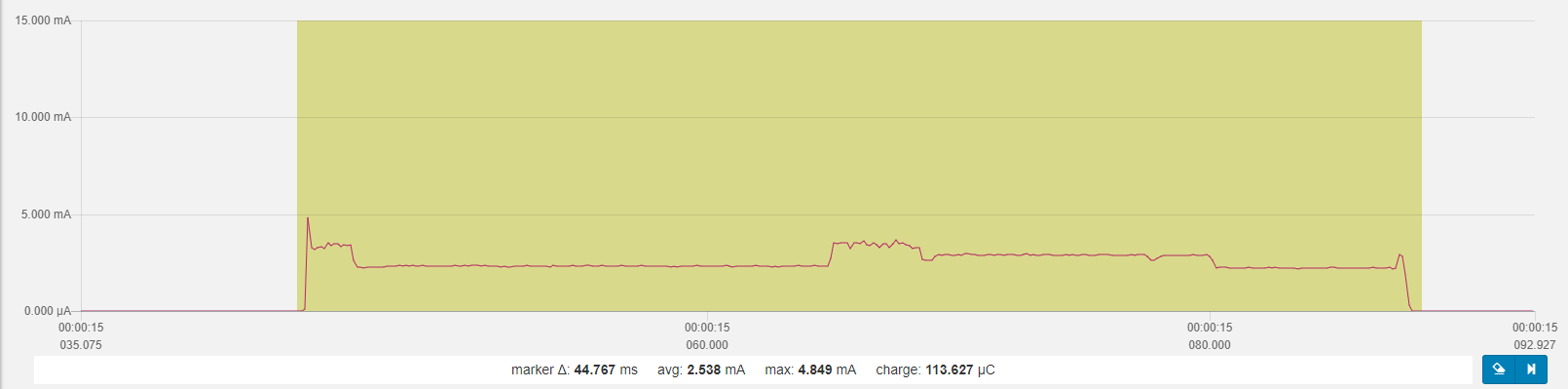
## Button functionality introduced

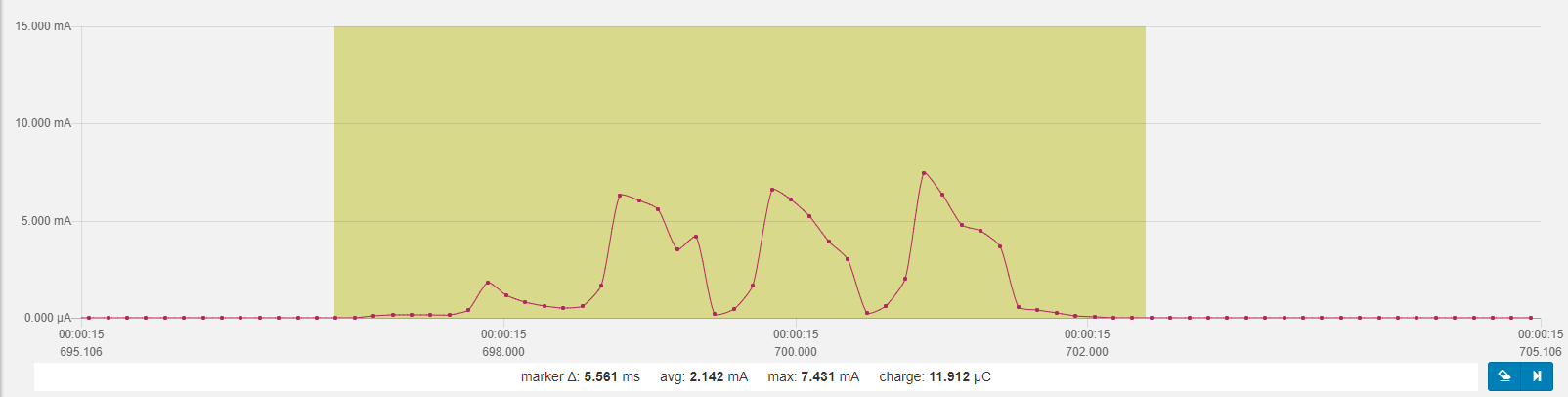


Single button press  


# Original Beacon Firmware (for comparison)



Frequent spikes (5 Hz)

Larger but rarer spikes (1 Hz)

# Used configuration

Tbd