Application Note
Energy Harvesting Solution for Electronic Shelf Label (ESL)

Abstract

This document presents a feasibility study on using energy harvesting to power Electronic Shelf Labels (ESL), which are widely used in supermarkets. The main objective is to use miniature solar cells as harvesters combined with Nowi NH2D0245 PMIC[1] in order to harvest ambient light in a supermarket and compensate the consumption of the ESL.

1. Application Environment

The light intensity was measured using Sekonic C-7000[2] spectrometer at 3 different shelves:

- Refrigerator
- Snacks
- Vegetables and Fruits

For each shelf, measurements were taken at 3 different levels as indicated in Figure 1:

- Top (T)
- Middle (M)
- Bottom (B)

Figure 1: *Measurement of light intensity in a real application environment using Sekonic C-7000 spectrometer.*

Furthermore, for each level, measurements were taken at 3 spots:

- Right
- Middle
- Left

2. Measurement of Light Intensity

Figure 2 shows the light intensity distribution in a typical supermarket environment where the maximum light intensity is around 1200 LUX at the vegetables and fruits section facing the ceiling spotlight (Figure 1). On the other hand, the light intensity is the lowest at the bottom shelves where the minimum value is around 200 LUX. The rest of spots have light intensities varying between 400 and 700 LUX on average.

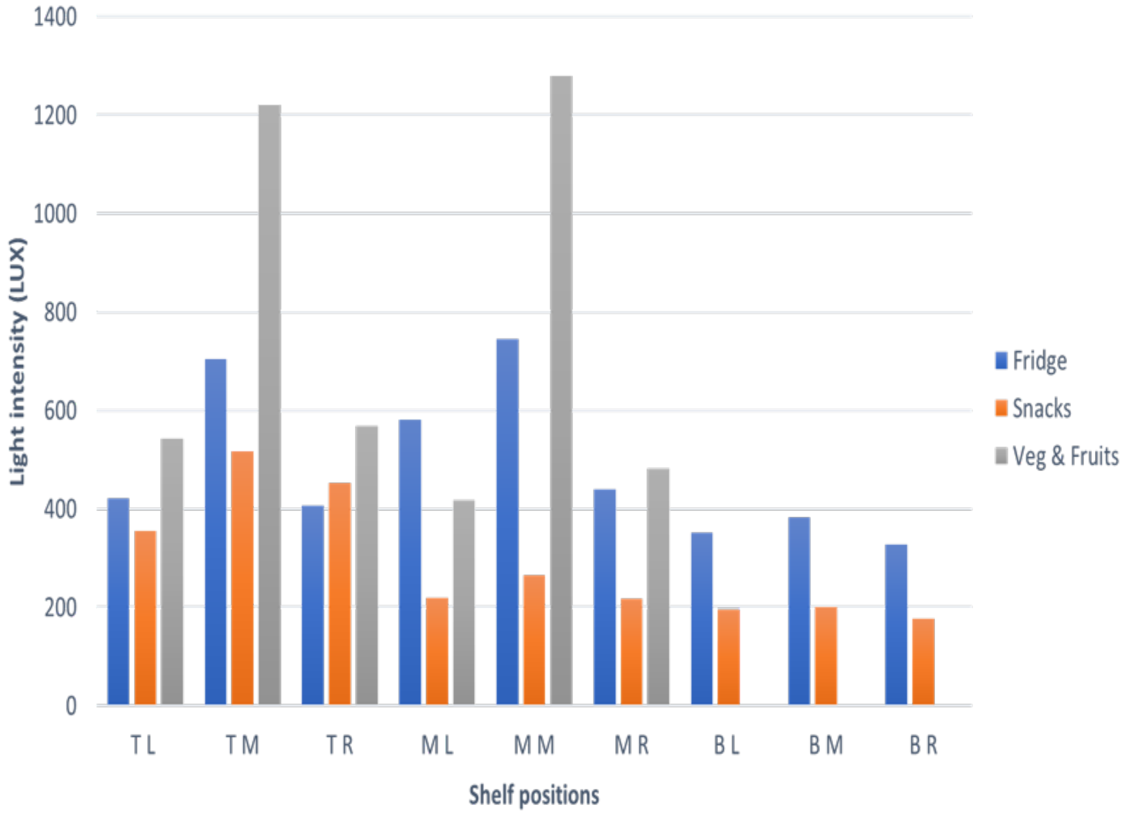


Figure 2: *Light intensity at different spots in a supermarket.*

3. ESL Power Consumption

In this section, the power consumption of the ESL is measured in both operating modes (idle and update mode). The measurement setup consists of Telink TLSR8258 ESL[3] (1) and a gateway (2) to establish communication. The ESL power profile is characterized using Joulescope DC energy analyzer[4] (3) and an external 3V rechargeable battery as shown in Figure 3.

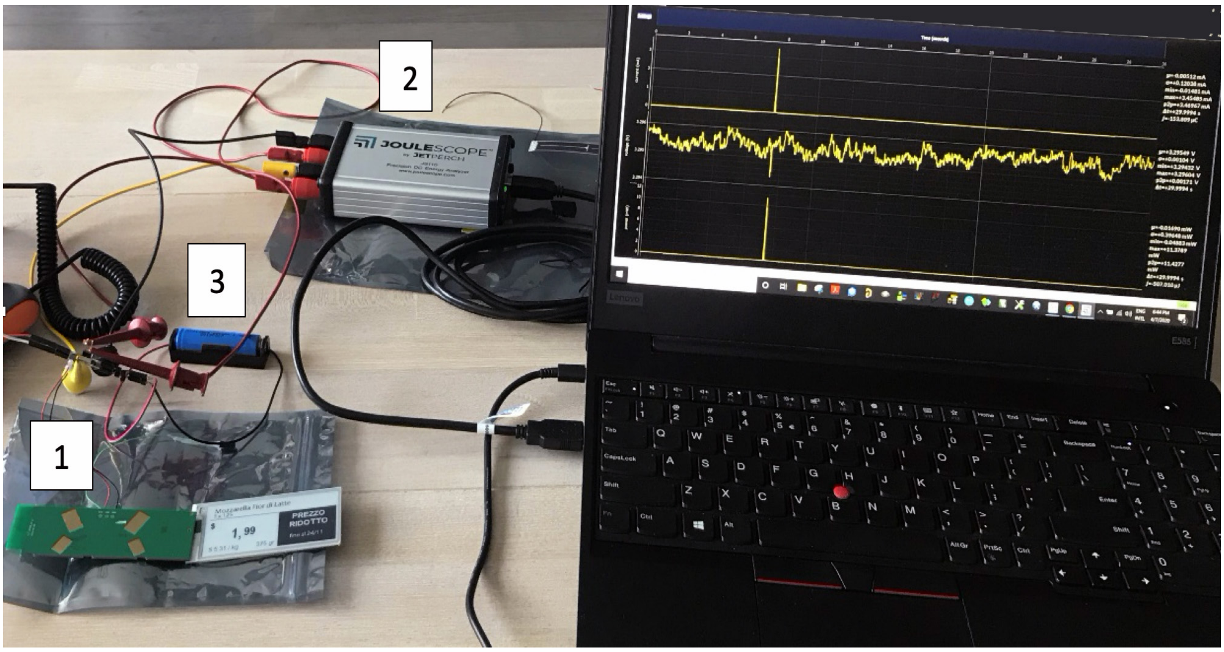


Figure 3: *ESL power profile measurement setup.*

4. Idle Mode

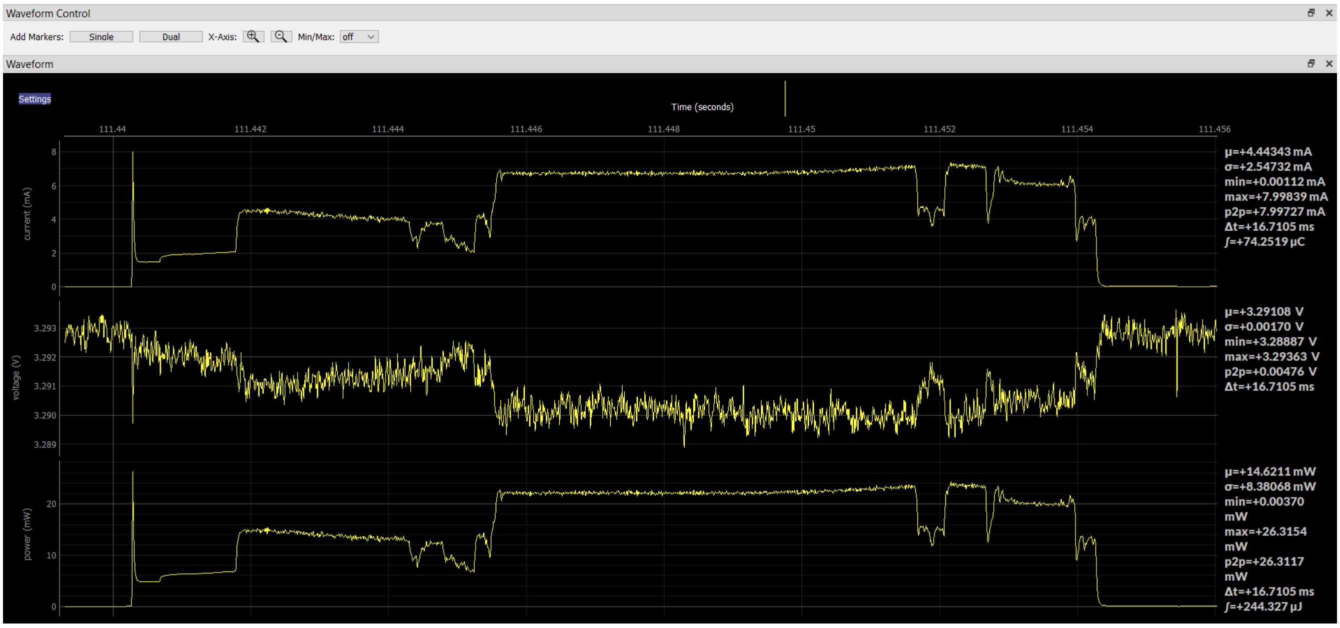


Figure 4: *Power profile of ESL in idle mode.*

Idle peak time ≈ 16 ms and it is repeated every 30 seconds. The idle peak consumption ≈ 245 μJ while the idle consumption between 2 peaks ≈ 227 μJ.

The daily idle consumption = (245+ 227)e-6 x 2 x 60 x 24 = 1.35 Joules (= 0.377 mWh).

5. Update Mode

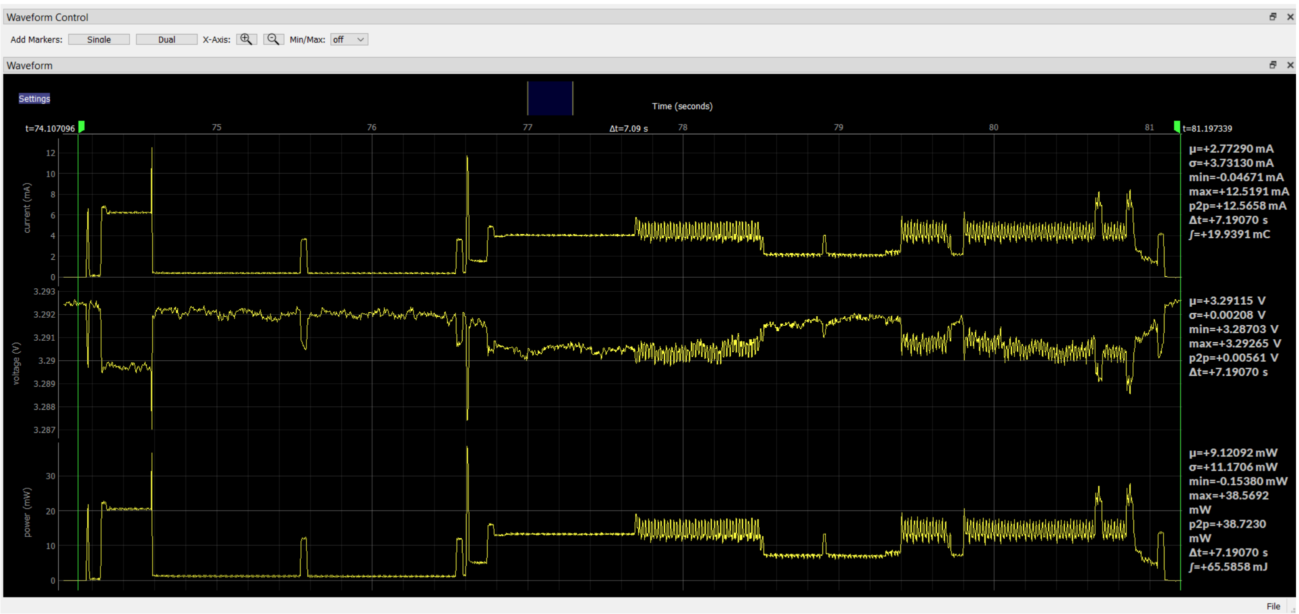


Figure 5: *Power profile of ESL in update mode.*

The update peak time is ≈ 7 s and the update peak consumption is ≈ 65 mJ. For a typical scenario of two updates per day = 2, the daily update consumption = 65e - 3 x 2 = 0.13 Joules (= 0.036 mWh). Therefore, for 2 updates per day approach, the total daily consumption is around 0.413 mWh per day.

6. PV Size Estimation

The equivalent PV area to compensate the typical consumption of 0.413 mWh will mainly depend on the light intensity available at different positions in the market.

The table below shows the equivalent estimated PV area in cm^2 at three different spots in a supermarket where fluorescent lights are on for 15 hours.

	Incident Energy Calculation per cm² (mWh)				Harvested Energy per cm² (mWh)			
	Illuminance (Lux)	Hours	Incident Energy (mWh)	PV efficiency	PMIC efficiency	Harvested energy (mWh)	Daily Reuired energy (mwh)	equivalent PV area to compensate consumption(cm²)
LOW Light spot	200	15	5	0.02	0.8	0.08	0.413	5.16
Average spot	500	15	12.5	0.02	0.8	0.2	0.413	2.07
High Light spot	1000	15	25	0.02	0.8	0.4	0.413	1.03

Table 1: *PV size estimation for ESL at different LUX levels assuming fluorescent light for 15 hours a day..*

7. Schematic

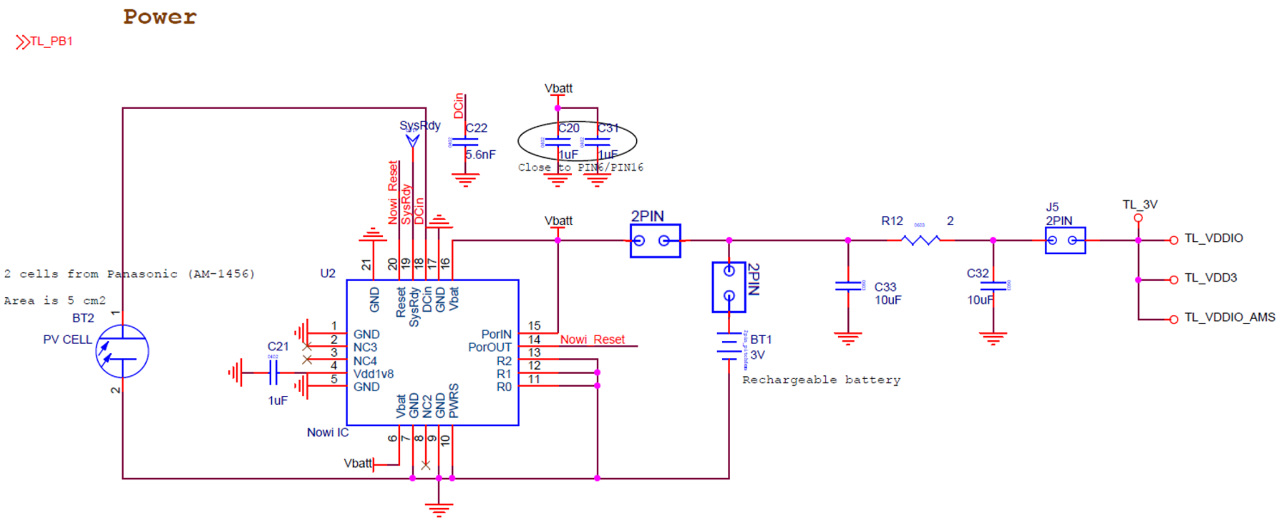
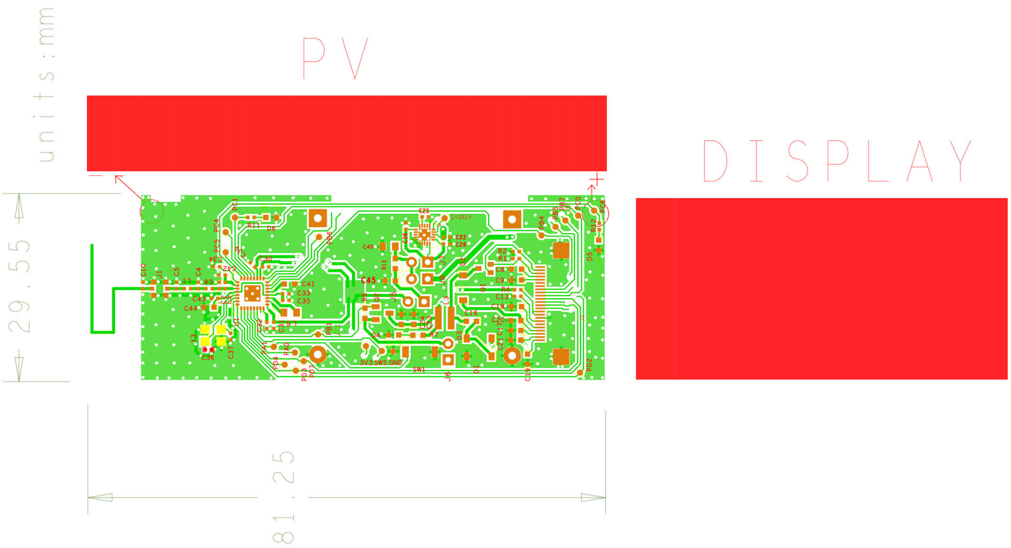


Figure 6: *ESL Power block schematic design with NOWI NH2D0245 PMIC.*

8. PCB Layout

a



b

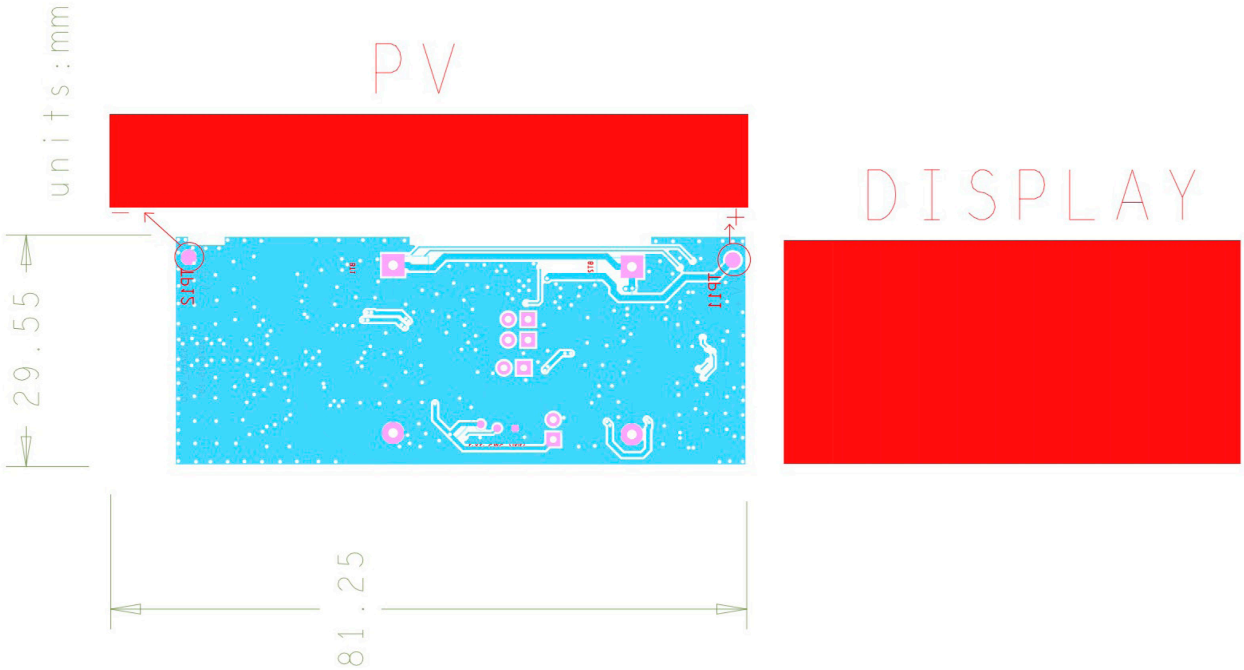


Figure 7: *ESL PCB layout and dimensions a -Top b - Bottom.*

9. ESL Prototype

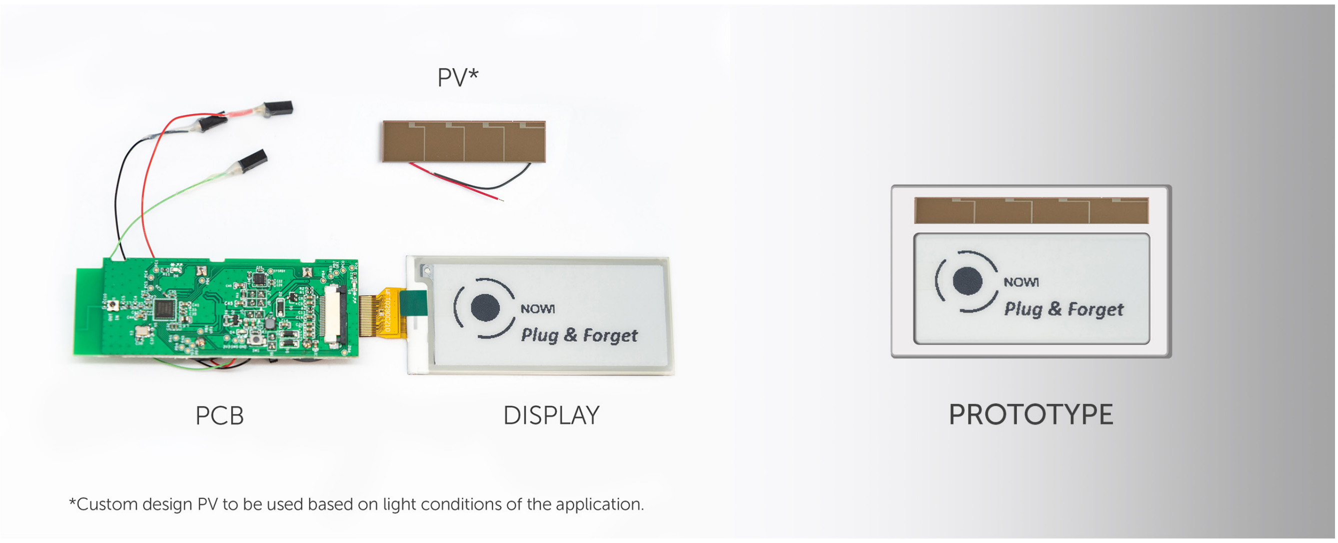


Figure 8: *ESL prototype based on Telink TLSR8258 IC, Nowi NH2D0245 PMIC, Panasonic PV AM-1424CA and Maxell 2023 3.3V rechargeable Li coin cell.*

10. ESL Charging Profile Measurements

The ESL power profile is measured during idle mode while charging the battery by Nowi NH2D0245 PMIC and Panasonic AM-1424CA PV. Figure 9 shows the measured current profile of the ESL during operation where the current peaks correspond to the idle mode peaks and the negative current correspond to the charging between two idle peaks.

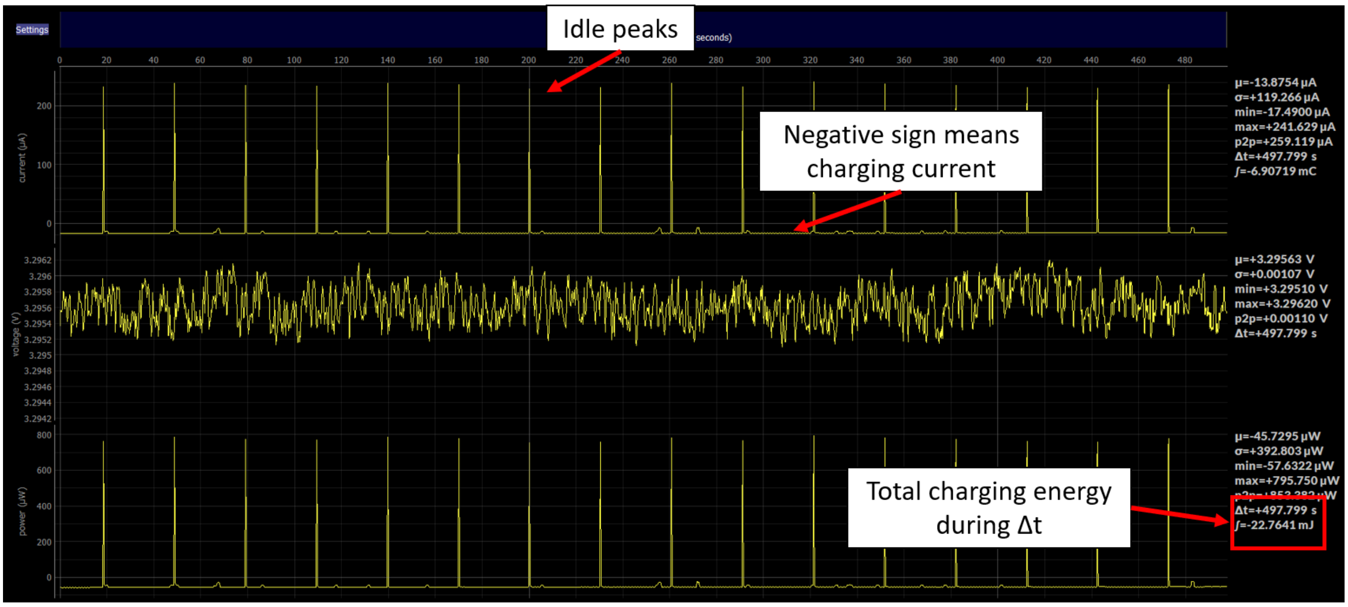


Figure 9: *ESL power profile measurement during operation mode while Nowi NH2D0245 PMIC is charging the battery in continuous.*

Another measurement was realized by monitoring the battery voltage level over longer period. The ESL was left to operate at indoor light of around 500 LUX while making several screen updates (≈6 updates). The battery voltage was monitored also during period where lights are turned off where the battery level slowly decreased (as shown in figure 10) due to idle mode consumption. The battery level starts to increase in the following day when lights are turned on and the NH2D0245 starts to charge the battery.

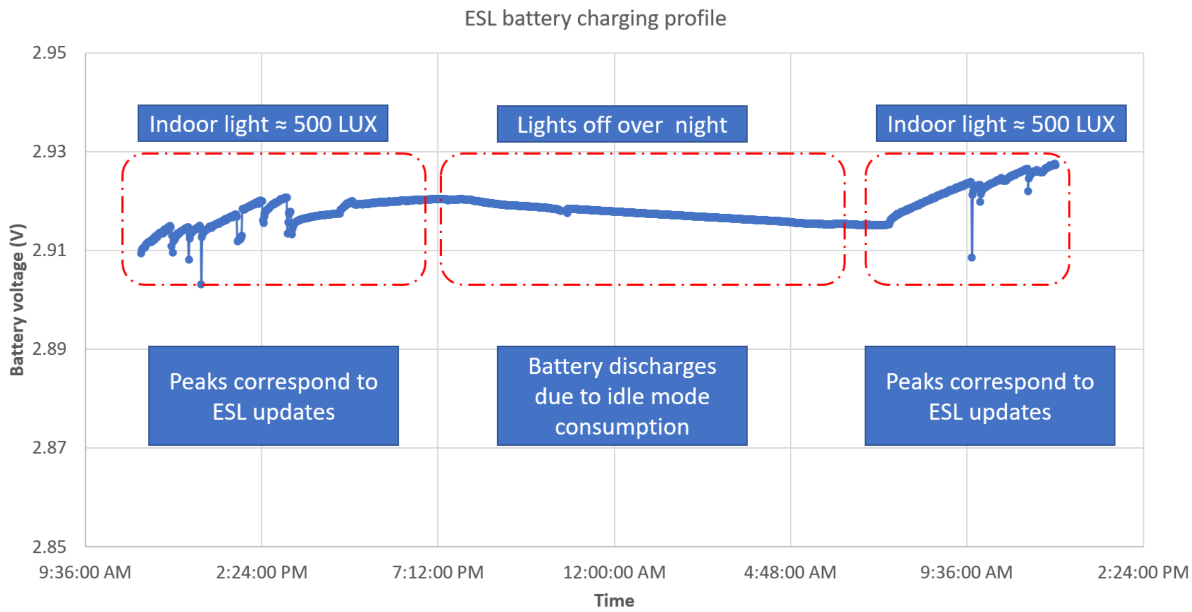


Figure 10: *Measurement of ESL battery level during lights on and off periods.*

11. Summary

We can summarize the main points of this application as following:

- Light intensity measurements on different spots of a Market (200 LUX minimum & 1200 LUX maximum)
- Power profile measurements of Telink ESL label in idle and update modes
- For a typical approach of 2 updates per day, the total estimated energy consumed is around 0.411 mWh

- PV area required to compensate 0.413 mWh depends on the light intensity.
- At 200 LUX (lowest possible), 5 cm^2 is required assuming 15 hours of Fluorescent light
- Power profile measurements of Telink ESL label + Nowi NH2 PMIC + Panasonic PV cell

12. Conclusion

Measurements showed the possibility of compensating the basic ESL consumption and the possibility of adding more features to the label while using more area for the PV or just by exposing the labels to more light.

References

[1] https://www.nowi-energy.com/nh2/
[2] https://www.sekonic.com/industrial/c-7000
[3] https://www.telink-semi.com/products/bluetooth-low-energy/
[4] https://www.joulescope.com/