Application Note
Energy Harvesting Solution for Smart TV Remote Control

Abstract

This document presents a feasibility study on using energy harvesting to power two different Smart TV remote controls, which are based on IoT modules for communicating, and compare them to the consumption of a typical IR remote control. The main objective is to estimate the daily energy budget of each remote control in terms of the number of key presses, voice events, as well as the idle mode and sleep mode consumption. Based on the daily total energy consumption, the size of the solar photovoltaic (PV) harvester is estimated to guarantee continuous charging of the storage unit for a typical home user environment.

1. Remote Control development board (RC1) based on BLE SoC.

1.1. Key Press

The consumption of 1 key press corresponds to the average current drawn during a button being pressed and then released within one second, such as Home button, Return button, etc. Figure 1 shows the current profile of 1 keypress, where the average current is 0.4 mA for around 290 ms.

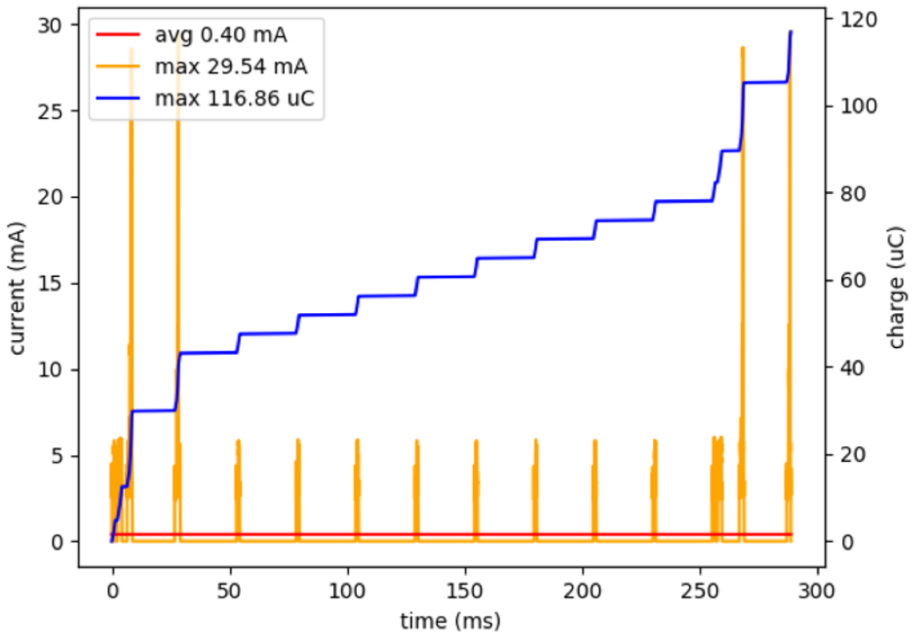

Figure 1: *RC1 Current Profile of 1 keypress.*

Assuming a typical use case of 300 keypresses per day and LED consumption of 5 mA during the keypress period, then the average energy consumption related to keypresses is: **1.4094 Joules.**

1.2. Voice events

The consumption of 1 voice event corresponds to the average current drawn during the voice event procedure. Figure 2 shows the current profile of 1 voice event where the average current is 6.35 mA for around 700 ms.

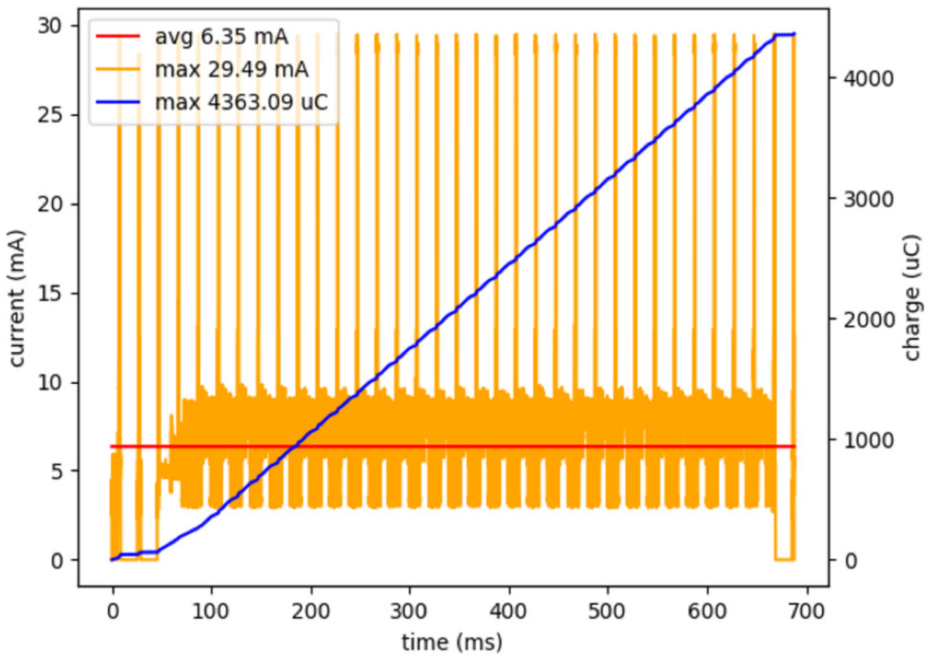

Figure 2: *RC1 Current Profile of 1 voice event.*

Assuming a typical use case of 50 voice events per day, then the average energy consumption related to voice searches is: **0.66675 Joules.**

1.3. Idle mode

The idle mode consumption corresponds to the average current drawn while TV Host is on and remote is connected to the TV. Figure 3 shows the current profile of idle mode where the average current of each connection peak is 6.74 mA over a period of around 2.5 ms and BLE slave latency that results in one wake up every 500 milliseconds. This interval is typically configurable by the BLE master.

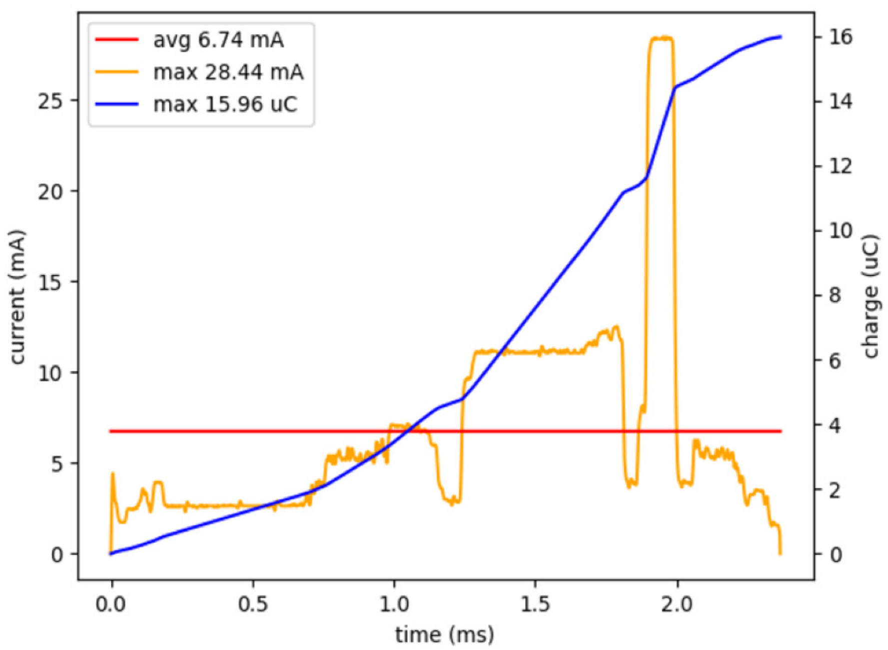

Figure 3: *RC1 Idle Current Profile.*

Assuming a typical use case of watching TV for 4 hours per day, then the average energy consumption related to idle mode is: **1.45584 Joules.**

1.4. Standby Sleep Mode

When TV is turned off, the remote control goes to deep sleep, and the communication is stopped. The average current during deep sleep is around 2 μA; then the energy consumption would be: **0.518 Joules**.

1.5. Summary

MODE	DAILY CONSUMPTION (JOULES)
Key press (300 presses)	1.4094
Voice search (50 voice events)	0.66675
Idle mode (TV on 4 hours)	1.45584
Standby sleep mode (TV off 20 hours)	0.518
Total	4.05

2. Remote Control 2 (RC2) based on Bluetooth 5.0-compliant SoC

2.1. Key Press

The consumption of 1 key press corresponds to the average current drawn during a button being pressed and then released within 1 second. Figure 4 shows the current profile of 1 keypress, where the average current is 1.9 mA for around 220 ms.

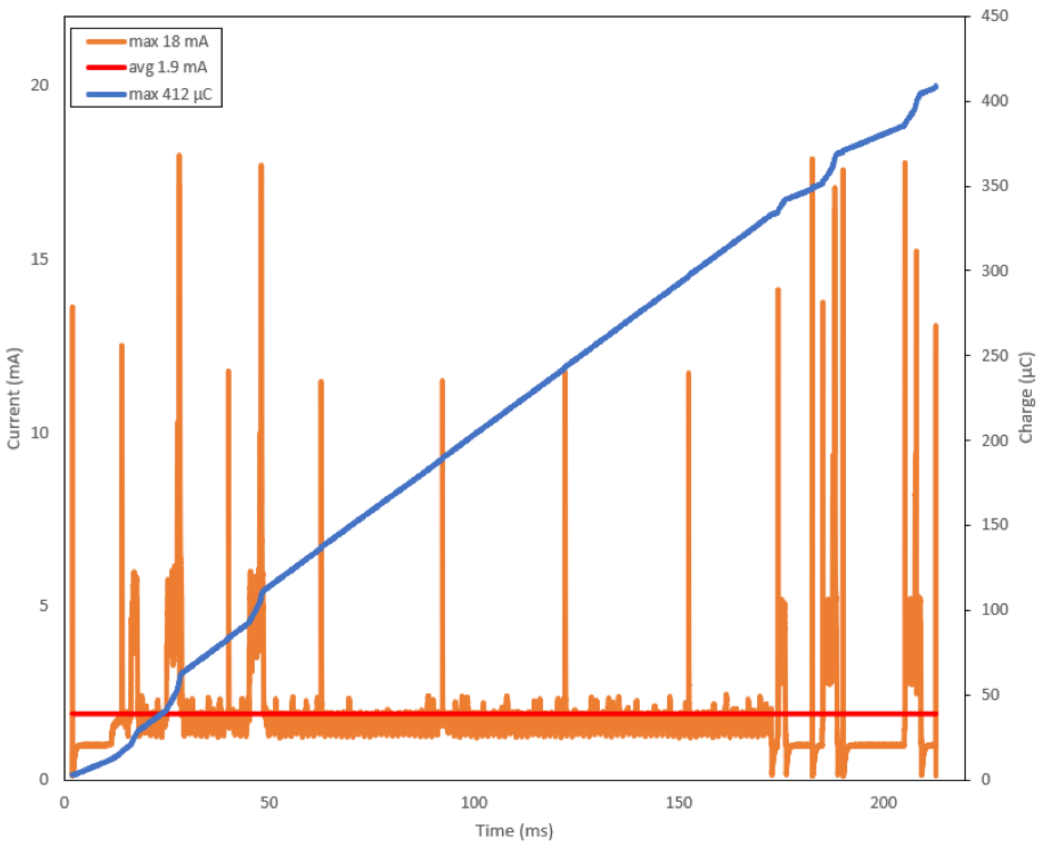

Figure 4: *RC2 Current Profile of 1 keypress.*

Assuming a typical use case of 300 keypresses per day, then the average energy consumption related to keypresses is: **0.3762 Joules**.

2.2. Voice events

The consumption of 1 voice event corresponds to the average current drawn during the voice event procedure. Figure 5 shows the current profile of 1 voice event where the average current is 4.97 mA for around 410 ms.

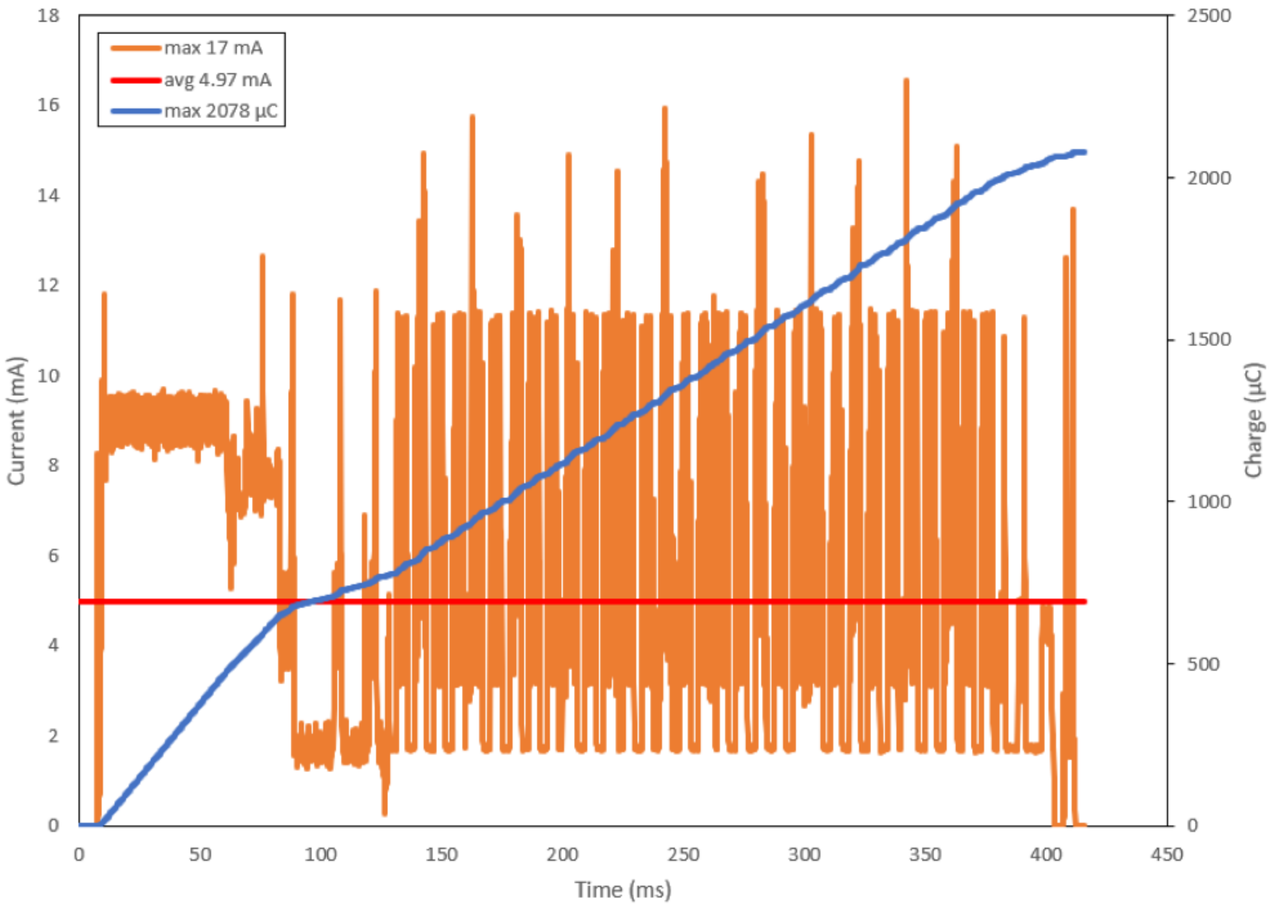

Figure 5: *RC2 Current Profile of 1 voice event.*

Assuming a typical use case of 50 voice searches per day, then the average energy consumption related to voice searches is: **0.3056 Joules**.

2.3. Idle mode

The idle mode consumption corresponds to the average current drawn while TV Host is on and remote is connected to the TV. Figure 6 shows the current profile of idle mode, where the average current of each connection peak is 4 mA for around 3.65 ms and a rate of 2 peaks per second.

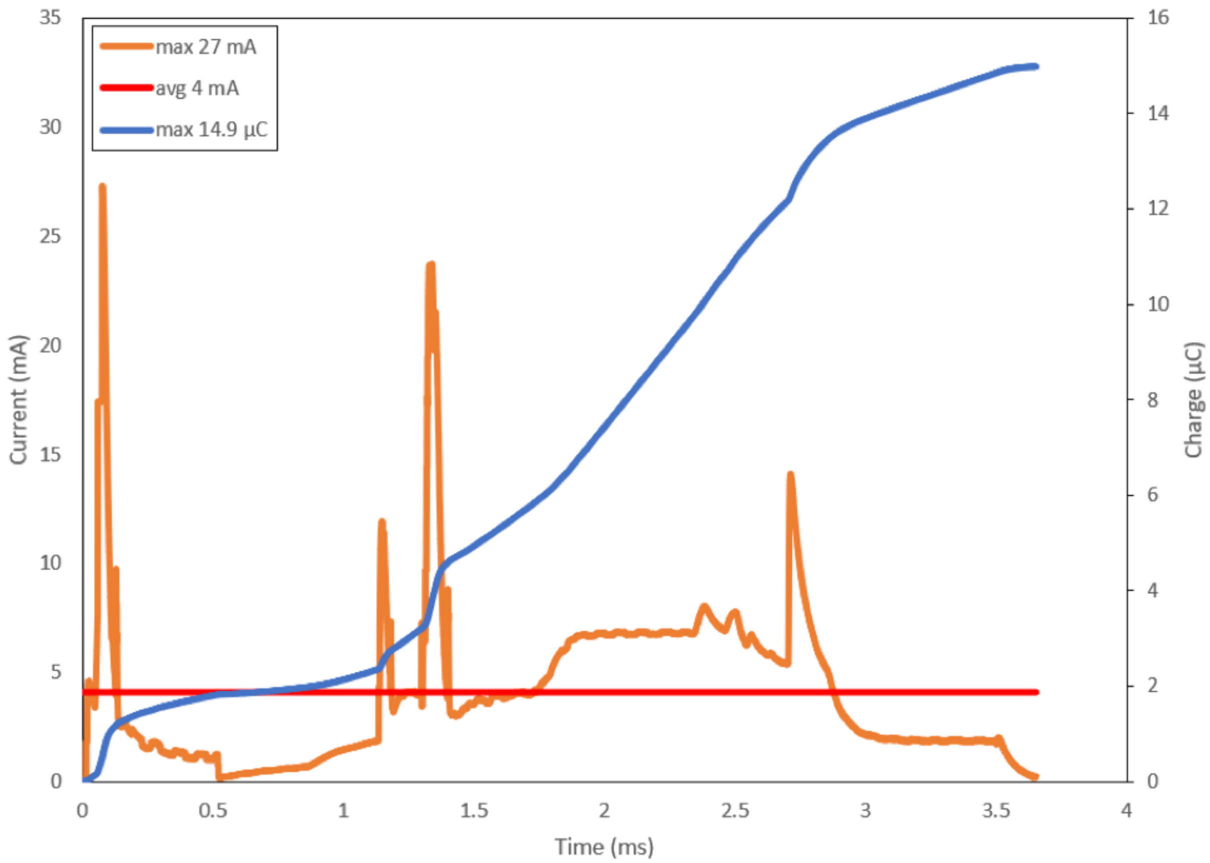

Figure 6: *BLE RC2 Idle Current Profile..*

Assuming a typical use case of watching TV for 4 hours per day, then the average energy consumption related to idle mode is: **1.26144 Joules**.

2.4. Sleep mode

When TV is turned off, the remote control goes to deep sleep, and the communication is stopped. The average current during deep sleep is around 3.2 µA; then the energy consumption would be: **0.829 Joules**.

2.5. Summary

MODE	DAILY CONSUMPTION (JOULES)
Key press (300 presses)	0.3762
Voice search (50 voice events)	0.30565
Idle mode (TV on 4 hours)	1.26144
Standby sleep mode (TV off 20 hours)	0.829
Total	2.77

3. Typical IR remote control

For a conventional IR remote control, the average LED current is 15mA, and the standby current is around 2uA. On average, a user presses the keys 300 times a day, and the average time interval of one keypress is 500 milliseconds, as shown in Figure 7. The total daily energy consumption for 300 keypresses scenario is around **7.2675 Joules**.

	AVERAGE OPERATING CURRENT (M4)	AVERAGE TIME FOR 1 KEY PRESS (S)	OPERATING VOLTAGE (V)	NUMBER OF KEY PRESSES	CONSUMED ENERGY (JOULES)
IR	15	0.5	3	300	6.75
Standby	0.002	-	3	-	0.5175
Total consumed energy per day					7.2675

Figure 7: *Average daily energy budget of an IR remote control.*

4. Application environment

This section presents an estimation of typical light conditions for a remote-control application. For an energy harvesting solution based on solar cells, the application environment and light conditions can be very different from one user to another, which can significantly affect the overall efficiency of the solution. For this feasibility study, we assumed two scenarios, as shown in Figures 8 and 9.

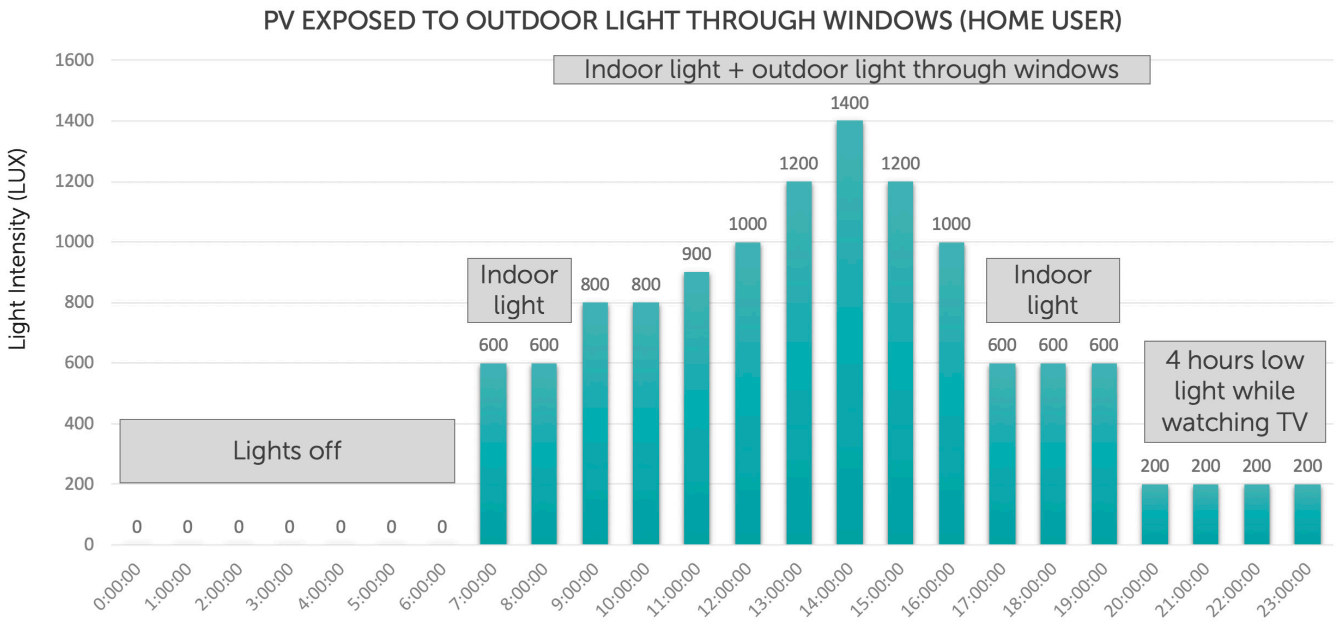

Figure 8: *Estimated daily light intensity profile for a home user.*

For a typical home user, the light conditions will vary during the day, and the remote control will be exposed to light for an average of 17 hours, as illustrated in Figure 8. For such a scenario, the average light intensity during this period would be around 700 LUX.

On the other hand, remote control in companies' environment would be quite different compared to a home user. The light conditions would be constant, and the average time would be around 10 hours as illustrated in Figure 9. For this scenario, the average light intensity during this period would be around 600 LUX.

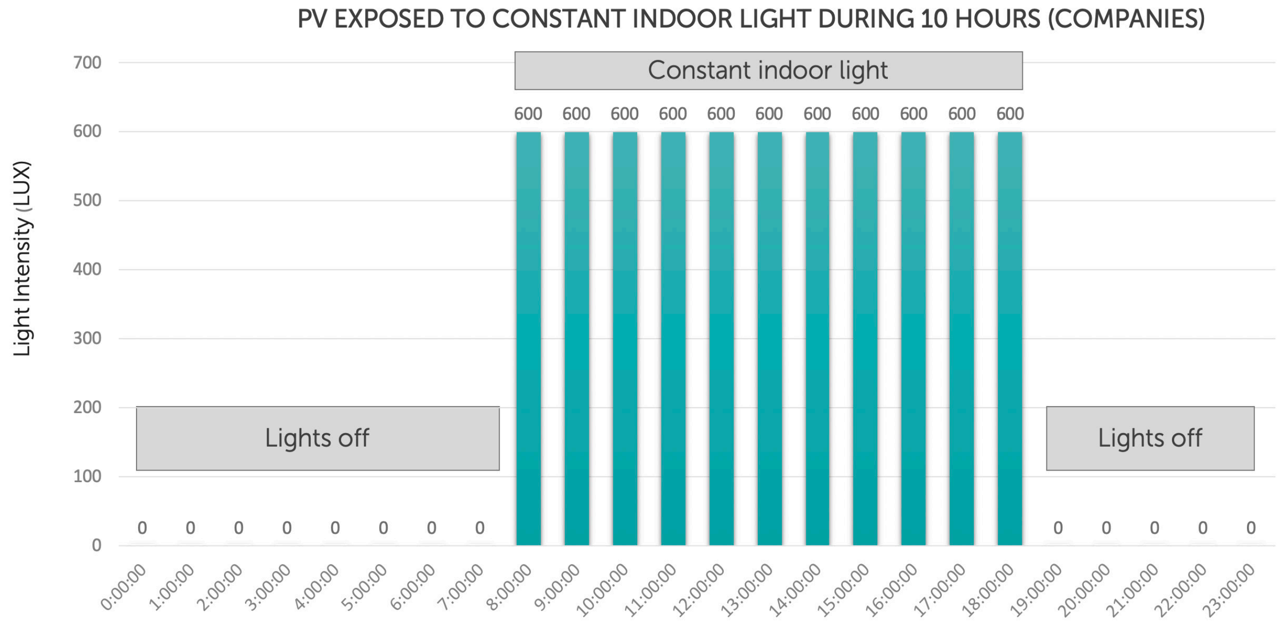

Figure 9: *Estimated daily light intensity profile for a constant indoor environment.*

5. PV size estimation

The equivalent PV area to compensate for the typical consumption of remote control will mainly depend on the average daily light intensity available as well as the efficiency of the PV material. Figure 10 shows a comparison between the estimated PV size required to power different remote controls at two different indoor scenarios.

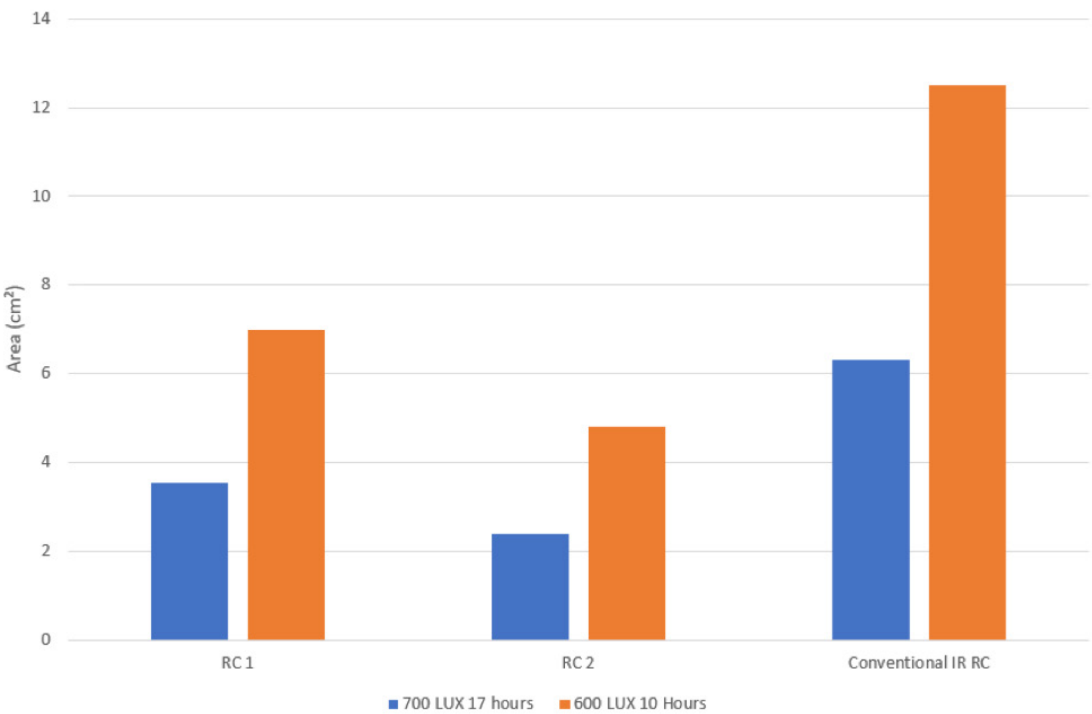

Figure 10: *PV size estimation for different remote controls assuming ≈2% PV efficiency.*

The PV cell can be placed on the top of the remote control as well as on the remote control's back as shown in Figure 11.

Figure 11: *PV cell configuration placed on the back of a remote control.*

6. Nowi NH2D0245 (NH2) PMIC

The Nowi NH2 is a high-performance energy harvesting solution for low power applications owing to its state-of-the-art DC-DC converter design. The boost charger is designed to work efficiently in the range of microwatts (μW) to milliwatts (mW) of power. The NH2 PMIC is designed to extract the low power output of an energy harvesting source, for instance, photovoltaic (solar), to charge a rechargeable battery that powers the remote control. It can effectively extract power from low voltage output solar cells, outputting voltages down to 1.1 Volt minimum (DC_IN), and boost these low voltages by a factor of 2 to 2.3 with conversion efficiency up to 80 %.

NowiI's advanced maximum power point tracking block (MPPT) is completely self-programmable and uses a flexible algorithm to find the exact maximum power point delivered by the harvester. Moreover, the MPPT circuit can detect the maximum power point delivered in less than one second resulting in maximal efficiency in various environments where energy can rapidly change over time.

This performance is combined with an ultra-small PCB-assembly footprint, 10-15 times smaller than alternative products, thanks to the inductor-less design approach, which allows saving up to 94% of BOM cost by reducing the number of external components needed. These features make Nowi's solution highly adaptive and most suitable for achieving Plug and Forget™ smart remote controls.

7. Conclusion

This application note presents a feasibility study on using energy harvesting for powering smart TV remote controls. The consumption of a remote control varies depending on the communication approach used, as well as the features supported. In this study, the daily energy budget of three different remote controls was measured and analyzed where the average daily consumption varies between ≈ 4 Joules for a BLE remote control and up to ≈ 7 Joules for an IR remote control.

The first estimations showed the possibility of powering a remote control using compact PV cells that can fit into the limited surface area of a remote control combined with Nowi's boost converter PMIC (NH2) that can guarantee continuous charging of the batteries used in smart TV remote controls.