A System on Chip for Energy Harvesting and Wireless Power Transfer

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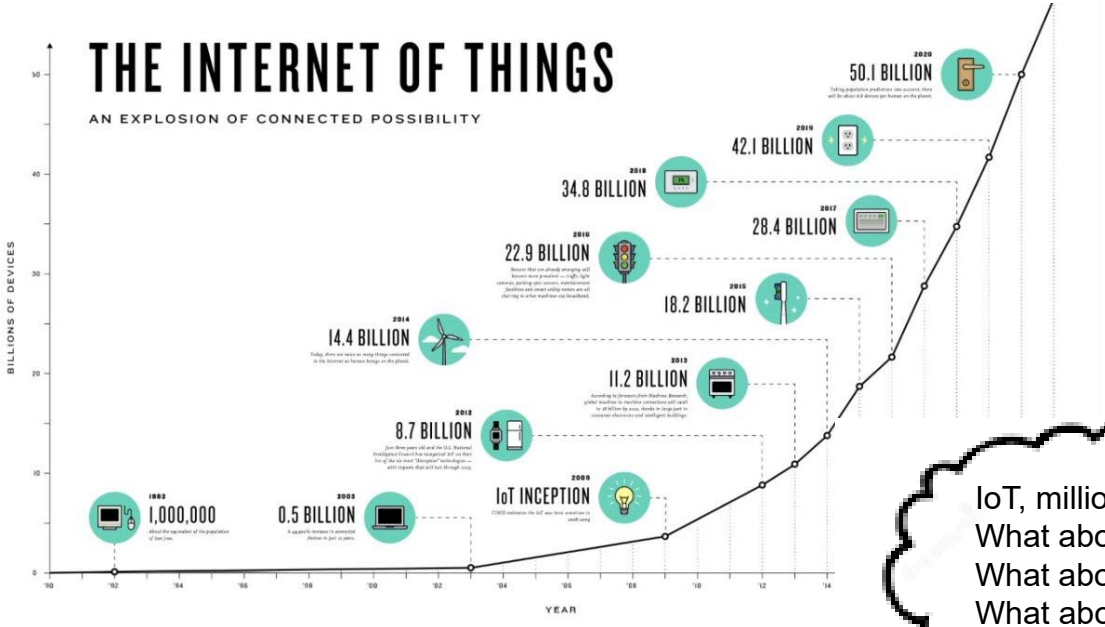
Presentation Outline

- Motivation
- Introduction
- Overview
- System Description
- Design Notes
- Experimental Results
- Conclusions

Impact of Energy Harvesting and WPT on IoT



IoT node

IoT, millions of nodes !!!
What about Batteries ???
What about maintenance?
What about costs ?

To be ubiquitous, IoT needs sensor technology that is:

- Maintenance Free
- Inexpensive enough
- Wireless
- Able to address a large number of sensors

WPT and Energy Harvesting Solutions:

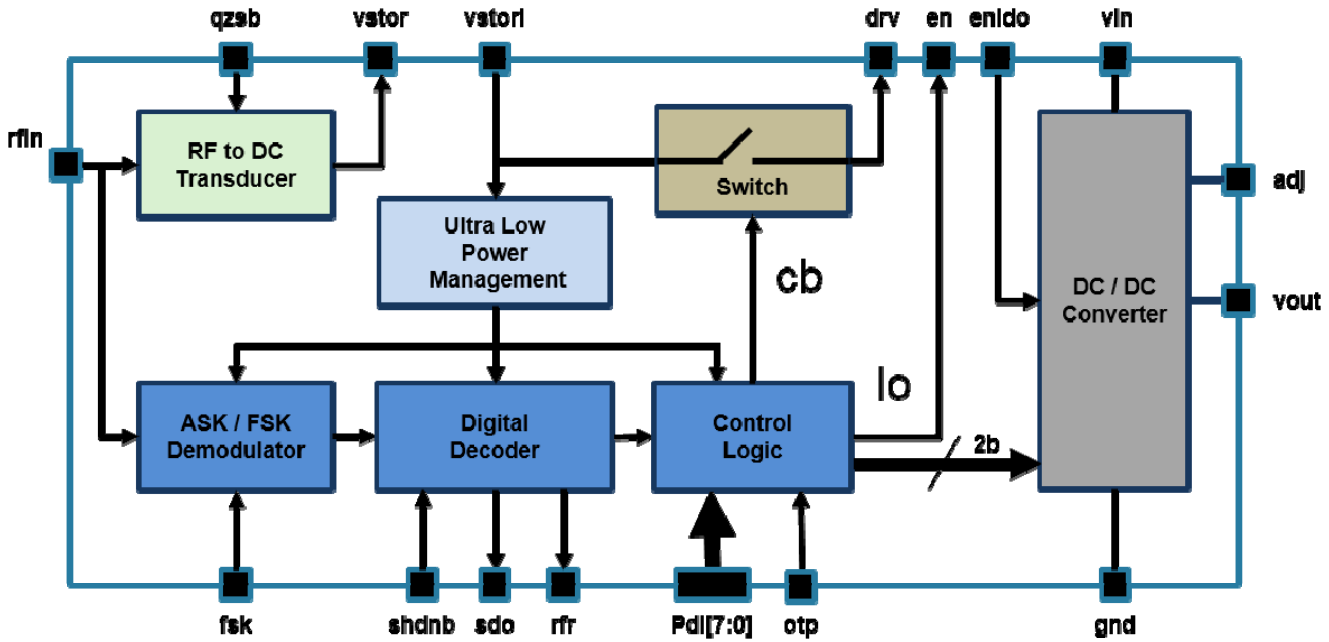
- **Battery Life extension**
- **Wireless Battery Charger**

Battery Driven Devices:
- **IoT**
- **WSN**

- **Avoid Batteries**

Battery Free Devices:
- **IoT**
- **WPSN**

A Self-Powered RF IC for Energy Harvesting



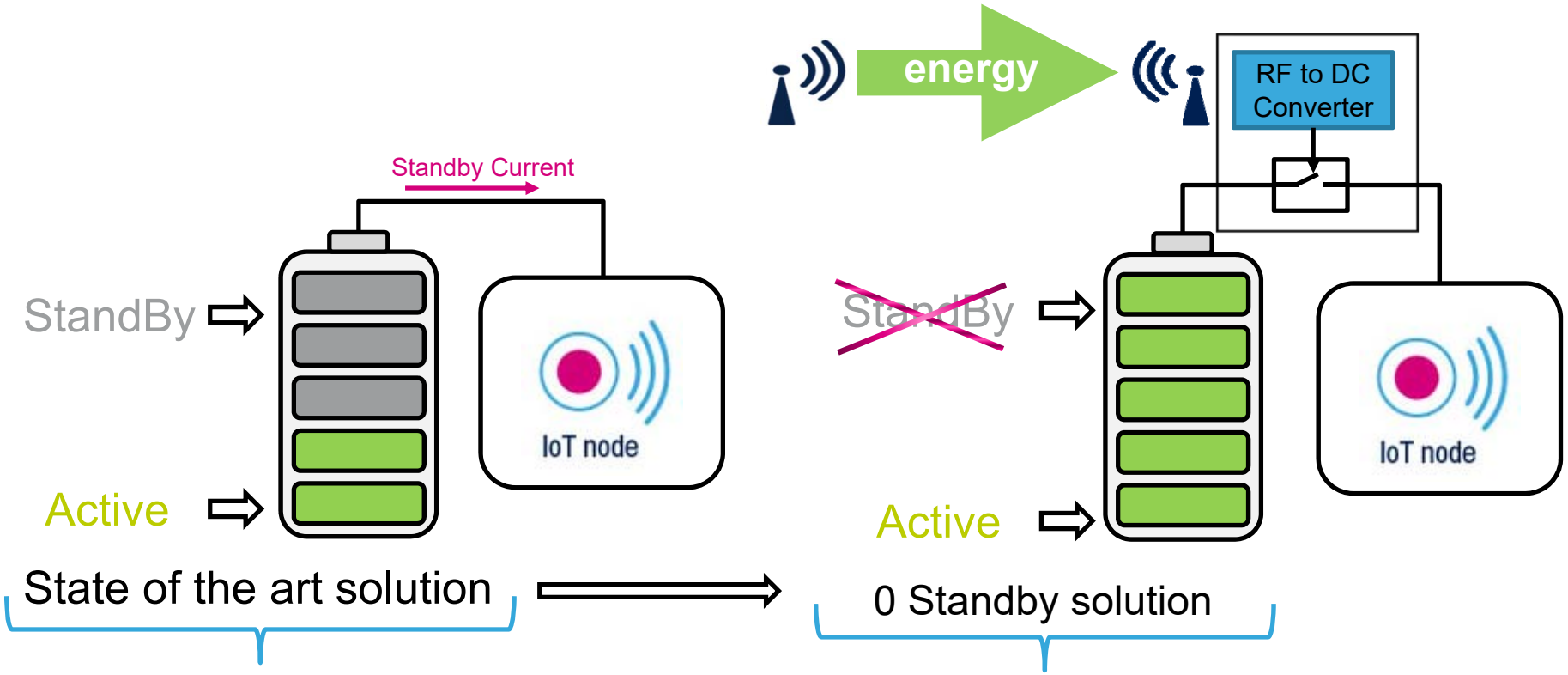
Ultra low power management (100nA quiescent)

RF-to-DC Sensitivity -20 dBm @ 433MHz
-18 dBm @ 900MHz
-10 dBm @ 2.4 GHz

RF-to-DC Efficiency 45% @ -10 dBm @ 900 MHz

- Ultra Low Power management (100nA quiescent current)
- Addressable Device
- ASK and FSK data modulation
- Manchester and FM0 Codification supported
- ETSI & FCC Compliant
- Digitally programmable embedded LDO
- Dynamic configuration for LDO output voltage
- Demodulated data available through the sdo
- 433 MHz and 900 MHz carrier frequency

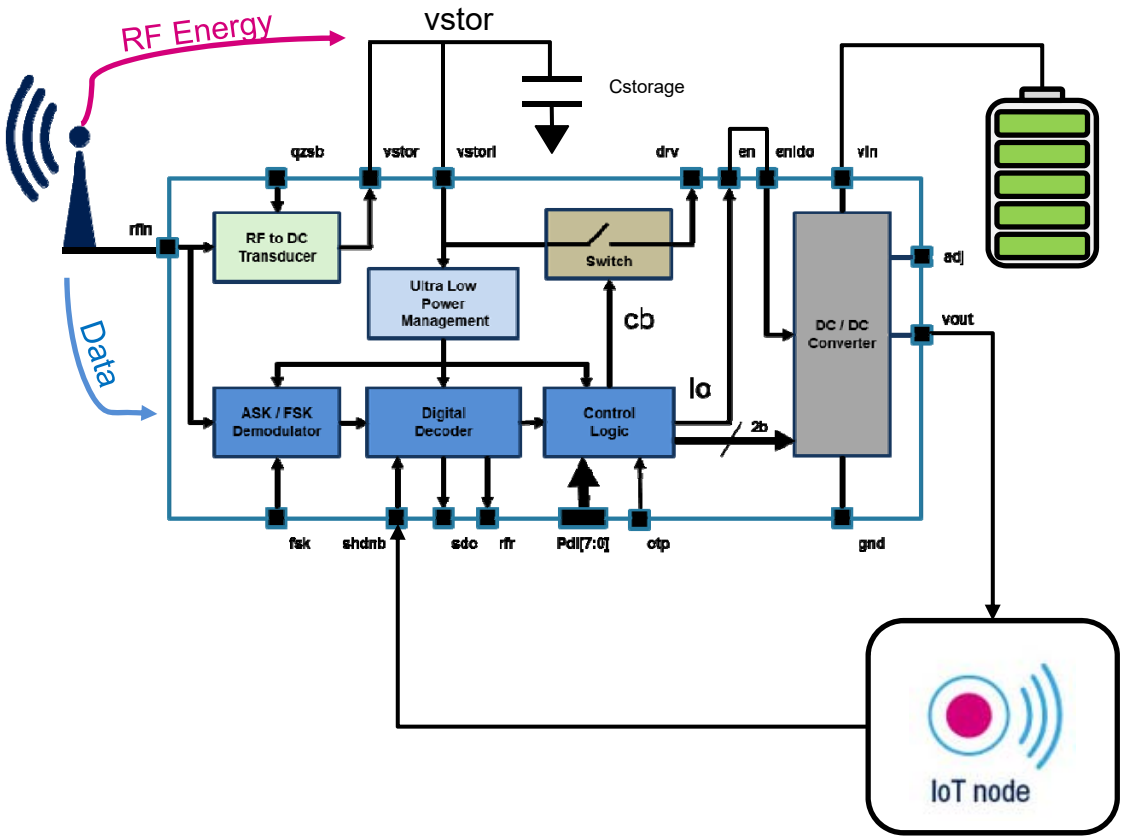
Nulling Stand-by using Wireless Power Transfer

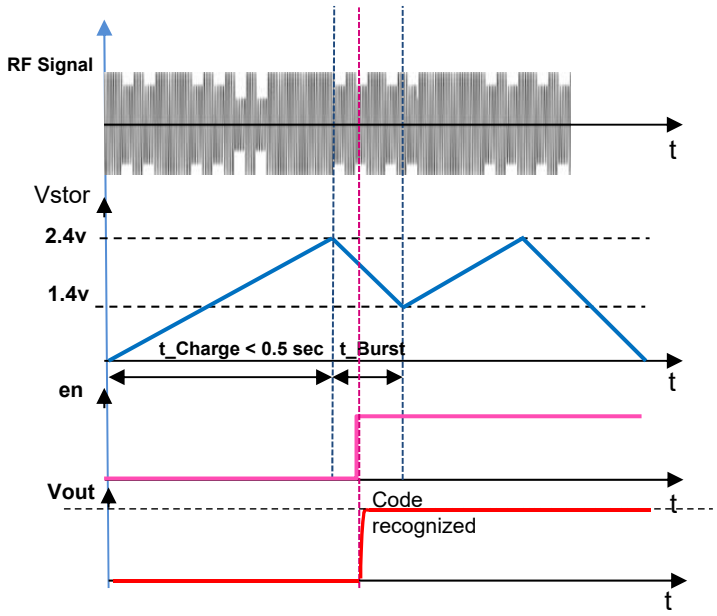


- Event Driven Wake Up
- Null Standby Power Consumption
- Extend Battery Life

Nulling Stand-by in battery powered appliances

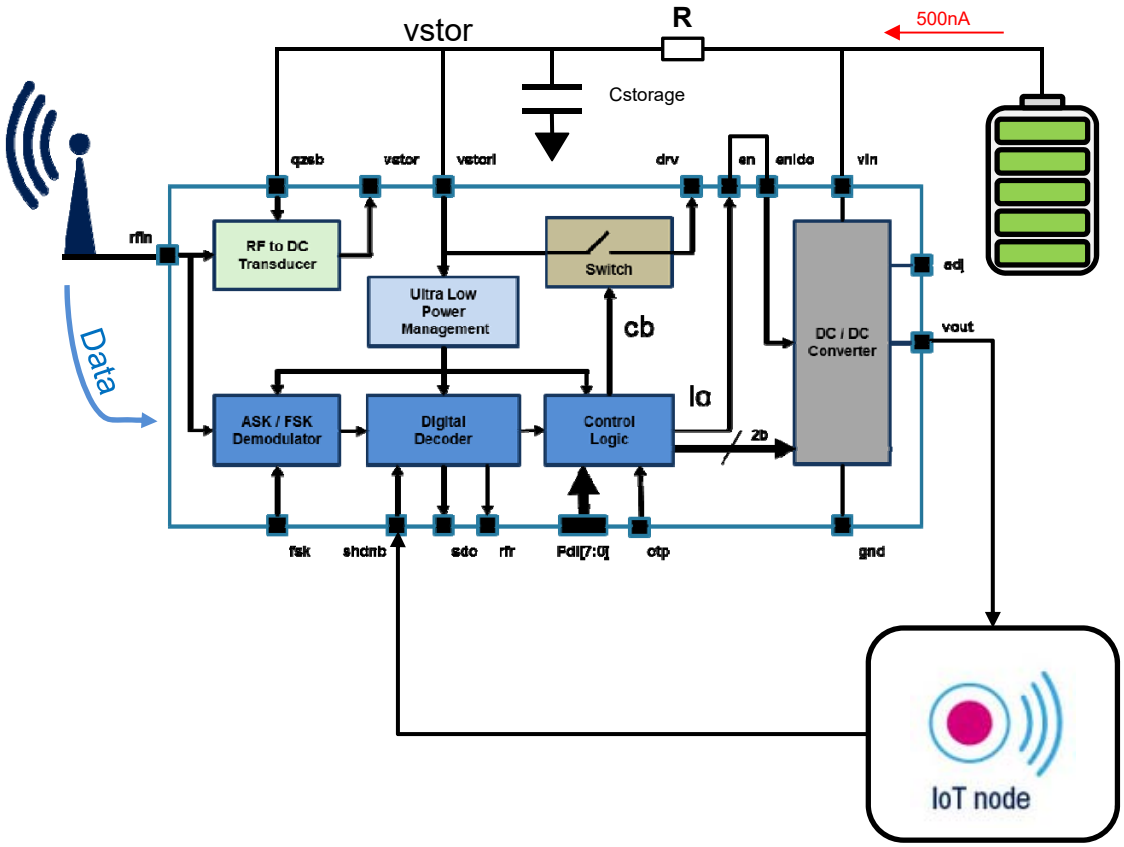
- **No Static Current Consumption, d <= 7 mt (free-space) @ Pt=0.5 Watt**

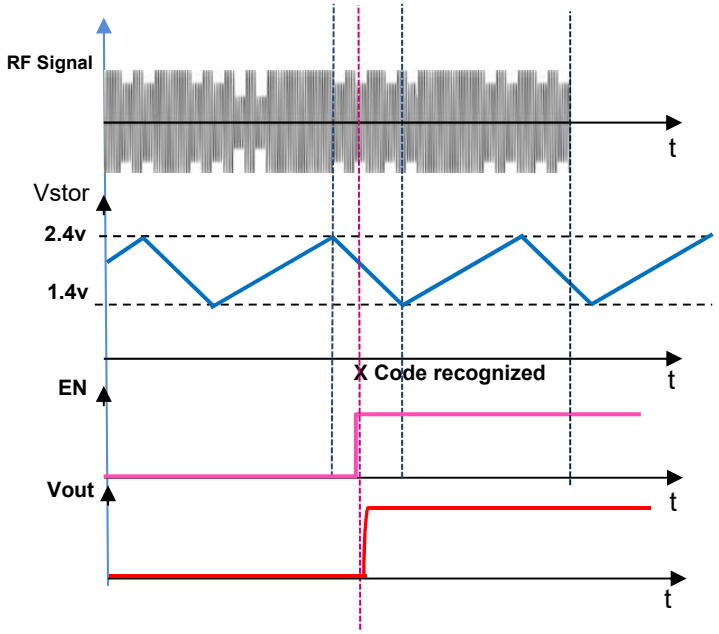




Quasi Nulling Stand-by in battery powered appliances

- **Static Current Consumption <= 1uA, d <= 65 mt (free-space) @ Pt=0.5 Watt**





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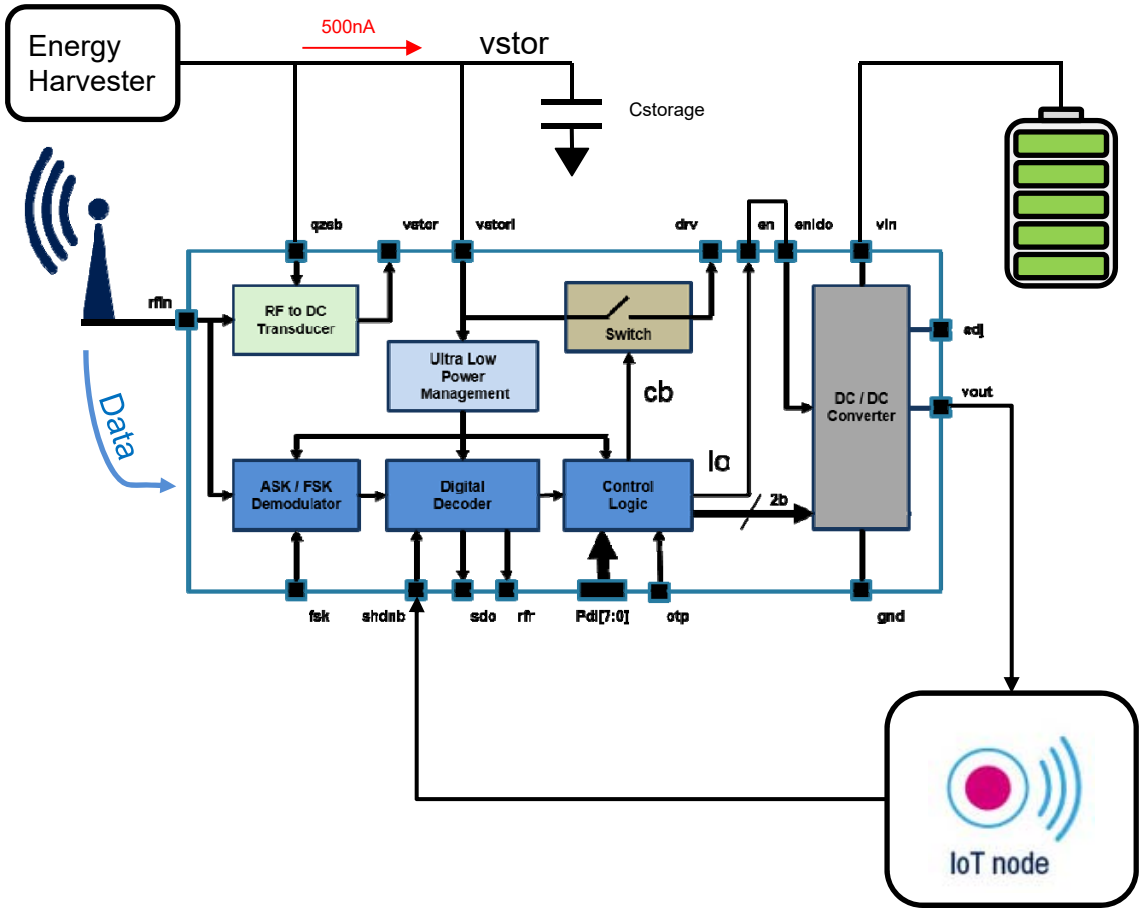

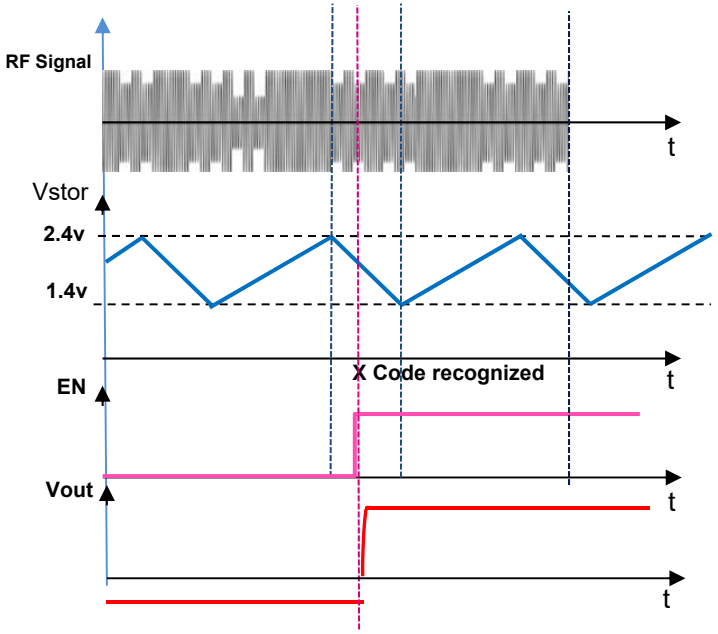

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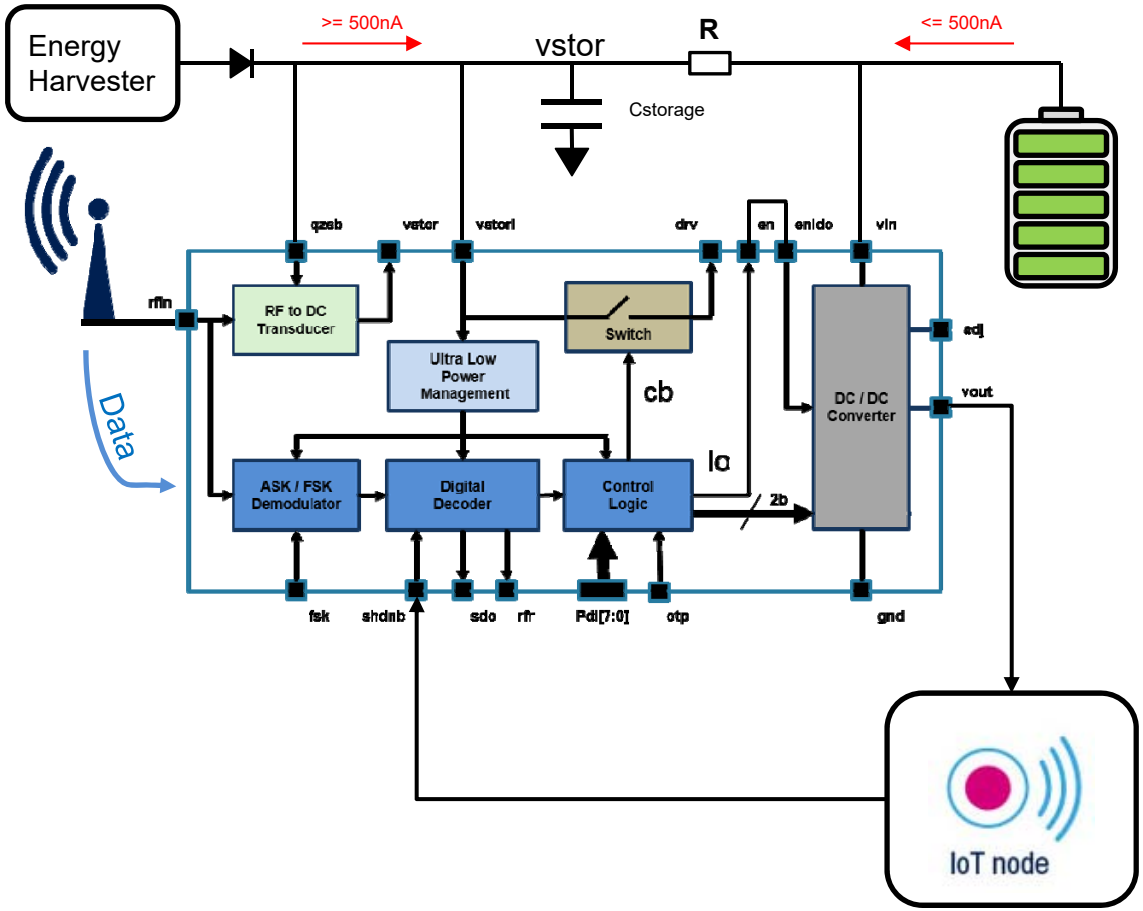
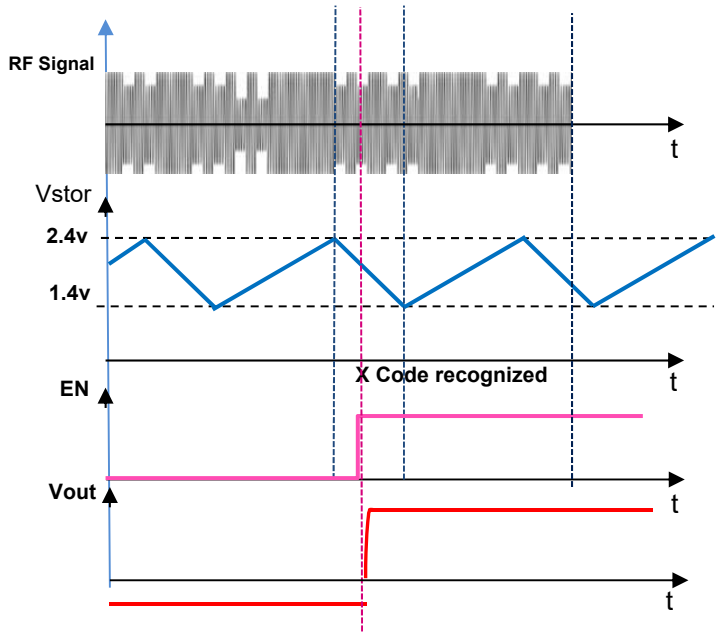




Nulling Stand-By in Europe would imply:

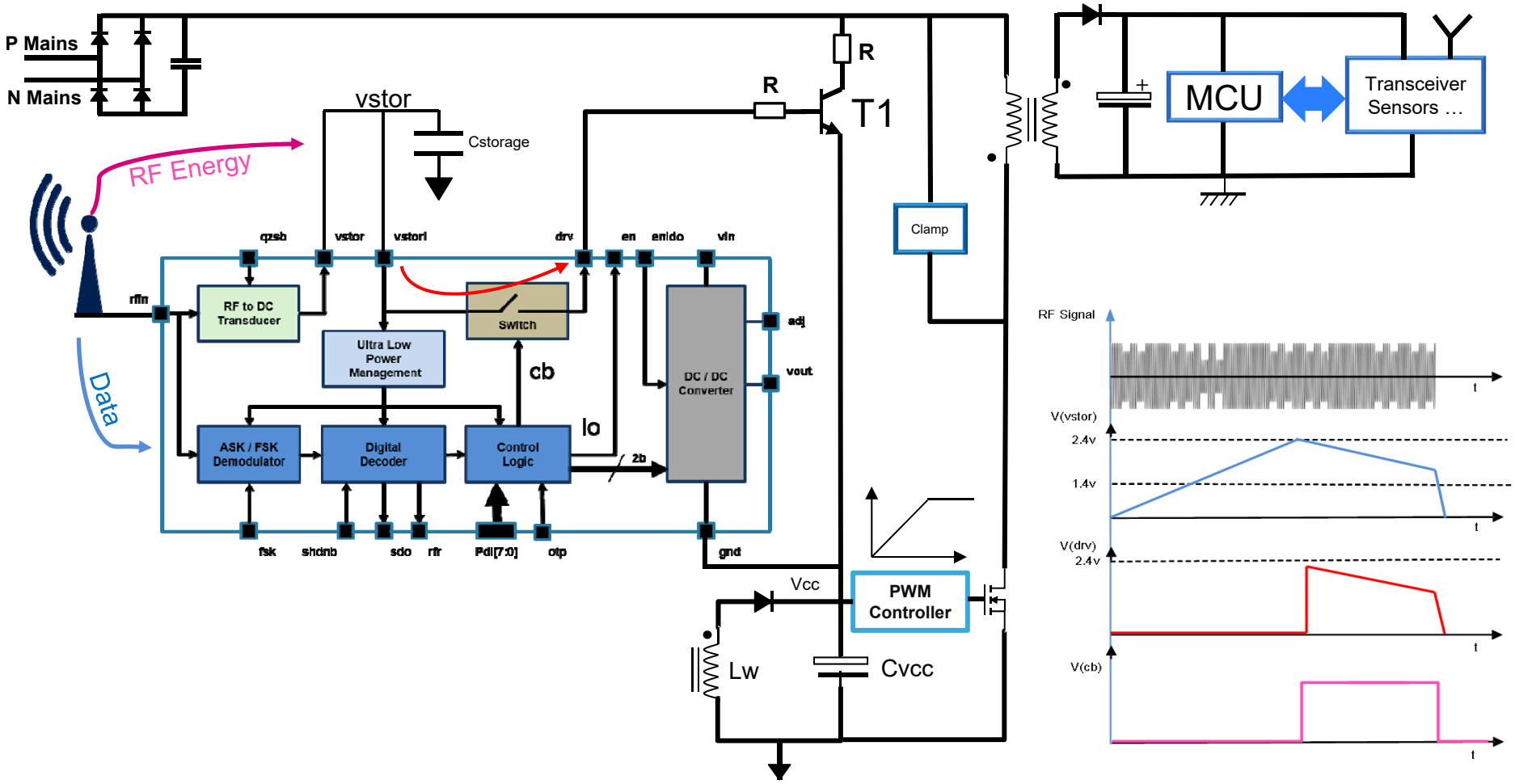
- Saving 43 TWh / Year 4 Nuclear Power plants of 1.6 Gwatt

- 19 Mtons of CO_2 / Year

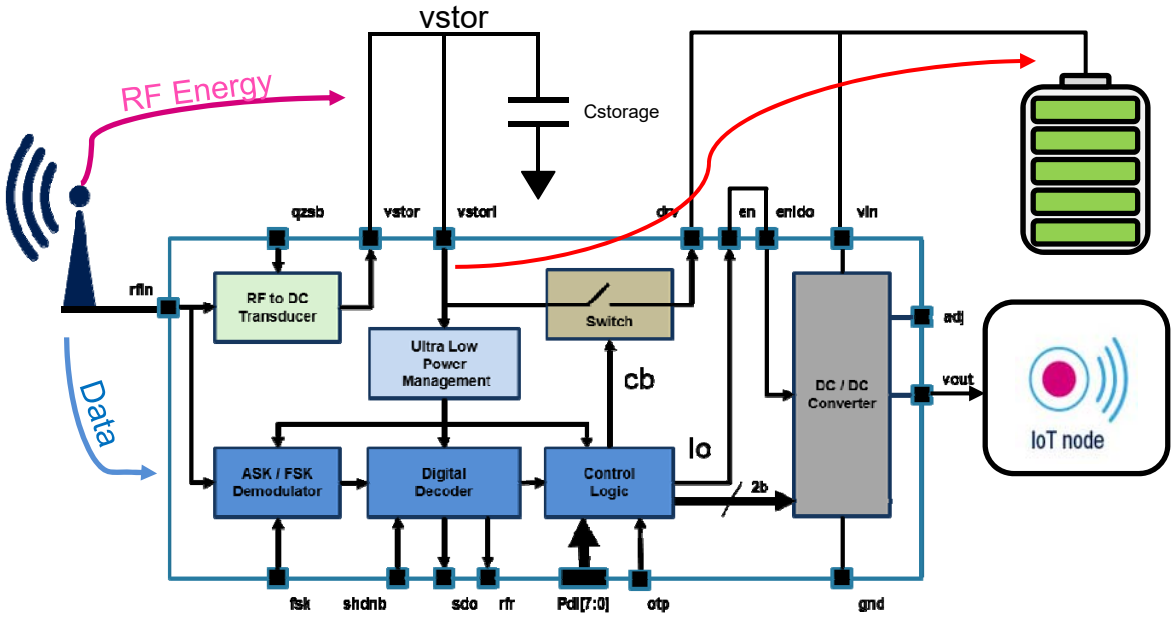
- 10 Million Euro / Year

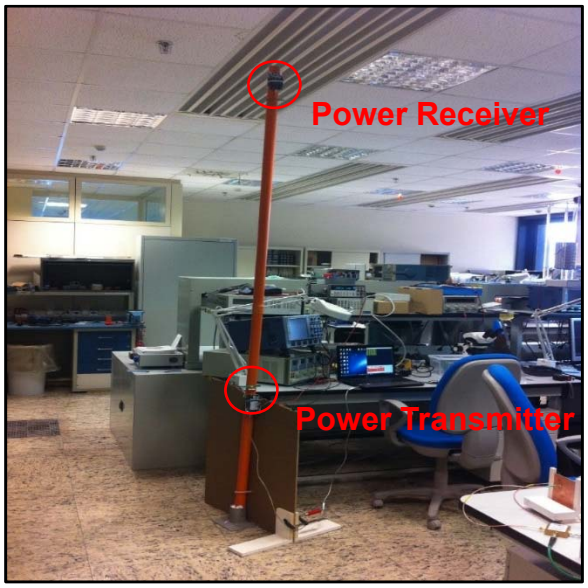
- 11% of Domestic power consumption

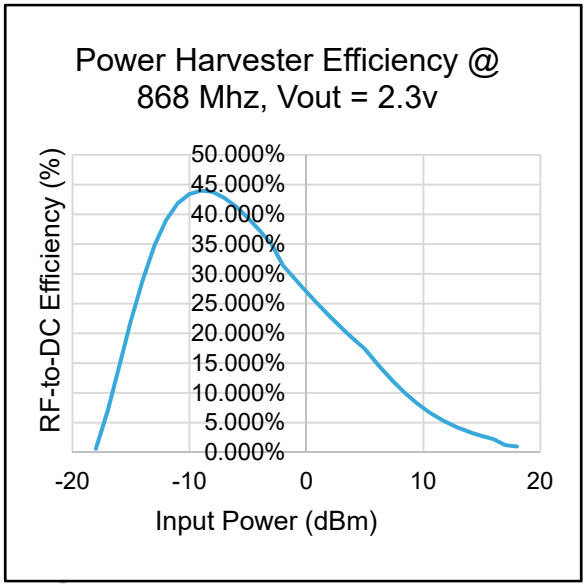
Nulling Stand-by in AC powered appliances

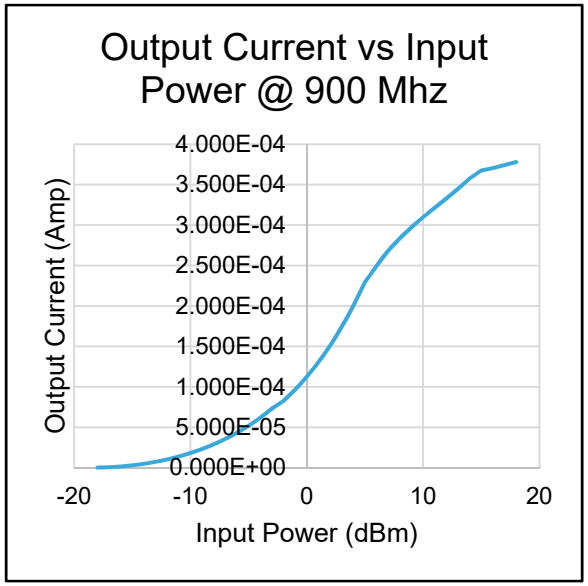


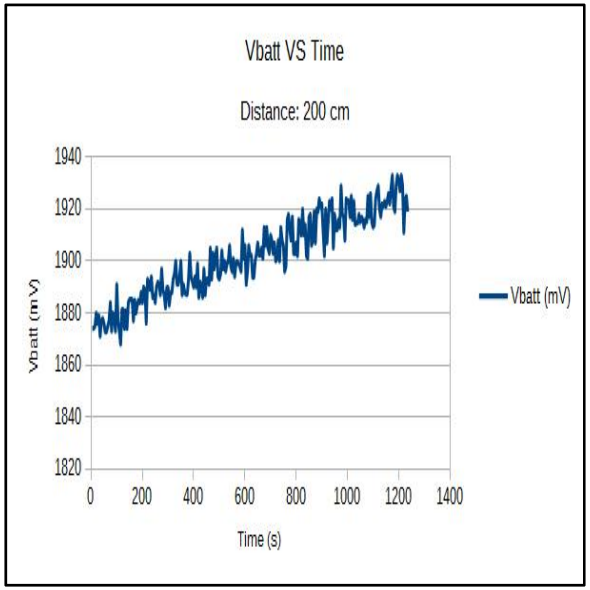
Over the distance Wireless Battery Charger



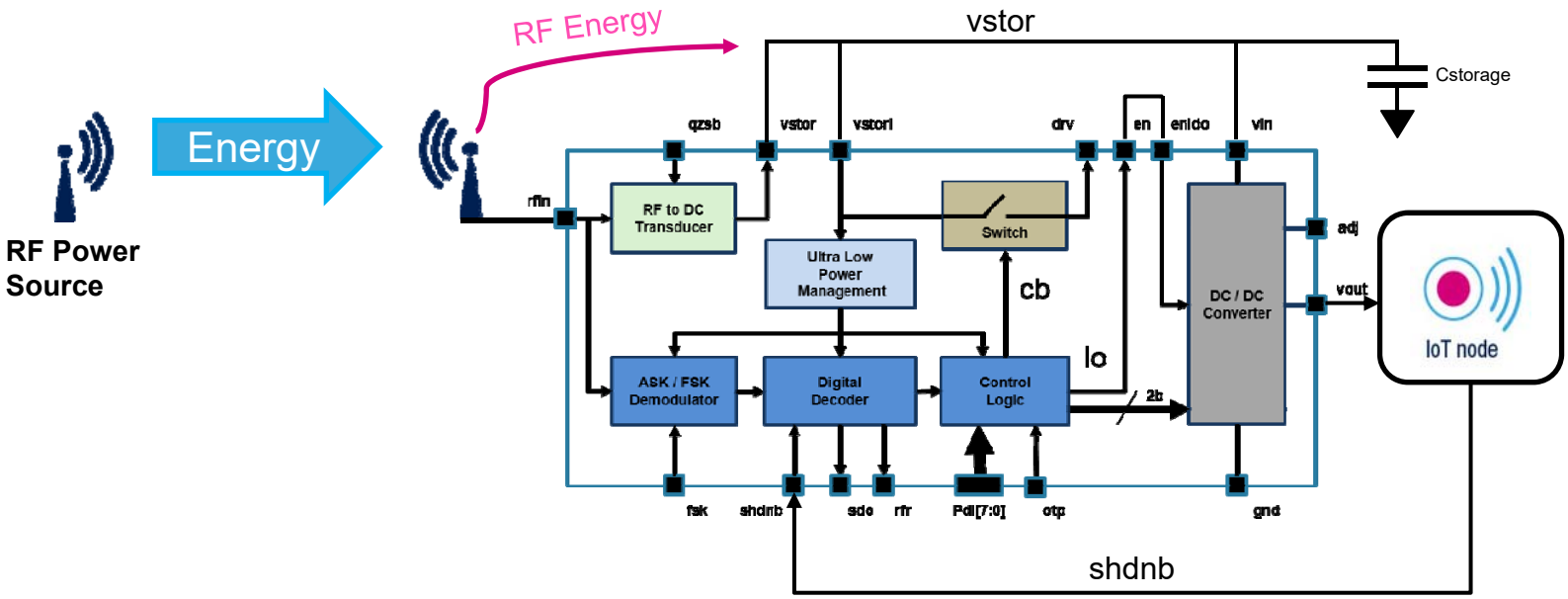


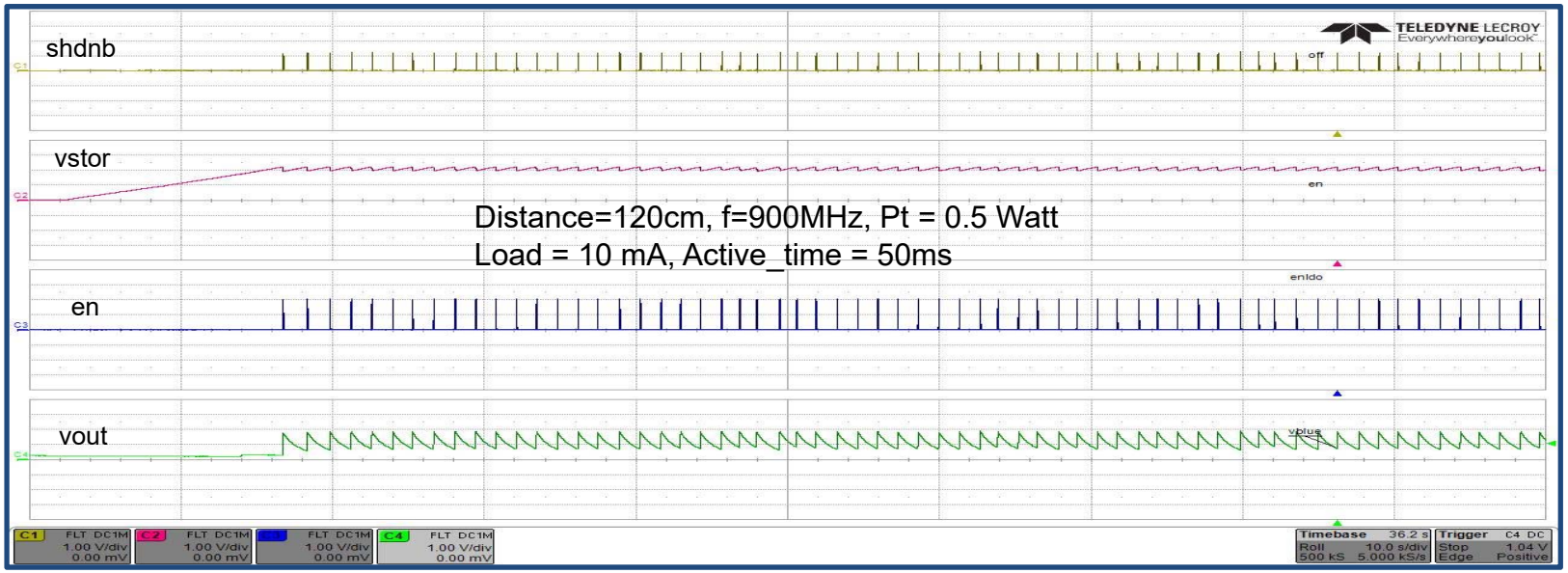






Powering Battery-Free Systems with WPT





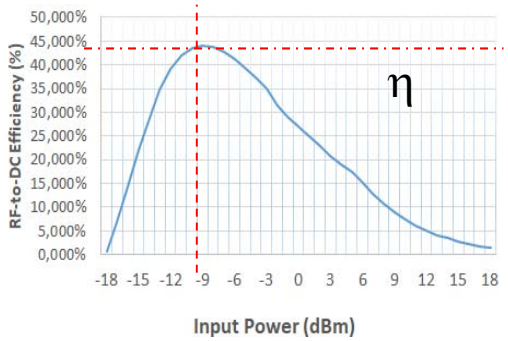
Powering Battery-Free Systems with WPT

Design Notes

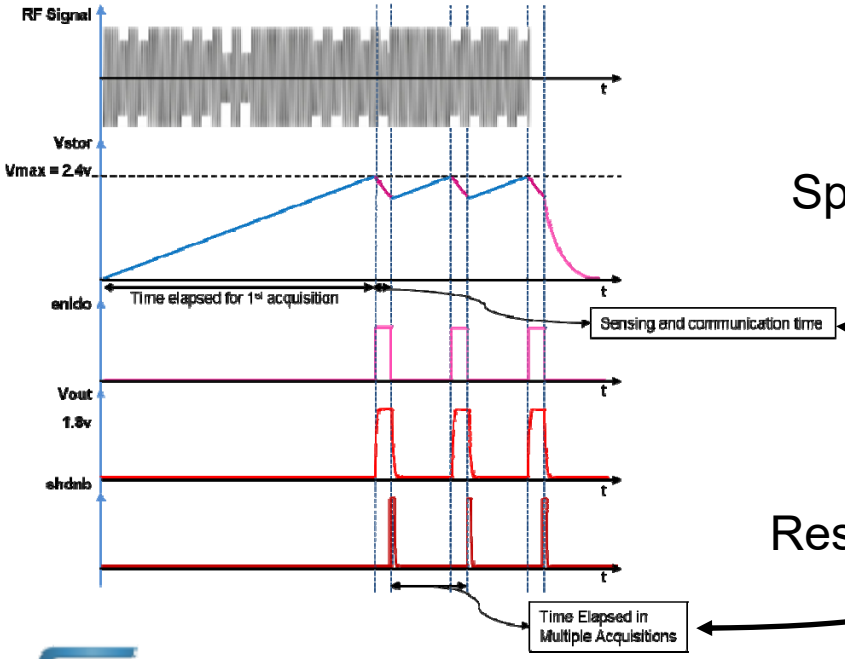
Free space

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi R}\right)^2 \qquad P_{Cstorage} = \eta\, P_R$$

$$f = 900\ MHz\ ;\ G_T = G_r = 1 \qquad P_T = 0.5\ Watt\ /\ 27\ dBm$$



$$if:\ R = 2m \rightarrow P_R = -10.5\ dBm \rightarrow \eta = 42\ \% \rightarrow P_{Cstorage} = 37\mu W \rightarrow \mathbf{Icharge = 20\mu A}$$



Specs

$$\text{Iload} = 10\ \text{mA}$$
$$T_{active} = 50\ ms$$
$$Vdrop_{max} = 2.4\ - 2.0 = 0.4\ \text{V}$$
$$Cstorage = 1\ \text{mF}$$

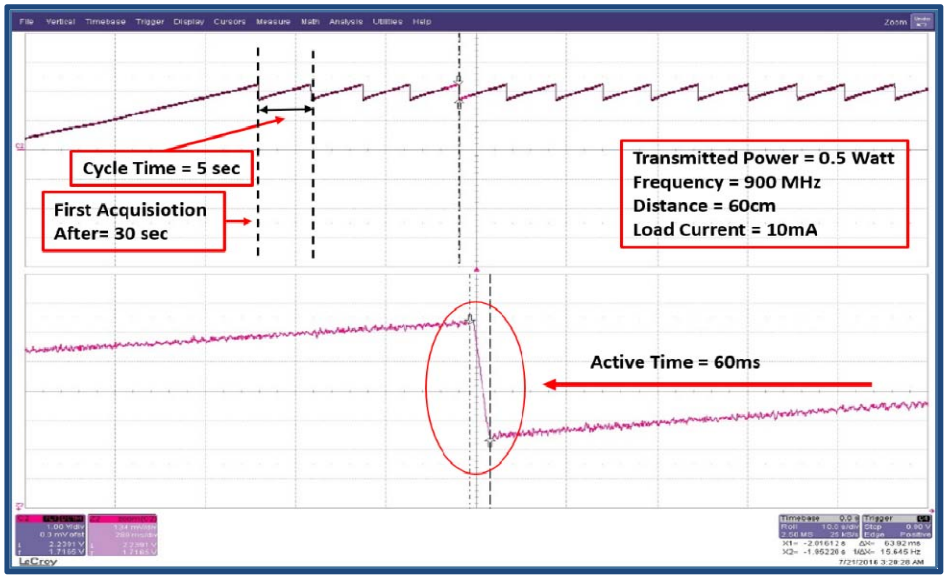
Results

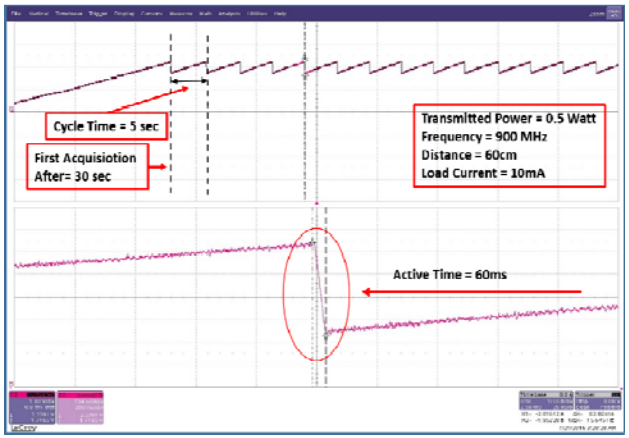
$$T_{facq} = 1mF * \frac{2.4\ v}{20\mu A} = \mathbf{120\ s}$$

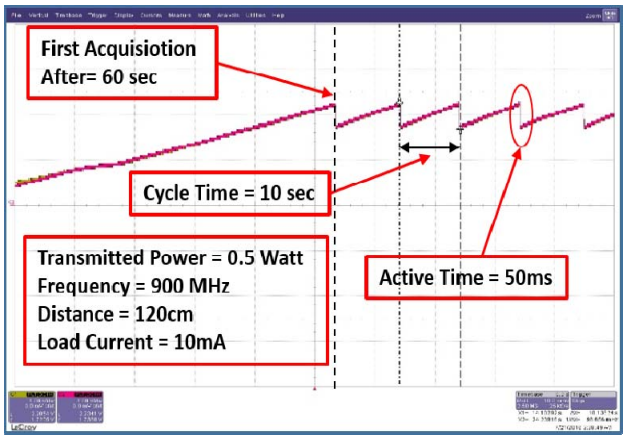
$$T_{macq} = 1mF * \frac{0.4v}{20\mu A} = \mathbf{20\ s}$$

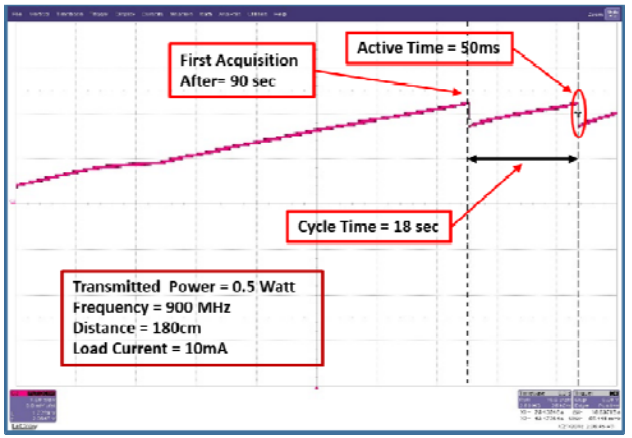
Powering Battery-Free Systems with WPT

Experimental Results

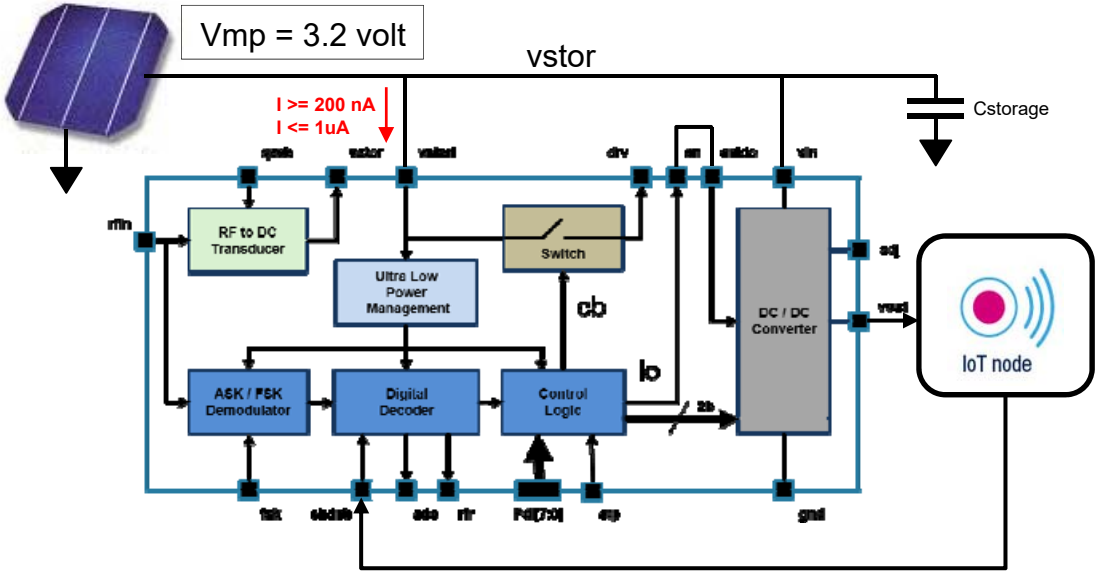


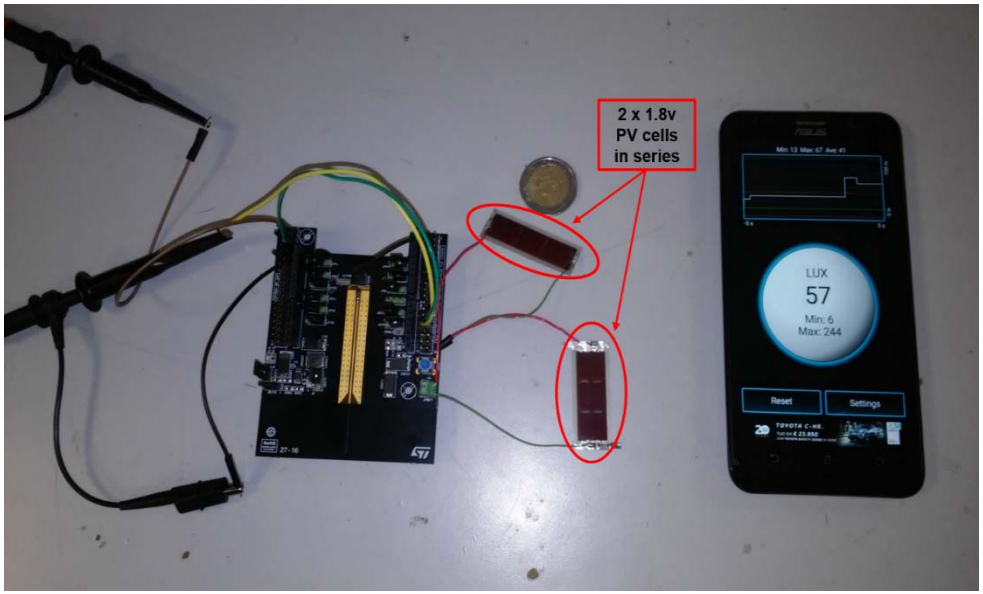


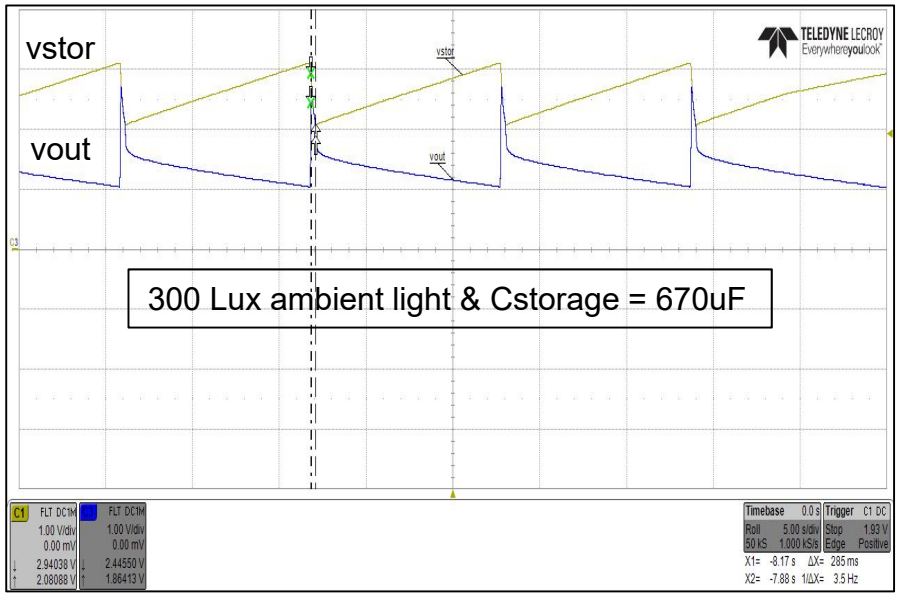




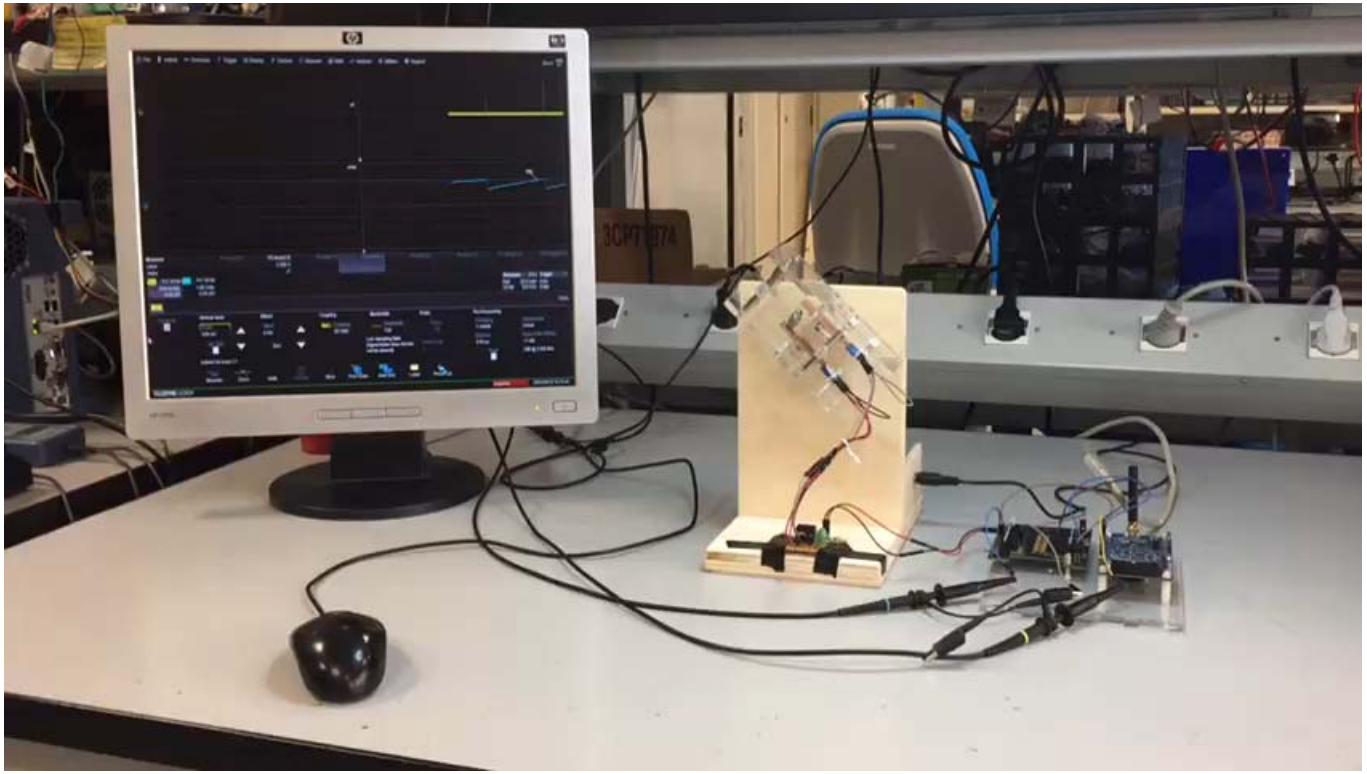
Powering Battery-Free Systems with PV cell







Powering Battery-Free Systems with Vibrations



Conclusions

RF Energy Harvesting is still far to be effective

RF WPT (Wireless Power Transfer) is an effective way to increase the battery life of remotely controlled devices

RF WPT (Wireless Power Transfer) is an effective way to increase to reduce World Wide Energy consumption

Efficient RF WPT can be a convenient way to recharge batteries over the distance reducing maintenance costs in WSN

Efficient RF WPT allows Battery-Free wireless sensor nodes in low duty cycle sensors

Energy Harvesting in combination with efficient power management IC solutions allows no mainteinance Set-and-Forget sensors