EnerHarv 2022

PSMA International Energy Harvesting Workshop • April 5-7, 2022 • Raleigh, NC, USA

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EnerHarv 2022 Workshop:

An Ultra-Low-Power MPPT technique for systems powered through Energy Harvesting and Wireless Power Transfer.

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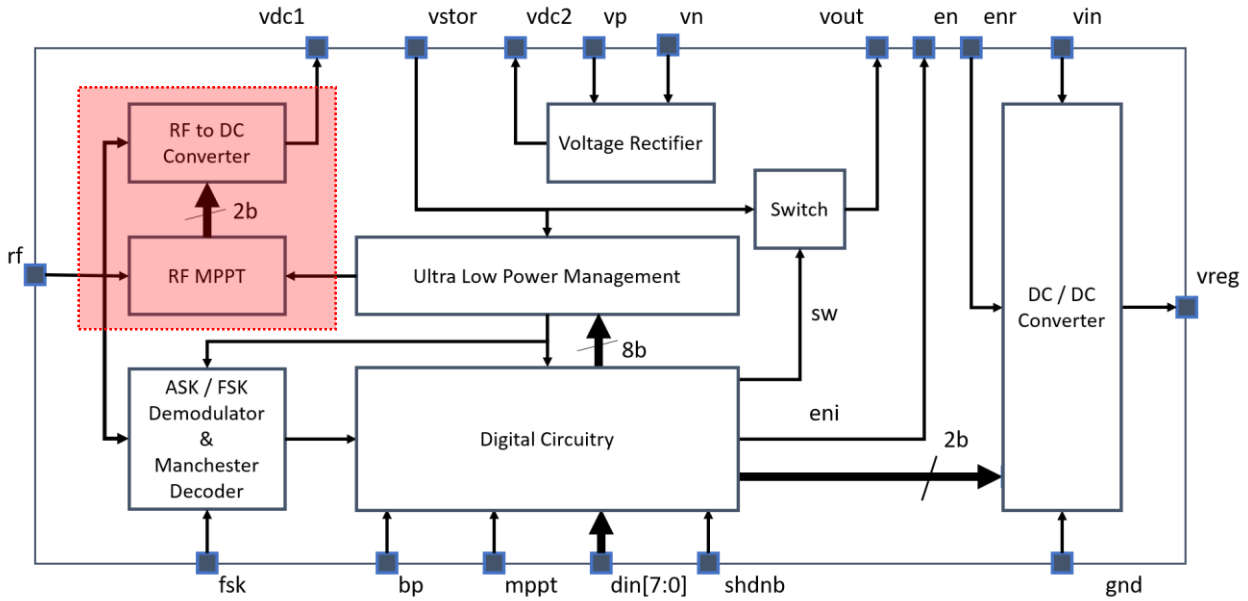
life.augmented

Tuesday, April 5, 2022

OVERVIEW

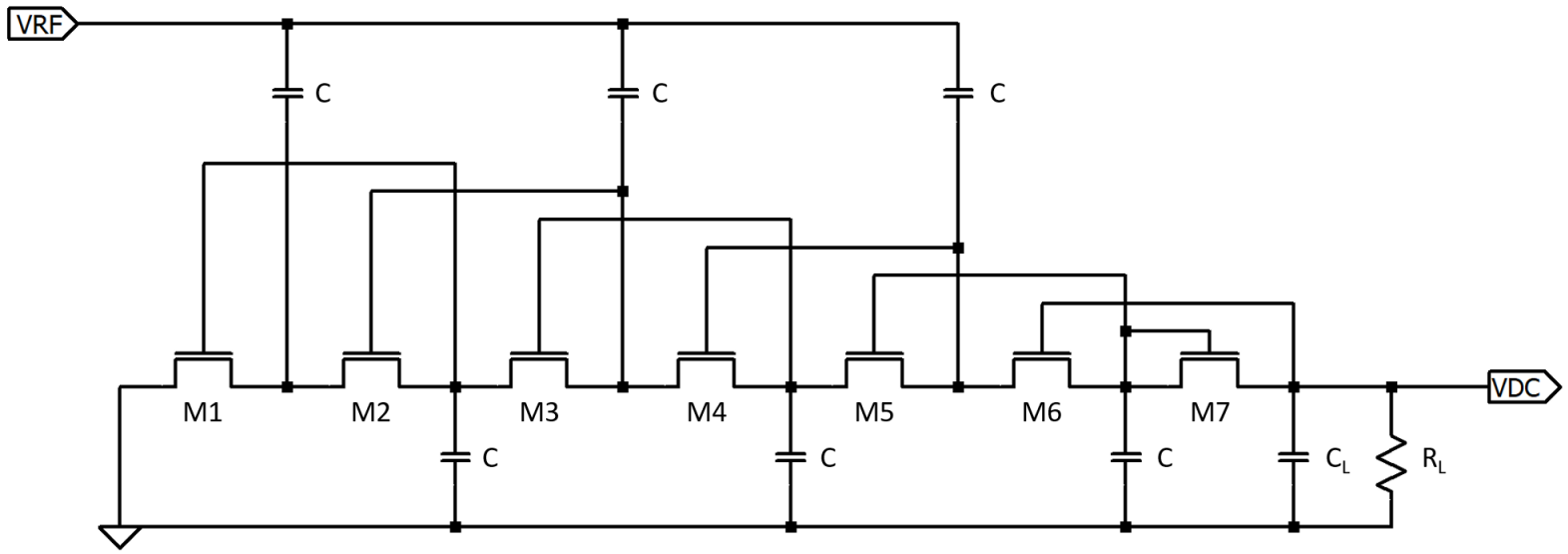
- **A SoC for EH and WPT**
- **MPPT for Ultra Low Power Systems**
- **Conclusions**

A Self-Powered SoC for EH and RF WPT



Ultra low power management (100 nA quiescent)	• Ultra Low Power management • MPPT • Addressable device • ASK and FSK data modulation • Manchester Codification supported • ETSI & FCC Compliant • Digitally programmable embedded DC/DC converter • 433 MHz, 868 MHz and 2.4 GHz carrier frequency
RF-to-DC Sensitivity -23 dBm @ 433 MHz -22 dBm @ 868 MHz -21 dBm @ 2.4 GHz	
RF-to-DC Max Efficiency 55% @ 868 MHz	

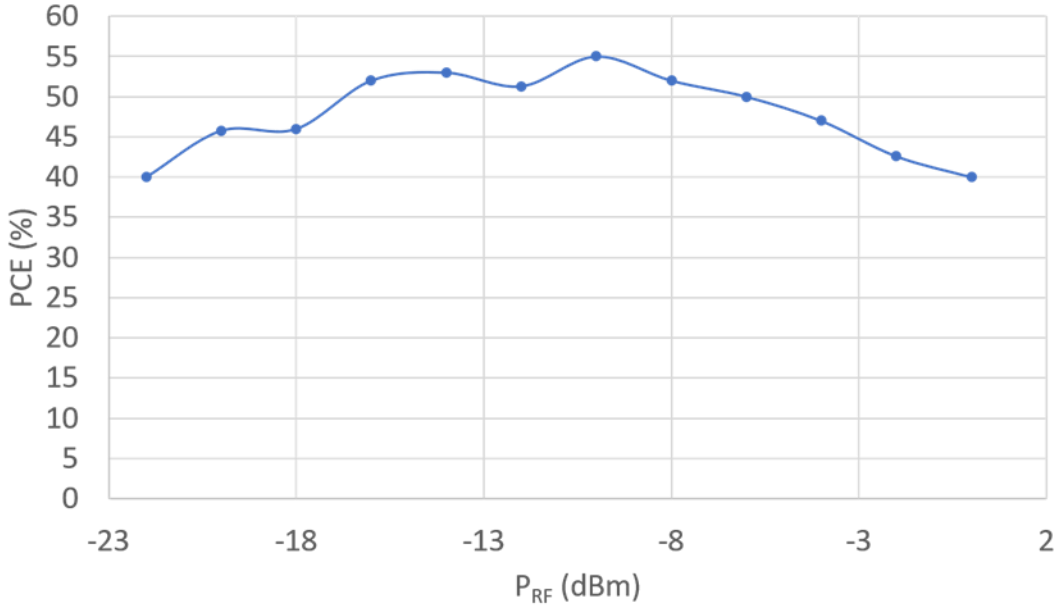
RF to DC Converter



- Six stage NMOS Dickson Rectifier
- Max DC Output Voltage 2.5 V @ I_{load} = 1 uA
- Min Output Power = 2.5 uWatt (-26 dBm)
- Voltage Threshold compensation

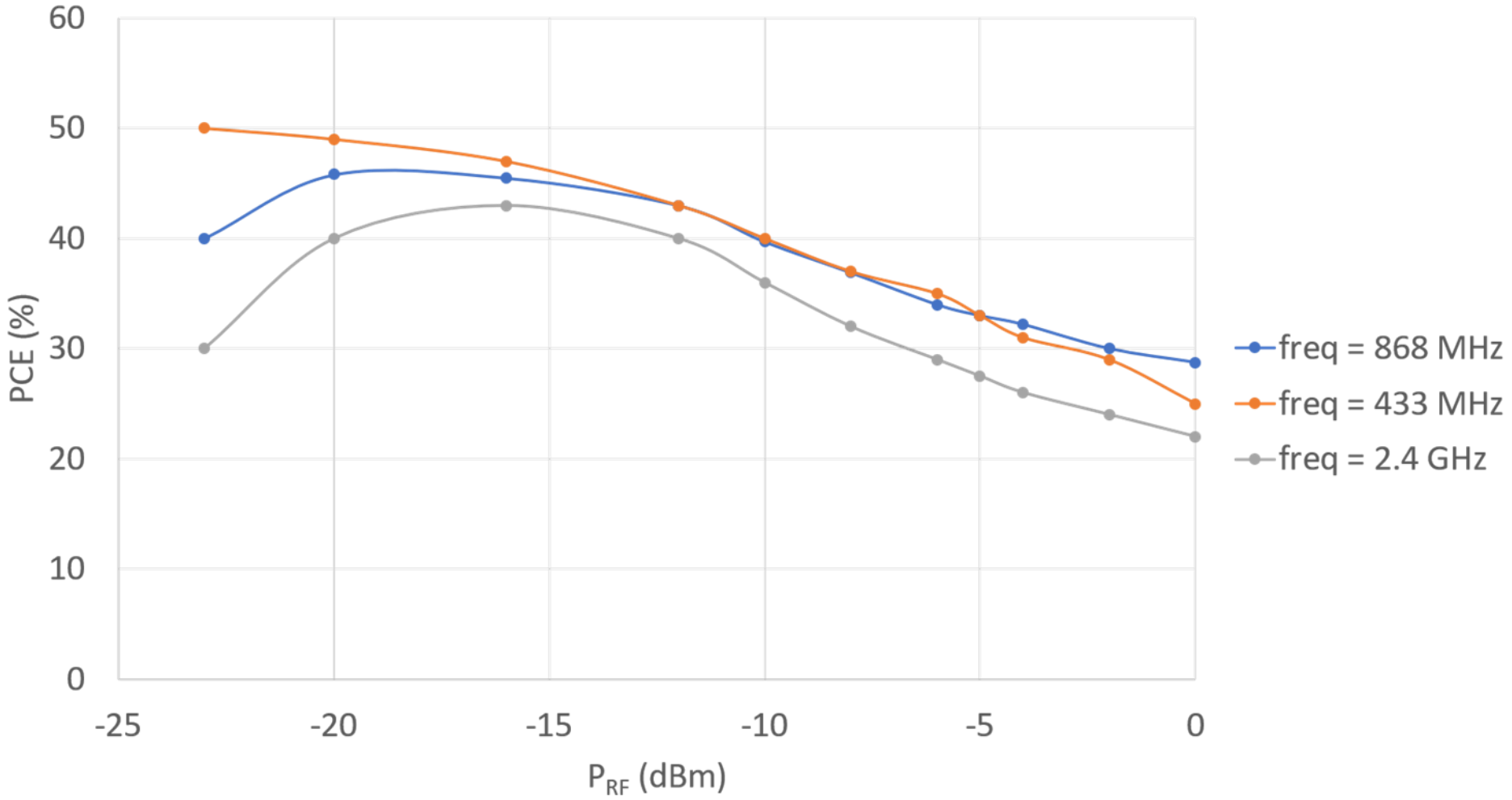
RF to DC Converter Performance

Freq	P_{RF_min}(dBm)	P_{RF_min}(µW)	P_{DC_min}(µW)	PCE at P_{RF_min}
433 MHz	-23	5	2.4	50%
868 MHz	-22	6.3	2.4	40%
2.4 GHz	-21	7.9	2.4	35%

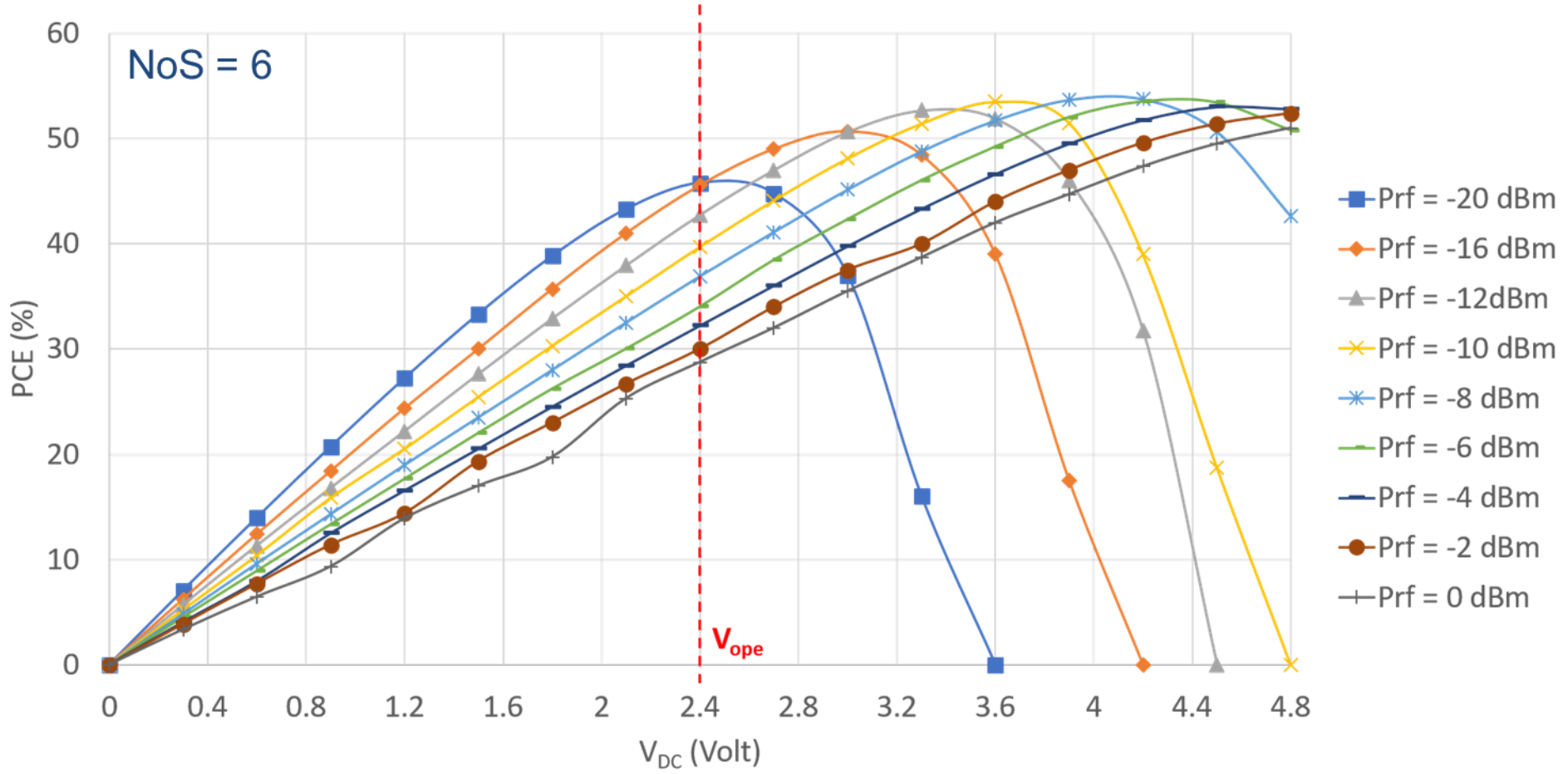


RF to DC PCE characterization results at 868 MHz.

RF to DC Converter with no MPPT

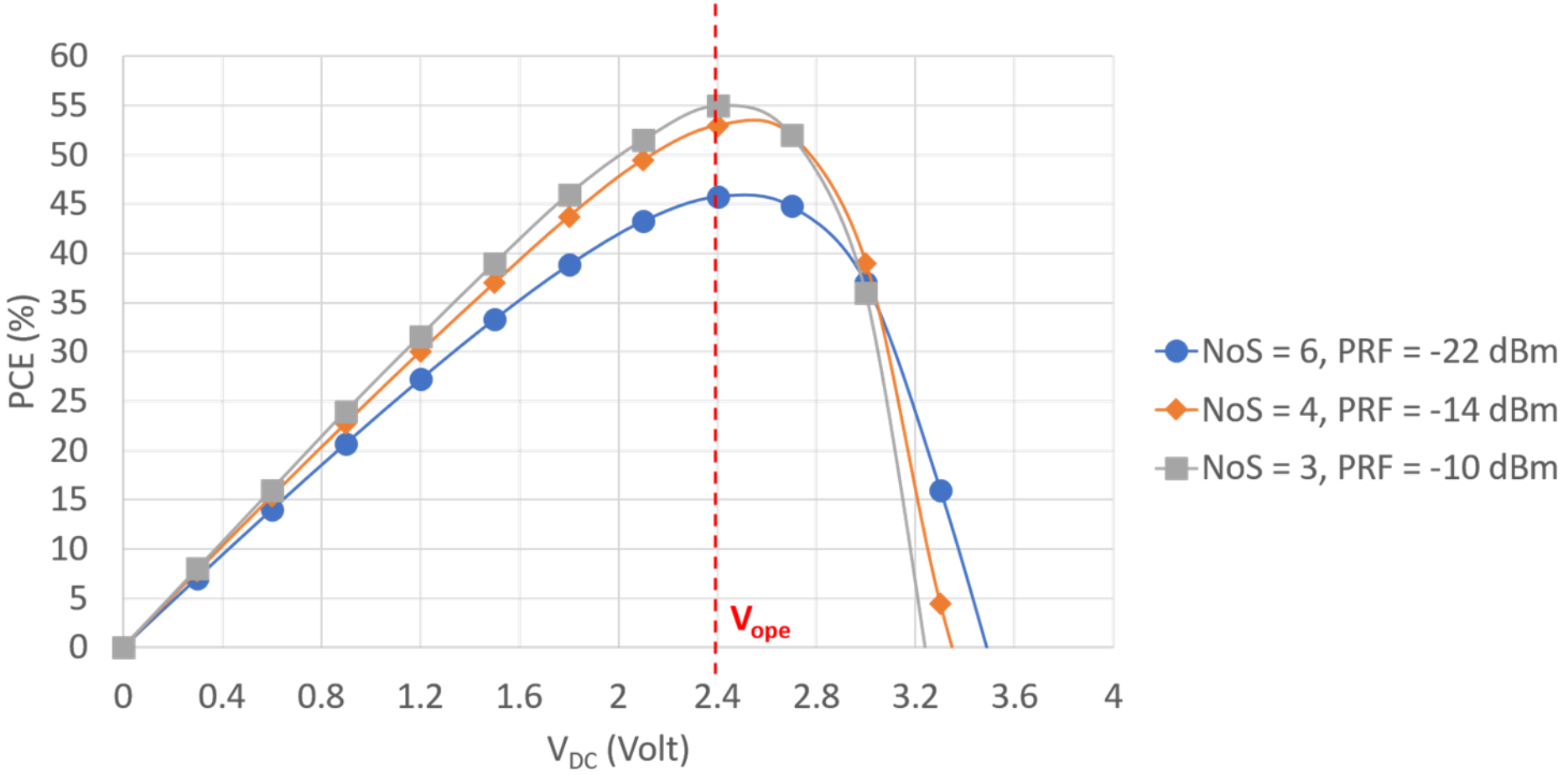


RF to DC Converter with no MPPT



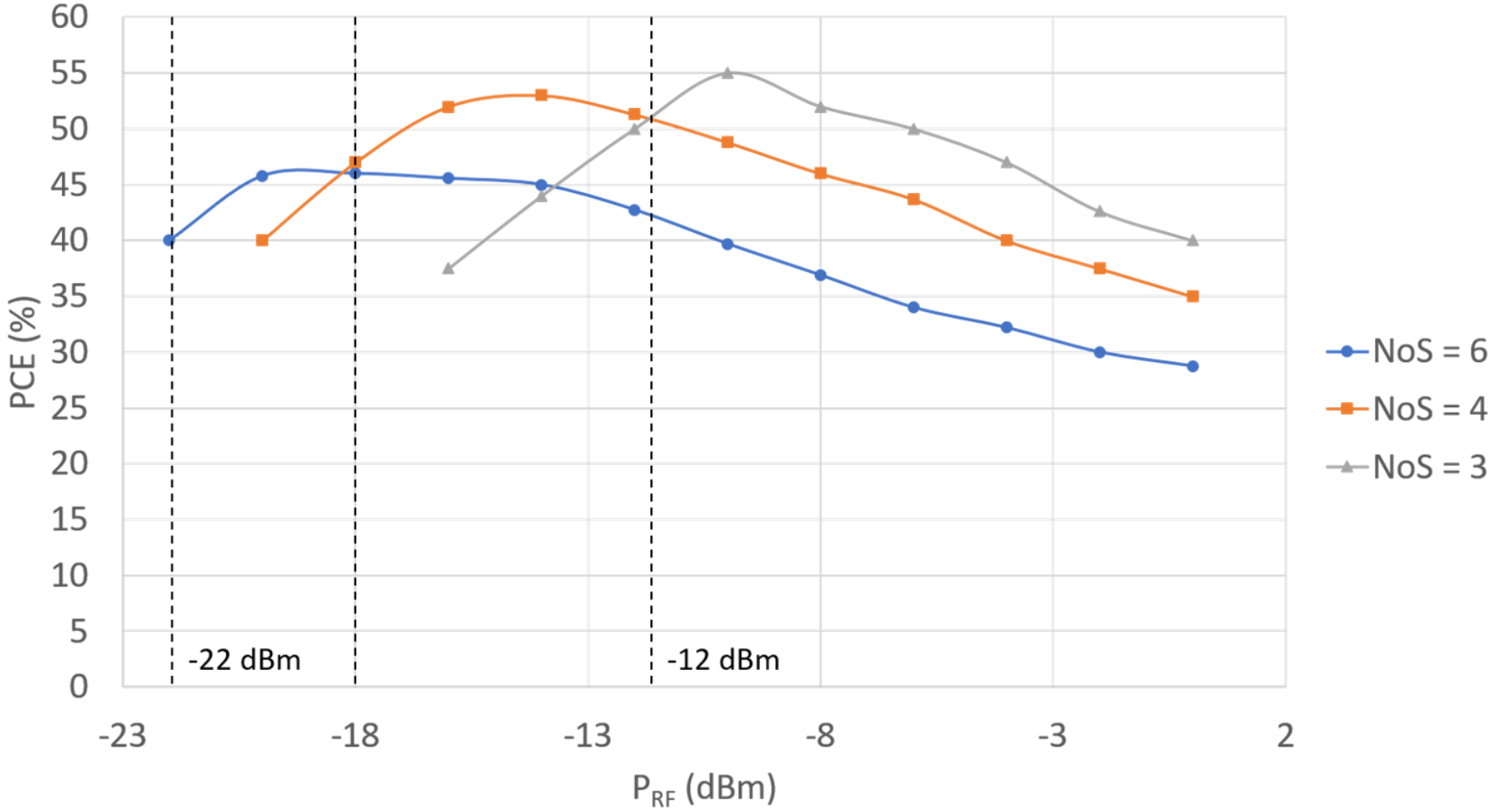
NoS = Number of Stages of the RF to DC Converter.
RF to DC converter with no MPPT at 868 MHz.

RF to DC Converter / MPPT



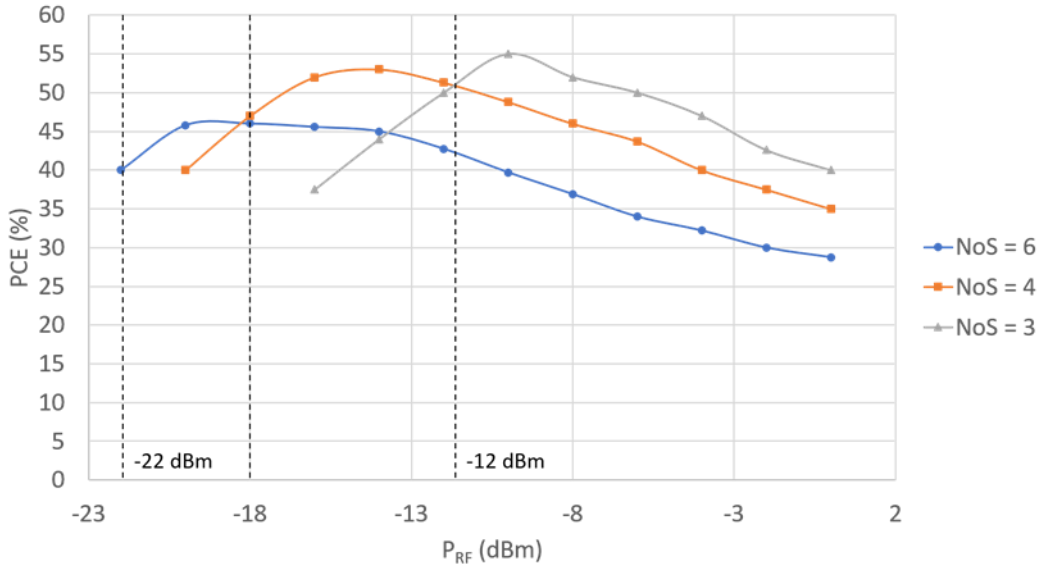
NoS = Number of Stages of the RF to DC Converter.
Varying the Number of Stages NoS of the RF to DC converter at 868 MHz.

RF to DC Converter / MPPT

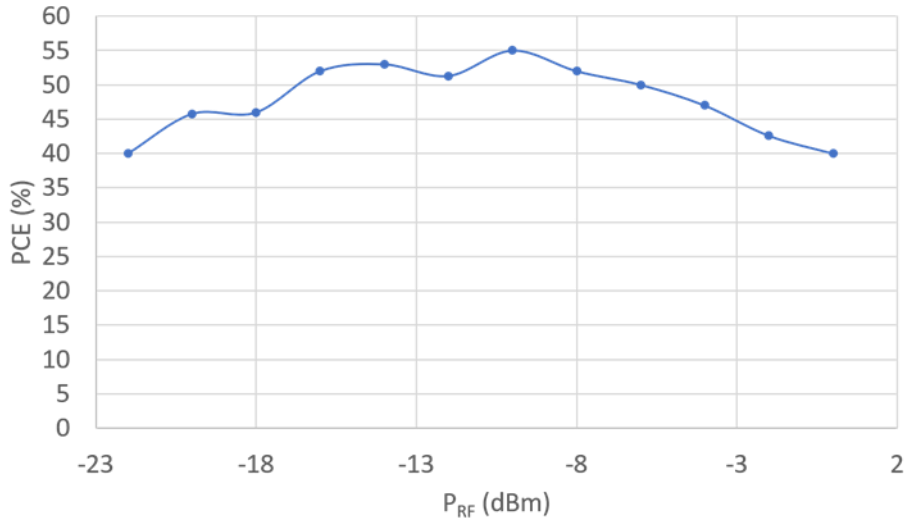


NoS = Number of Stages of the RF to DC Converter.
Varying the Number of Stages (NoS) of the RF to DC converter at 868 MHz.

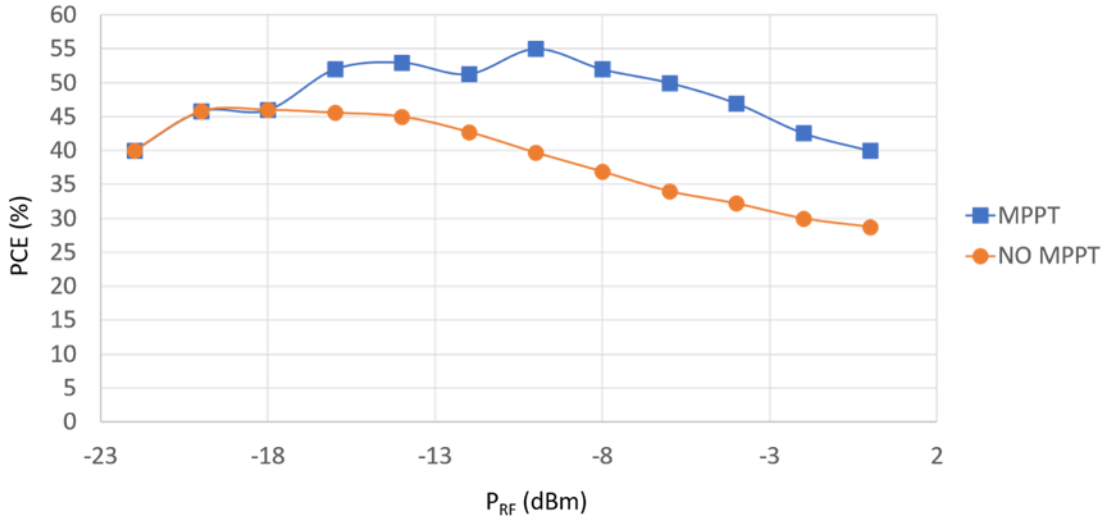
RF to DC Converter with MPPT

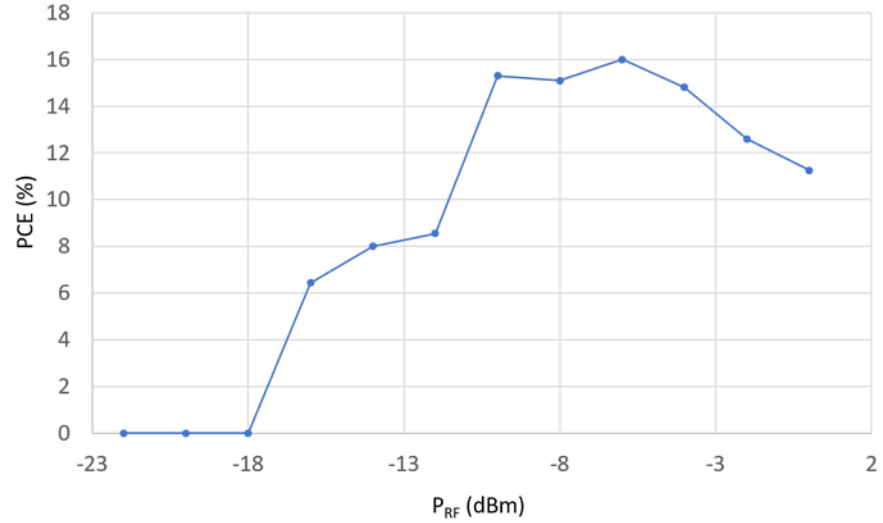


868 MHz



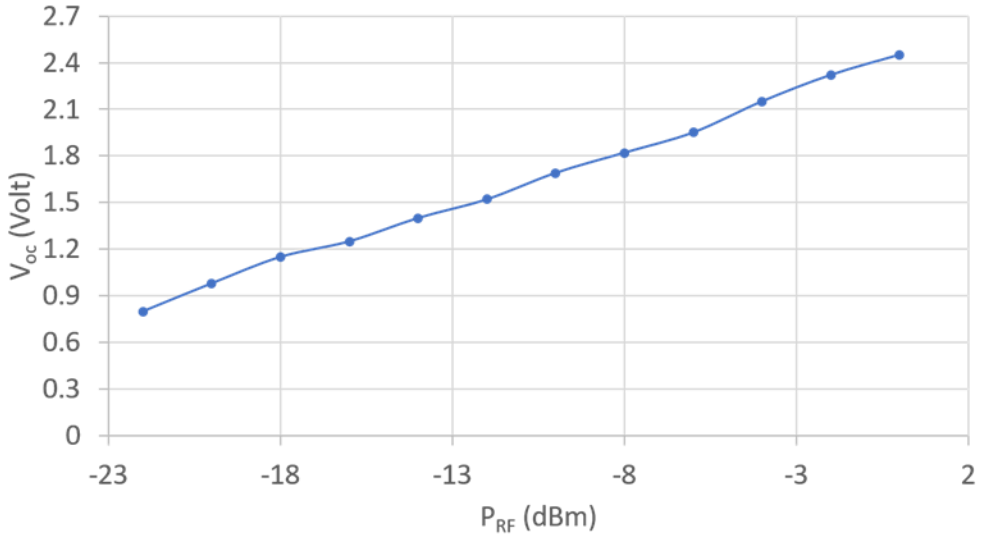
RF to DC Converter with and without MPPT

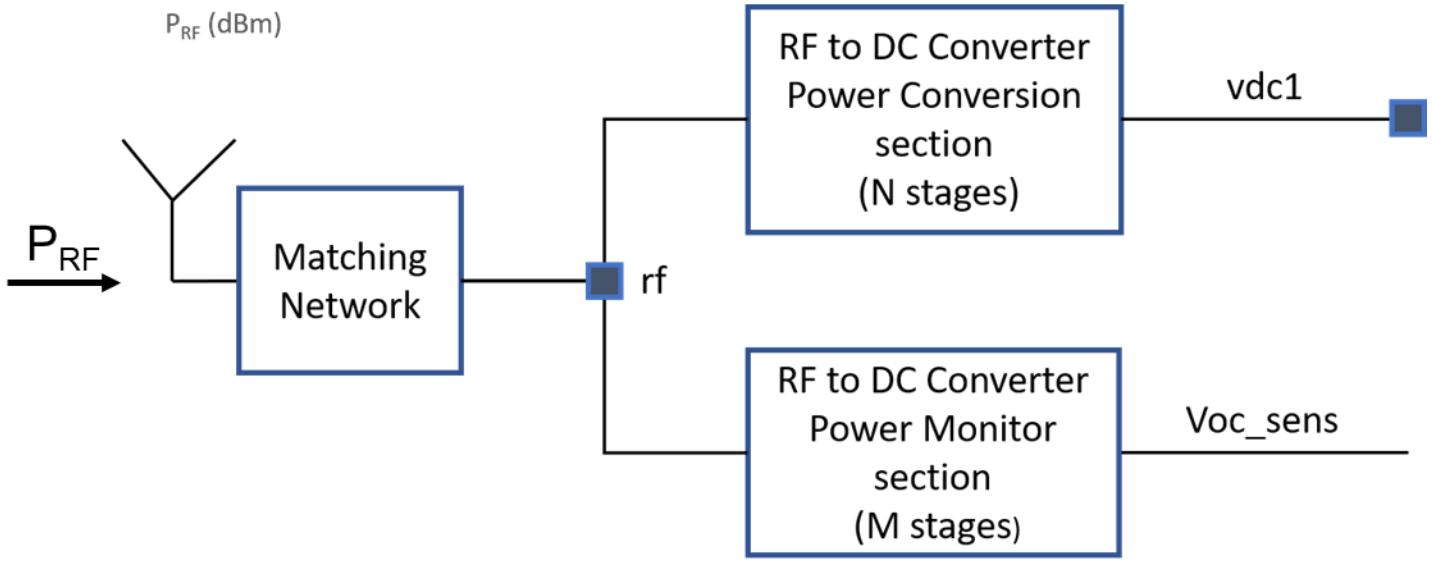




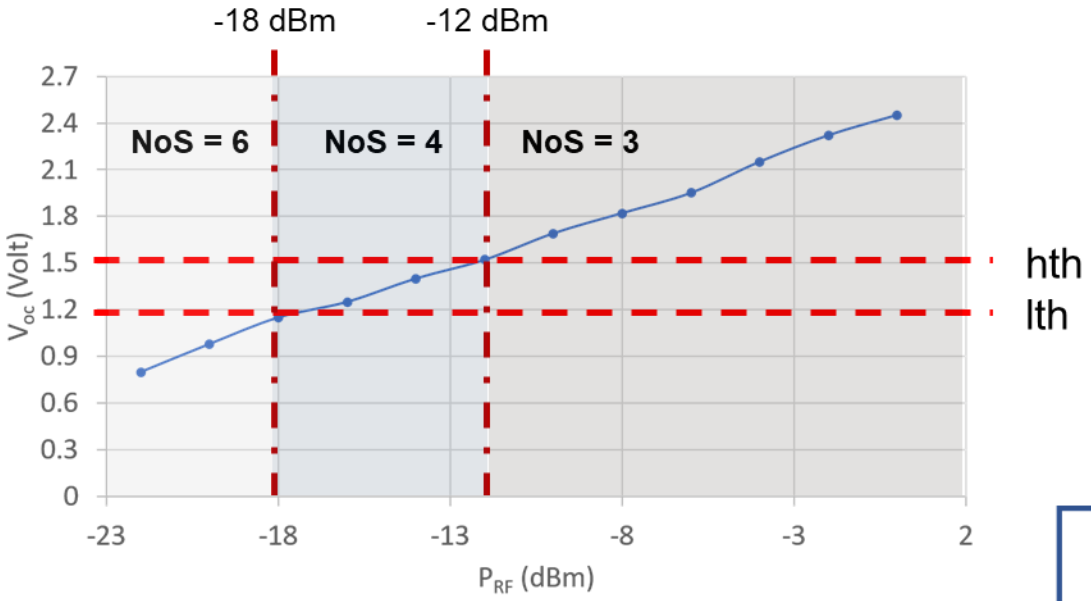
- Up to 16% improvement on the PCE performance with MPPT.

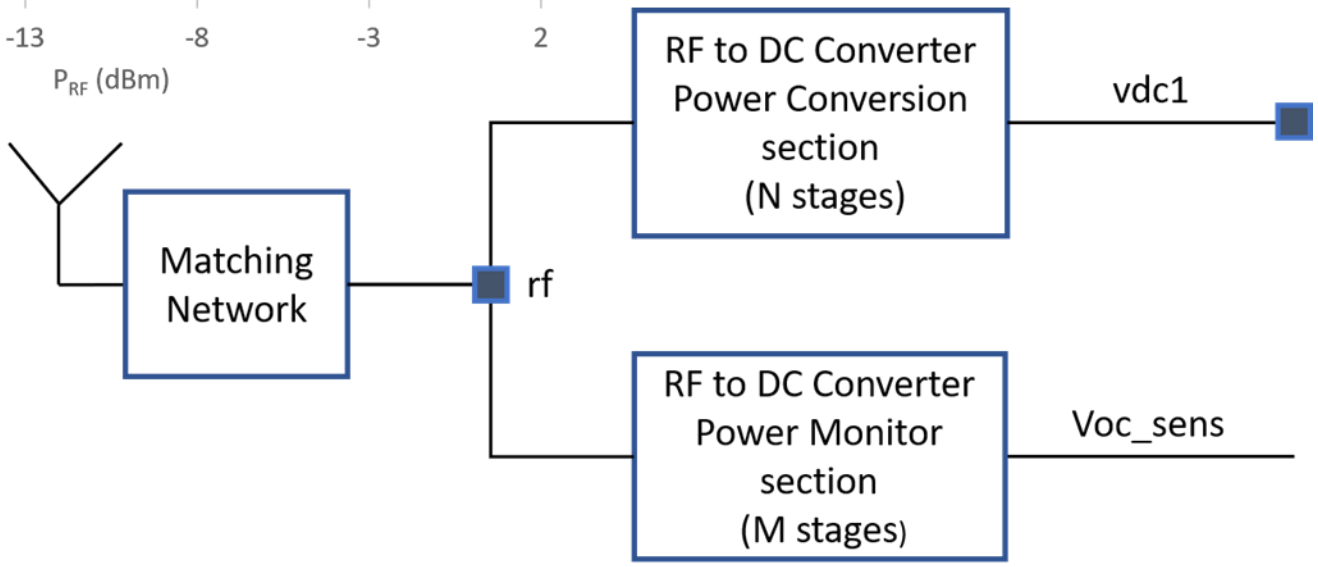
RF to DC Converter / MPPT / Voc sensing



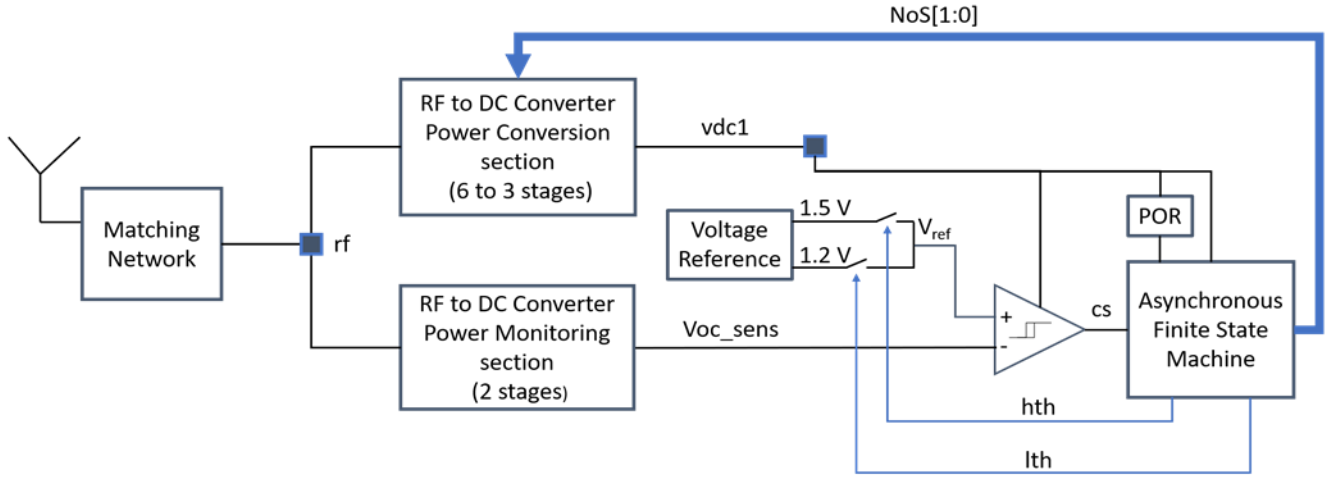


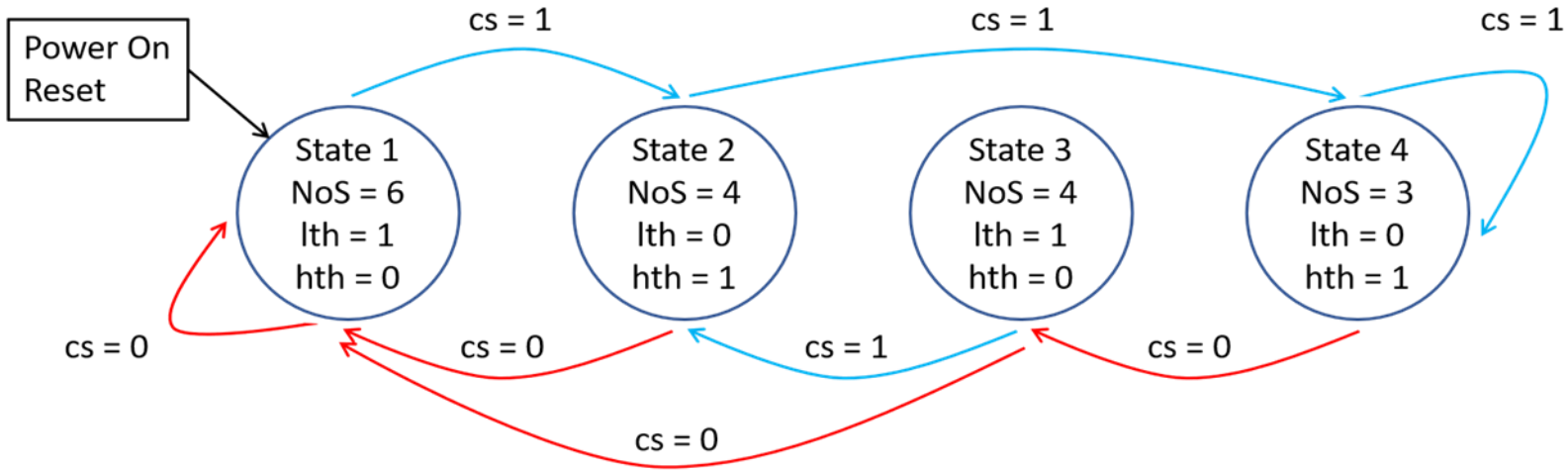
RF to DC Converter with MPPT





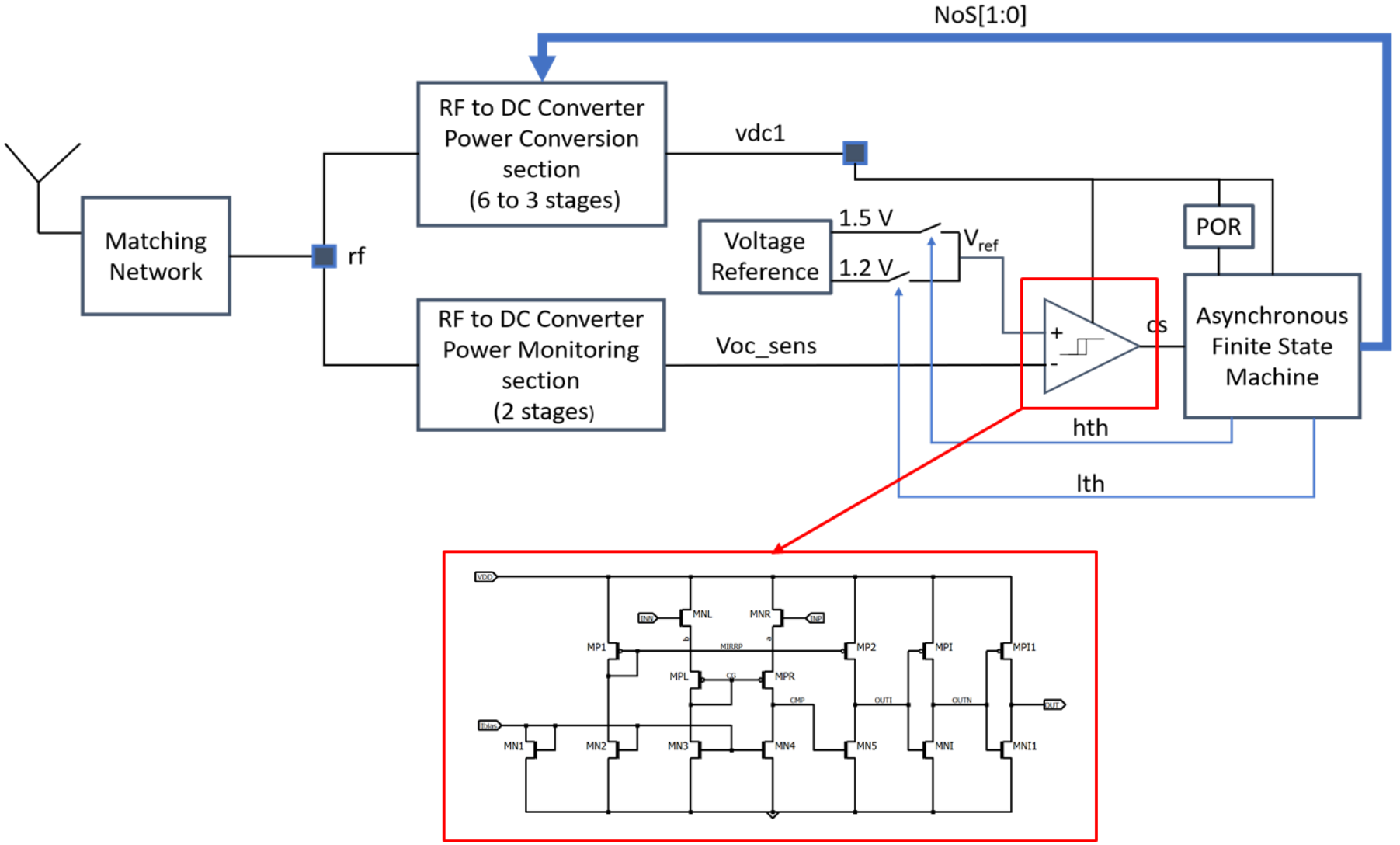
MPPT System Architecture



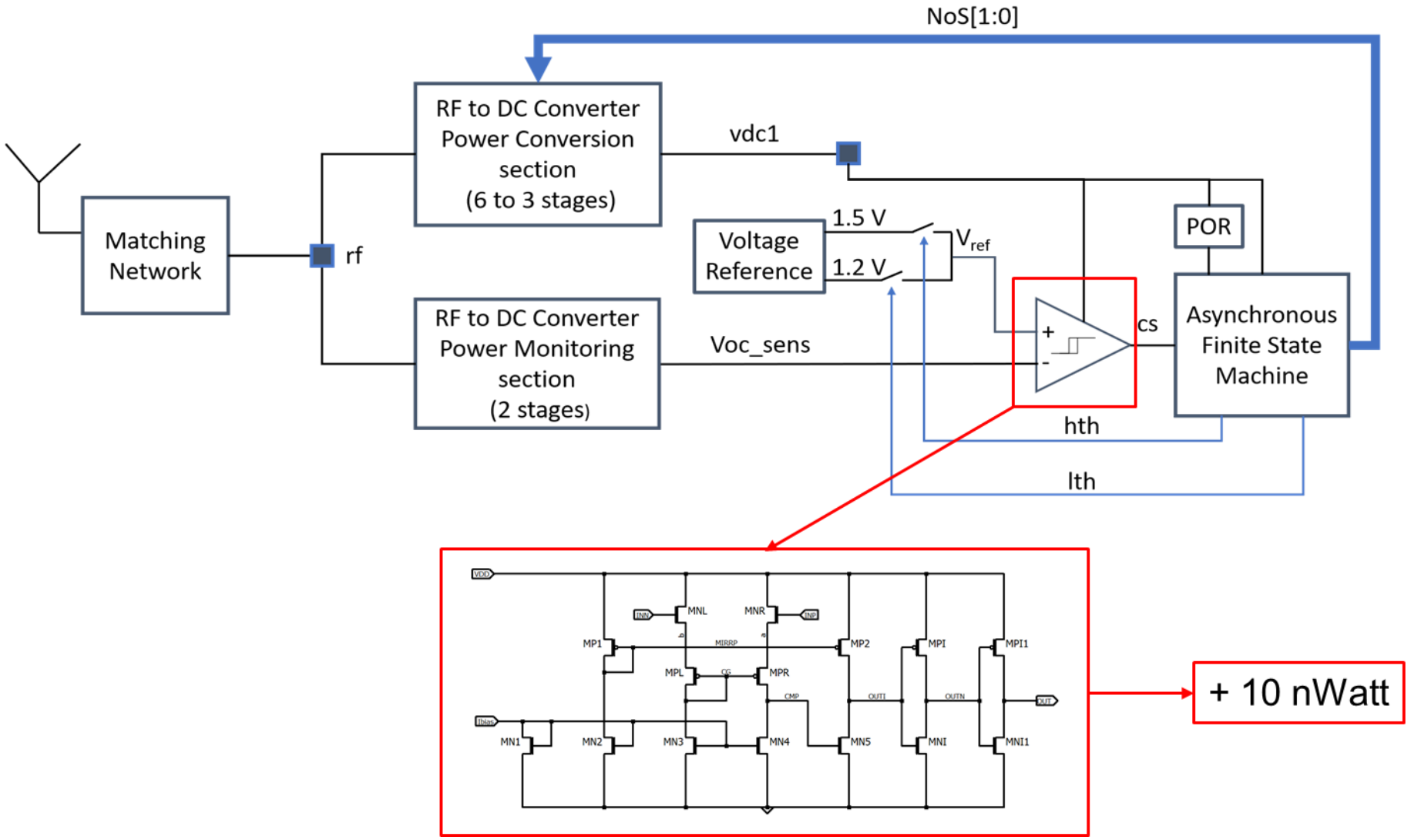


cs = Change State digital signal

MPPT System Architecture

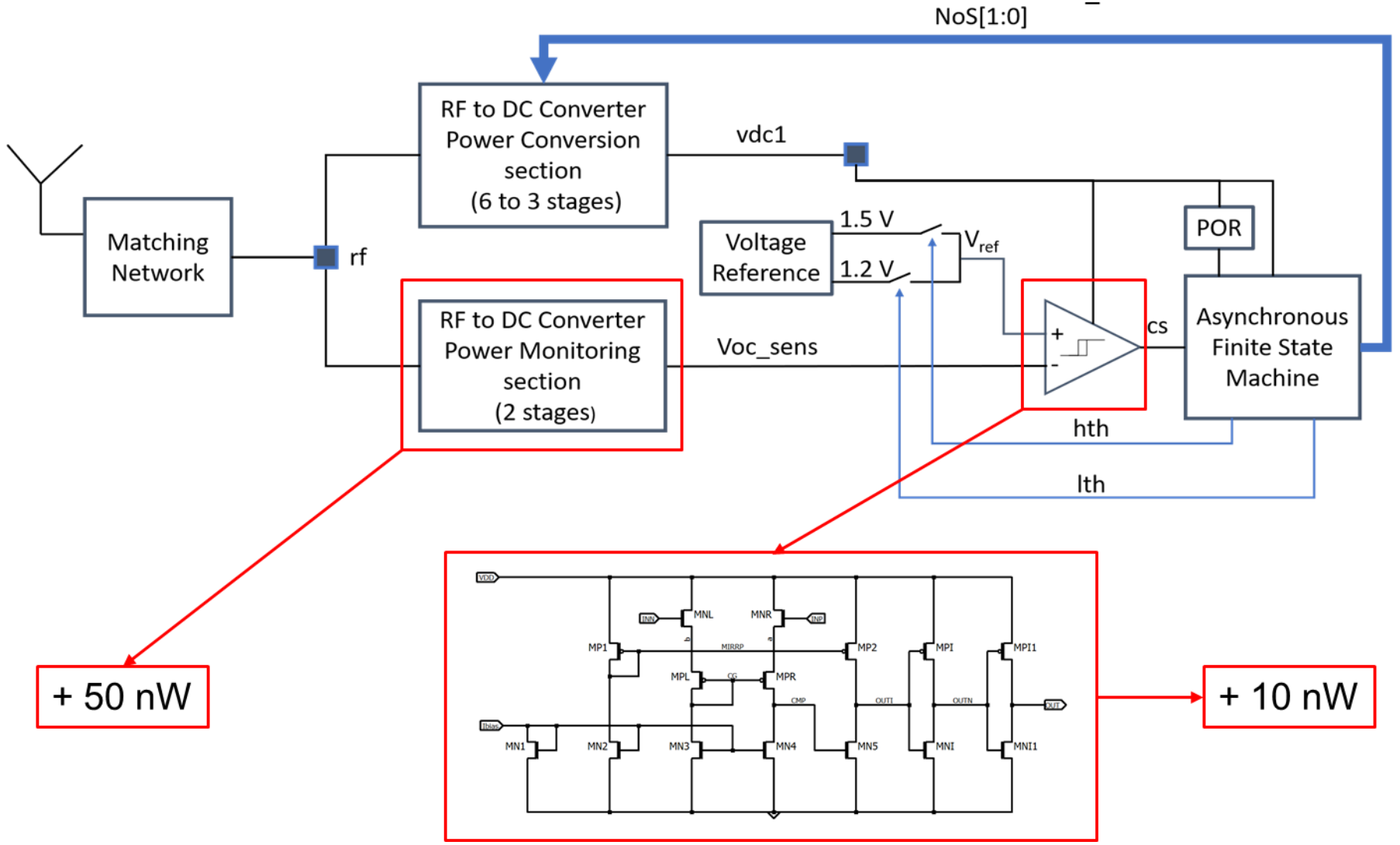


MPPT System Architecture

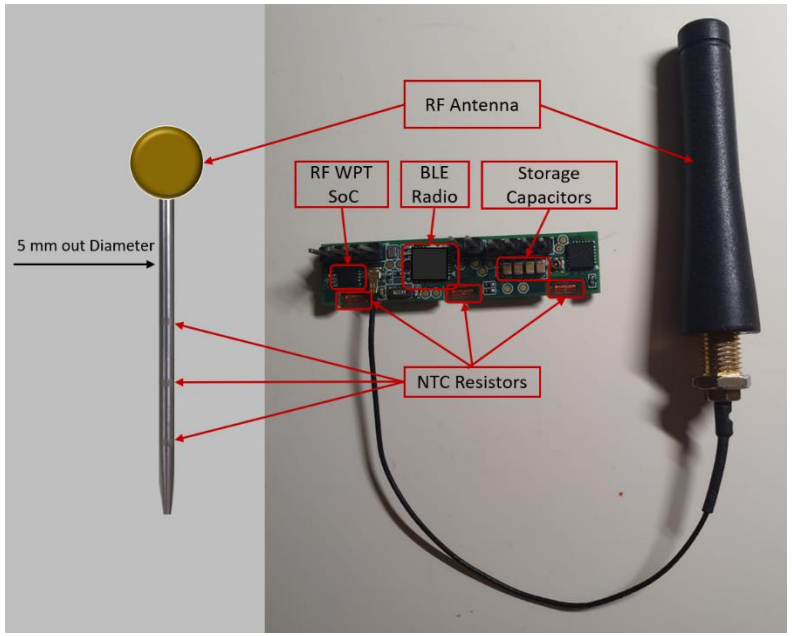


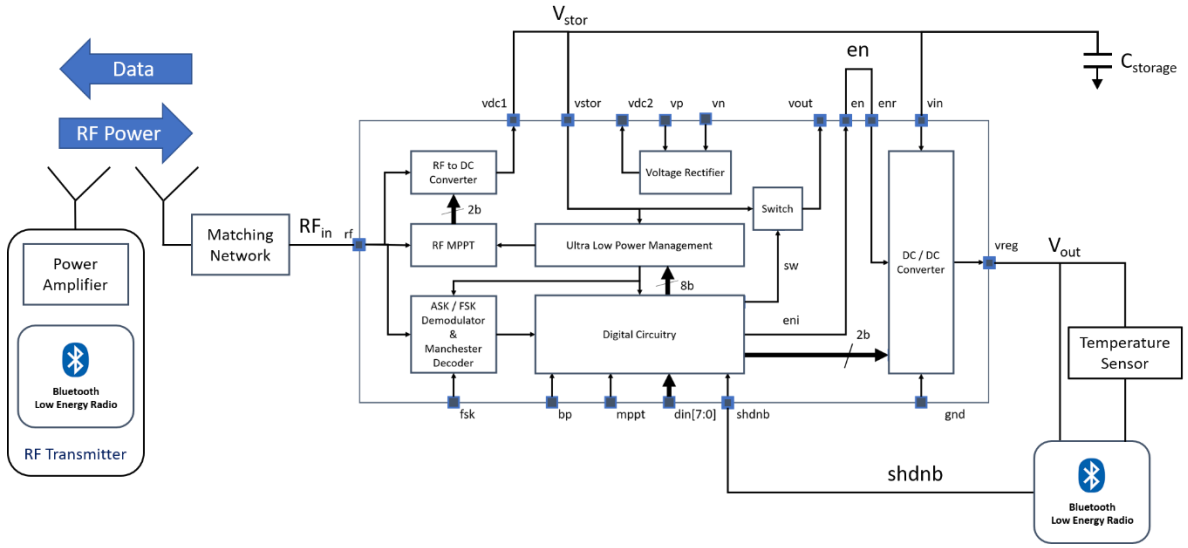
MPPT System Architecture

Total extra power consumption = 60 nW ➔ 1% of 6 uW or P_{RF_min} = -22 dBm

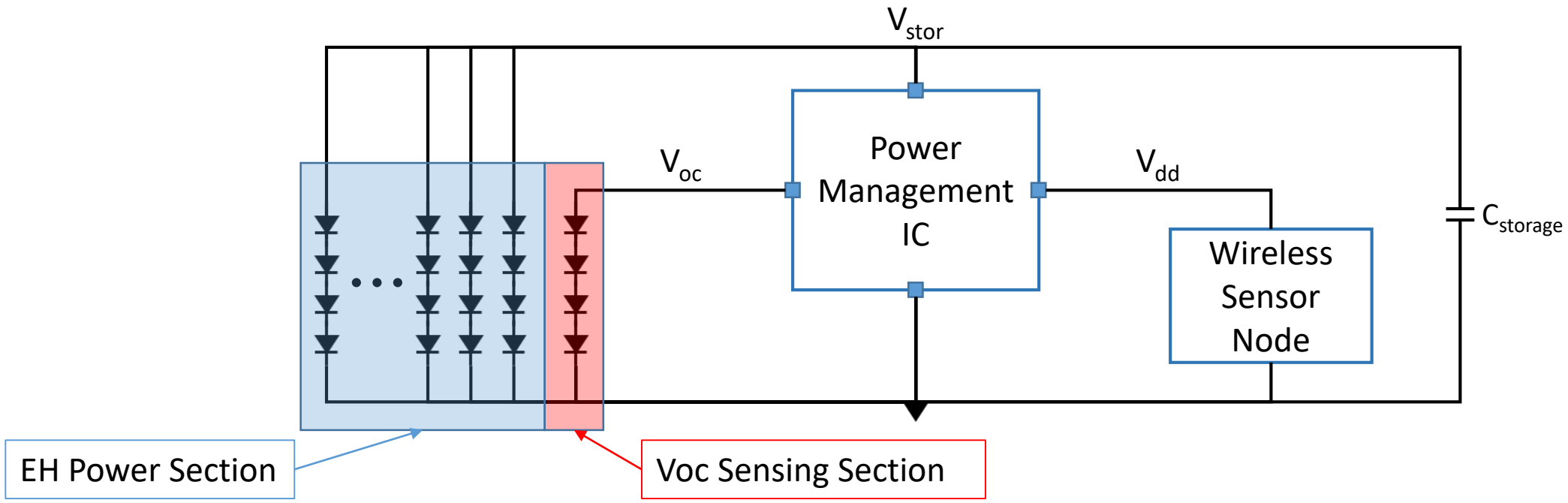


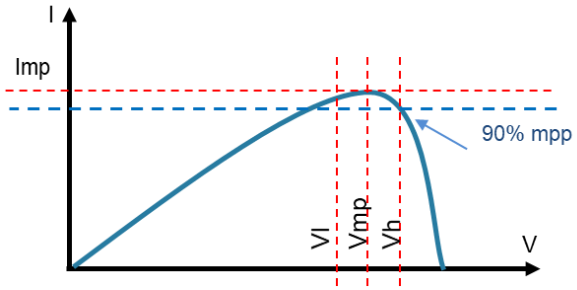
MPPT System Architecture

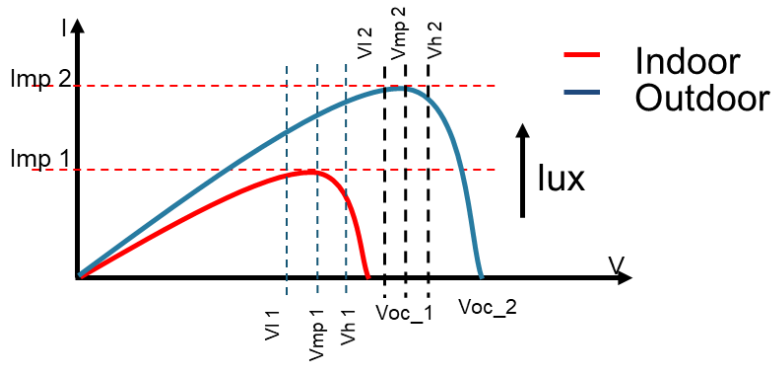


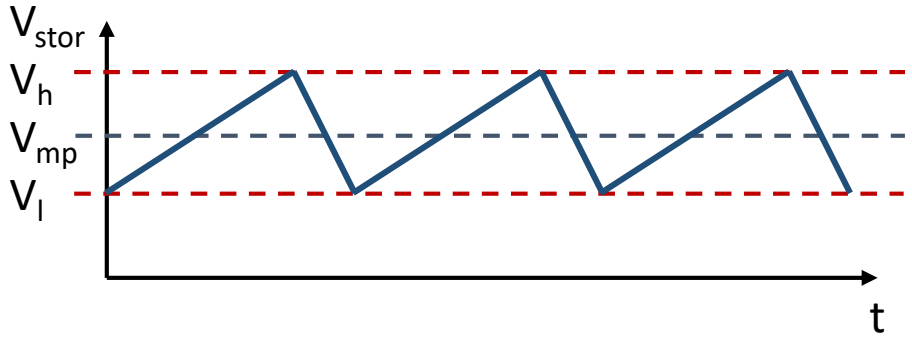


MPPT System Architecture

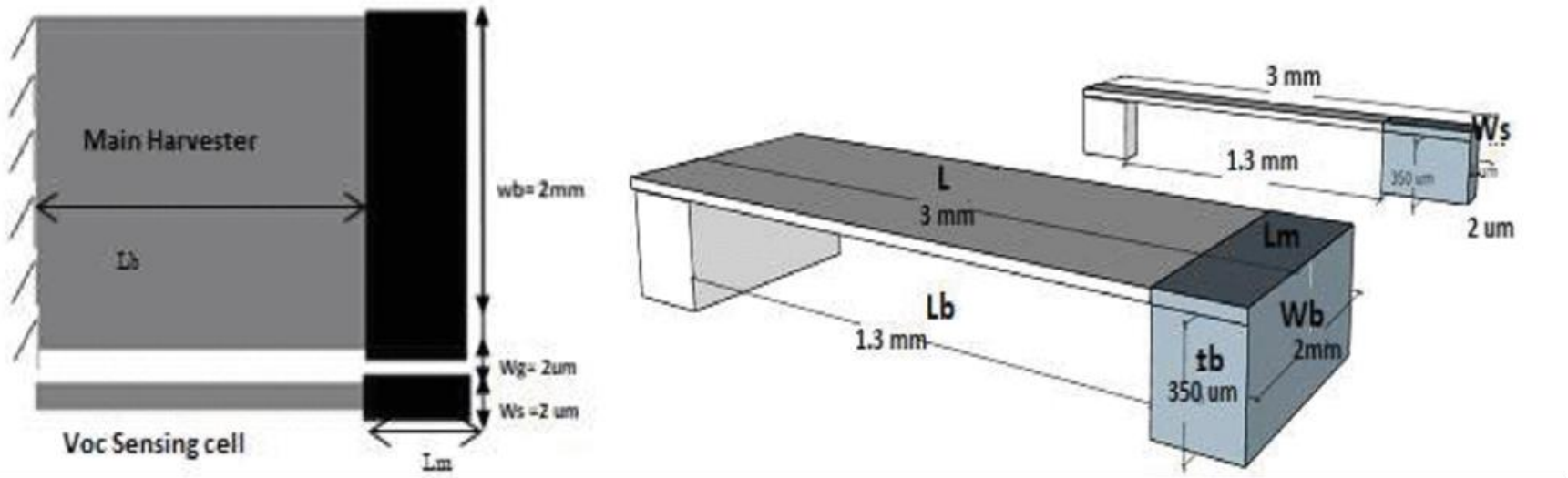








MPPT System Architecture for Vibrational EH



1) Roberto La Rosa. Power tracking circuit, corresponding system and method. US Patent App. 16/283,067. Aug. 2019.
2) Panayanthatta, N., et al. "Three terminal piezoelectric energy harvester based on novel MPPT design." *2019 19th International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications (PowerMEMS)*. IEEE, 2019.

Conclusions

- **A SoC for EH and WPT**
- **Power sensitivity -22 dBm at 868 MHz.**
- **Maximum PCE of 55% at 868 MHz.**
- **Innovative MPPT architecture improves PCE performance up to 15% in Ultra-Low-Power systems.**
- **Adding a Voc sensor in power transucer …**

Q & A

Thanks very much for your time and attention!

Questions/comments???

References

1) R. La Rosa et al. "Strategies and Techniques for Powering Wireless Sensor Nodes through Energy Harvesting and Wireless Power Transfer." *Sensors* (2019).
2) Roberto La Rosa. Power tracking circuit, corresponding system and method. US Patent App. 16/283,067. Aug. 2019.
3) Roberto La Rosa and Alessandro Finocchiaro. Energy harvesting circuit, corresponding system and operating method. US Patent App. 17/109,345. June 2021.
4) Roberto La Rosa and Alessandro Finocchiaro. Radiofrequency-powered device, corresponding system and method. US Patent App. 16/862,850. Nov. 2020.
5) Panayanthatta, N., et al. "Three terminal piezoelectric energy harvester based on novel MPPT design." *2019 19th International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications (PowerMEMS)*. IEEE, 2019.
6) Roberto La Rosa, Patrizia Livreri, Catherine Dehollain, Mario Costanza, and Carlo Trigona. “An Energy Autonomous and Battery-Free Measurement System for Ambient Light Power with Time Domain Readout”. In: Measurement "Accepted for pubblication" (2021).
7) Roberto La Rosa, Catherine Dehollain, Andreas Burg, Mario Costanza, and Patrizia Livreri. “An Energy-Autonomous Wireless Sensor With Simultaneous Energy Harvesting and Ambient Light Sensing”. In: IEEE Sensors Journal 21.12 (2021).
8) Panayanthatta, Namanu, et al. "A Self-Powered and Battery-Free Vibrational Energy to Time Converter for Wireless Vibration Monitoring." *Sensors* (2021).