Energy Management: Enabling the IoT

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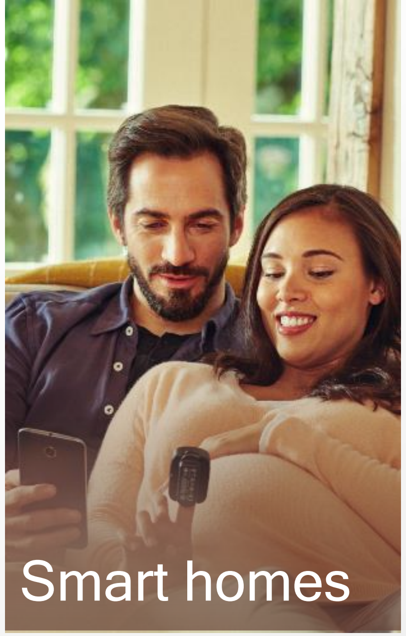
#whywait

IoT

25B

permanently connected things by 2020*

Smart cities



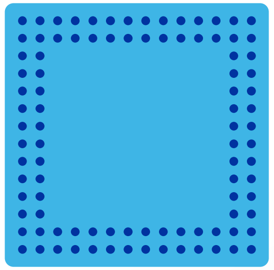
Smart homes

Robotics

Smart body

Fueling the needs of the Internet of Things

Most IoT devices share similar - but different - requirements



Thinner, lighter, sleeker

- Highly integrated
- 3D packaging

Ultra-long battery life

- Low power / high efficiency
- Platform optimizations
- Wireless charging

Always on, always sensing

- Low power sensing/processing
- End-to-end sensor optimizations

Always connected

- LTE and 3G
- Wi-Fi
- Bluetooth, BLE
- GNSS

Size matters!

Parasitic elements reduction

Higher operating frequencies

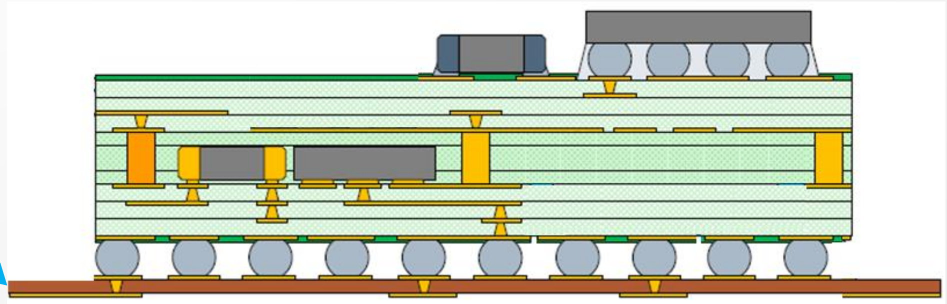
Heterogeneous integration

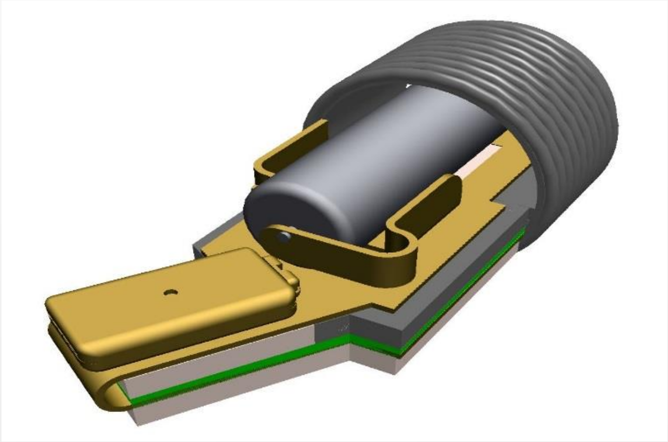
Printed Electronics

What about power density?

Integration for wearables

Wireless Power Transfer antenna embedded in the Flex circuit





Hearing aid prototype

Solving the Energy Equation

$$\int P_{in} * dt \geq \int (P_{conv}/\eta_{conv} + P_{comp} + P_{RF}) * dt$$

Efficient Energy Harvesting and Power Conversion

High Density Energy Storage

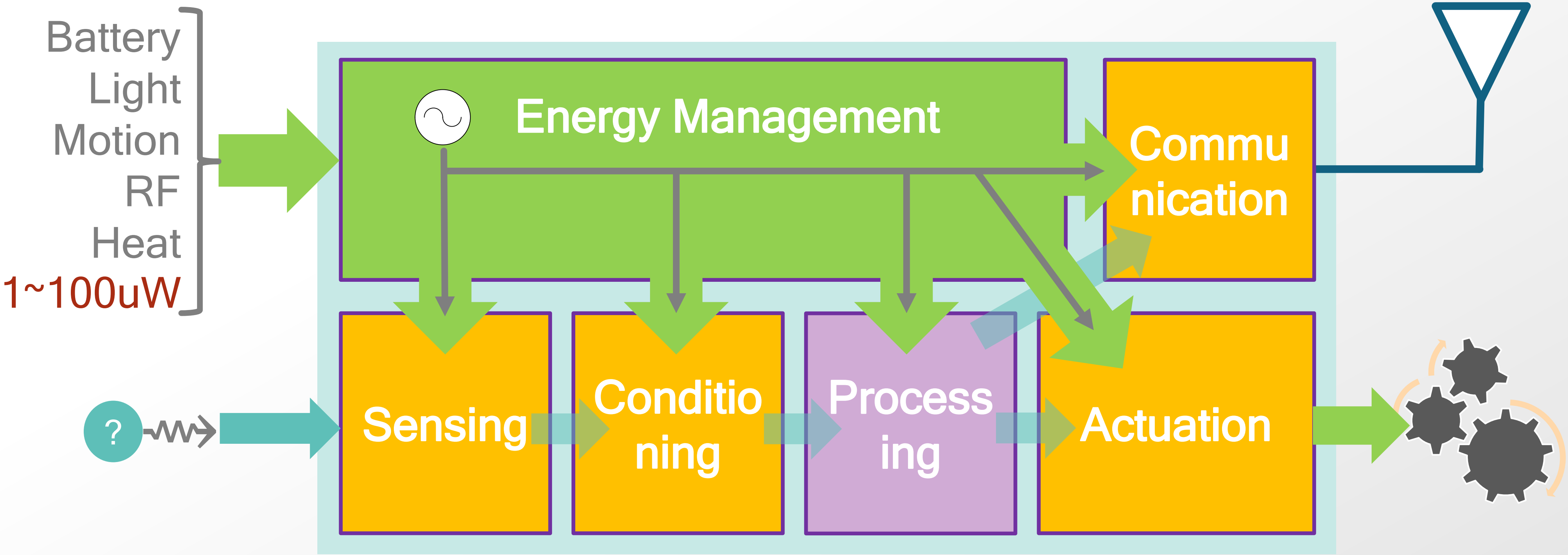
IoT Enablers

Ultra-low Power Computing

Low Energy RF Communication

Block as well as system level optimizations are required

Each function's energy requirement can be traded off against the others



Sampling rate
Resolution
S/N ratio

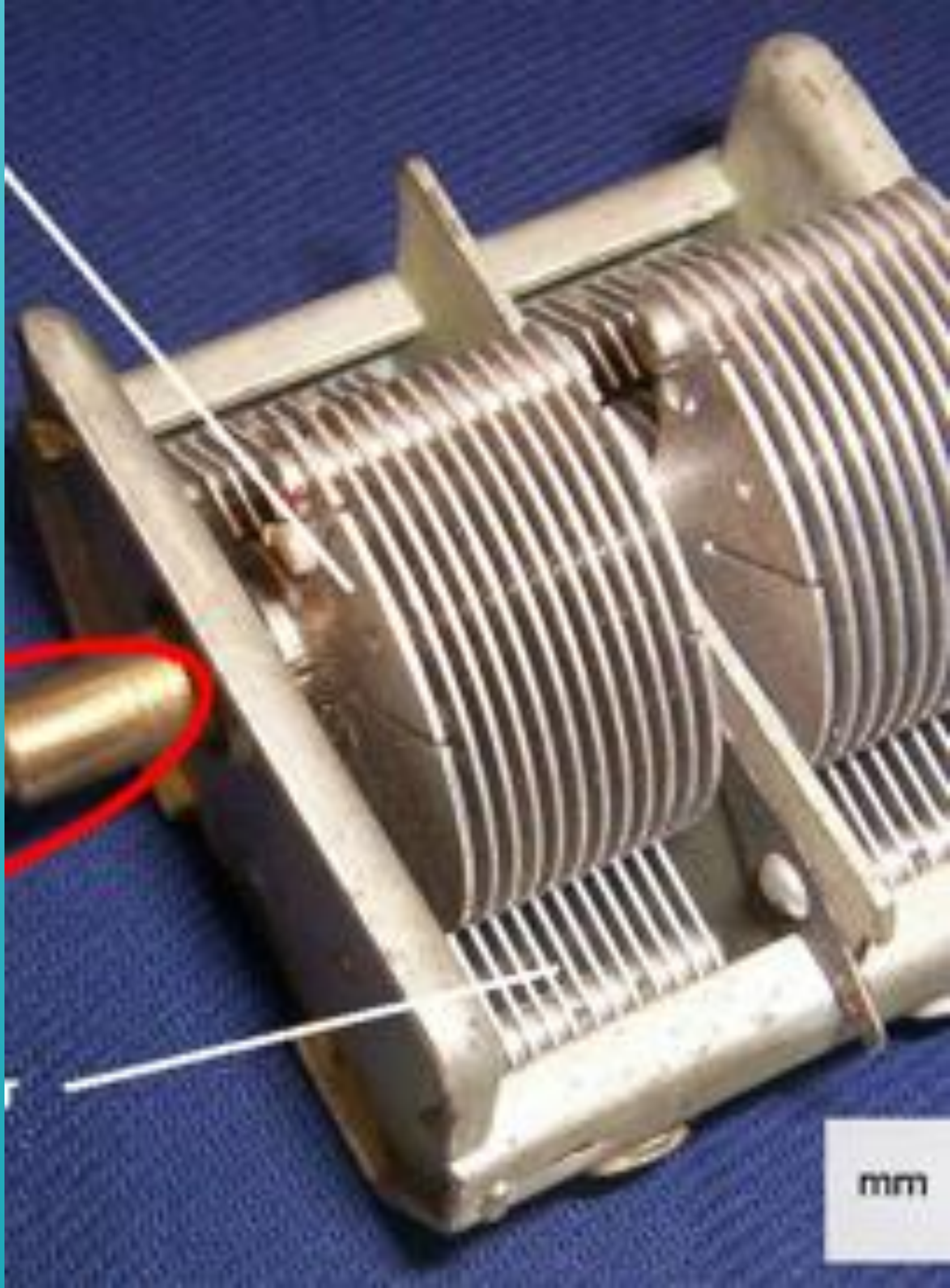
Amplifying
Filtering
Compressing

Transform.
Statistics
Conditional P.

Conversion
Protocol
Data Rate

Using Variable Reactances

A new approach to Power Management



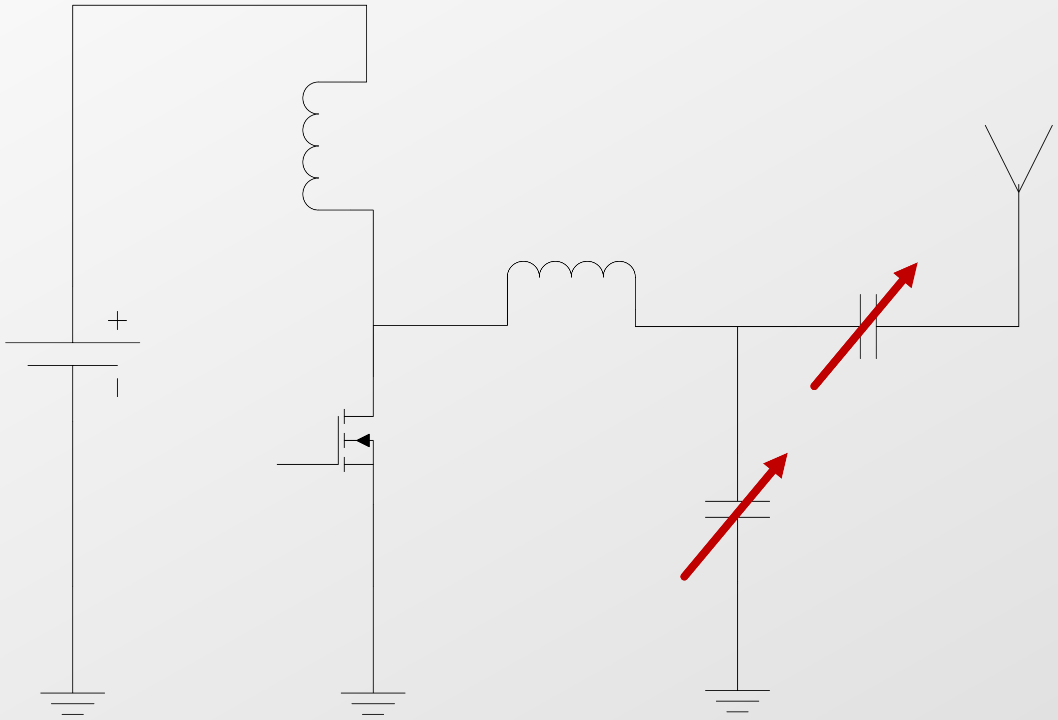
Tunable RF Front End for IoT

Reducing cost, increasing flexibility

Tuning for component tolerances and frequency changes

Compensation of VSWR

Efficiency optimization of RF PA for different power levels and load changes



What about Resonant Power Conversion and Resonant Power Transfer?

Can we use tunable capacitors for:

Resonant Class D, E, EF or LLC converters

→Tuning load resonance instead of frequency

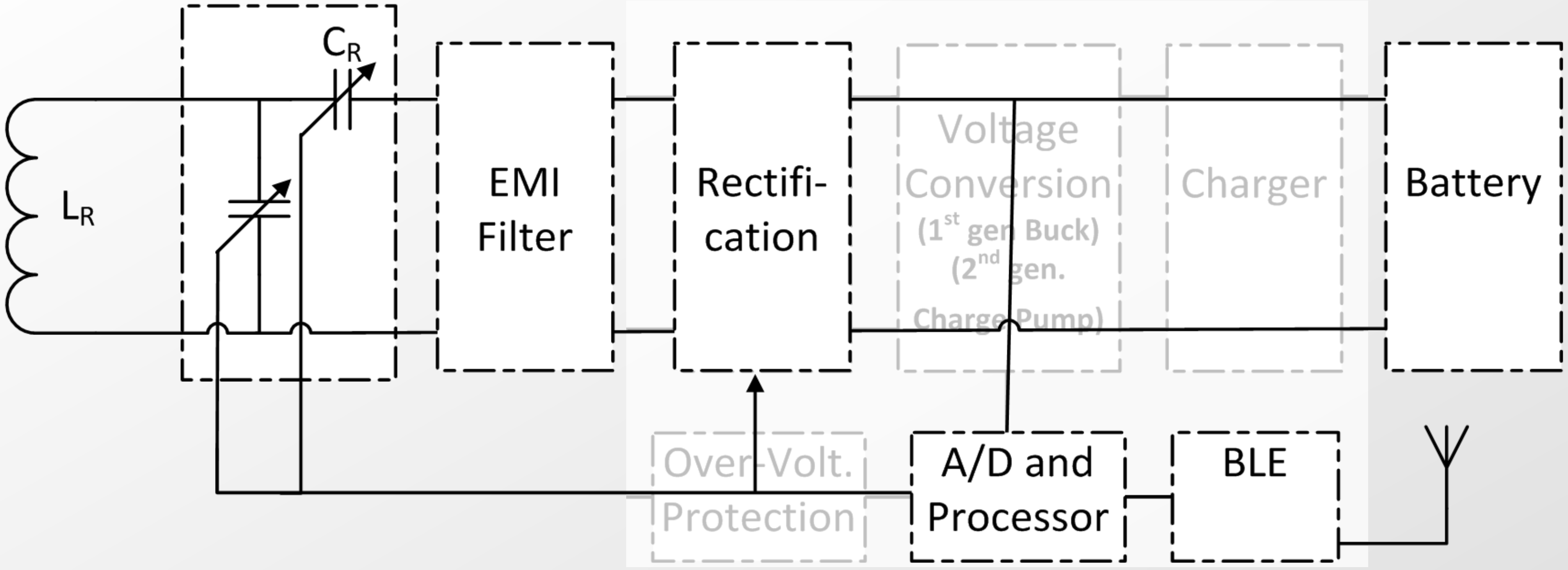
→Tuning drain capacitance instead of duty-cycle or delay

How about completely re-thinking an architecture…

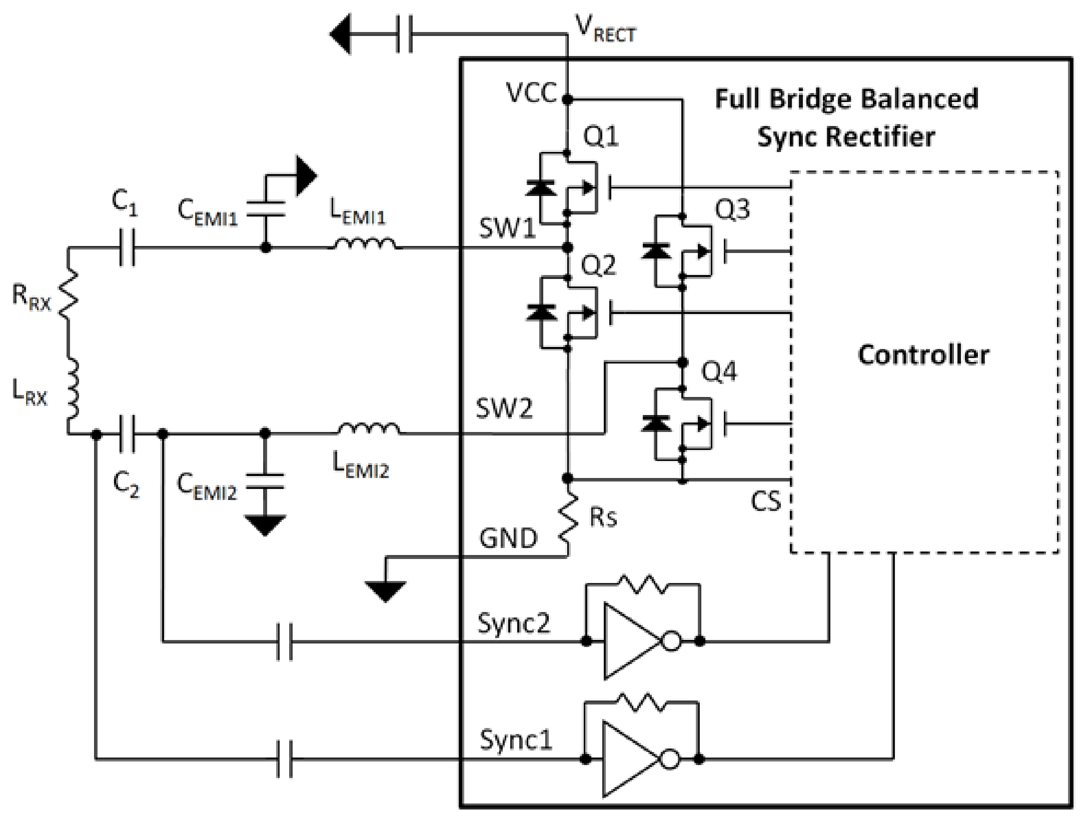
RF Energy transfer

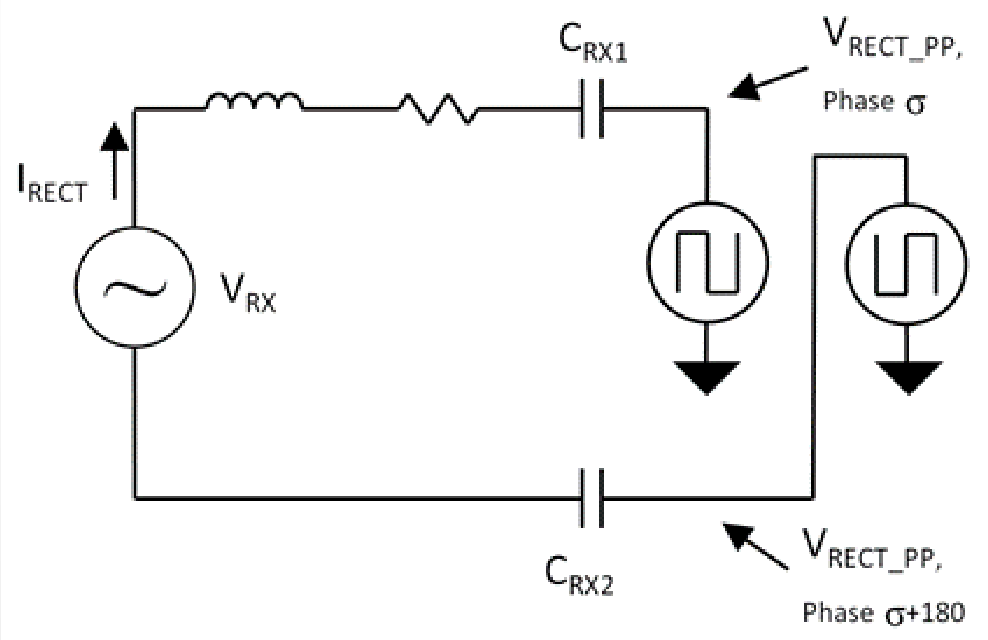
Near Field or Far Field, for fixed and mobile applications

Overcoming the variability of signal strength
with highly resonant systems and tunable elements
that eliminate DC-DC conversion (and their magnetic elements)



Controlling the phase angle of the synchronous rectifier

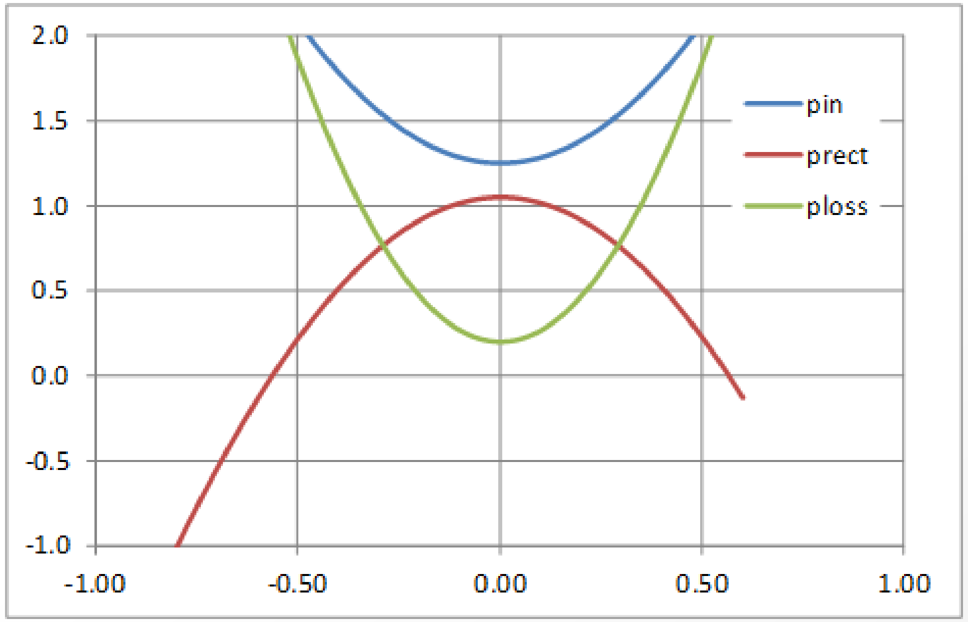


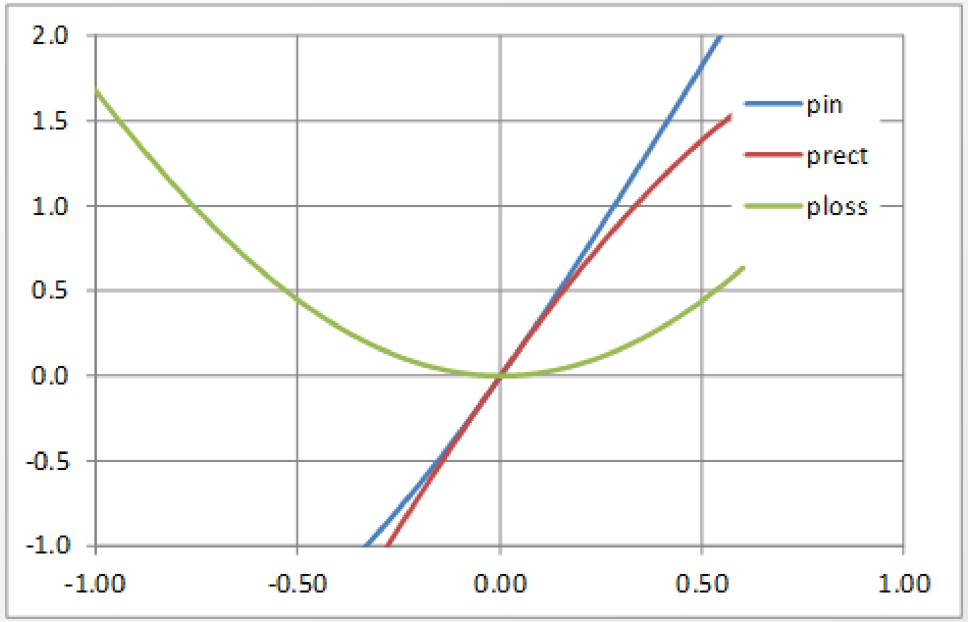


Simplified model for analysis

…but it works only if you can control the residual reactance

If tuned, the series resonant LC can provide the appropriate impedance



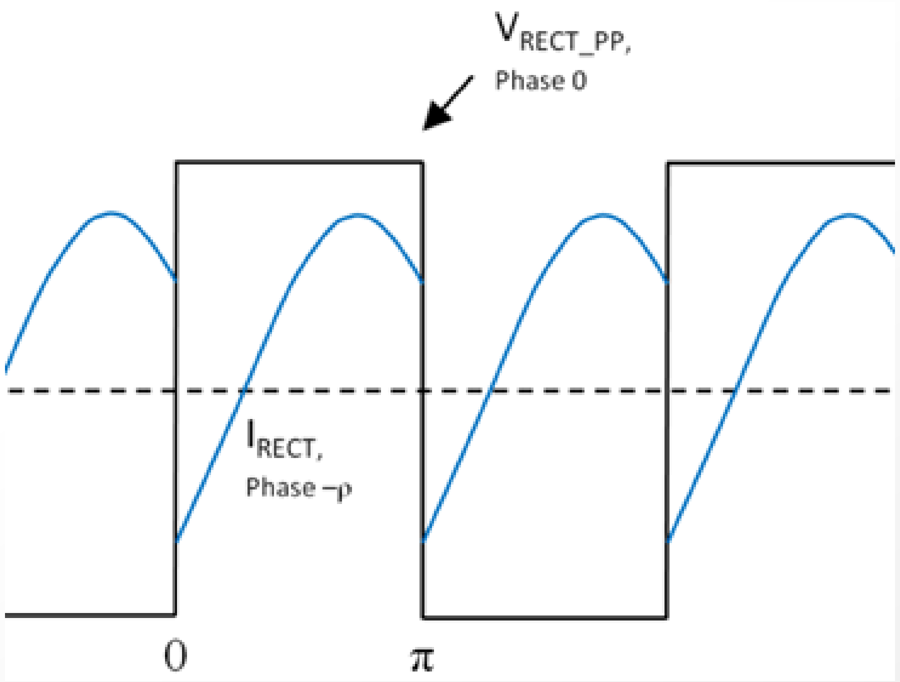


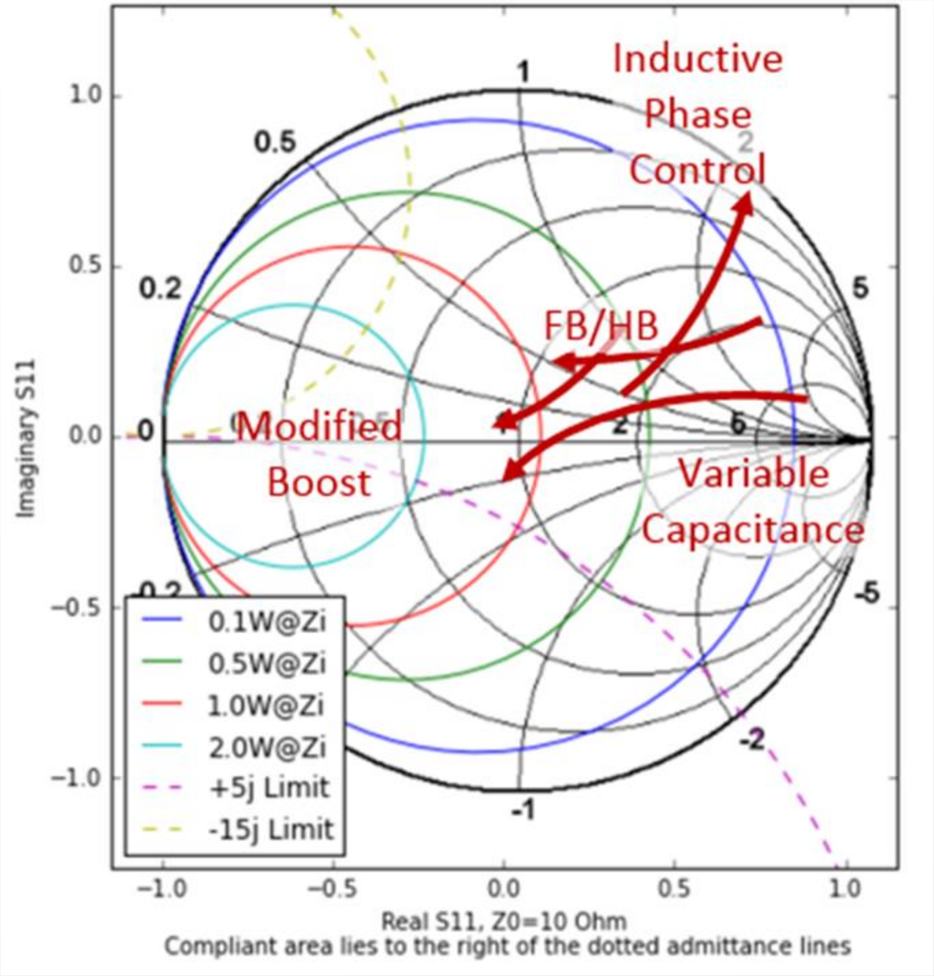
Coupling impedance tuned to zero reactance. Under these conditions phase adjustments modestly affect load power but at significant efficiency penalty in losses

Tuning the reactance significantly modifies the power curves where phase adjustments effectively modulate transfer. Under these conditions it is possible to regulate power transfer from 0 to 1W, with moderate power loss.

Buck and Boost operations

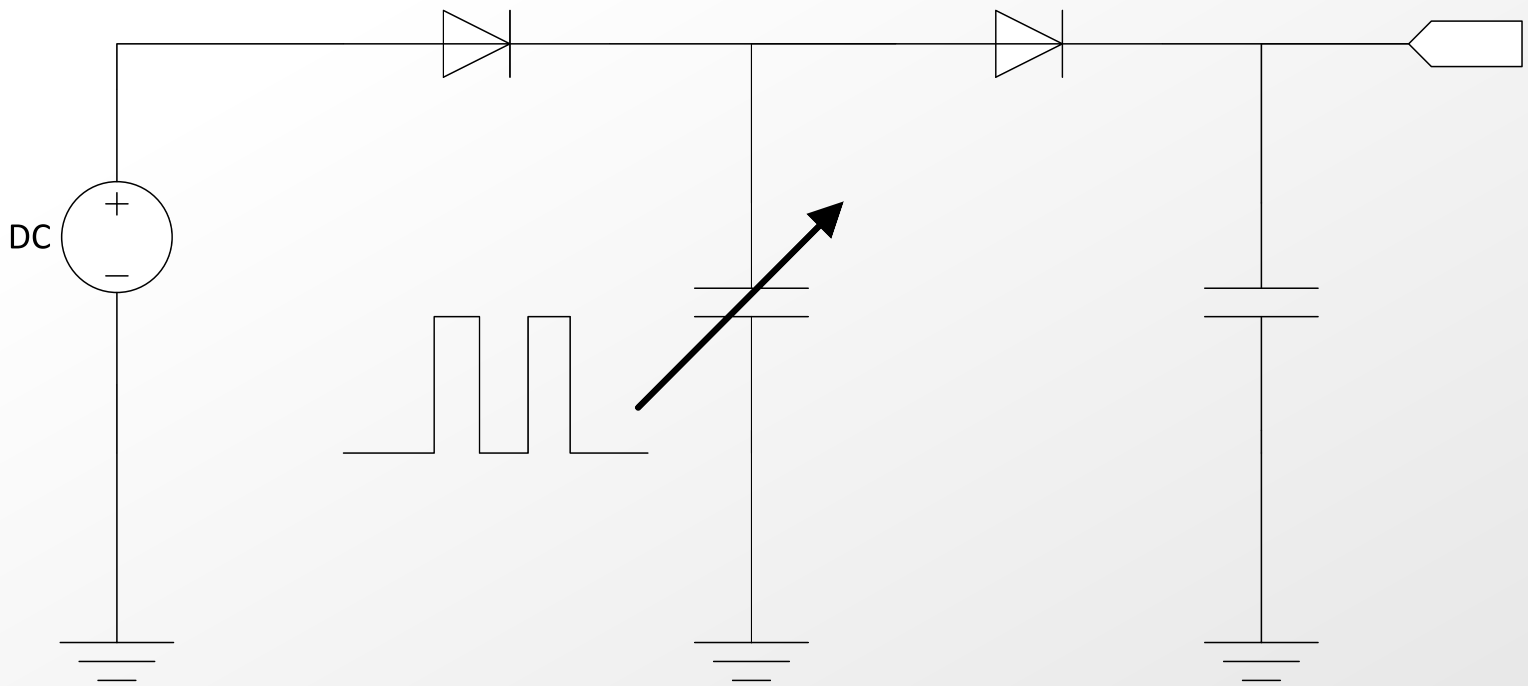
Combining reactance and phase changes





…by the way, perpetual motion is not yet achievable

This does not work!



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