Energy Management: Enabling the IoT

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#whywait
IoT

25B
permanently
connected things
by 2020*
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

\[ \int P_{\text{in}} \, dt \geq \int (\frac{P_{\text{conv}}}{\eta_{\text{conv}}} + P_{\text{comp}} + P_{\text{RF}}) \, dt \]

Efficient Energy Harvesting and Power Conversion

High Density Energy Storage

Ultra-low Power Computing

Low Energy RF Communication

IoT Enablers
Block as well as system level optimizations are required

Each function’s energy requirement can be traded off against the others
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!
Thank you

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