University of BRISTOL

Power conditioning electronics and energy storage for MEMS/NEMS energy harvesters: Technical challenges

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Content

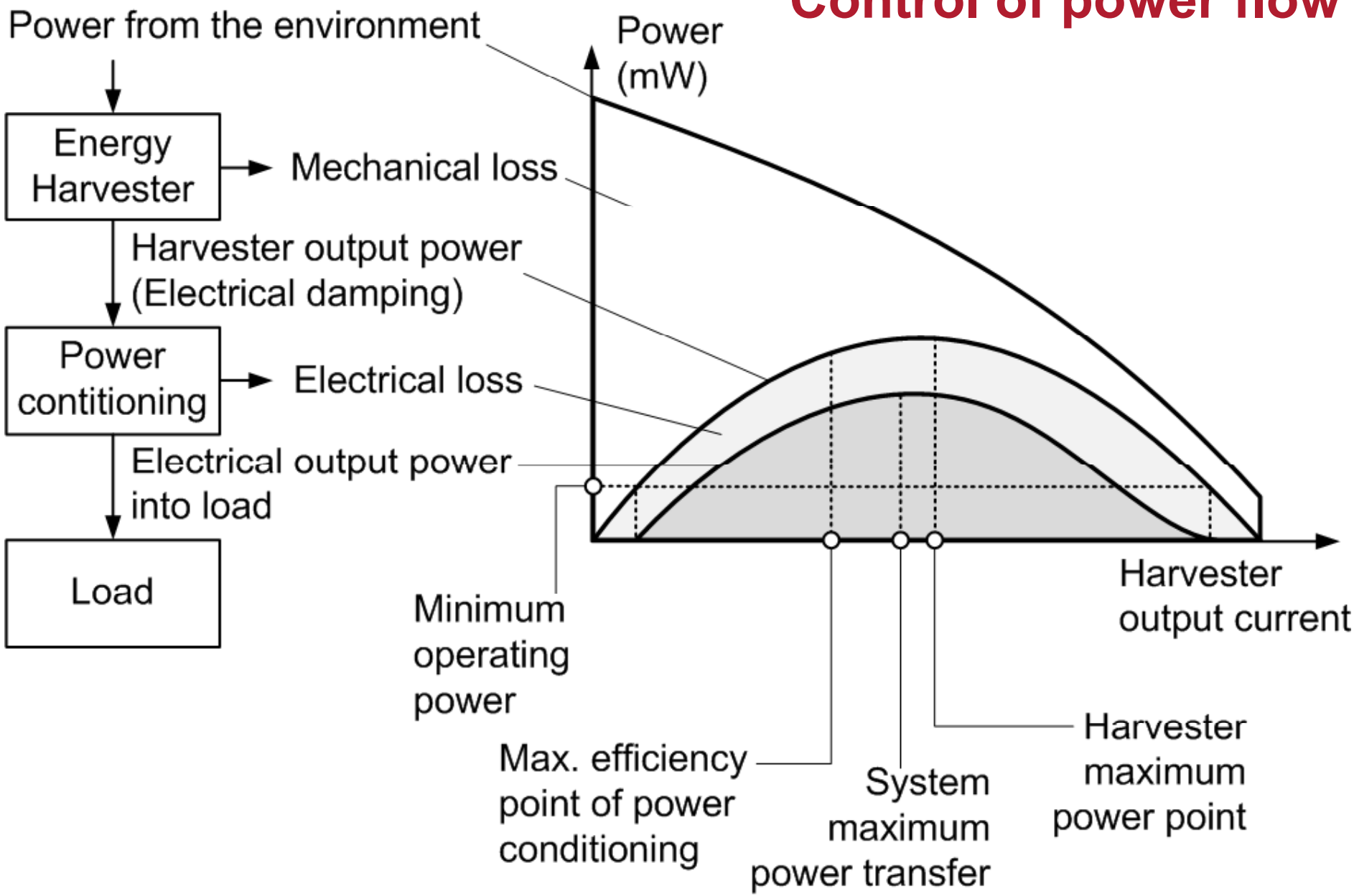
Conceptual challenges at low input power:

- Control of power flow
- Synthesis of specific input impedances
- Handling power variability
- Use of commercially available circuits

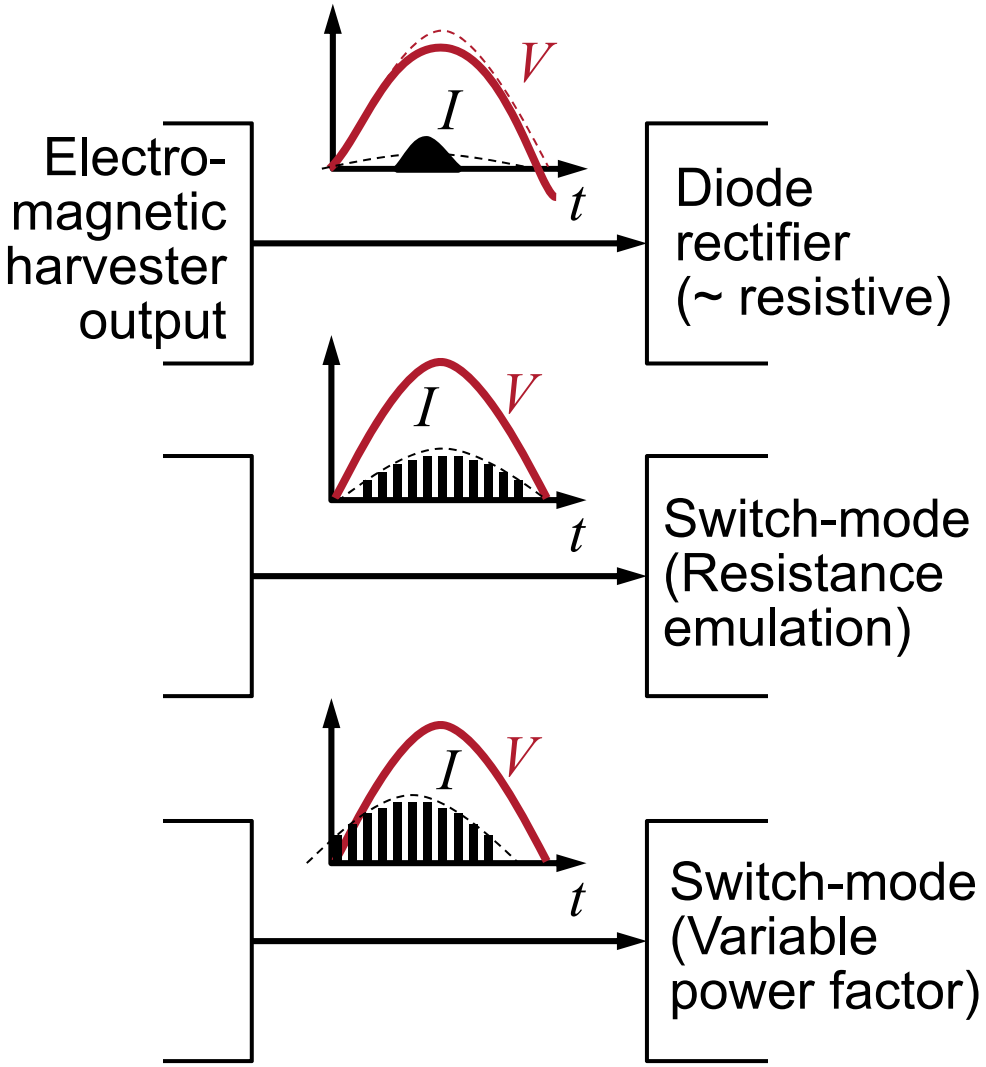
Some specifics:

- Break-even point between active and passive
- Power stage (technology and power losses)
- Gate driving, control etc (technology & power losses)
- Start-up (technology)

Control of power flow

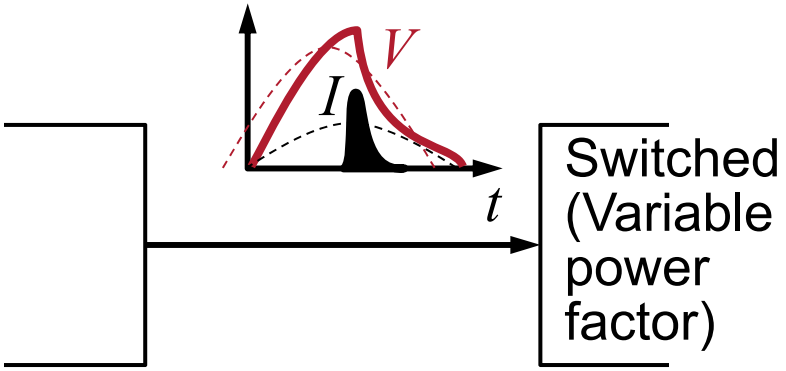


Synthesis of input impedances

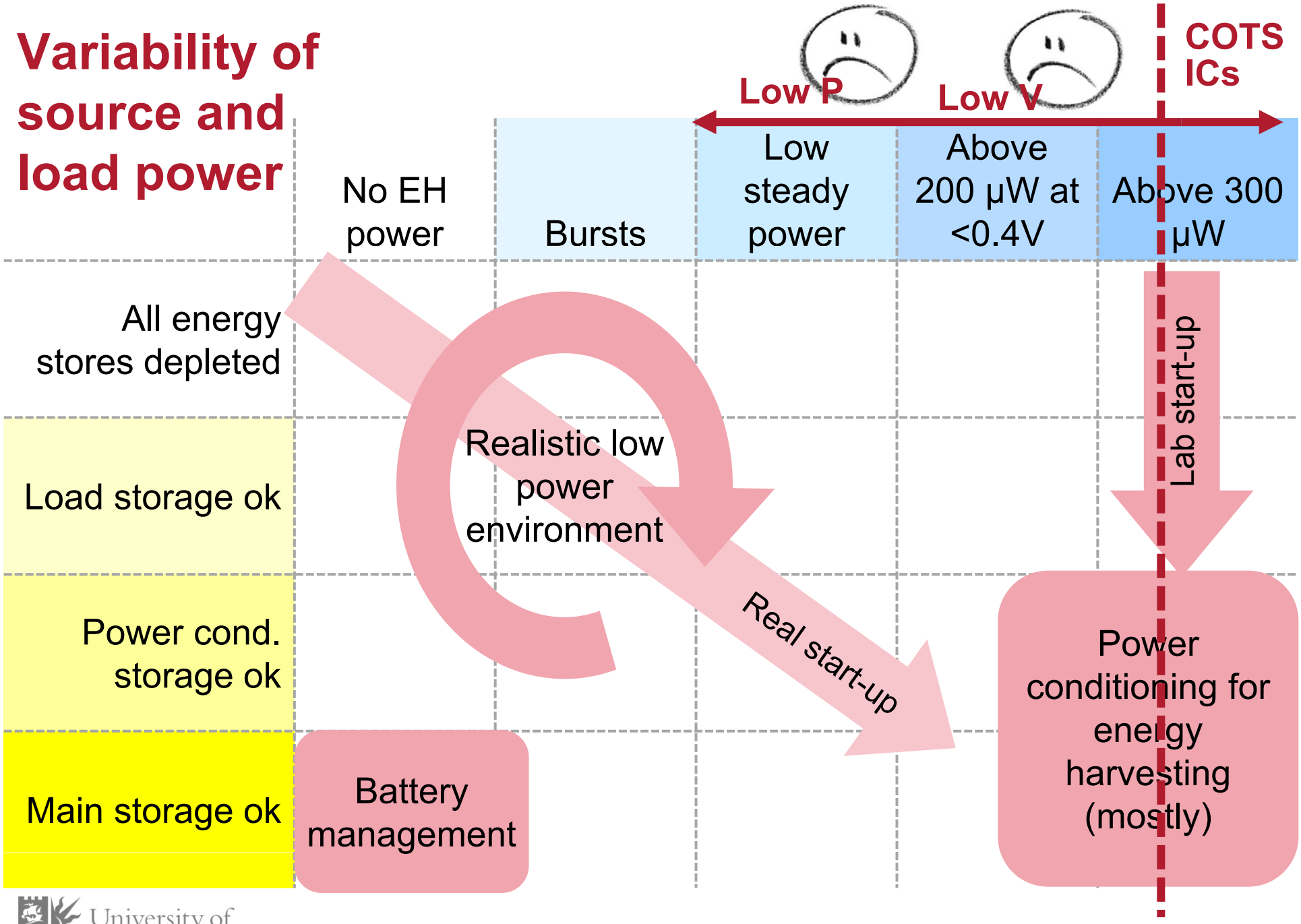


Piezo-electric is similar.

Special low-power case:



Variability of source and load power



Power and start-up voltage ranges

Reported in:

Degrenne et al., **"Self-starting DC:DC boost converter for low-power and low-voltage microbial electric generators."** *Energy Conversion Congress and Exposition (ECCE) 2011*

Seiko and LT struggle at 'start-up voltage' *and* 100 µW

ESTING DC:DC CONVERTERS COMPARISON

Circuit	Description				
	art-up voltage	*Power range*	*Vout*	*MPPT*	*Peak efficiency*
Linear technologies LTC310 (1:20) [16]	100mV	100µW to 100mW	2.35V to 5V	no	0.6
Enocean ECT310 [18]	20mV	100µW to 100mW	3V to 5V	no	0.3
Seiko S-882Z [19]	300mV	? to 150µW	1.8V to 2.4V	no	0.2
Markus [14]	70m	200µ to 16mW	2V to 5V	no	0.7
Qiu [20]	500mV	5µW to 10mW	0V to 5V	yes	0.7
Ramadass [11]	35mV	10µW to ?	1.8V	yes	0.58

Uses a 'kinetic' switch!

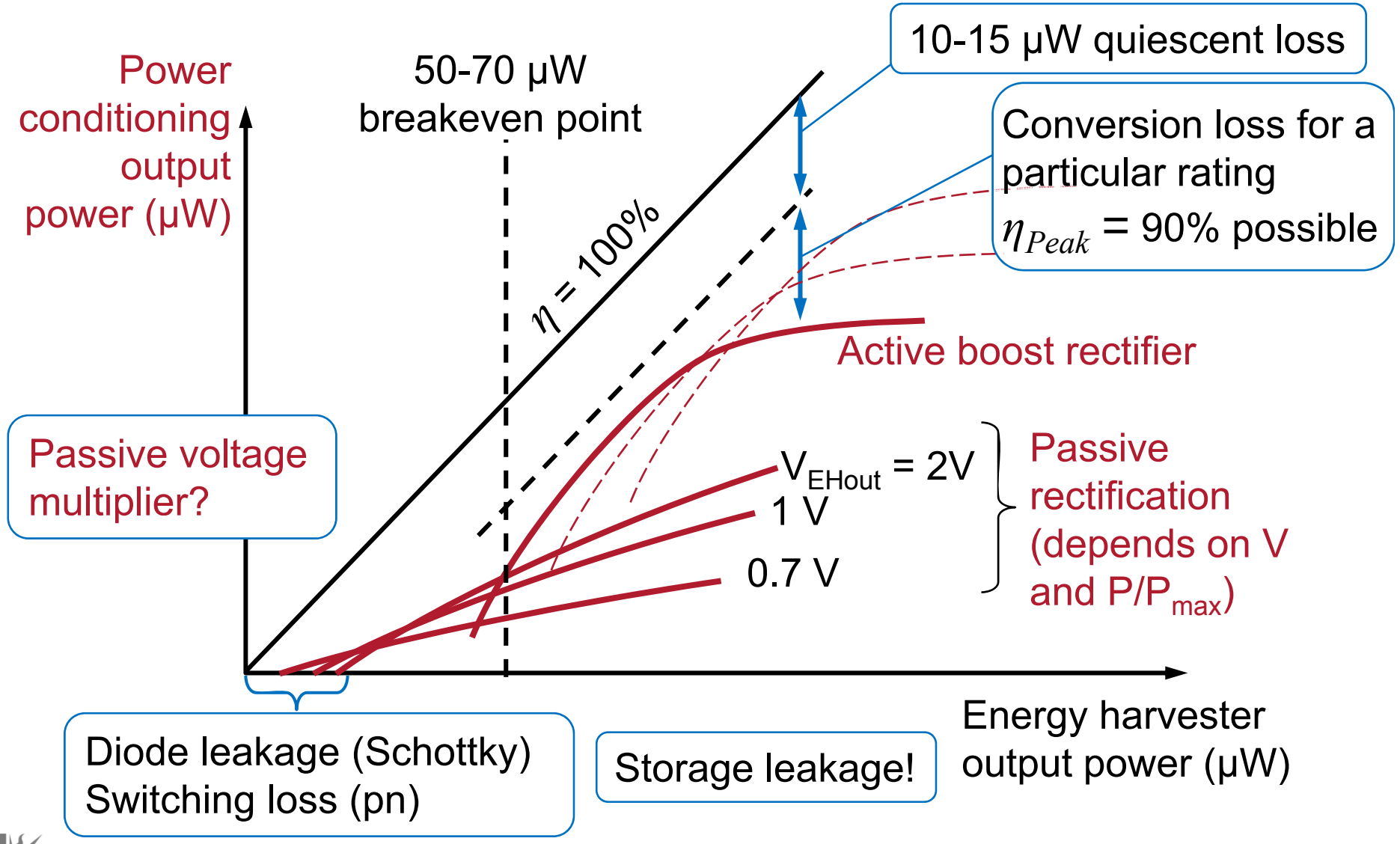
Requires many tens of mA to start up

Other good devices: LTC3588 (Piezo) & 3388 (Buck)

[11] Ramadass & Chandrakasan, "**A batteryless thermoelectric energy-harvesting interface circuit with 35mV startup voltage**," IEEE Journal of Solid-State Circuits, 2010.

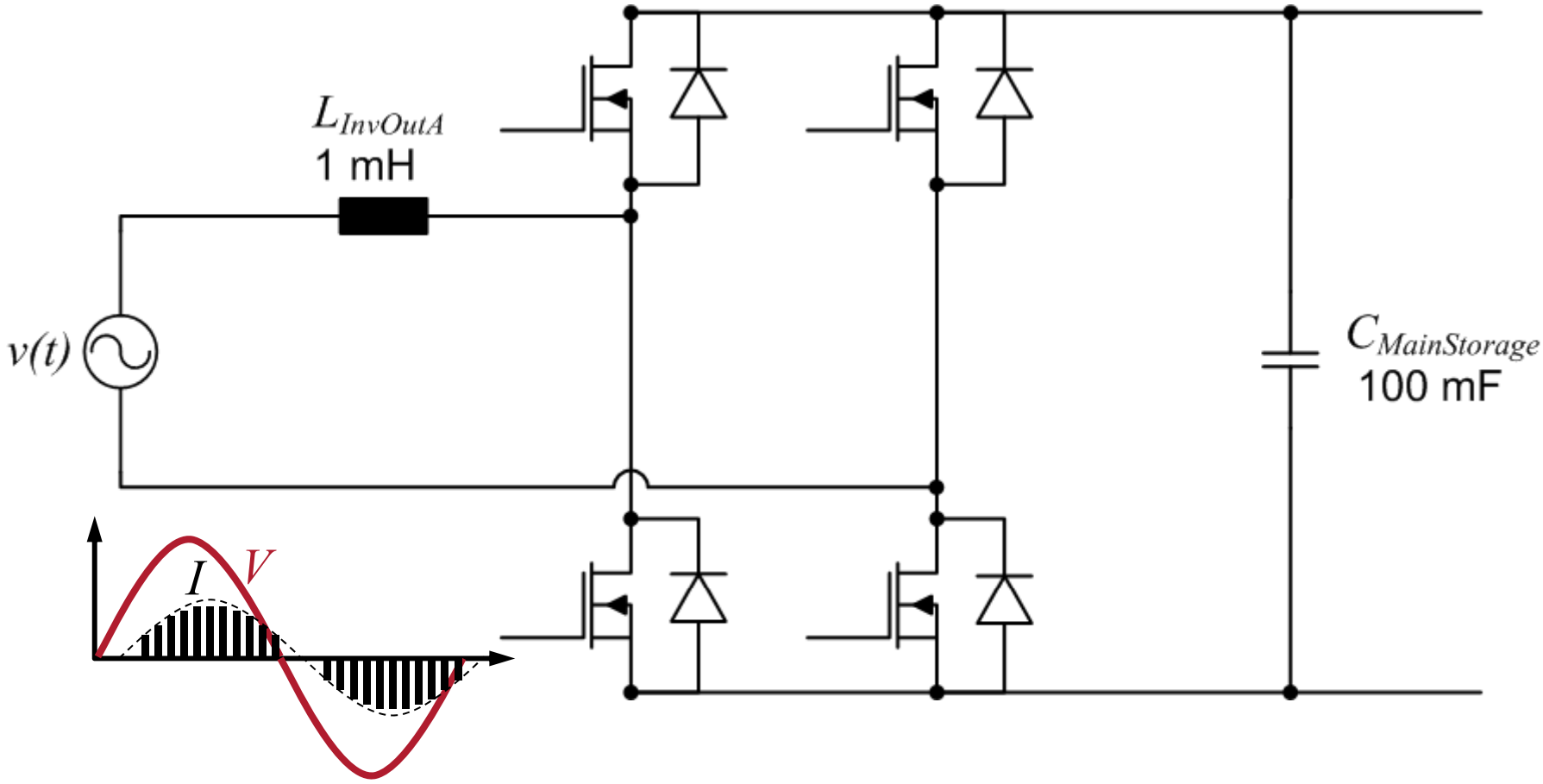
[20] Qiu et al., "**5µW-to-10mW input power range inductive boost converter for indoor photovoltaic energy harvesting with integrated maximum power point tracking algorithm**", IEEE International Solid-State Circuits Conference, 2011.

Break-even point between passive and active (discrete example)



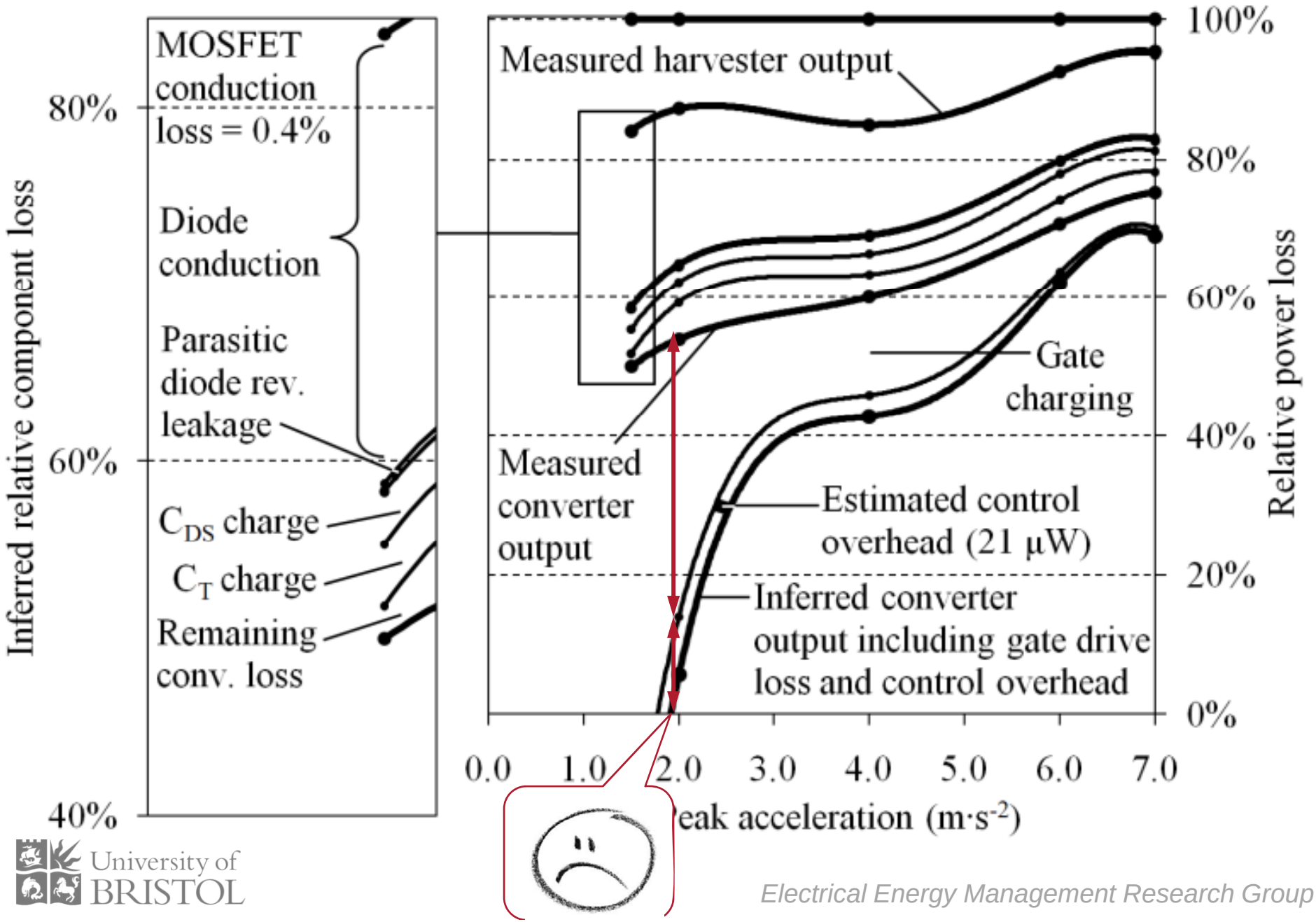
Example topology: Synchronous boost rectifier

- Passive diodes → Schottky diodes → “Active diodes”
- Boost converter DC/DC → Synchronous → AC/DC



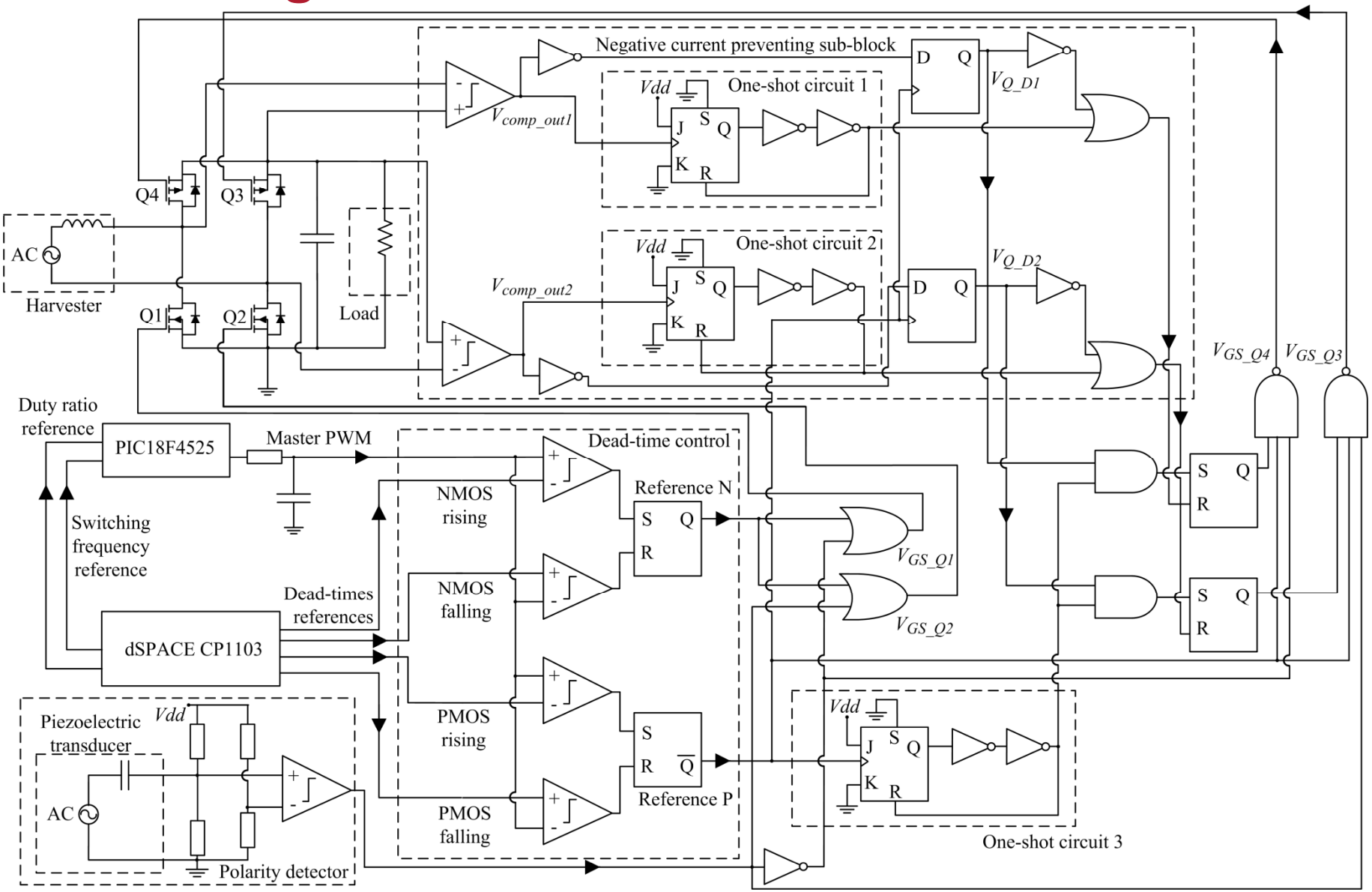
Source: Szarka et al., ISLPED'11

Typical losses in power stage



Gate driving etc.

Source: Proynov et al., APEC'12



Gate driving etc.

Source: Proynov et al., APEC'12

Prevent negative current

Sensing, filtering, noise immunity

Fast analogue circuits (<10ns delay, not currently available in low power)

Power circuit

5 V blocking and fast (10ns)

Low leakage

Fast reverse diodes

High- and low-side devices

Gate drives

Level-shifting

High-side V rail

"Analogue" circuits: Digital circuits provide enough power, 100 MHz gain-BW, 10 ns prop. delays.

(Low power COTS: 40 kHz, µs)

PWM and control

I/V measurement

Precision resistors

Low voltage

Use COTS

Dead times

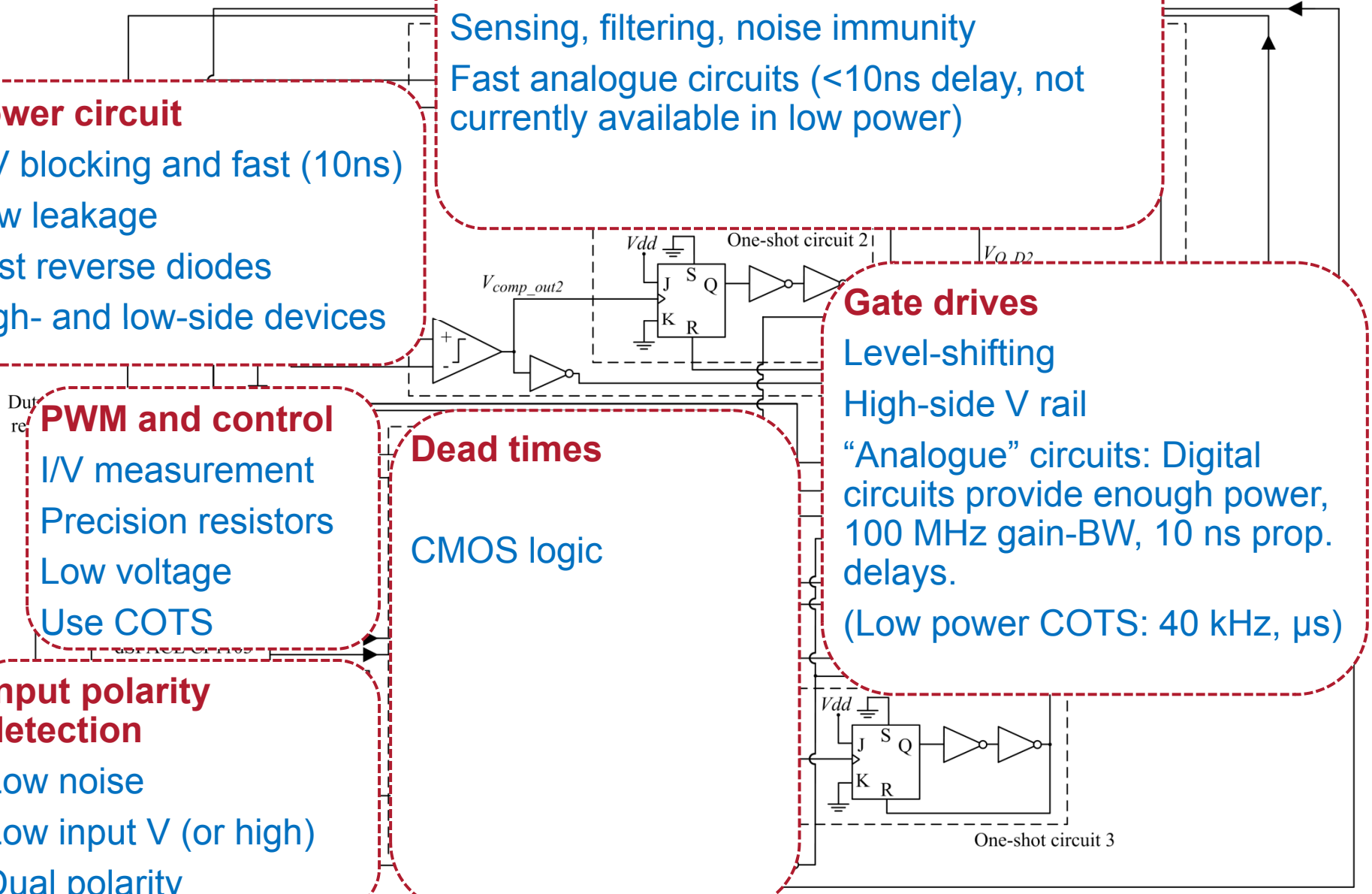
CMOS logic

Input polarity detection

Low noise

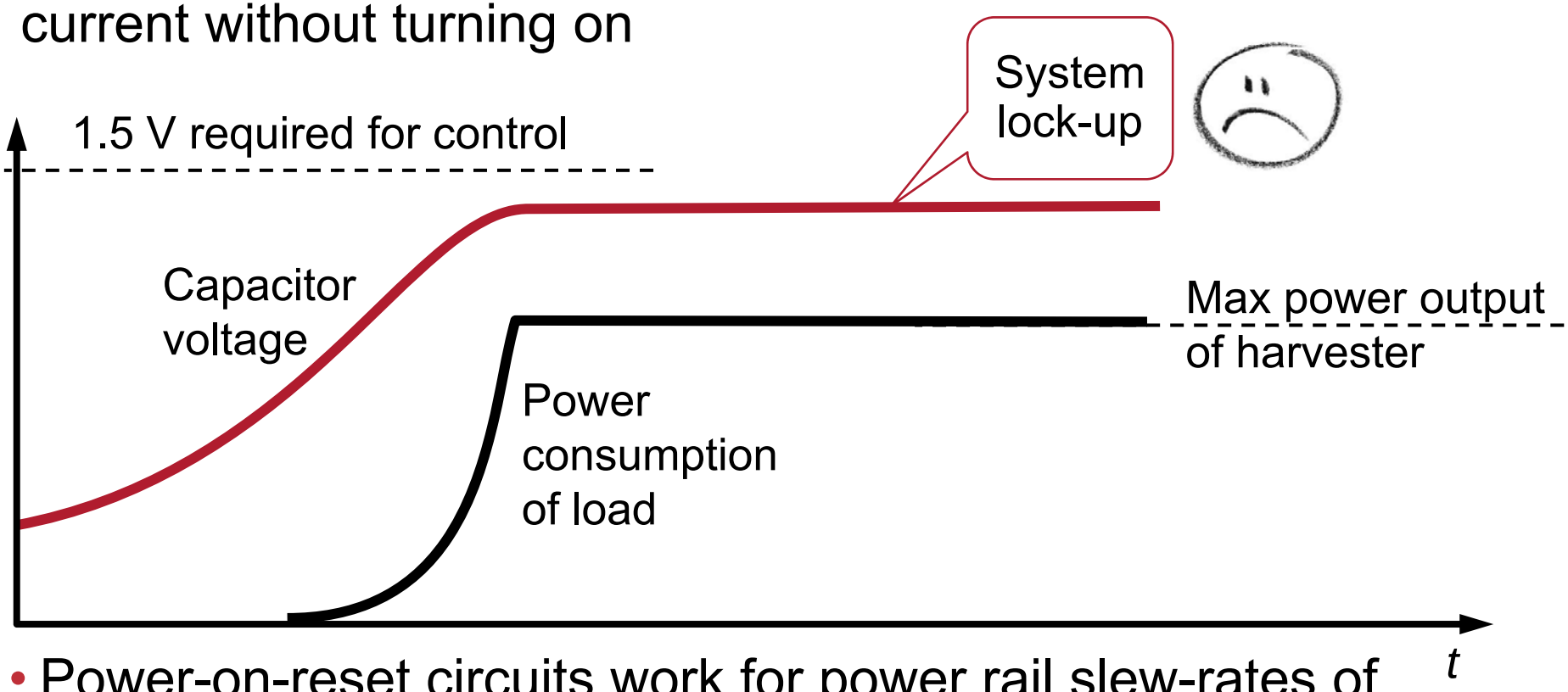
Low input V (or high)

Dual polarity



New circuits required with minimal start-up leakage

- Supply capacitor voltage rises gradually
- Control circuits enter faulty states where they draw a lot of current without turning on



- Power-on-reset circuits work for power rail slew-rates of V/ms but not for V/s or slower.
- Use ‘isolator’ circuits, e.g. Torex voltage detectors (**>1 µA**)