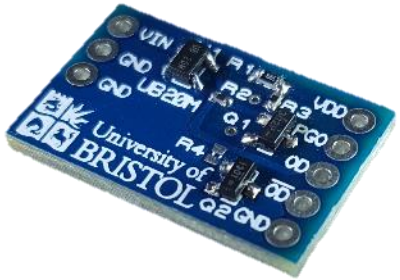
University of BRISTOL

Electrical Energy Management Research Group
www.bristol.ac.uk/engineering/research/em/



High-Voltage, Low-Threshold, Low-power Voltage Detector

for Energy Harvesting, Internet of Things, RF Power Transfer, and Event-Driven Sensing

Zero-Power Monitoring and Wake-Up for Energy Harvesting, Wireless Sensors, and Remote-Controlled Devices

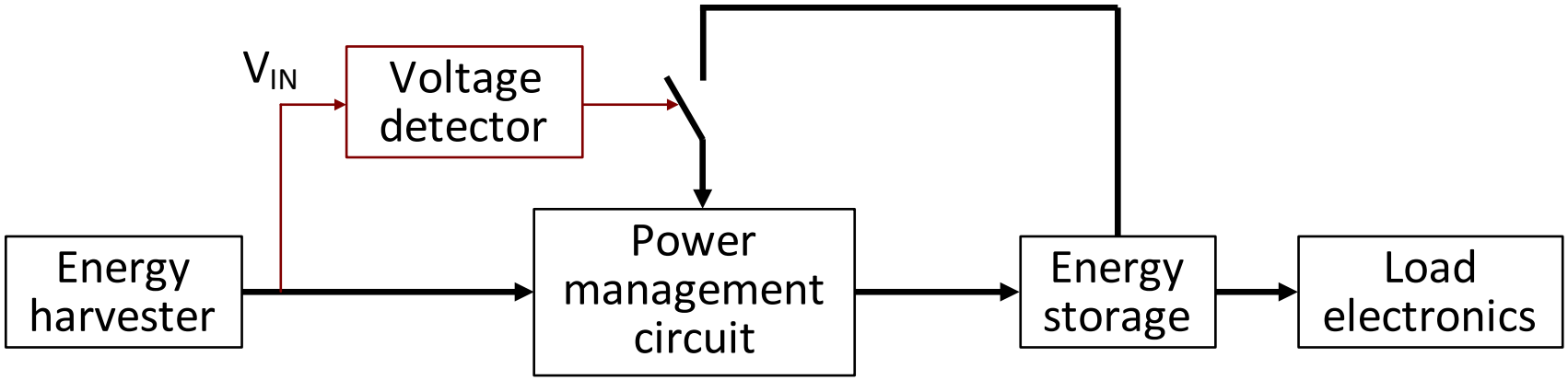
Plamen Proynov

5 April 2017

sphere

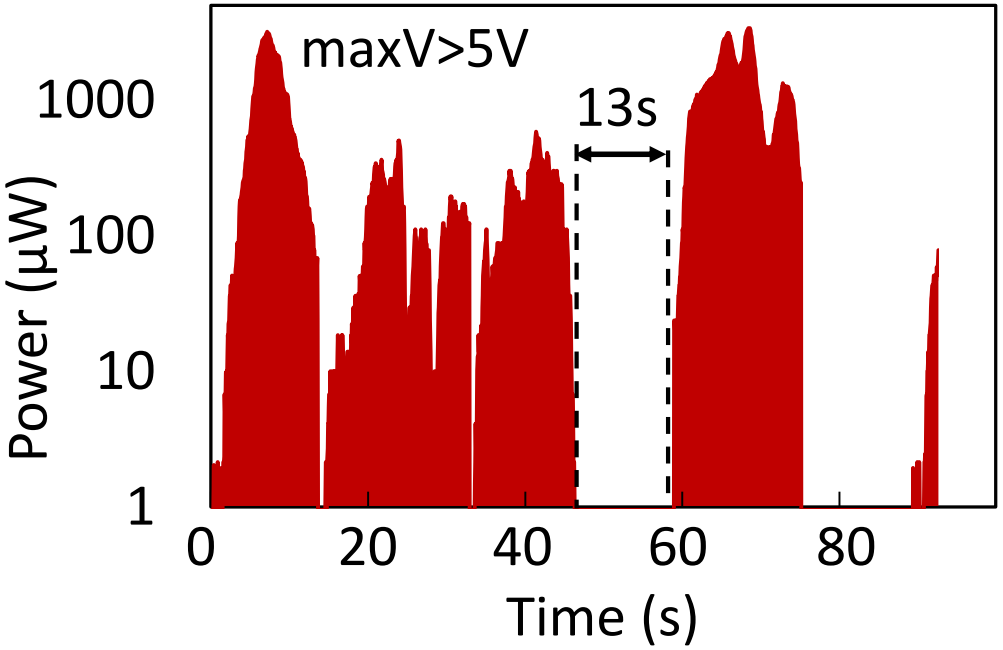
EPSRC
Pioneering research and skills

Typical energy harvesting system

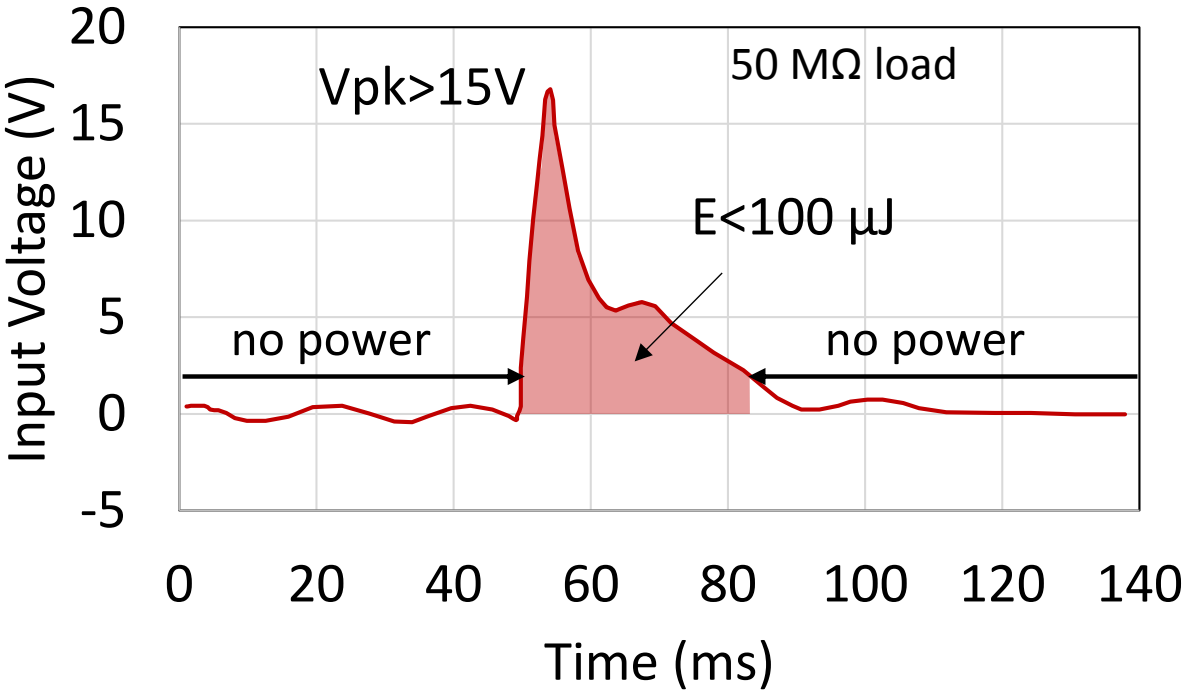


Inefficient with realistic sources e.g. body-worn 2.4GHz rectenna:

- Highly dynamic power
- Long gaps between pulses of energy



Ferroelectret energy harvester



Peak power: 6 µW
Source resistance: >50 MΩ
Pulse width (V>0.5V): 36 ms

Problematic features:

- Mostly gaps
- High voltage could damage electronics
- No current

Requirements for the voltage detector:

- Withstand high voltages (up to 20V)
- Low threshold
- Low source loading
- Low quiescent consumption

Commercially available options

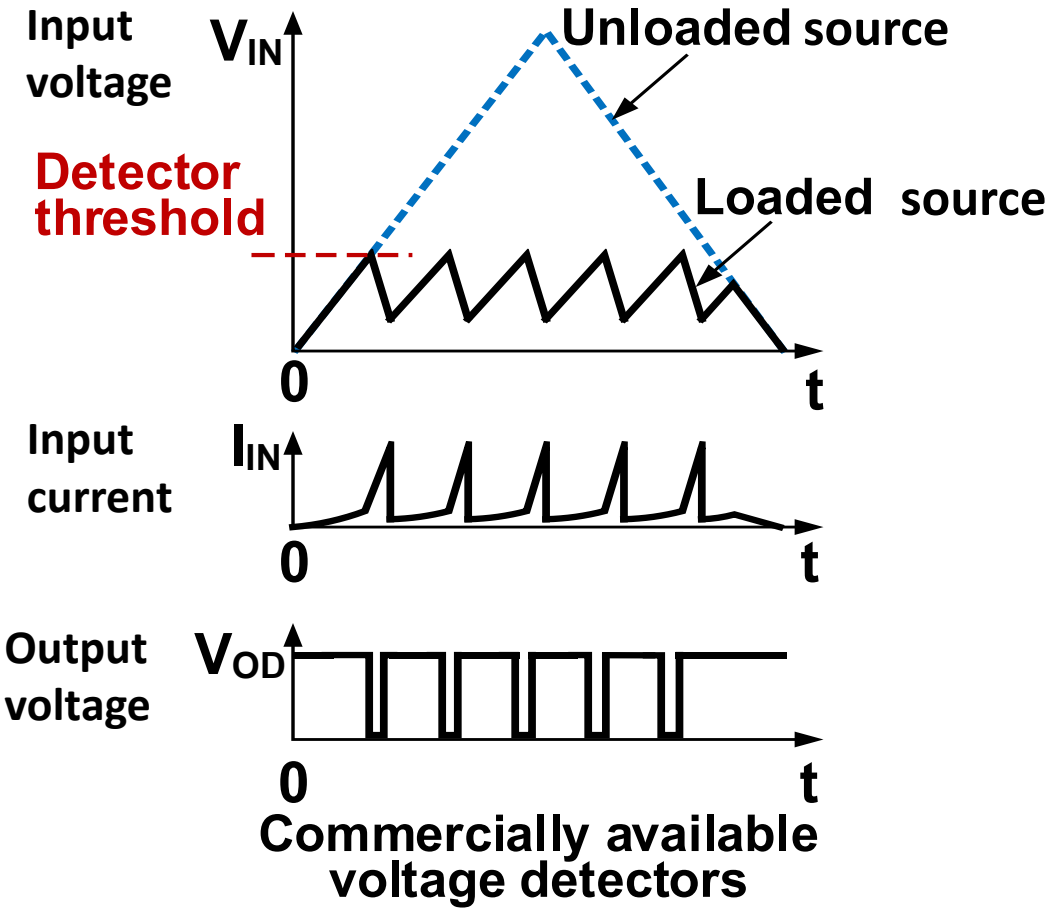
- Comparators – require continuous power supply, e.g. TS881:
  - Minimum supply voltage V_{CC} = 0.85V
  - Input bias current I_{IB} < 10 pA
  - Supply current I_{CC} = 210 nA (at 1.2V V_{CC})
- Voltage detectors – input powered

	ON threshold (V)	Max input voltage (V)	Input current @V_{IN}<V_{TH}(nA)	Input current @V_{IN}>V_{TH}(nA)	Output leakage (nA)	Max output voltage (V)
ZSPM4121	1.7	5.5	0.1	40	100	-
TS12001	0.78	2.5	0.1	590	20	-
XC6120	1	6	-	350	1	7
UB20M	0.6	20	0.03	0.013	<0.1	5.5

Low ON threshold leads to
low maximum input voltage

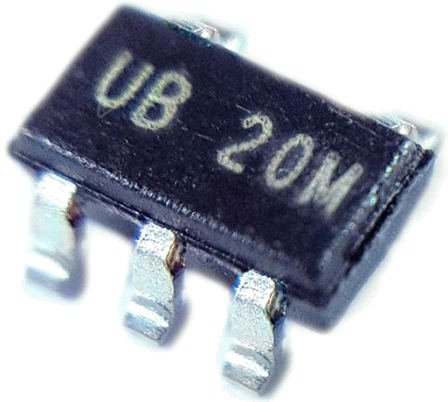
UB20M: lowest threshold, highest max input voalteg

Operation of a commercially available voltage detector with the ferroelectret source



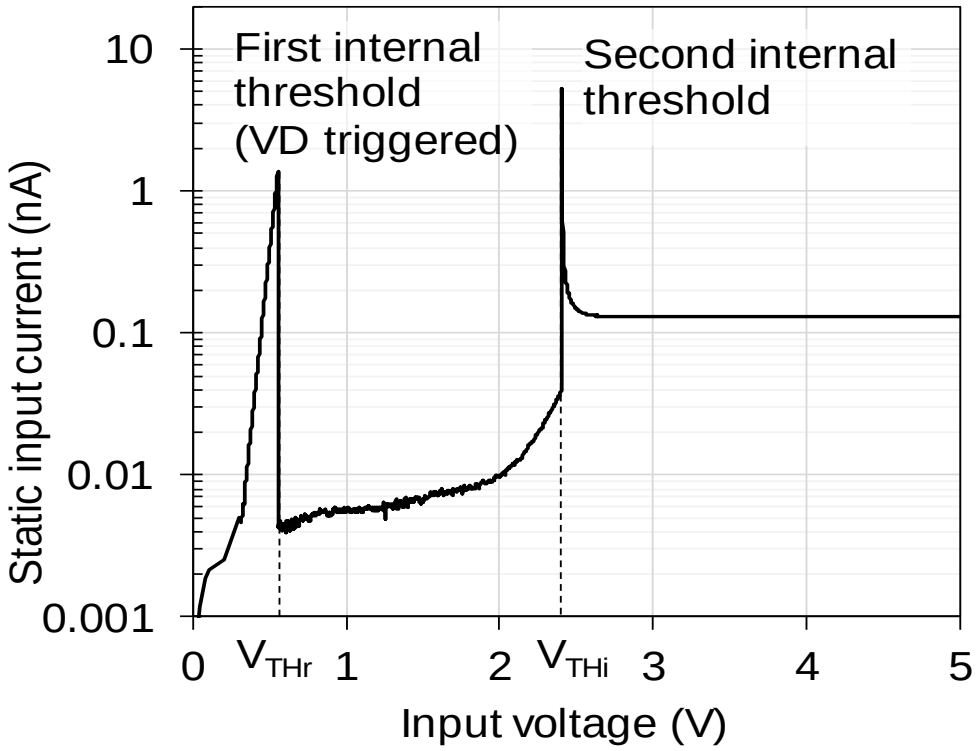
- Input is clamped
- Oscillations on the output

UB20M Voltage detector (SOT23-5)



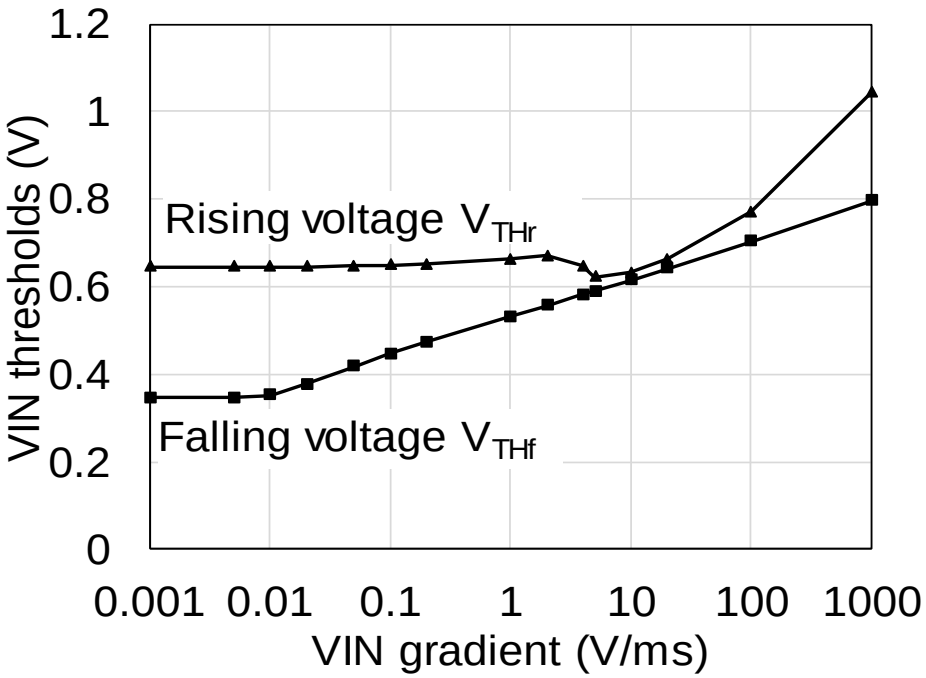
- Threshold voltage: 600mV
- Maximum input voltage: up to 20V
- Output leakage: below 100pA

- Power consumption: 5.4pA at 1V
- Peak static input current at turn-on: 1.5 nA

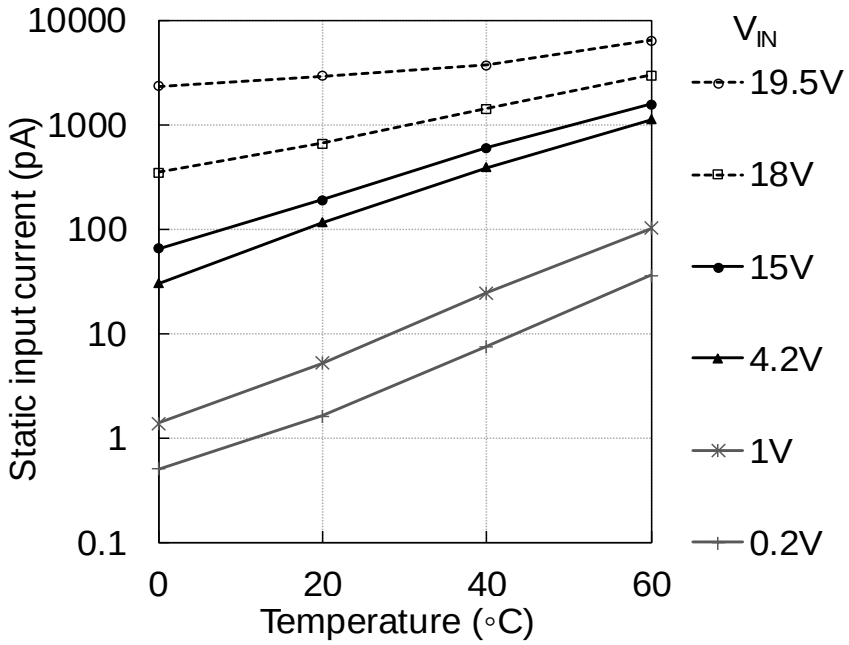


UB20M Voltage detector

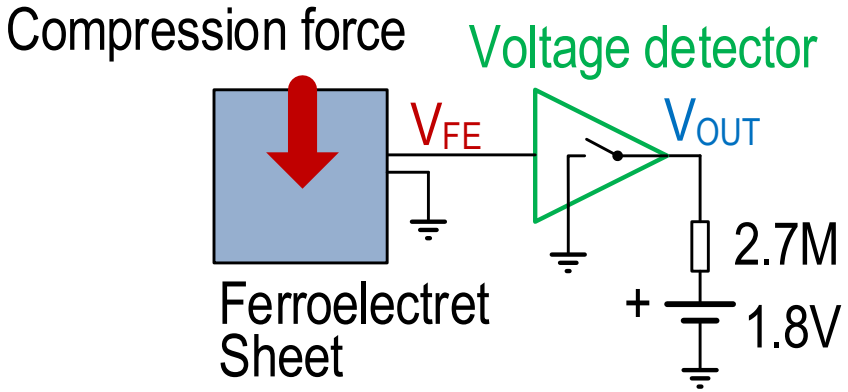
- Effect of dVin/dt:

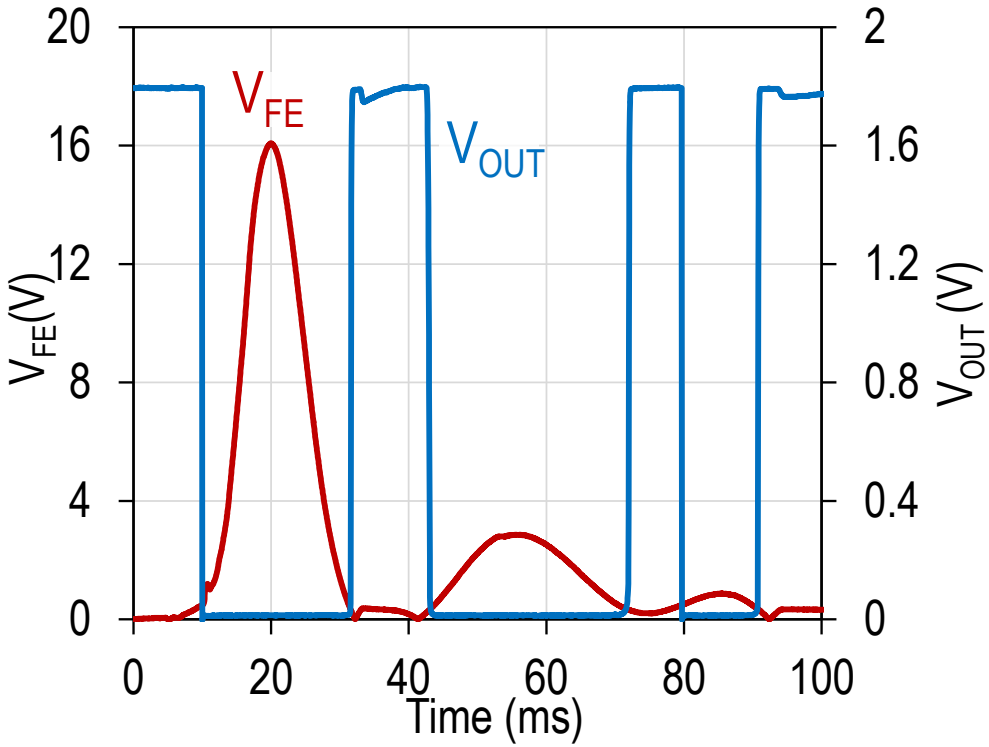


- Temperature effects:

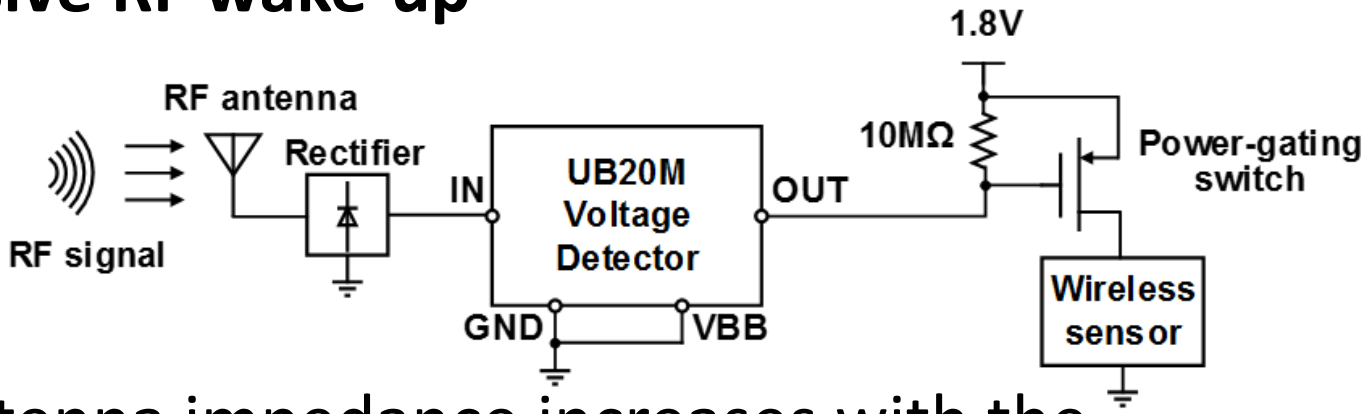


Captured waveform with the ferroelectret harvester

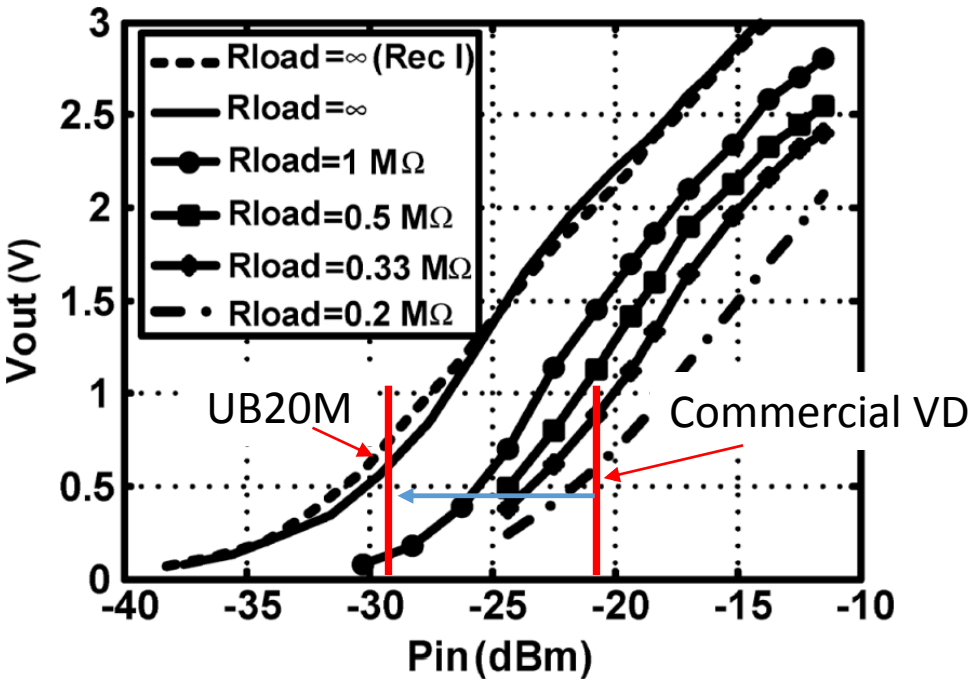


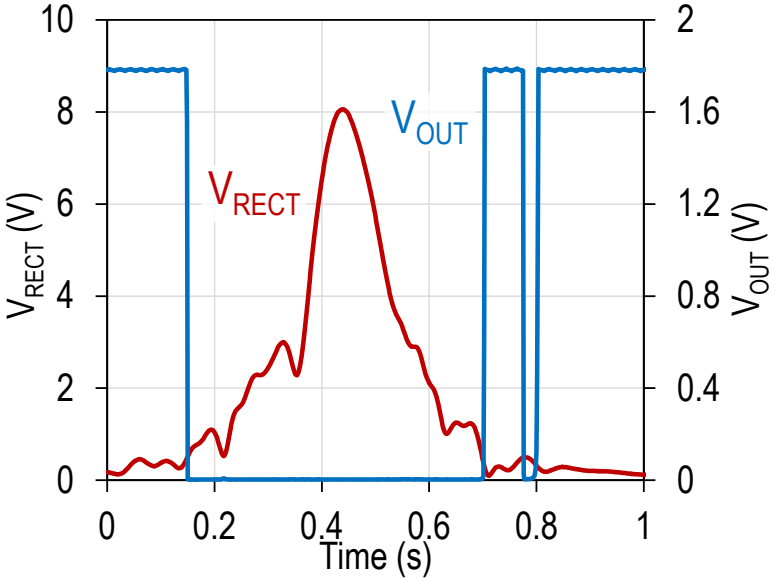


Passive RF wake-up



- Rectenna impedance increases with the distance, from 1kΩ up to GΩ

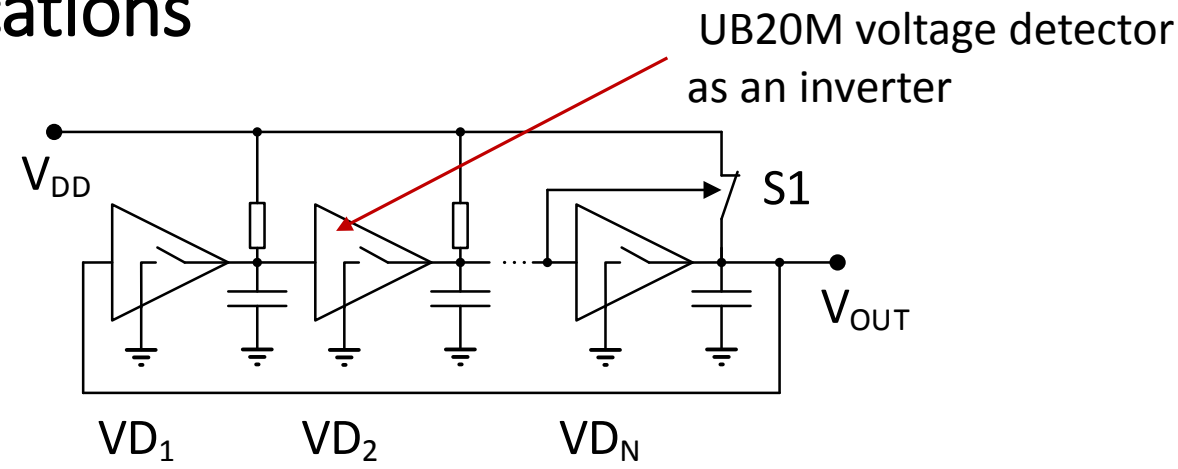




Rectenna output voltage as a function of the RF input power for different loads
source: Stoopman *et al.,* 2014

Other applications

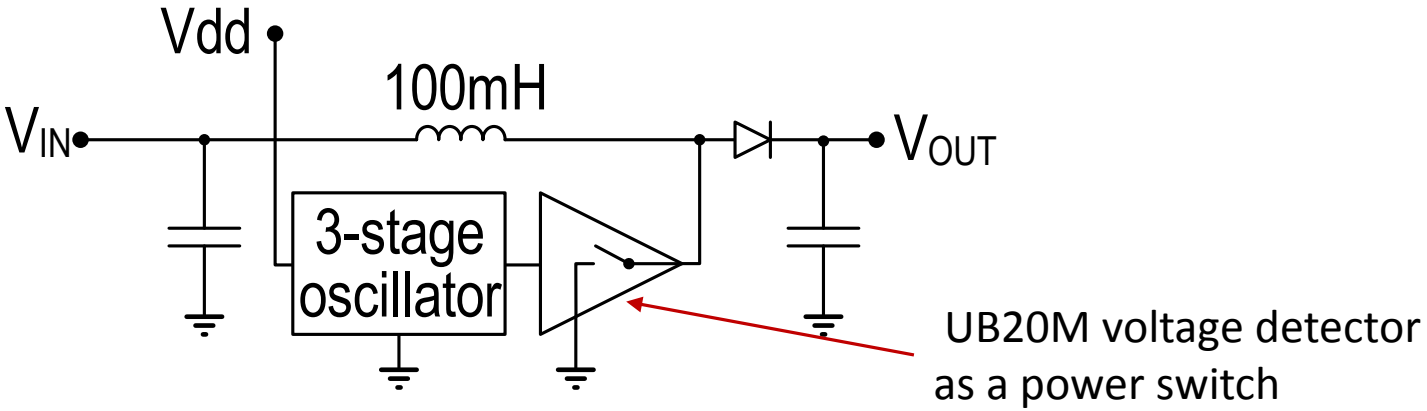
Oscillator:



VD as an inverter – n-stage ring oscillator:

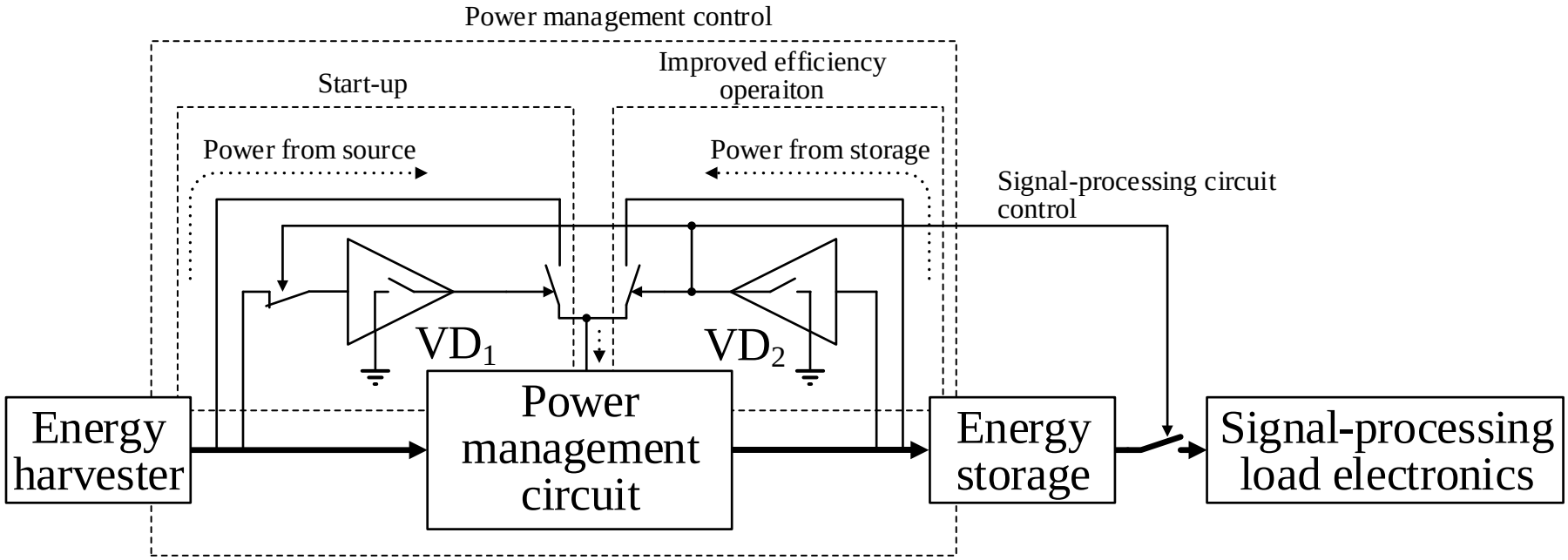
- Low power – 35nA at 1.1V
- Low duty cycle – 1.7%
- Frequency - 180 Hz

Application – gate driving for a low-power boost converter for high sensitivity RF monitoring and wake-up (-36 dBm / 250 nW)



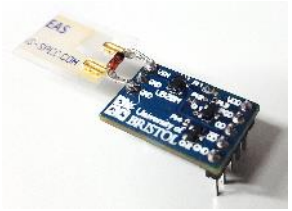
Power path control in energy harvesting systems with storage

- Power management can be powered from two sources:
  - Energy harvester during start-up (V_{IN}>450mV, $V_{STORAGE}$<600mV)
  - Energy storage when sufficient voltage is reached ($V_{STORAGE}$>600mV)

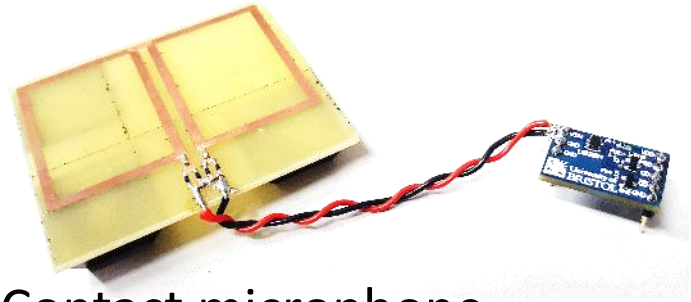


Other high impedance sources

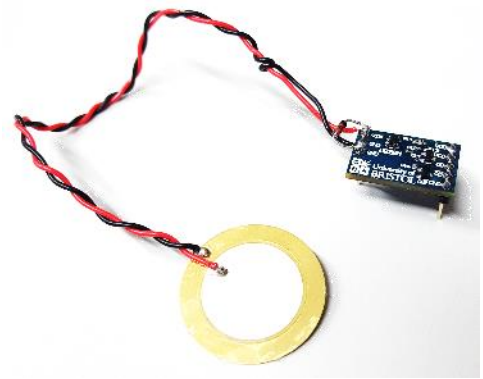
- Piezoelectric PVDF strips



- 2G, Sigfox, RF Rectenna for passive wake-up



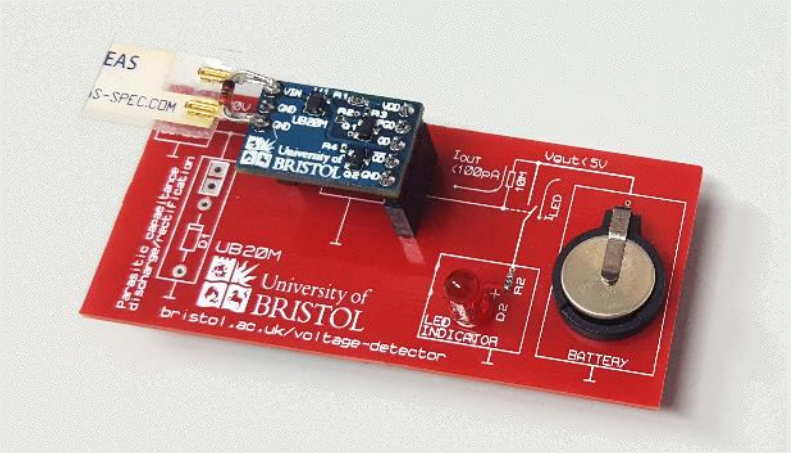
- Contact microphone



We are considering also:

- Infra-red receiver
- Ultrasound receiver
- Thermopile

Demos



Team

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Website and free samples

bristol.ac.uk/voltage-detector

Questions?