

ENERGY MANAGEMENT FOR HYBRID AUTONOMOUS TRANSCEIVERS

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Intro

- What are hybrid autonomous transceivers?
- The problem of the power supply and management
- Our approach: hybrid energy harvesting

General scheme

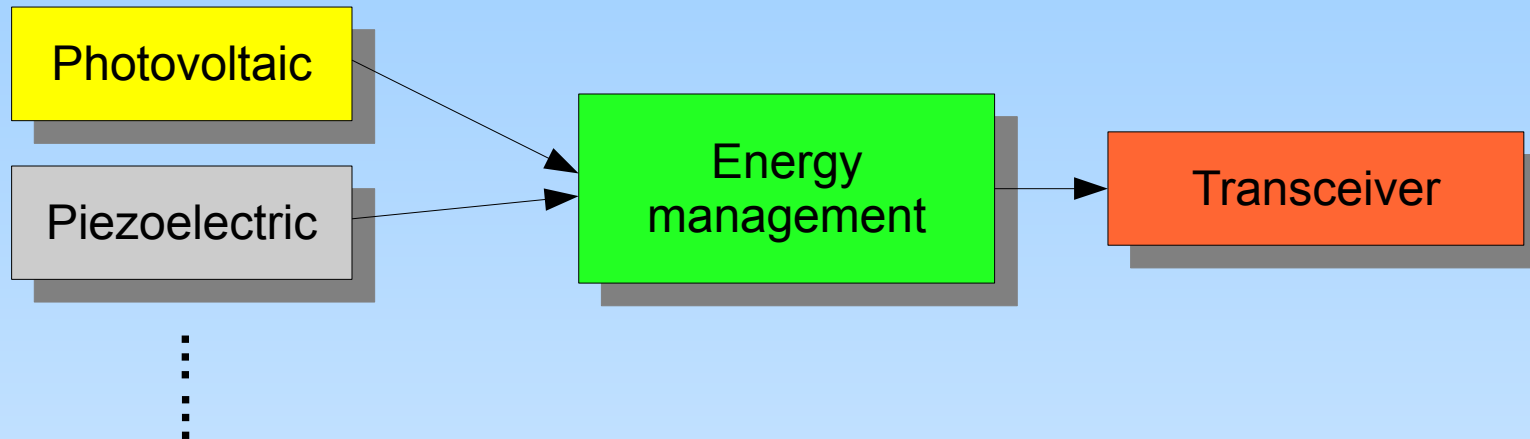
- **Energy harvesting + energy storage + energy management**

In detail

- Vibration harvesting: the nonlinear approach
- The alternative source: solar energy
- **Power conditioning**
- **Energy storage in the capacitors**
- **Power supervisioning**
- **A real application: HAT - Hybrid Autonomous Transceiver**
- Future perspectives



What are hybrid autonomous transceivers?



Hybrid autonomous transceivers are a class of self-powered battery-free transceivers in which the **source of power** is a combination of:

- piezoelectric harvester
- photovoltaic harvester
- thermoelectrics generator
- electromagnetic harvester
- radiofrequency harvester
- electrostatic harvester



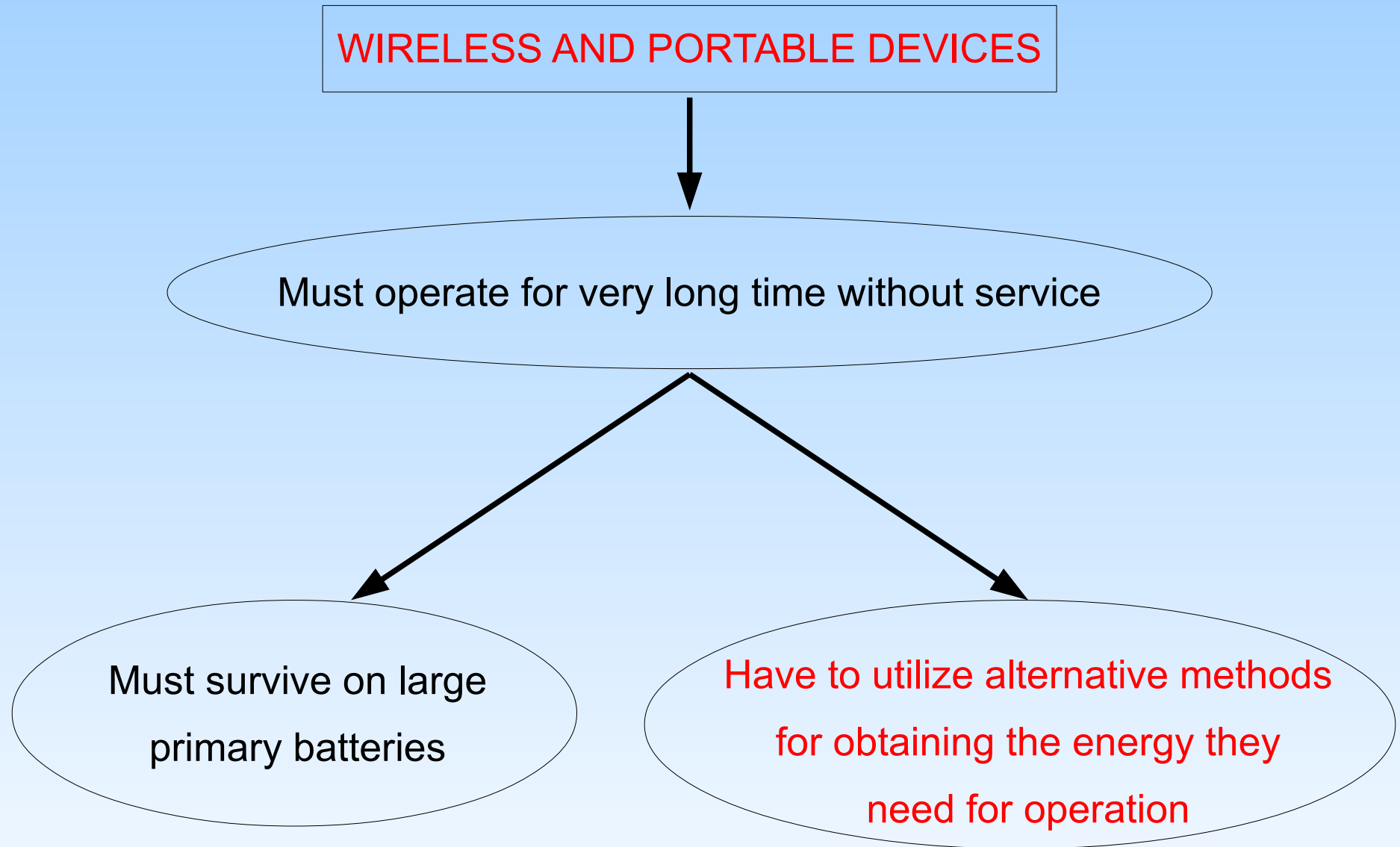
What are hybrid autonomous transceivers?



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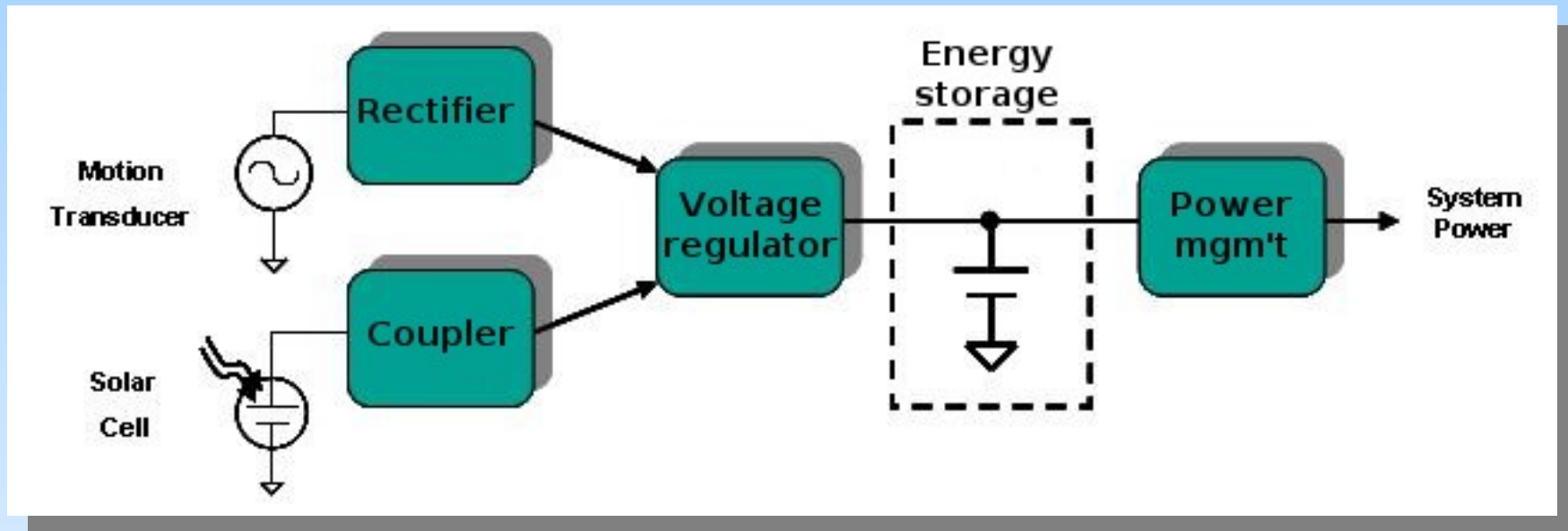


The problem of the power supply and management



Our approach: hybrid energy harvesting

Why not to use two or more energy harvesting technologies at the same time?



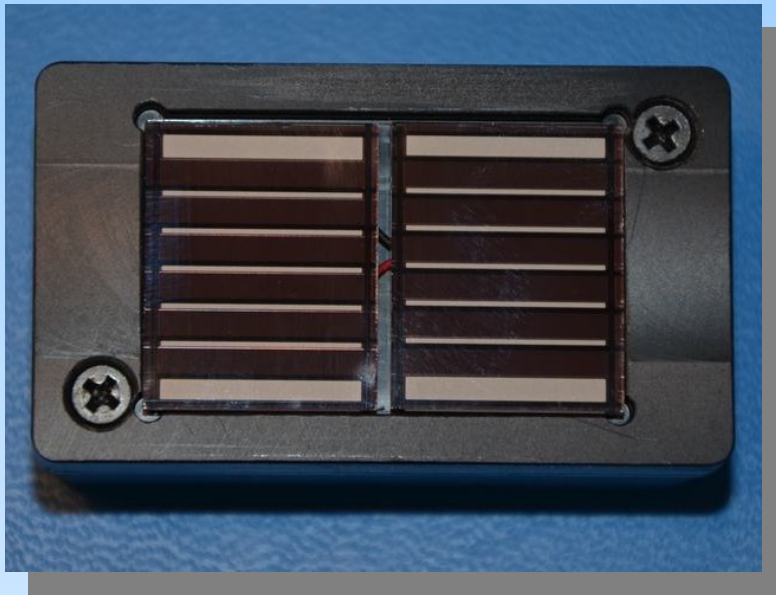
Different technologies work under different environment conditions



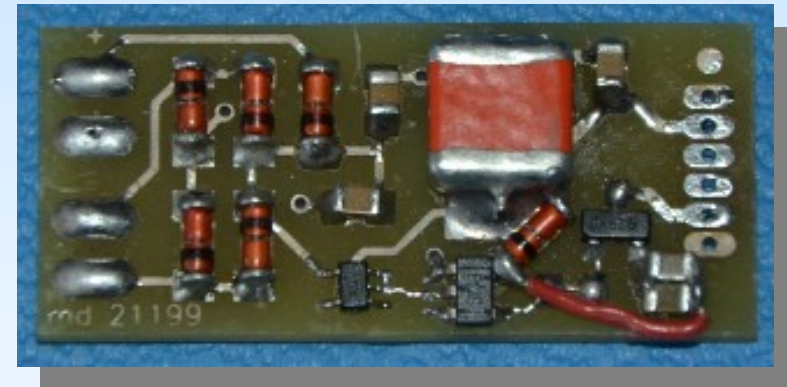
If vibrations are not present, PV cells can be used to power the system



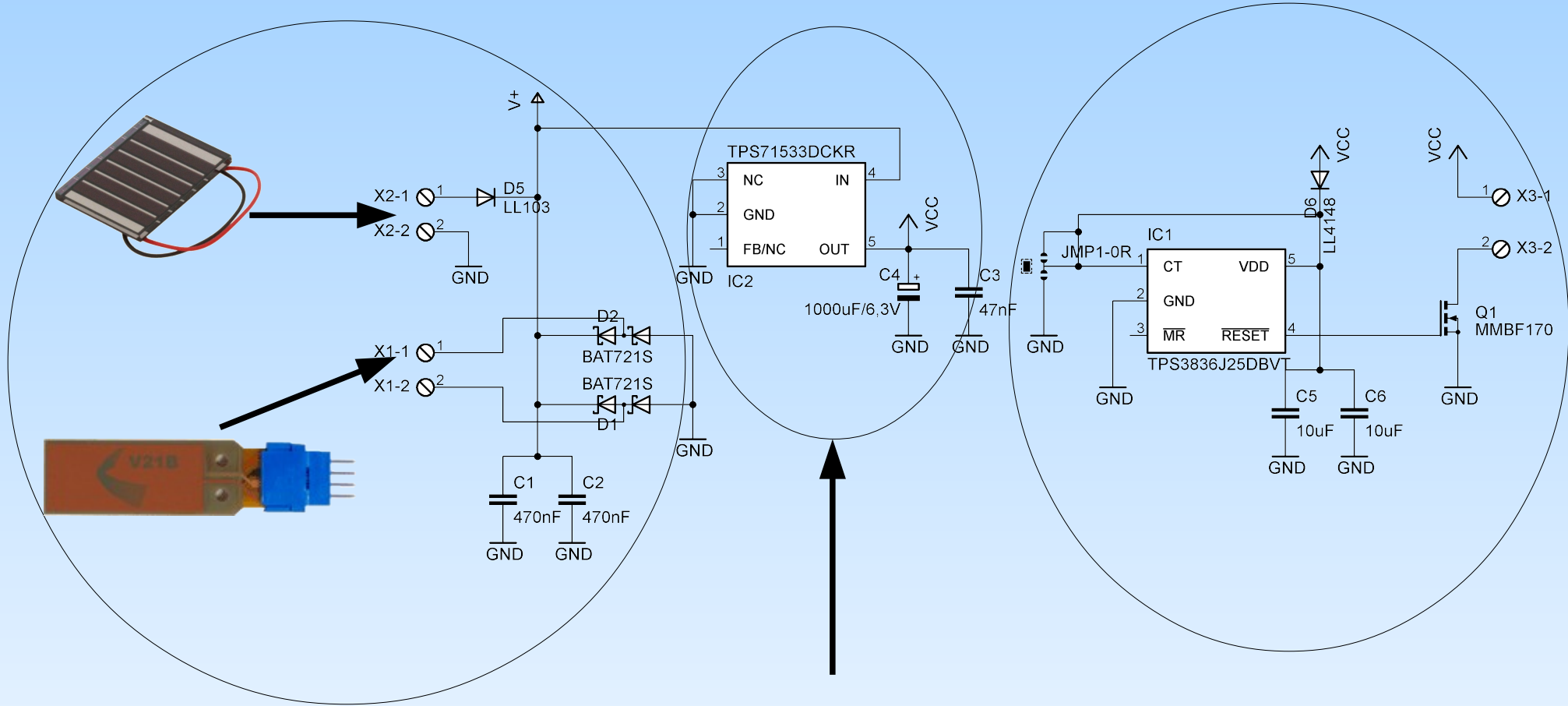
Energy harvesting + energy storage + energy management



- Small enclosure: 60 x 35 x 25 mm
- 2 solar cells: 20 x 25 mm, $P_{max} = 8 \text{ mW @ } 3,9 \text{ V}$
- 1 piezoelectric non-linear vibrations harvester
- 1 LDO voltage regulator: $V_{out} = 3,3 \text{ Vdc}$, $I_q = 3,2 \mu\text{A}$
- 1 high capacitance tantalum capacitor: $1000 \mu\text{F } 6,3 \text{ V}$
- 1 NanoPower Supervisory Circuits



Energy harvesting + energy storage + energy management



HARVESTERS

ENERGY STORAGE

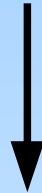
ENERGY MANAGEMENT



Vibration harvesting: the nolinear approach



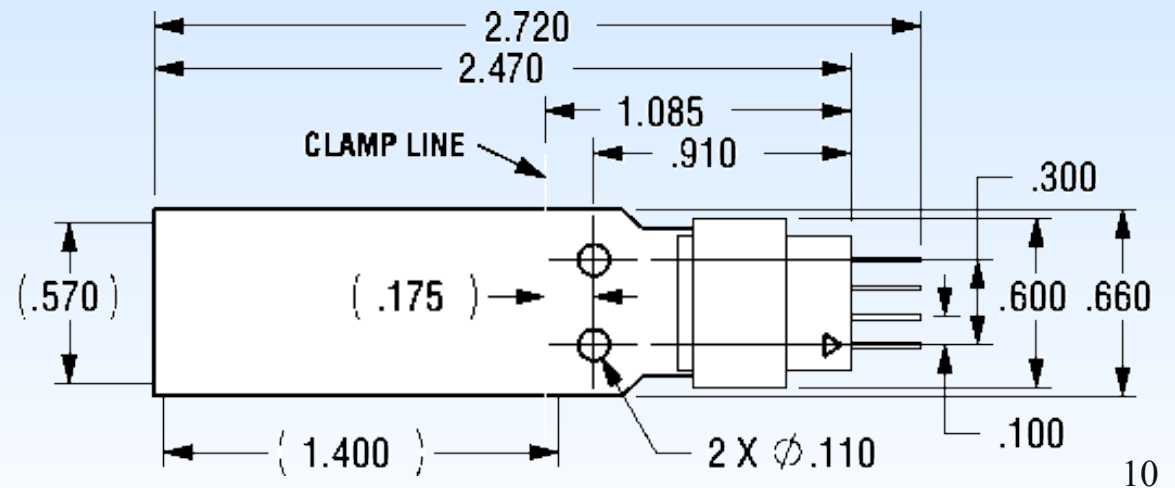
Tip Mass ≈ 20 grams



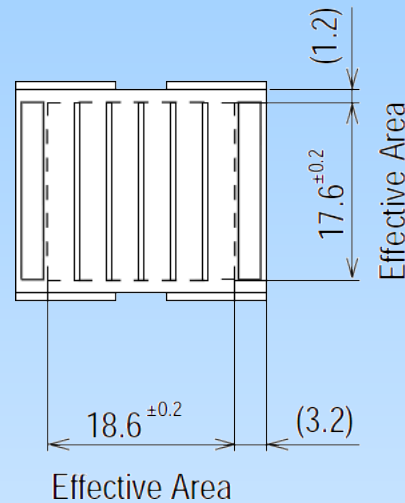
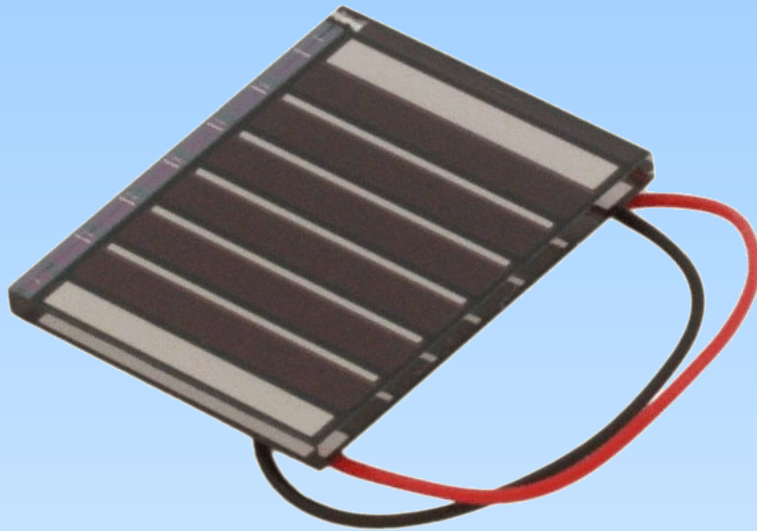
$F_n \approx 46$ Hz
(in the linear regime)

Tip Mass (gram)	F_n (Hz)	Amplitude (g)	Open Circuit Voltage*
0	275	0.25	4.1
0	275	0.375	5.9
0	275	0.5	7.6
0	275	1	12.3
1	175	0.25	7.6
1	175	0.375	10.9
1	175	0.5	13.6
1	175	1	23.5
2.4	140	0.25	10.9
2.4	140	0.375	15.2
2.4	140	0.5	18.8
2.4	140	1	32
4.8	105	0.25	15.9
4.8	105	0.375	21.6
4.8	105	0.5	28.1
4.8	105	1	46.5

* piezo wafers connected in series



The alternative source: solar energy



SANYO AM-5610 Amorphous Solar Cell

Ratings at $T_a = 25^\circ\text{C}$

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Open Circuit Voltage	Voc	SS 50kLx		5.1		V
Short Circuit Current	Isc	SS 50kLx		2.4		mA
Operating Voltage & Operating Current	Iope	SS 50kLx, Vope=3.0V	1.7			mA
		SS 50kLx, Vope=3.3V		2.3		mA
		AM-1.5, 100mW/cm ² , Vope=3.3V		5.1		mA
Maximum Output (Reference Value)	Pmax	SS 50kLx, Vop=3.9V, Iop=2.2mA		8		mW
		AM-1.5, 100mW/cm ² , Vop=3.9V, Iop=4.6mA		18		mW
Operating Temperature	Topr				-10 to +60	°C
Storage Temperature	Tstg				-20 to +70	°C

SS: Solar Simulator



Power conditioning

Voltage Regulator

TI TPS71533

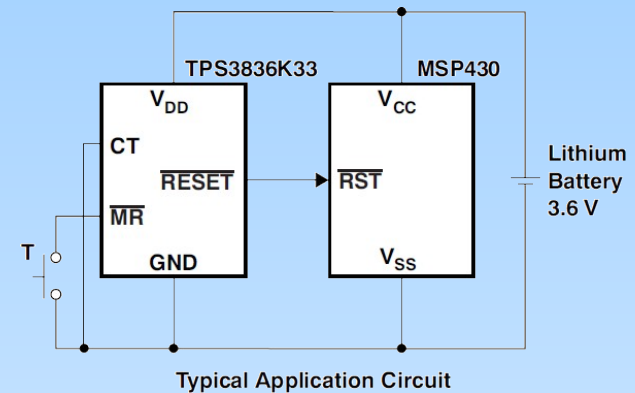


Actual Size
(2,15 mm x 2,3 mm)

- 2,5 V minimum input voltage
- 24 V Maximum input Voltage
- $V_{out} = 3,3 V$
- $I_{out} = 50 \text{ mA max}$
- Low 3.2 μA quiescent current
- Dropout voltage, typically, 415 mV at 50 mA of load current

Voltage supervisor

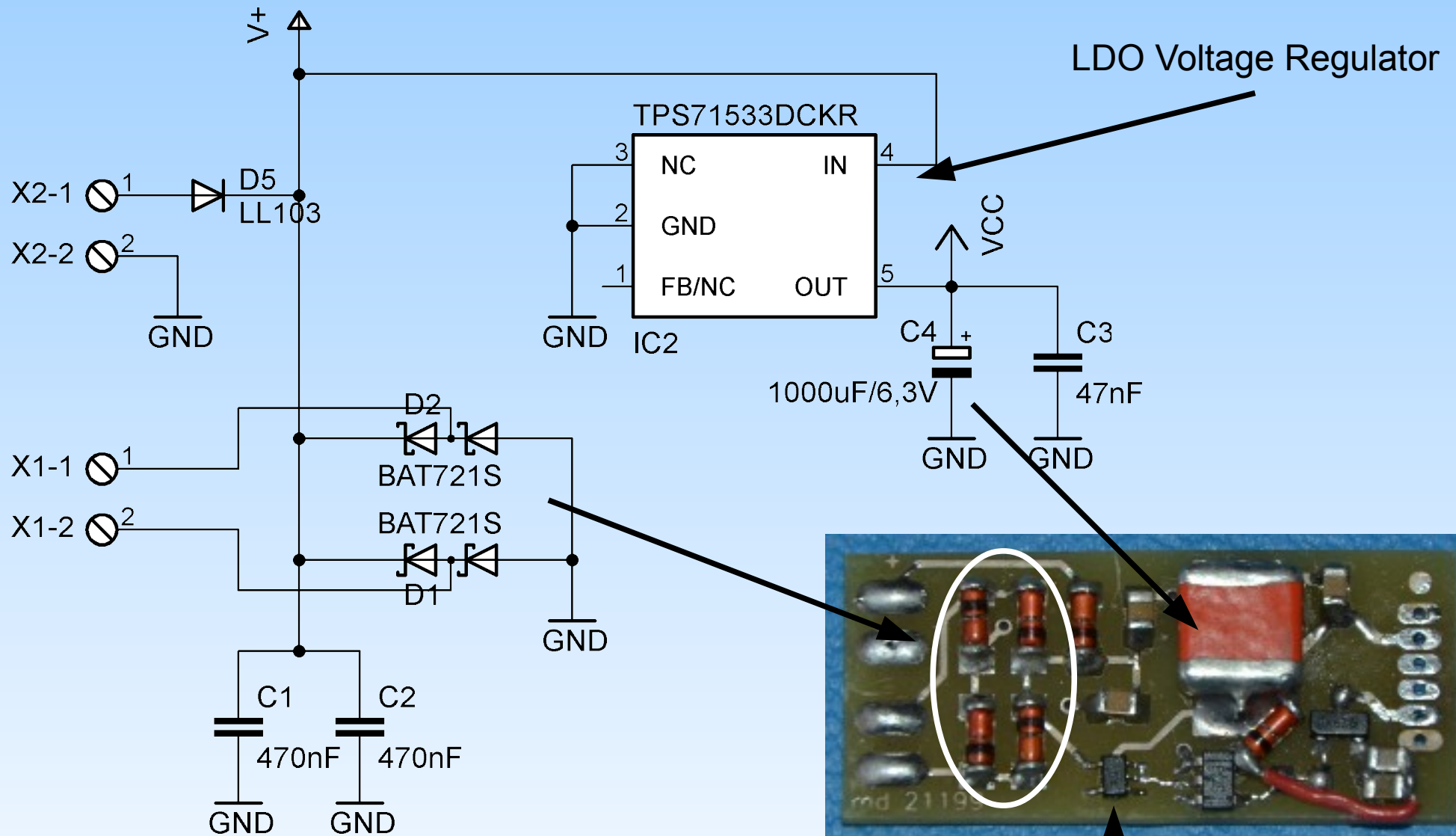
TI TPS3836



- Supply Current: 220 nA (typical)
- Threshold voltage: 2,25 V
- Typical hysteresis voltage: 40 mV
- Power-On Reset Generator With Selectable Delay Time: 10 ms or 200 ms
- Push/Pull active-low RESET Output
- Supply voltage: 1,6 – 6 V



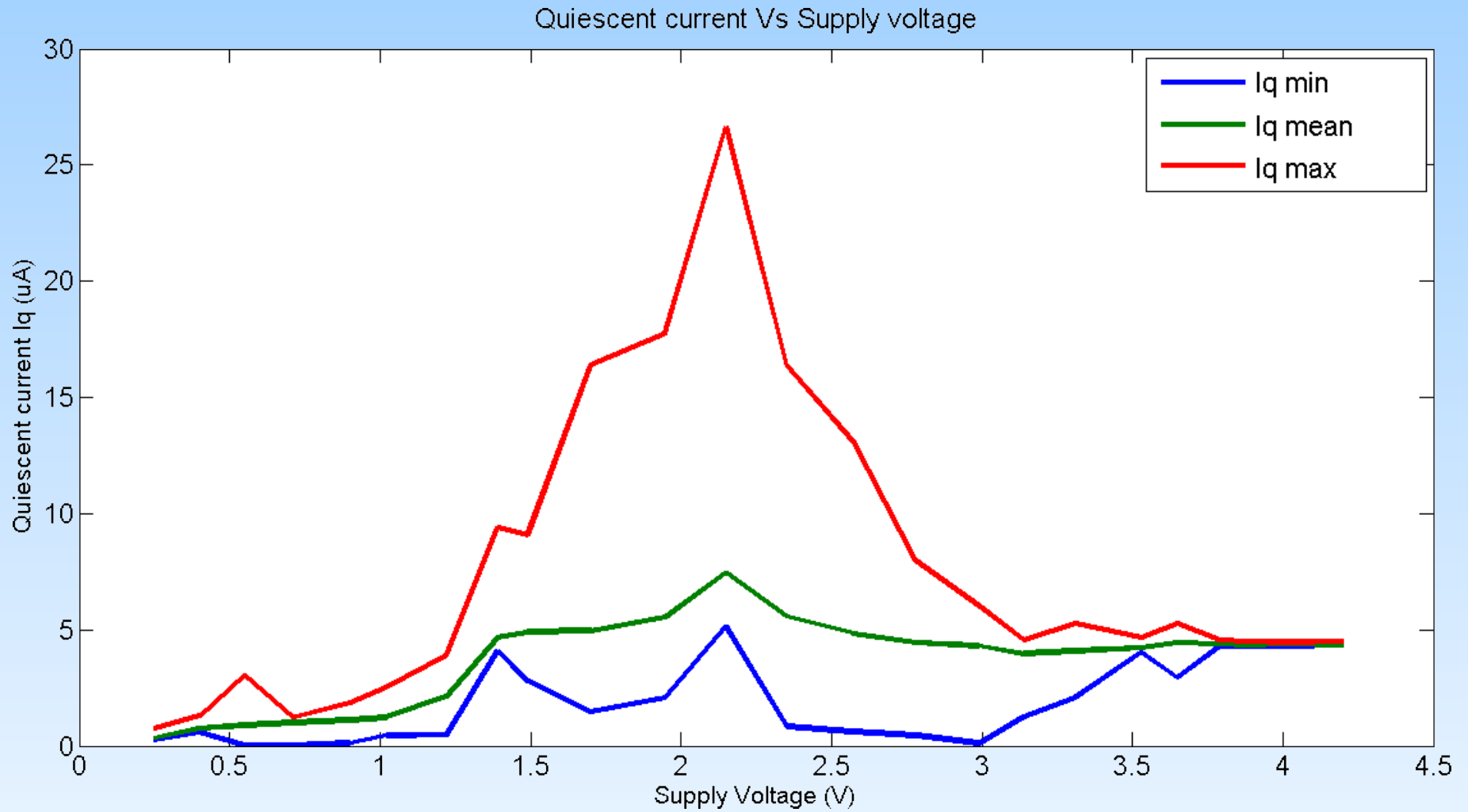
Power conditioning



LDO Voltage Regulator

LDO Voltage Regulator

Power conditioning



Energy storage in the capacitors

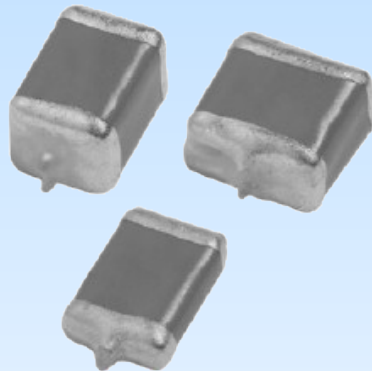
Tantalum capacitors exhibit very low electrical leakage (high leakage resistance). They will retain a charge for a long time.



597D

Vishay Sprague

Solid Tantalum Chip Capacitors TANTAMOUNT[®], Ultra-Low ESR, Conformal Coated, Maximum CV



PERFORMANCE CHARACTERISTICS

Operating Temperature: - 55 °C to + 85 °C
(To + 125 °C with voltage derating)

Note: Refer to doc. 40088

FEATURES

- New case size offerings
- Case profiles: E case (4 mm) and R case (3.6 mm)
- Low profile case: V case (2 mm)
- Terminations: Tin (2) standard
- Extremely low ESR
- Ripple current up to 4.1 A
- Compliant to RoHS directive 2002/95/EC

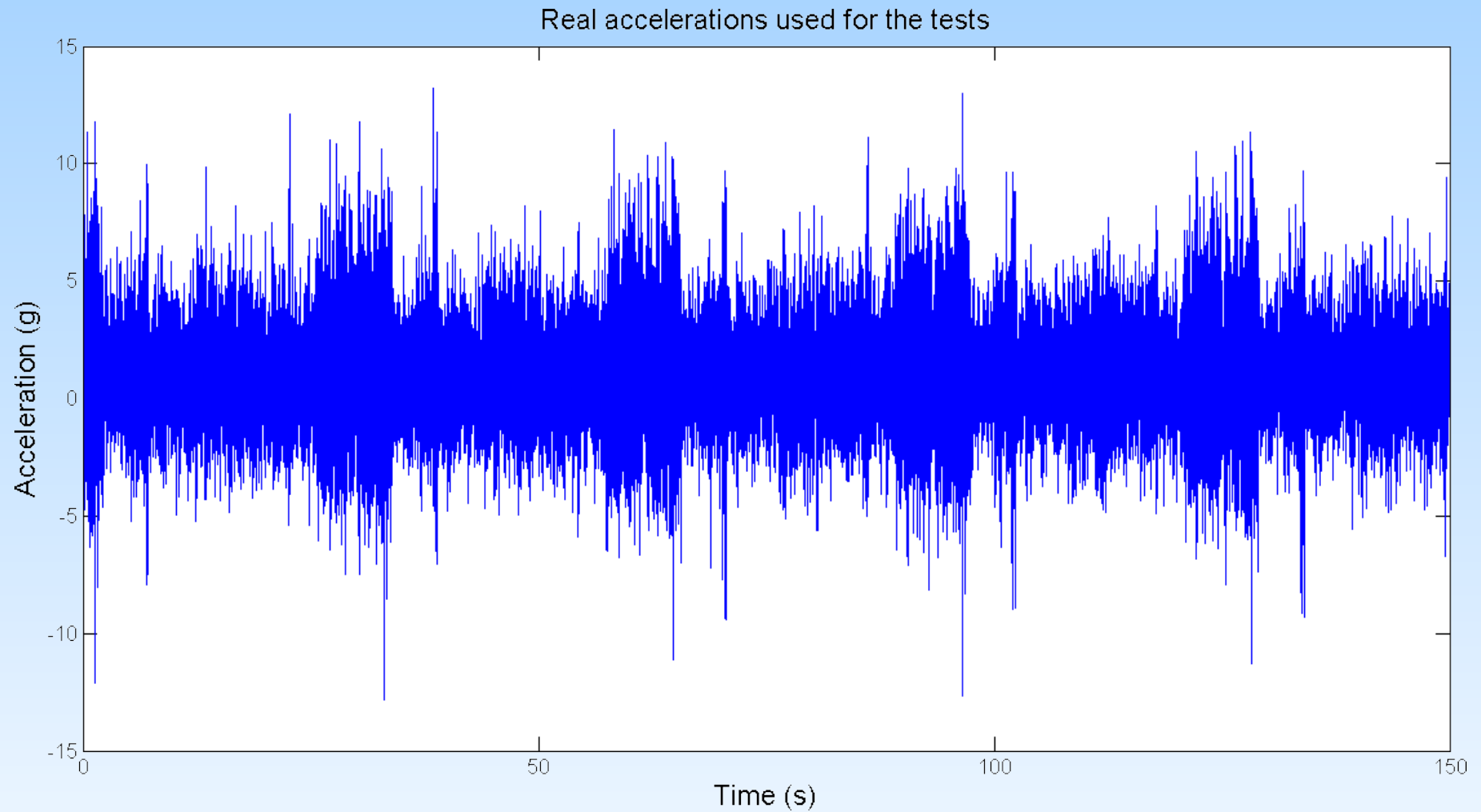
Capacitance Range: 10 μ F to 1500 μ F
Capacitance Tolerance: \pm 10 %, \pm 20 % standard
Voltage Rating: 4 WVDC to 63 WVDC



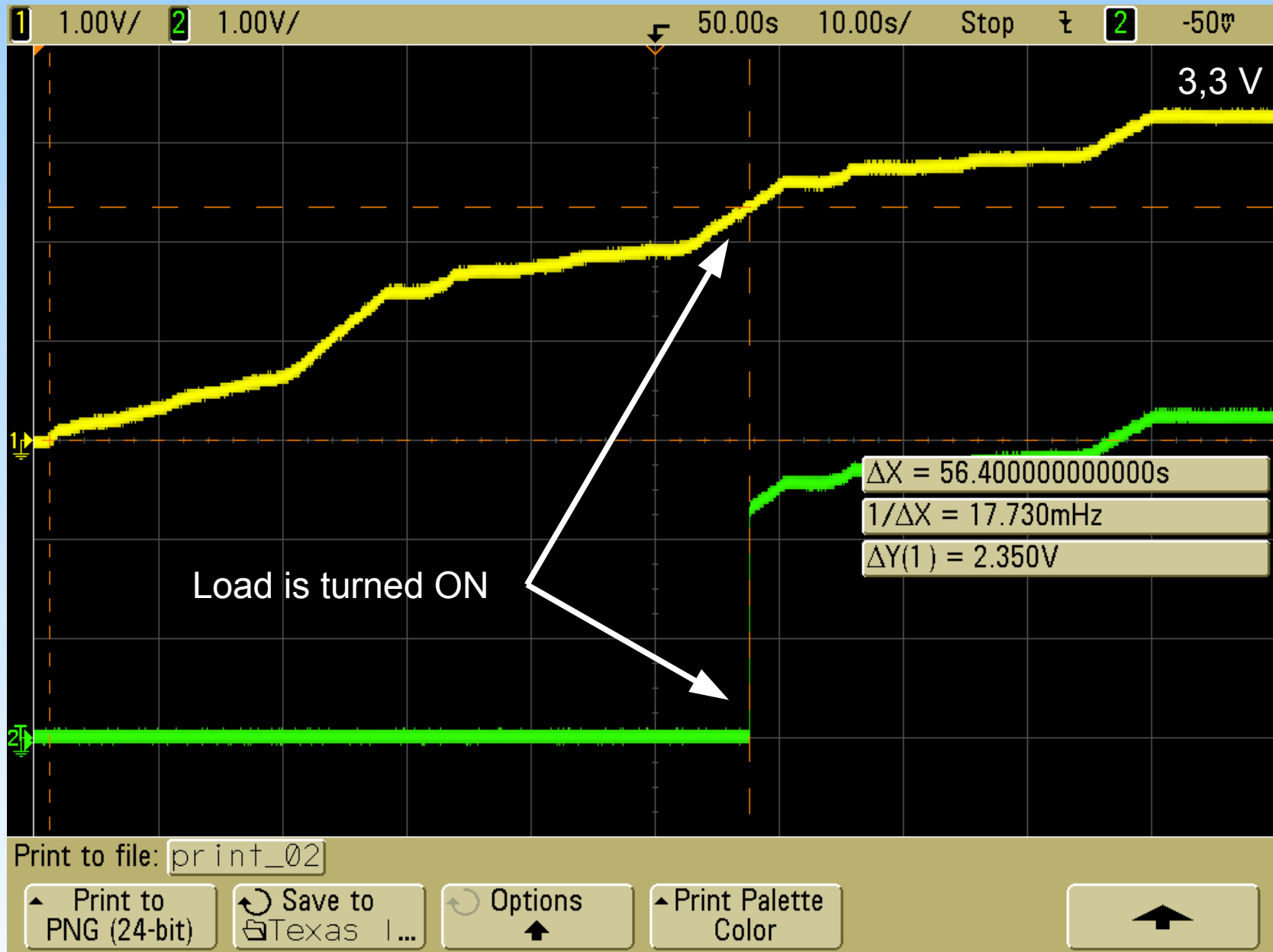
RoHS*
COMPLIANT



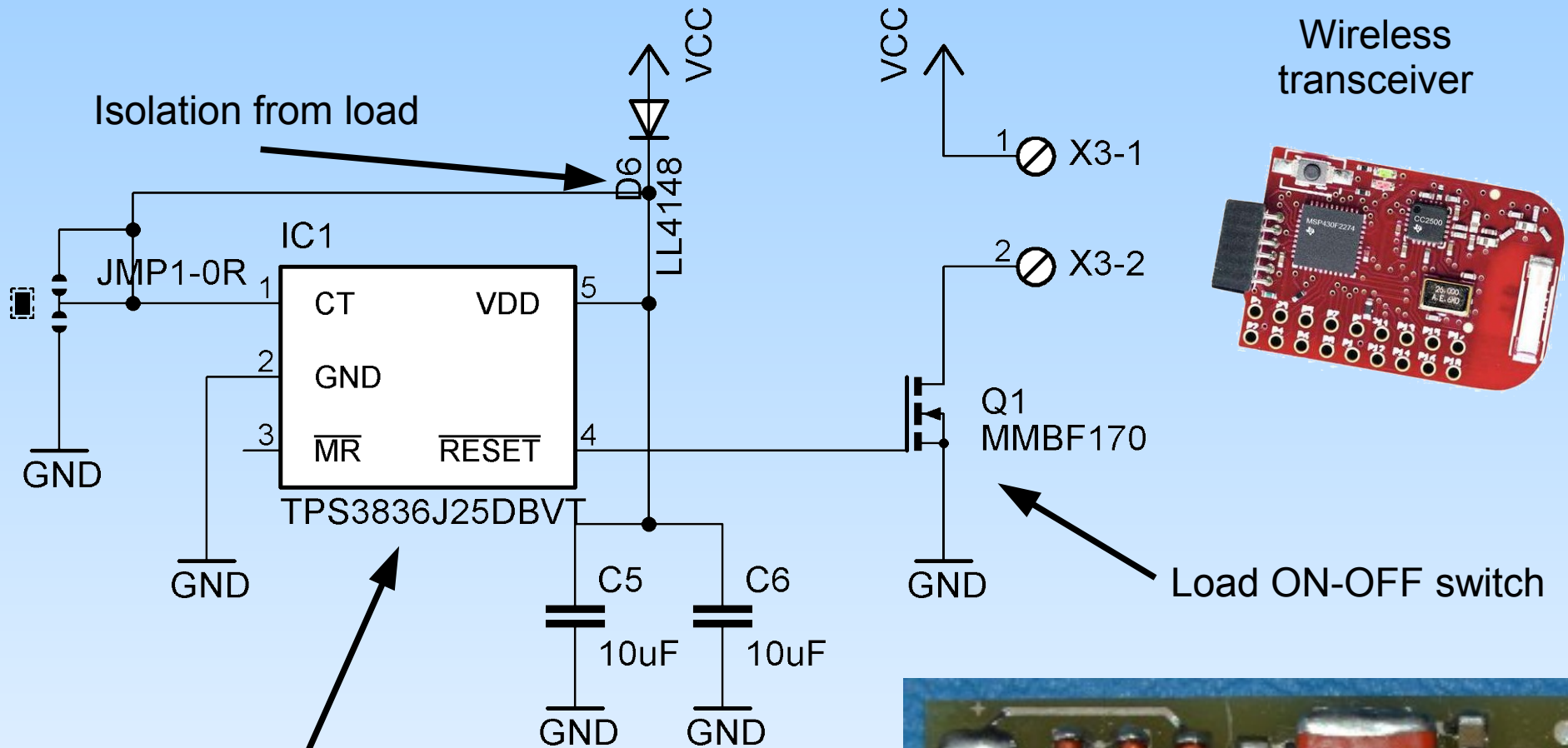
Energy storage in the capacitors



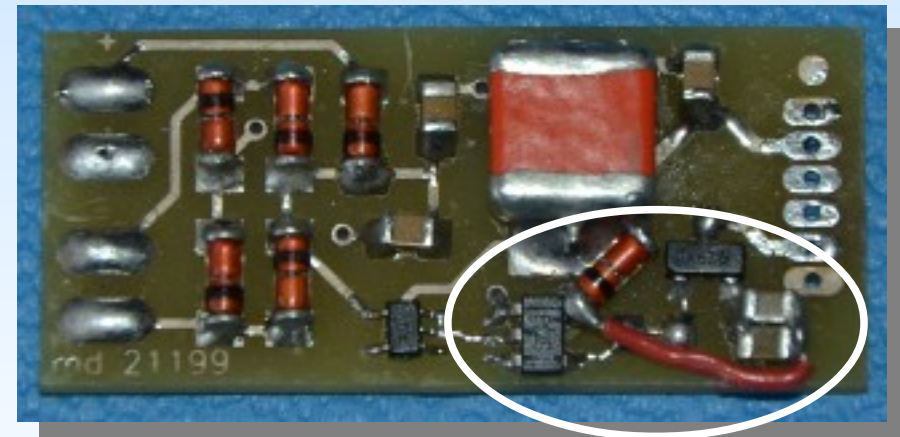
Energy storage in the capacitors



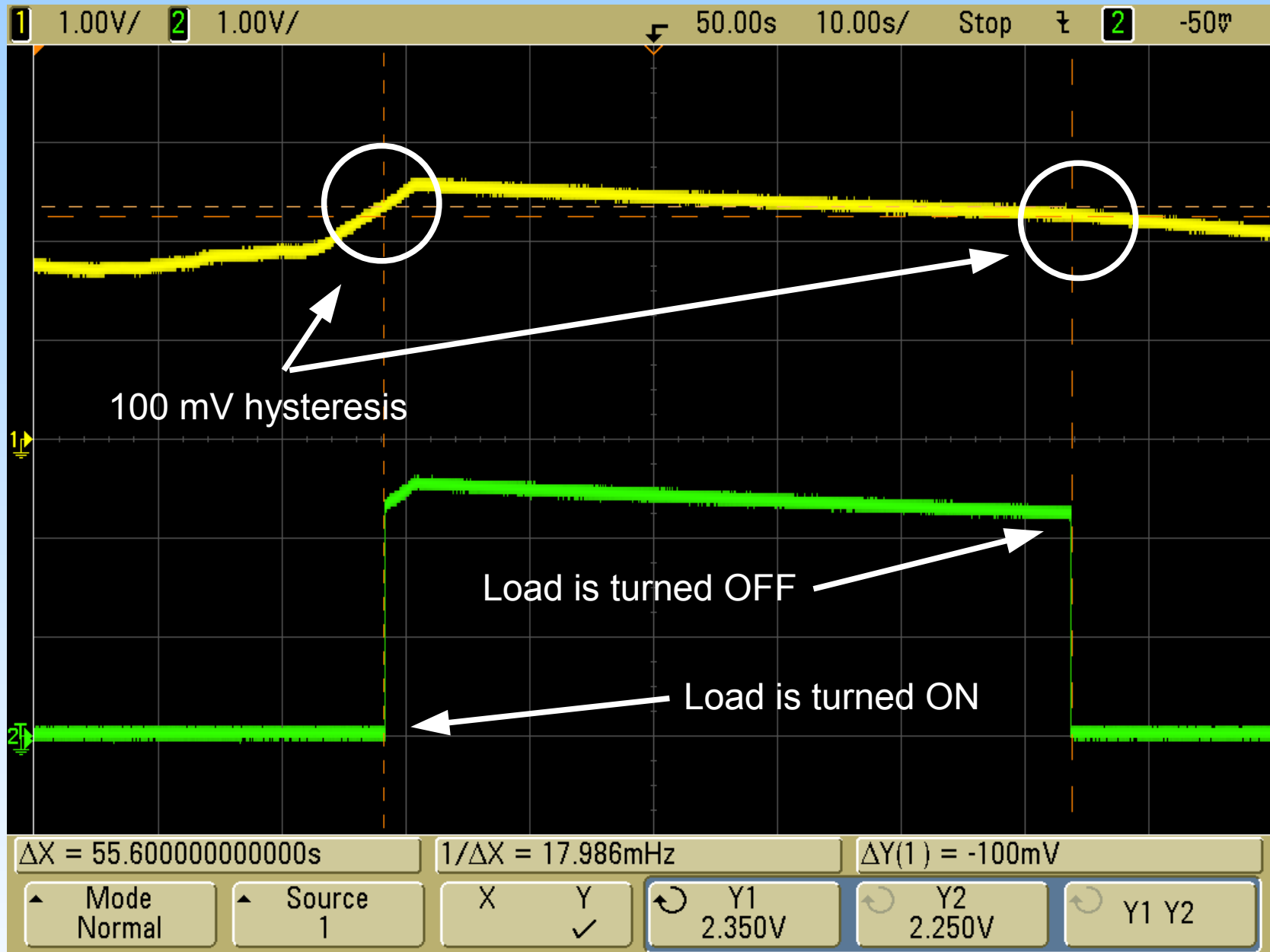
Power supervision



Voltage supervisor



Power supervision



A real application: HAT - Hybrid Autonomous Transceiver

Wisepower presents HAT

(Hybrid Autonomous Transceiver for automotive applications)

HATs are energetically autonomous devices that can be associated with a wide variety of sensors in order to measure and transmit physical quantities to a central control unit.



This video can be seen on Wisepower S.r.l. website:

<http://www.wisepower.it/HAT>



Future perspectives

- We need to reduce the size of the system
- Rectification: better efficiency in AC/DC conversion (lower threshold voltage diodes? new converter?)
- Power management circuitry: need integration, now it's made with off-the-shelf components
- Voltage regulator: reduce the dissipated power and the minimum operating voltage
- Energy storage: we need to increase the capacity and reduce the losses

Thanks for your attention

