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FAIL-SAFE
THROUGH
INNOVATION

Integrated Radio Systems for Energy Harvesting

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Outline

- Short introduction of SensorDynamics
- Why developing a radio IC for energy harvesting?
- Design Challenges
- Application Example: Tire Pressure Monitoring

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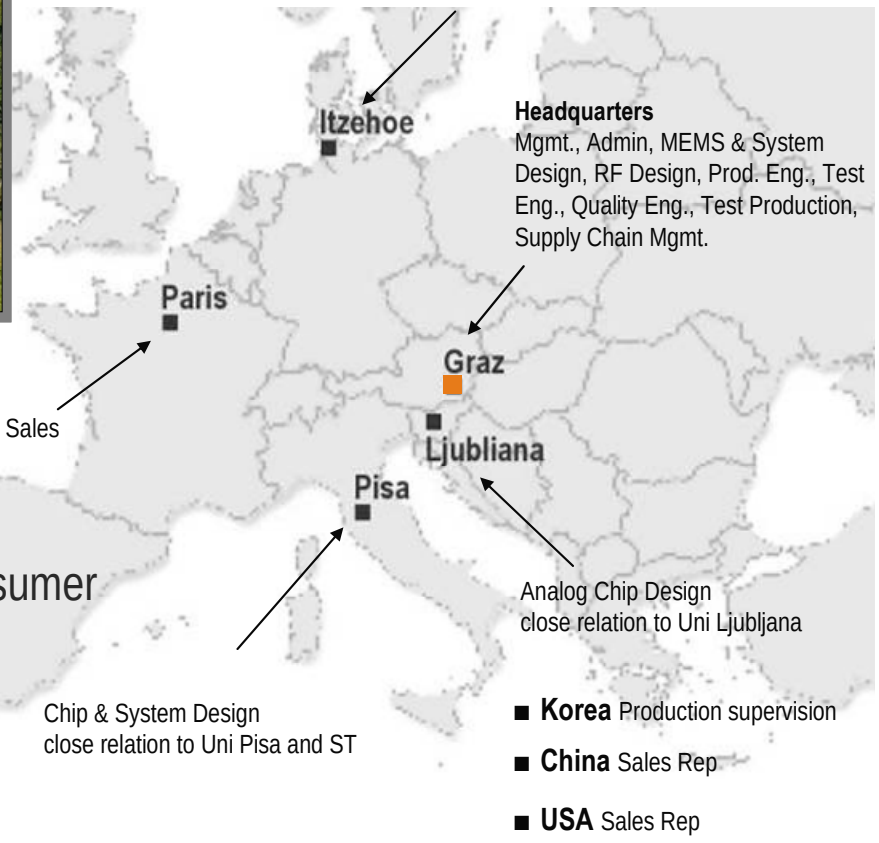
SensorDynamics - Locations



Business Focus: **fail-safe** microelectronics

Market: automotive, industry & consumer

Start of Operation: 2003

Manpower: 120 (90% Engineers)

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Key Partners & Suppliers

SensorDynamics cooperates with technology partners with best competence in their field.

TSMC, Taiwan

ST Microelectronics, Italien

ASE, Korea and Taiwan

Kionix, USA

Fraunhofer, Germany

Rood Technology, Germany

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Product Groups & Markets

IMSS

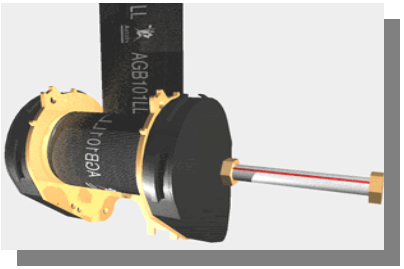
Inertial MicroSensor Systems

IMSS 'Inertial MicroSensor System'

ISIF

Intelligent Sensor InterFace

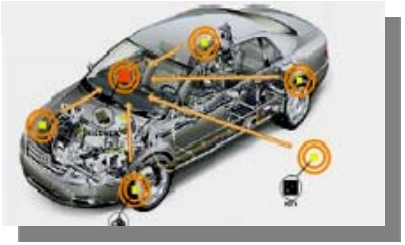
ISIF 'Intelligent Sensor InterFace'



WISE

WIreless SEnsors

WISE 'WIreless SEnsors'



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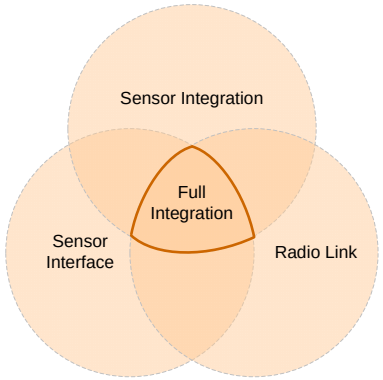
Why Developing an Radio IC for Energy Harvesting?

Energy harvesting generators became reliable, but the system cost disadvantage limited the applications.

Energy harvesting means no supply connection, and therefore a wireless link is mandatory



Conventional Radio ICs are specified under limited conditions and are therefore hardly usable for energy harvesting

Develop RF IC which meets technical and market requirements

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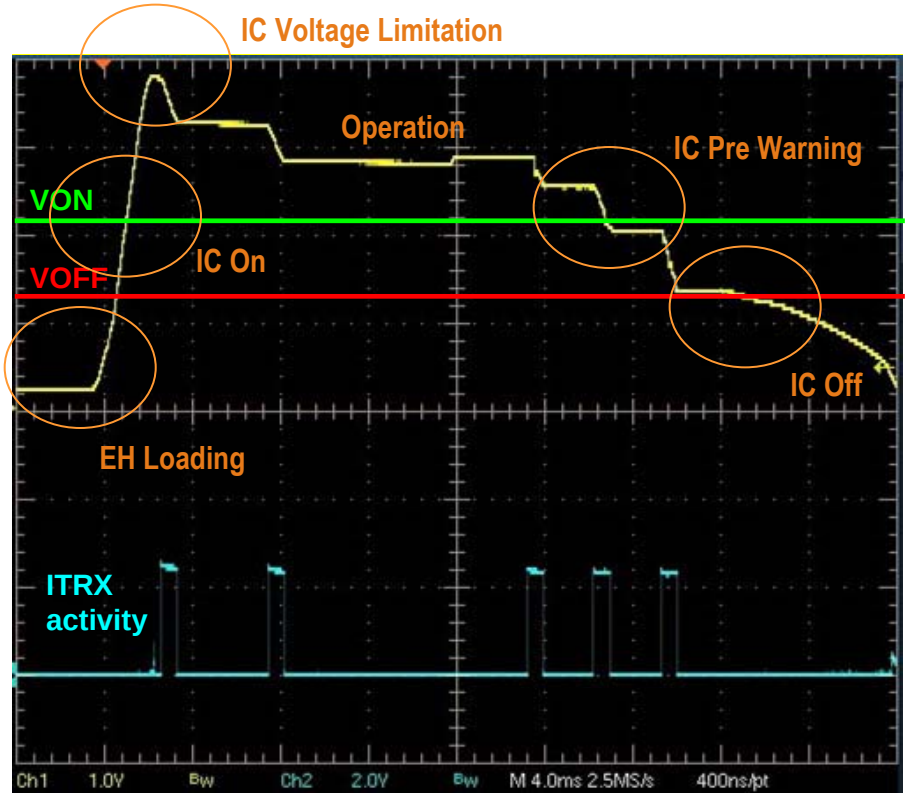
Energy Harvesting Supply Voltage

Typical supply voltage flows for kinetic power supply

VON: On threshold

VOFF: Off threshold



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Technical Requirements for Energy Harvesting?

- Variable supply voltage with all its problems
- Over voltage protection
- Fail safe power management and state machine support
- Low leakage circuit concepts in 180nm
- Special operation modes and sleep modes
- RF performance independent of supply voltage
- Ultra low power design (i.e. ~ 200nA with timer)
- Data availability after power down

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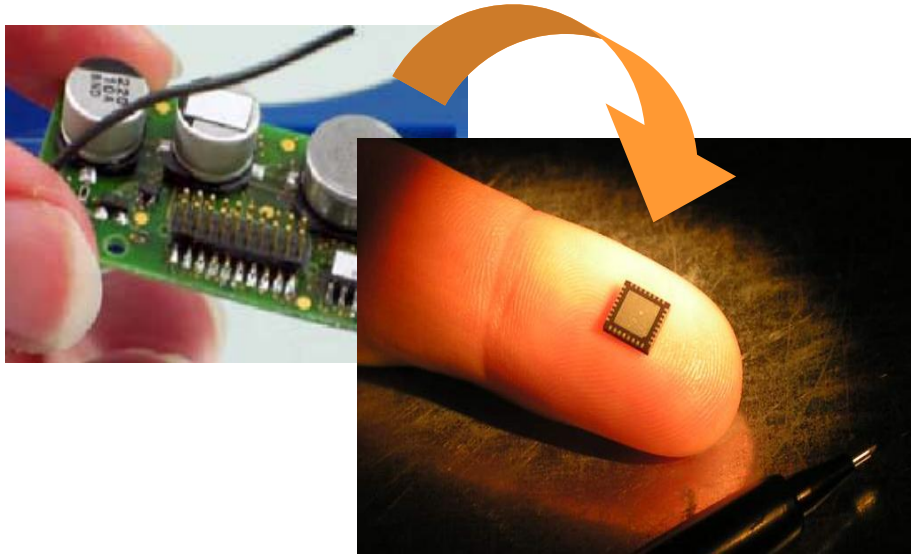
Market Requirements for Energy Harvesting Radio IC?

Full integration of system functionality with less externals to reduce system costs

- High performance radio transceiver
- Sensor interface
- µC with FLASH
- Ultra Low Power management



System on Chip Solution

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Radio Properties

EnOcean RF Module Example

- Multi band operation
- Multi channel operation
- High interference / blocking resistance
- Single chip radios with minimum externals
- Tolerance insensitive due to full digital signal processing
- Advanced state machines for energy harvesting applications
- Multiple usage of blocks for the sensor interface

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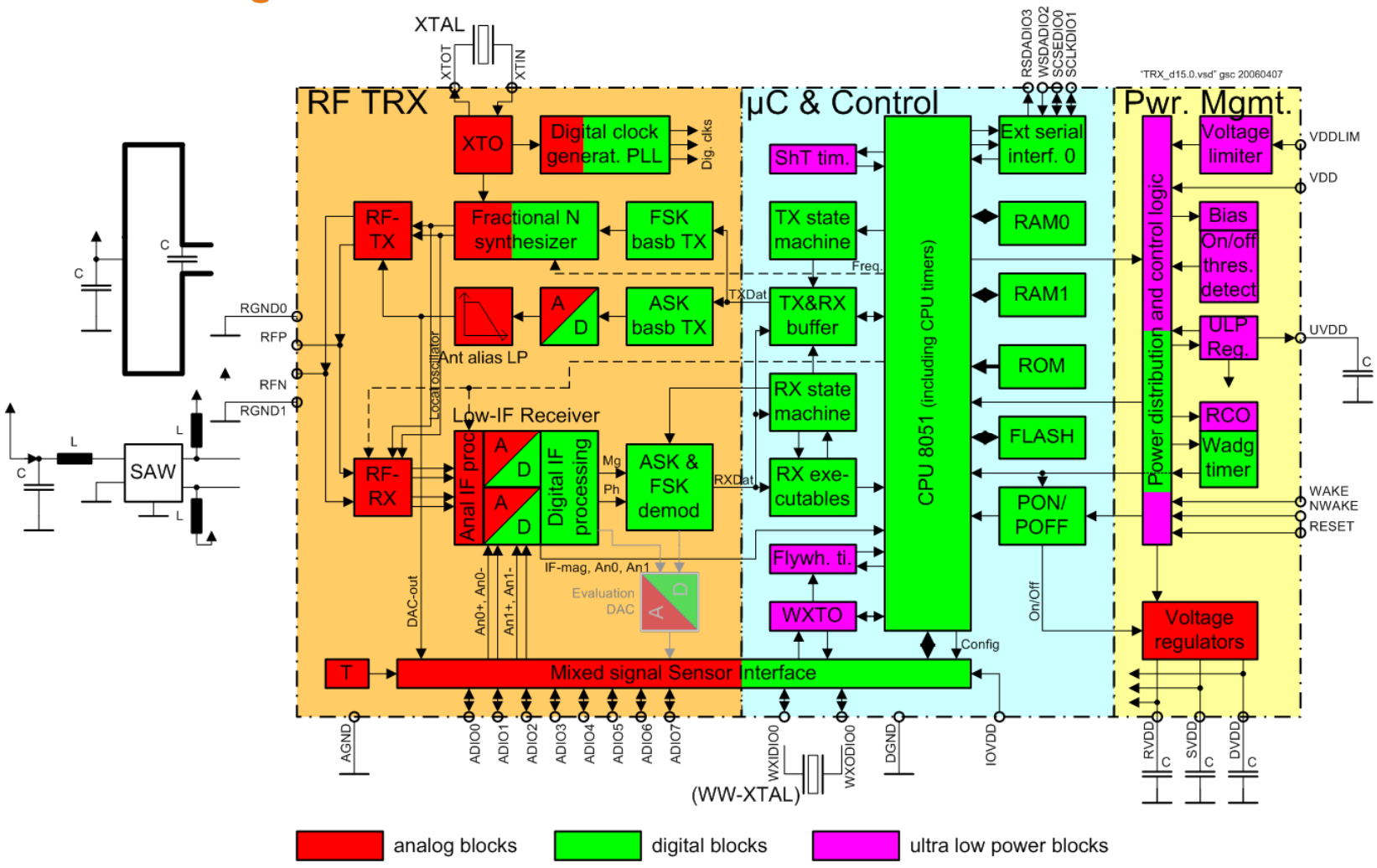
Block Diagram



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Challenges of Fast Ambient Power Sources

Examples: Piezo generators, inductive generators

- Low-leakage latch up prevention
- Frequency stability and spurious emissions.
- Accuracy of A/D converters
- Fast but controlled shut down at energy shortage

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Challenges of Slow Ambient Power Sources

Examples: Solar cells, thermoelectric generators

- Low-leakage current in circuit sub-threshold region (0,5-1,0 V) at startup.
- Generation of reliable (process and temperature stable) ON/OFF thresholds with nA current consumption.
- Accurate energy estimation at startup of any system task.
- Prevention against „low power dead-lock“.

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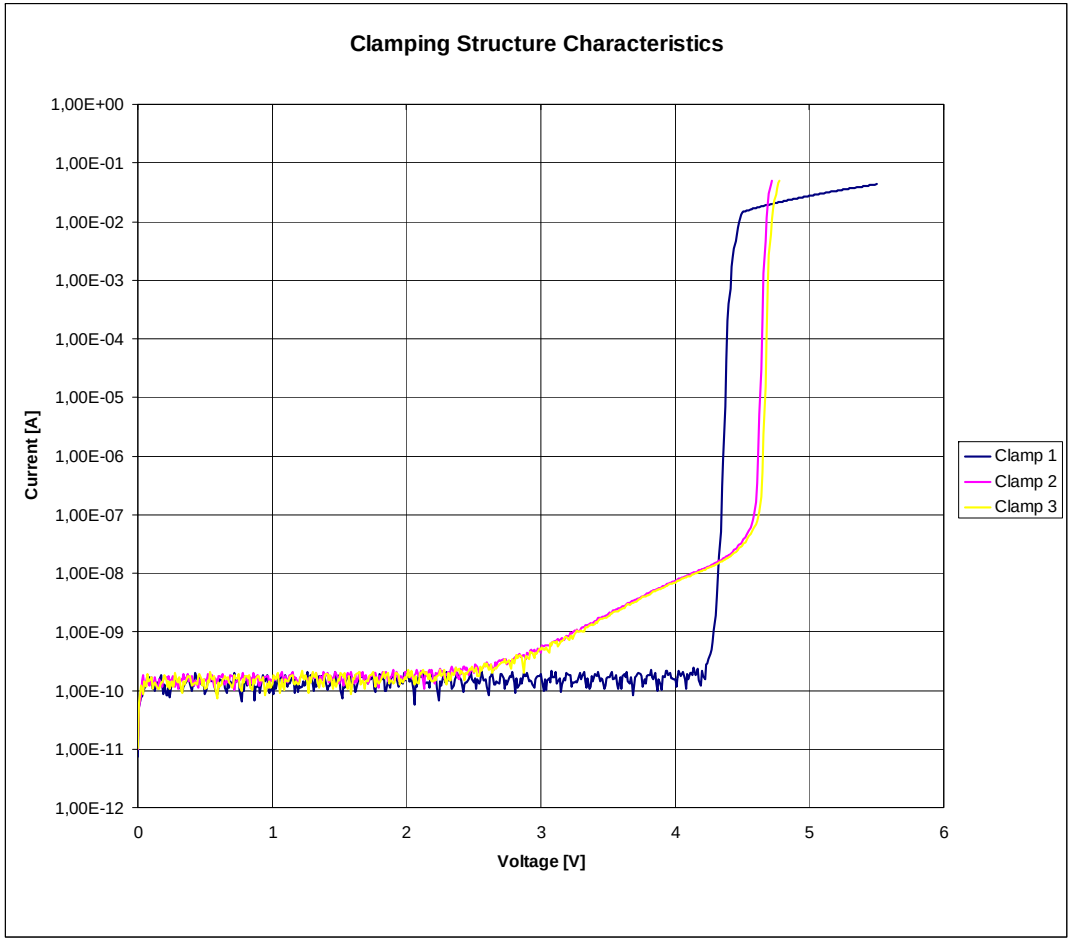
Voltage Limiter Implementation

- Low leakage
- Supply to Zero
- Fast limitation
- High threshold



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Power Saving Strategies

- Support of low duty-cycle synchronous networks.
- Low duty-cycle polling.
- Two step synchronization to minimize duty-cycle
- Various sleep modes.
- Transmission only on demand (delta case) assisted by unbuffered RAM.

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Current Consumption In Different Power Modes

Parameter	Conditions / Notes	Min	Typ	Max	Units
Current consumption turned "*OFF Mode*"	Into VDD pin at VDD= VDDS		20		nA
Current consumption "*Deep Sleep Mode*"	@ 27°C @ 85°C Voltage limiter threshold detector, UVDD regulator and watchdog timer running.		250 400	300 990	nA nA
Current consumption "*Flywheel Sleep Mode*"	@ 27°C: @ 85°C: Voltage limiter, threshold, detector, UVDD regulator, watchdog timer, wristwatch crystal and flywheel timer running.		500 2300	1000 [4)] 4000 [4)]	nA nA
Current consumption "*Short term Sleep Mode*"	@ 27°C: @ 85°C: Ultra low power blocks, UVDD regulator supplying, running short term timer and digital part (exclusive ROM and FLASH) without clock.		8 25	10 35	µA µA
Current consumption "*Standby Mode*"	Ultra low power blocks, R/S/DVDD regulators and XTAL oscillator running.		1.3	1.8	mA
Current consumption "*CPU Mode*"	R/S/DVDD regulators, XTAL 16M, and CPU 8051 at 16 MHz.		3.7	5.1	mA

Application Examples

Loading of energy generator

External wake or watch dog timer

Loading of Energy Generator with timer operation (WW synchronic)

Keep memory content with timer

State machine operation

Micro controller operation

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Application Example: Tire Pressure Monitoring

- Energy harvesting operation
- Tire pressure measurement.
- Tire temperature measurement.
- Reliable operation with fast measurement rates from minimum to maximum speed.
- No maintenance effort.

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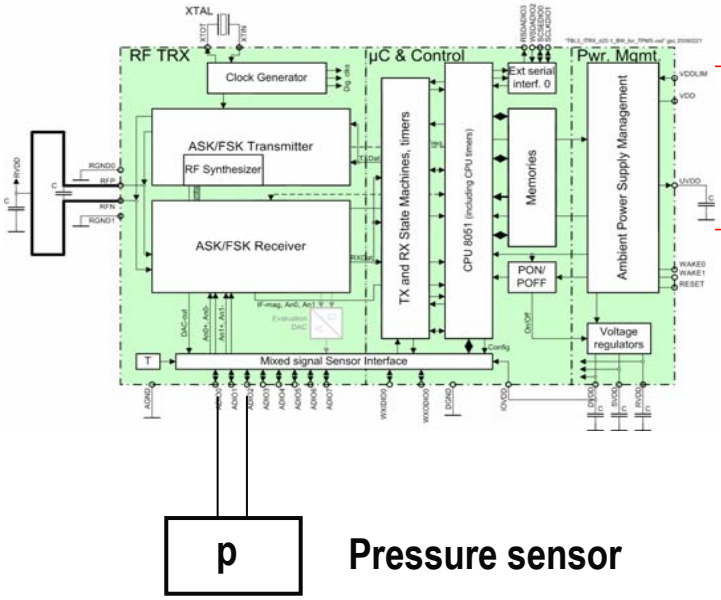
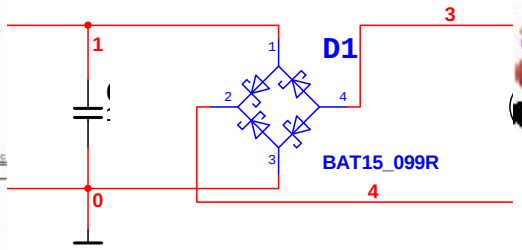
TPMS System Setup

Radio transceiver with energy management

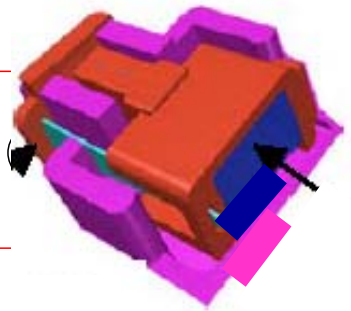


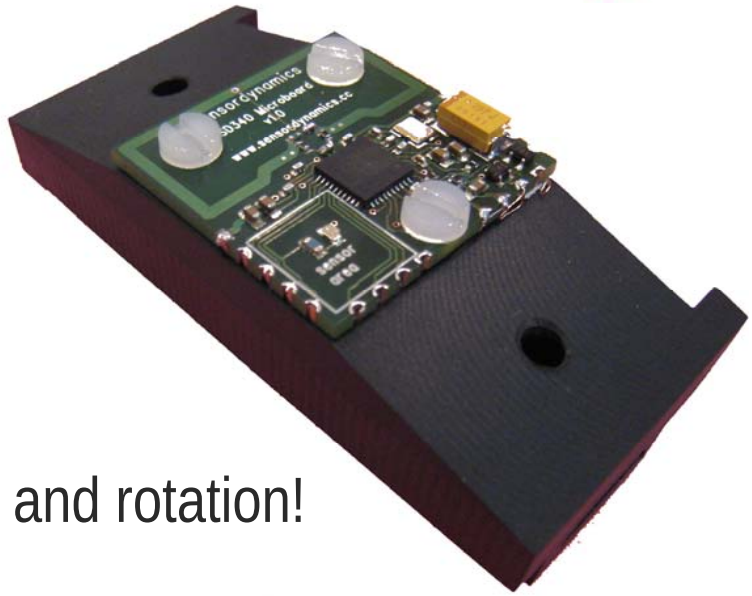
Pressure sensor

Energy harvester



Energy generator





Energy is taken from tire vibration and rotation!

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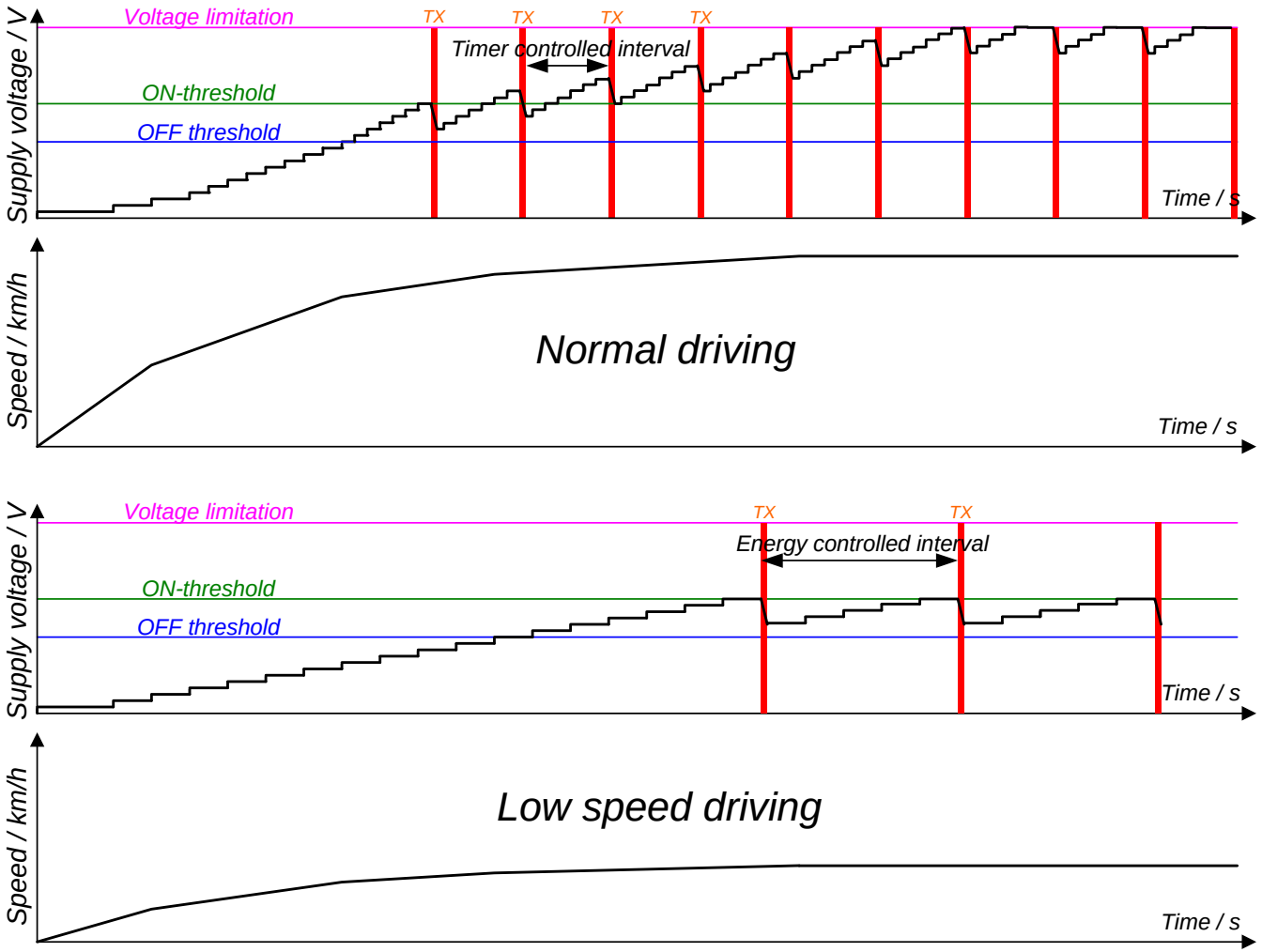
TPMS Energy Supply



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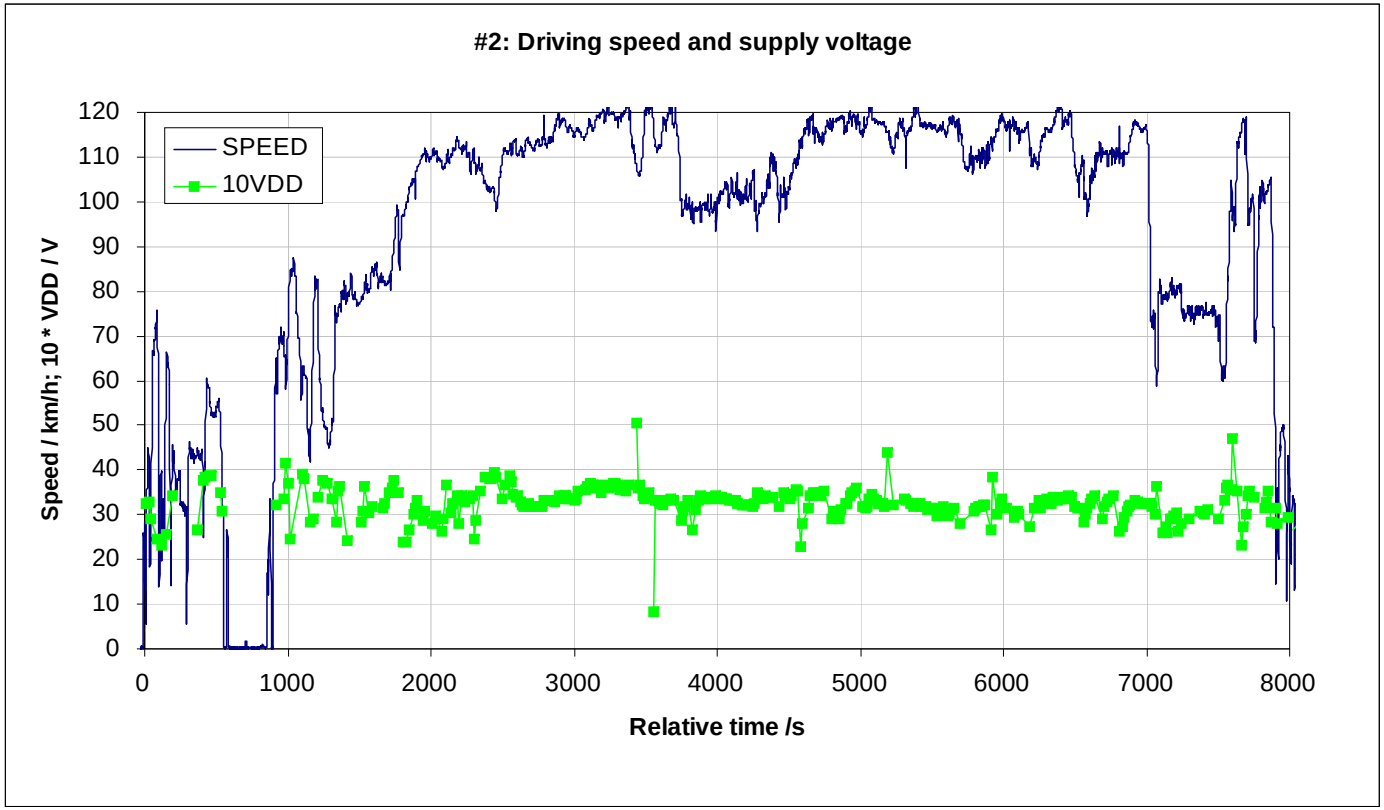
Energy Availability



Supply voltage measured with radio chip and transmitted to base station

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