



1

9.4. Snímače zrýchlenia

$$a = \lim_{\Delta t \rightarrow 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

SI jednotka je **m/s²**

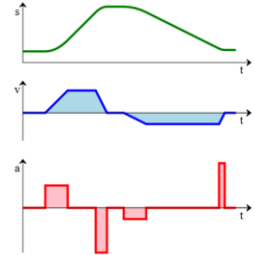
$$F = m \cdot a$$

$$F = k \cdot \Delta x$$

$$a = \frac{k}{m} \Delta x$$

$$a_g = \kappa \frac{M}{R^2}$$

9,764 – 9,834 m/s²



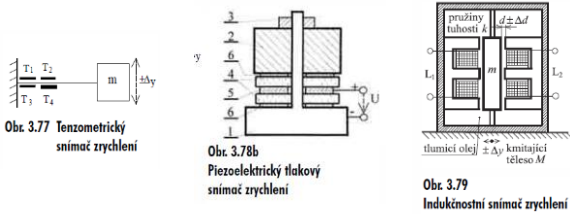
Zdola nahor:
časový priebeh zrýchlenia $a(t)$,
integrál zrýchlenia je rýchlosť $v(t)$,
a integrovaním rýchlosti získame
priebeh dráhy $s(t)$.

2

9.4. Snímače zrýchlenia

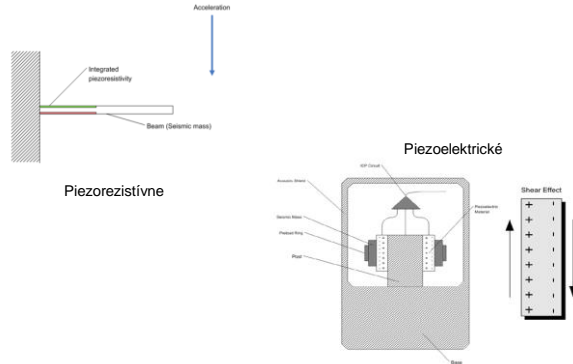
- Zrýchlenie $a = dv / dt$
- Newtonov zákon $F = m \cdot a$

Pri známej hmotnosti telesa m je sila F merítkom zrýchlenia a .



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9.4. Snímače zrýchlenia – akcelerometre



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9. 4. Meranie zrýchlenia

Applications of MEMS Accelerometers

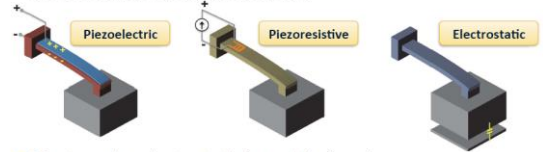
- Industrial**
 - Platform stabilization
 - Oil drilling orientation
 - Robotic telepresence
- Automotive**
 - Airbag deployment
 - Rollover, anti-skid control
- Consumer**
 - Interactive gaming
 - Free-fall detection
 - Camera stabilization
 - Indoor navigation
- Military**
 - Aircraft flight control
 - Dead-reckoning

5

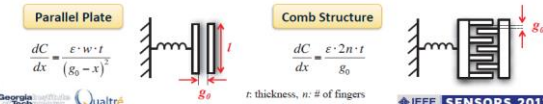
9. 4. Meranie zrýchlenia

Electromechanical Transduction

- Displacement has to be converted into electrical signal
- Most common sensing mechanisms:



- Most popular: electrostatic (capacitive) sensing



Georgia Tech, Qualcomm, Qaltré, IEEE SENSORS 2013

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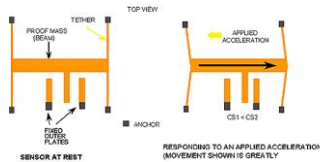
9. 4. Meranie zrýchlenia

MEMS akcelerometer

ADXL202: ±2 g Dual Axis Accelerometer

Features

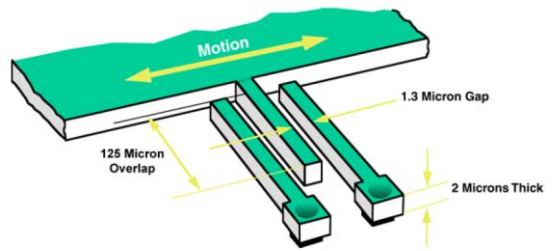
- X and Y Axis on a single chip = Small size and lower cost
- 250uA per Axis = Low power battery operation
- 3.0V to 5.0V Operation = Low power battery operation
- Surface mount package = Small size and ease of use
- High resolution PWM converter = Direct interface to micro (No A/D)
- iMEMS = Low cost AND high performance



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9. 4. Meranie zrýchlenia

MEMS akcelerometer

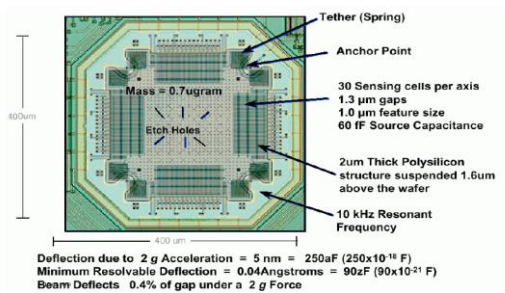


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9. 4. Meranie zrýchlenia

MEMS akcelerometer

ADXL 202: Micromachined Beam

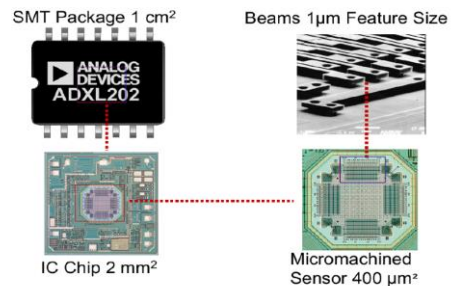


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9. 4. Meranie zrýchlenia

MEMS akcelerometer

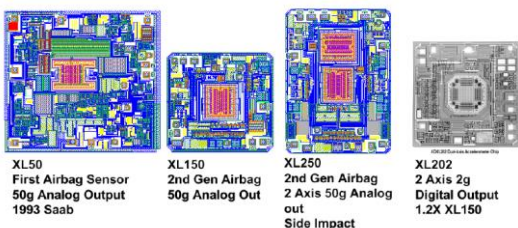
ADXL 202: acceleration sensor



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9. 4. Meranie zrýchlenia

MEMS akcelerometer



XL50 First Airbag Sensor 50g Analog Output 1993 Saab
 XL150 2nd Gen Airbag 50g Analog Out
 XL250 2nd Gen Airbag 2 Axis 50g Analog out Side Impact
 XL202 2 Axis 2g Digital Output 1.2X XL150

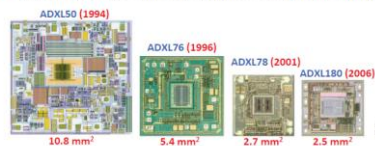
11

9. 4. Meranie zrýchlenia

Evolution of MEMS Accelerometers

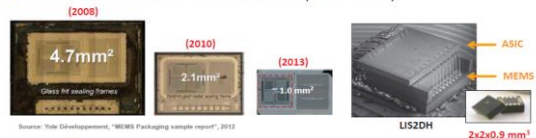
3

- Analog Devices Accelerometer (Automotive)



M. Judy, Proc. Solid-State Sensors, Actuators, and Microsystems Workshop, Hilton Head Island, SC, Jun. 2004

- STMicroelectronics Accelerometer (Consumer)



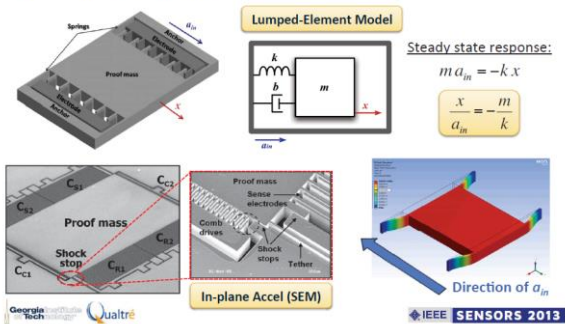
Source: Yole Développement, "MEMS Packaging sample report", 2012

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9. 4. Meranie zrýchlenia

MEMS Capacitive Accelerometers

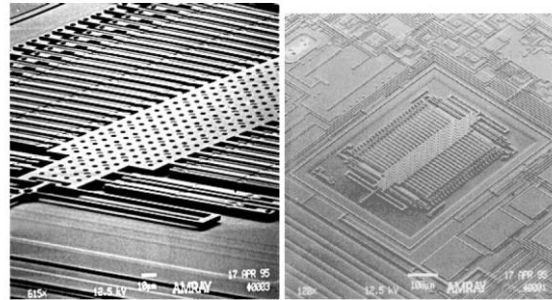
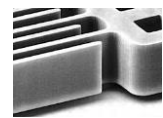
- Conventional MEMS accelerometer architecture



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9. 4. Meranie zrýchlenia

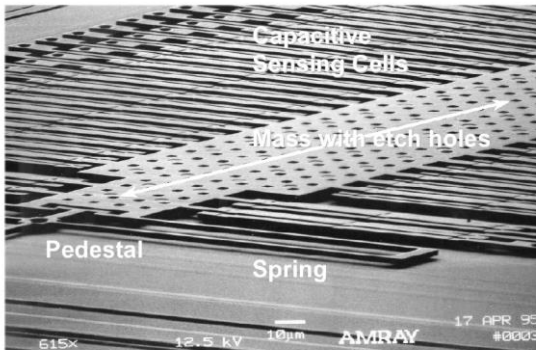
MEMS akcelerometer



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9. 4. Meranie zrýchlenia

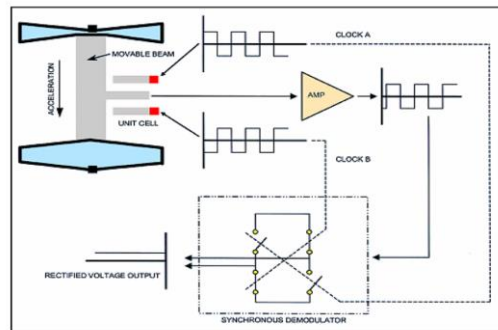
MEMS akcelerometer



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9. 4. Meranie zrýchlenia

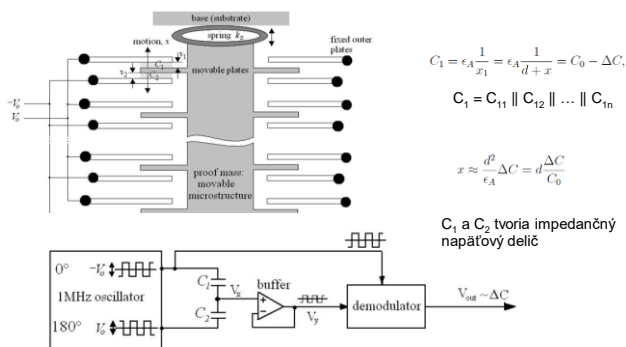
MEMS akcelerometer



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9. 4. Meranie zrýchlenia

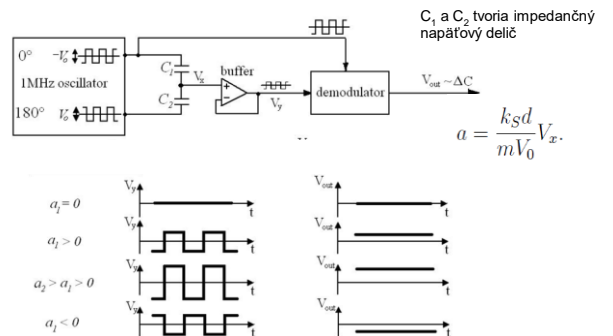
MEMS akcelerometer



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9. 4. Meranie zrýchlenia

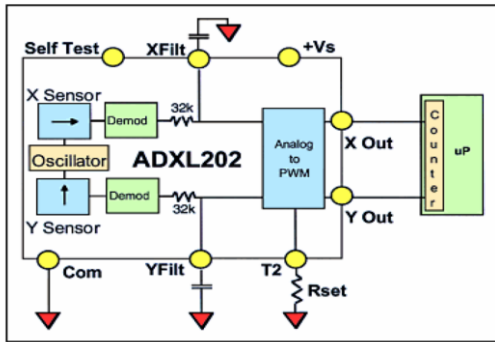
MEMS akcelerometer



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9. 4. Meranie zrýchlenia

MEMS akcelerometer



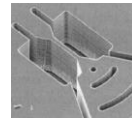
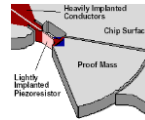
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9. 4. Meranie zrýchlenia

MEMS akcelerometer

•Piezoresistive MEMS accelerometer

–Operating Principle: a proof mass attached to a silicon housing through a short flexural element. The implantation of a piezoresistive material on the upper surface of the flexural element. The strain experienced by a piezoresistive material causes a position change of its internal atoms, resulting in the change of its electrical resistance
 –low-noise property at high frequencies

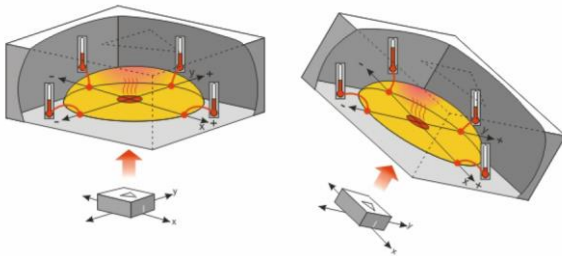


Courtesy of JP Lynch, U Mich.

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9. 4. Meranie zrýchlenia

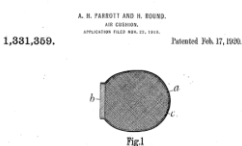
MEMS MX2125 hot bubble



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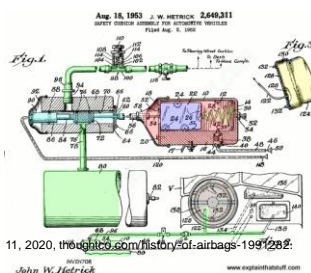
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United States patent submitted in 1919 by two dentists, **Harold Round & Arthur Parrott** of Birmingham, England



John Hetrick's original airbag design from 1953



Allen K. Breed (1927–2000), who developed a variety of different ways of triggering the explosion of gas inside an airbag just before the impact of a crash.



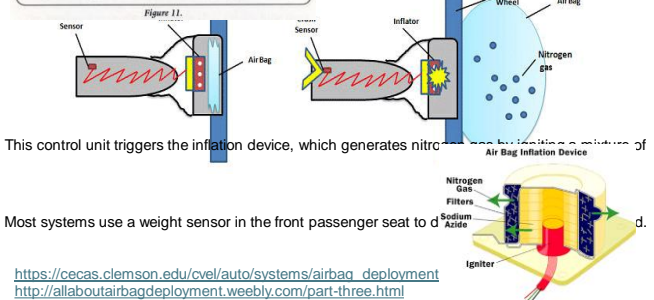
Bellis, Mary. "The History of Airbags." ThoughtCo, Feb. 11, 2020, <https://www.thoughtco.com/history-of-airbags-1991262/>

John W. Hetrick

AUTOMOBILE AIRBAG
 AIRBAG VOLUME: 2.3 cubic feet
 AIRBAG FILLING TIME: 0.030 seconds

Chemical Reaction:
 $2 \text{NaAz} \rightarrow 2 \text{Na} + 3 \text{N}_2 \text{ (gas)}$
 sodium azide

Gas-Generator Reaction	Reactants	Products
First Reaction (Triggered by Sensor)	NaN ₃	N ₂ Na ₂ O
Second Reaction	Na KNO ₃	K ₂ O Na ₂ O N ₂ O
Final Reaction	K ₂ O Na ₂ O SiO ₂	alkaline silicate (glass)



This control unit triggers the inflation device, which generates nitrogen gas by initiating a reaction of sodium azide.

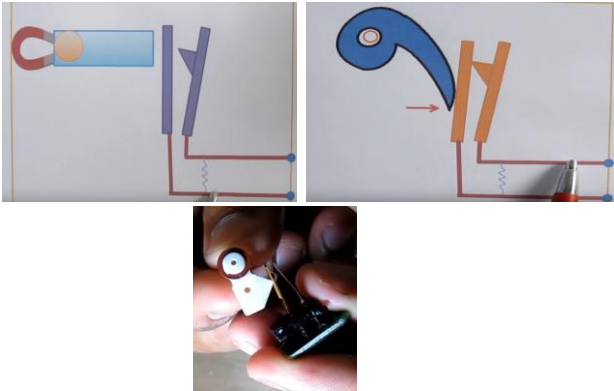
Most systems use a weight sensor in the front passenger seat to determine if an occupant is present.

https://cecas.clemson.edu/cvel/auto/systems/airbag_deployment
<http://allaboutairbagdeployment.weebly.com/part-three.html>

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Mechanické



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Mechanické

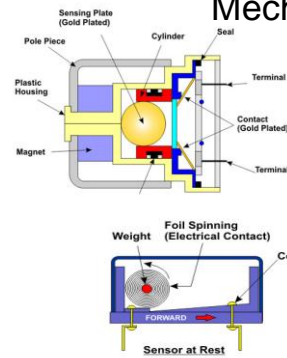


Figure 1. Structural components to an Inerti

Figure 2. Functional principle to a typical roller type airbag sensor. Source: Erjavec, J. (2010). Au

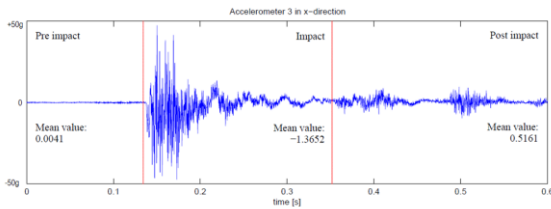
<https://www.azosensors.com/article.aspx?ArticleID=40>

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Airbagy – deploy or not deploy?



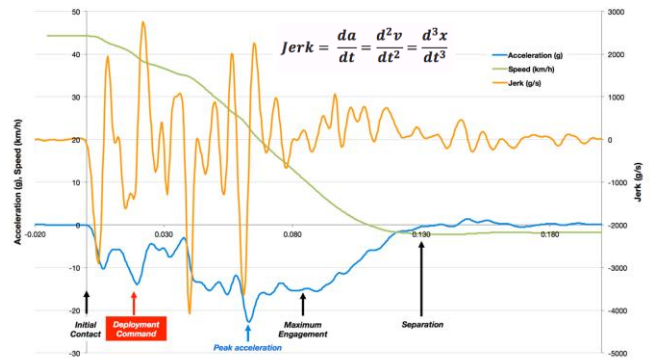
the airbag deployment decision depends upon acceleration and jerk



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Longitudinal Speed, Acceleration & Jerk

Offset Head-on Crash Test - Bullet Vehicle (2016 Crash Test #2)



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