PVDF Sensors for Dynamic Pressure Metrology in Extreme Environment

High Pressure Workshop
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Plan

1. Air blast measurement
2. Sensor problematic
3. Piezoelectric model
4. Packaging considerations
5. Shock tube experiment setup
6. Experimental results
7. Conclusion and perspectives

Air Blast Measurement

Extreme environment :

- Pressure > 100 bar
- Temperature > 1000 $°C$
- Ultrasonic shock wave
- Discontinuity (rise time) $\approx ns$

Fig1: Experiment setup

Fig2: The air blast

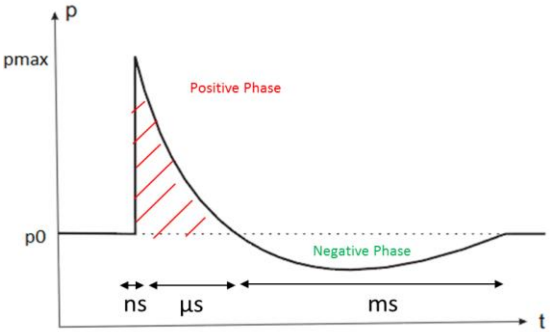
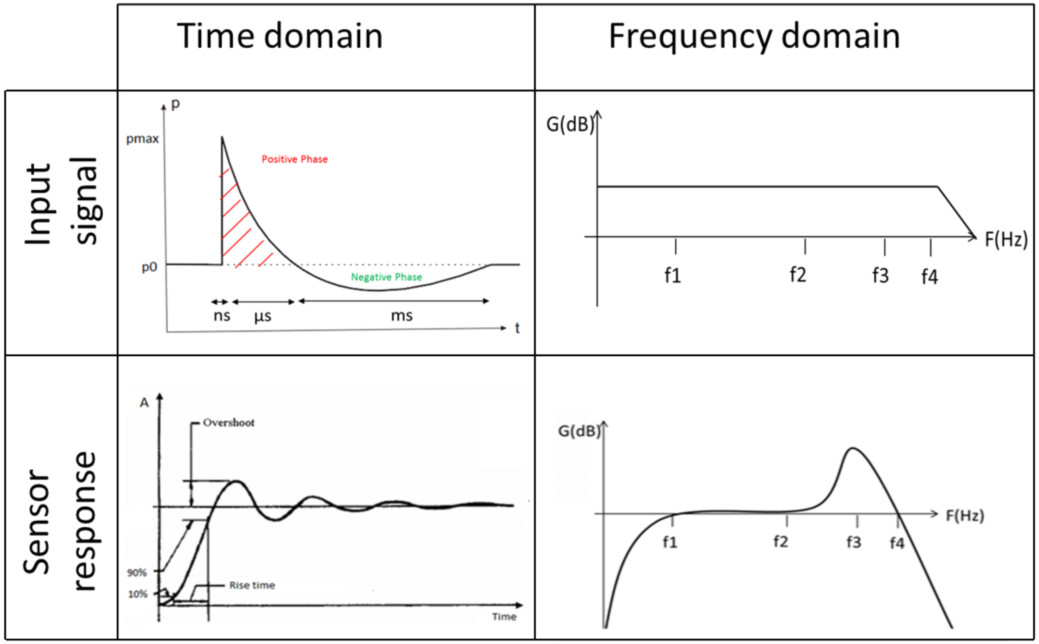


Fig3: Typical pressure signal

Sensor Consideration

Fast dynamic signal => large bandwidth signal
Sensor transfer function (low cut off frequency, resonant frequency,)
Objective : design a sensor with large bandwidth



Main measurement artifacts :

- Overshoot
- Rise time
- Parasite oscillation
- Decrease time constant

- Low cutoff frequency
- High cutoff frequency
- Resonant frequency

Actual dynamic pressure sensors

- Main manufacturers : PCB piezotronic, Kysler
- Quartz technology
- Embedded electronics (charge amplifier)
- Vibration compensation
- Rise time <1us and bandwidth < 100Khz

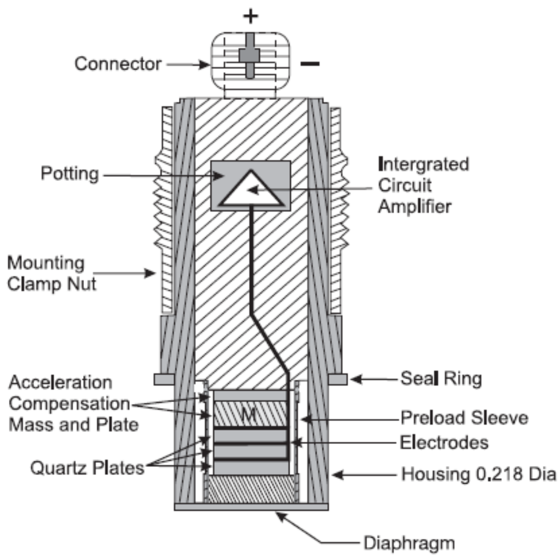


Fig1: PCB sensor technology

Fig2: PCB sensor 102M

Piezoelectric Model

Objectives :

- Understand the piezoelectric physics
- Generate the sensor response to a specific input (step)
- Simulate the influence of front layer and backing material
- Optimize sensor characteristics (rise time, bandwidth, sensitivity , …)

Solution:

- Masson Model
- Acoustic / electrical analogies
- Easy to simulate on electrical software (like Pspice)

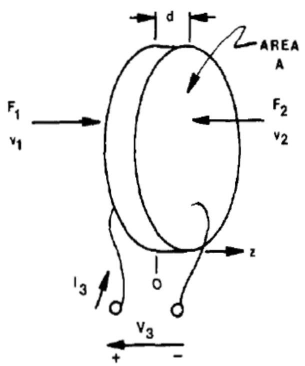


Fig1: Disk of quartz

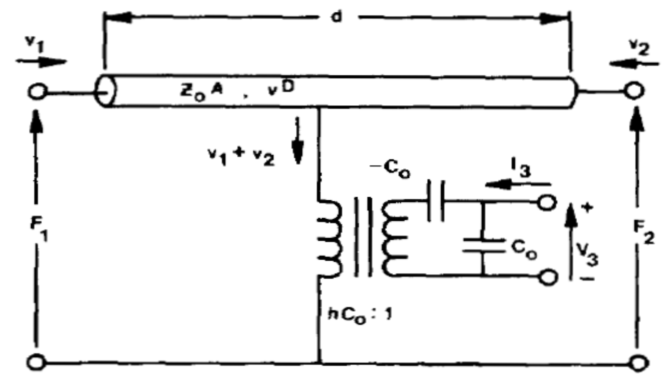
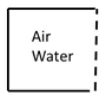
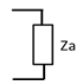
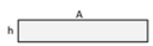
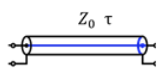
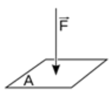


Fig2: Masson Model

Sensor Model

Acoustical / Electrical Analogies:

	Acoustic	Electric
Boundary conditions		
Material layer		
External load		

Sensor Model :

- Air external medium (1)
- Front layer thermal protection (2)
- Piezoelectric disk (3)
- Backing absorber (4)
- Aluminum packaging (5)

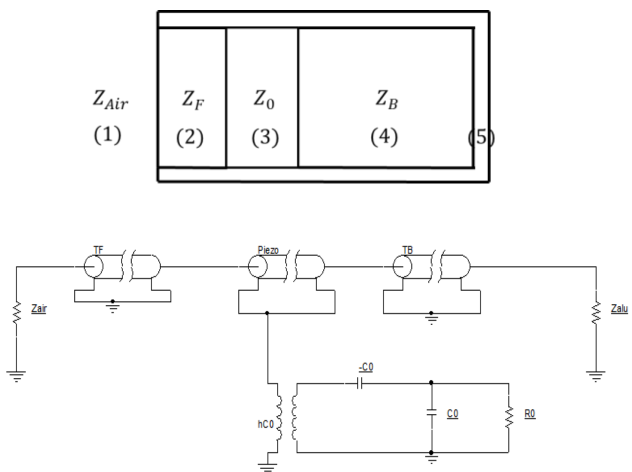


Fig1: Electrical sensor model

Simulation results

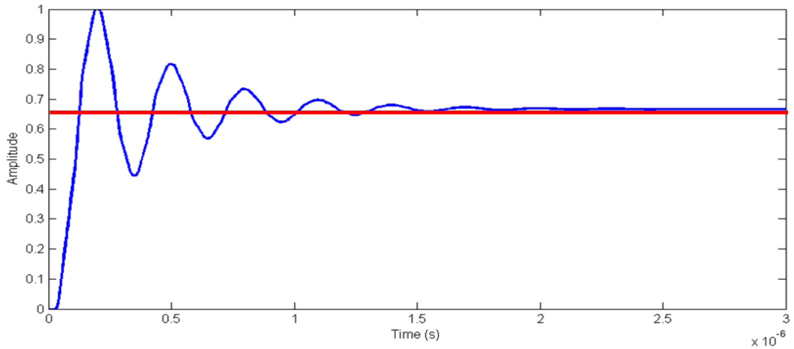


Fig1: Sensor response to a unit step

- Rise time < 100 ns
- Sensor resonant frequency ≈ 20Mhz

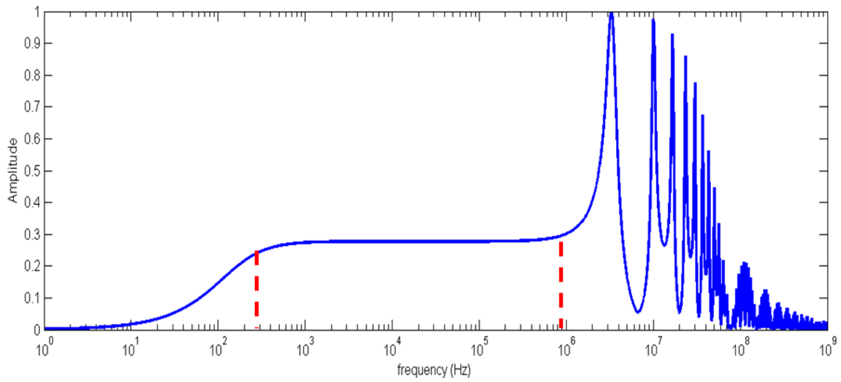


Fig2: Sensor transfer function

- Low cutoff frequency ≈ 100 KHz
- Sensor resonant frequency ≈ 20Mhz
- Bandwidth ≈ 500 Khz

Packaging considerations

Front layer perturbations:

- Time delay due to wave propagation in the material
- Multiple wave reflections

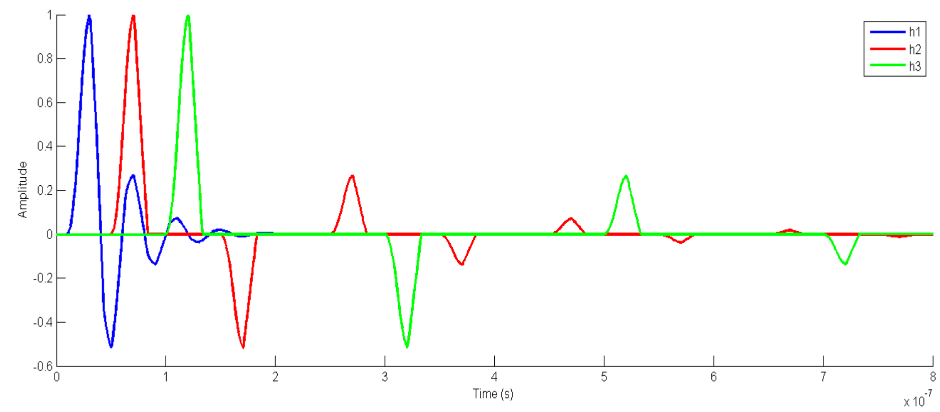


Fig1: Layer influence on the sensor response

Cables perturbations:

	$d\,(mm)$	$D\,(mm)$	$C\,(pF/m)$	$L\,(nH/m)$
RG58-50JF	.9	2.95	100	250

The main characteristics are :

- $v = 2 \cdot 10^8 m/s$ and a time delay of 500ns for 100 m cable length.
- Attenuation of $1.6\ dB\ at\ 1MHz$
- Rise time (at 50%) of 5 ns

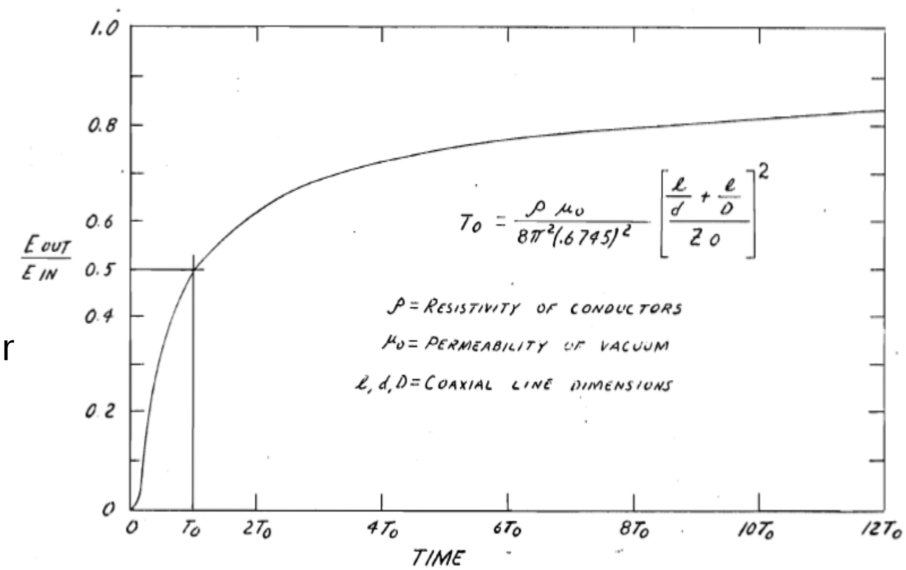


Fig2: Step response of a coaxial cable

Shock tube experiment

- High pressure and low pressure separates by a diaphragm
- Generate a shock wave with ns rise time
- Ultrasonic wave is propagating through the tube
- Pressure up to 100 Bar

- Sensors are mounted on the end of the tube

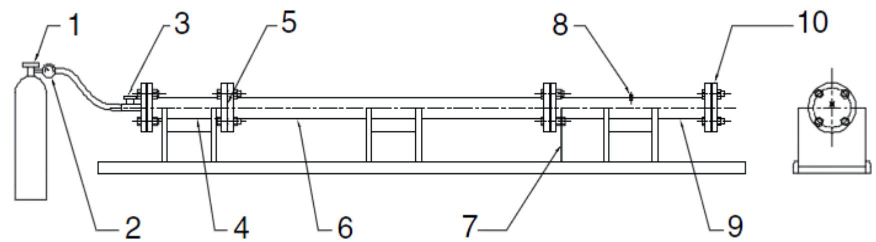


Fig1: Shock tube


Fig2: Sensors mounted

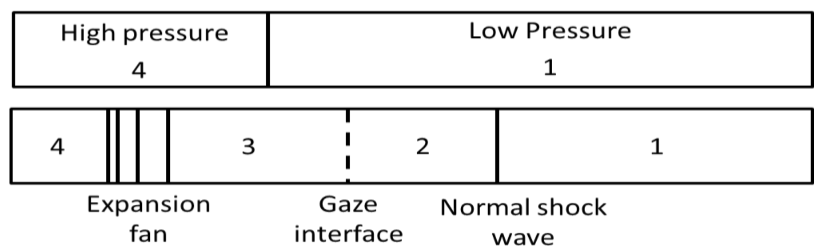


Fig3: Time sequence of pressure in a shock tube

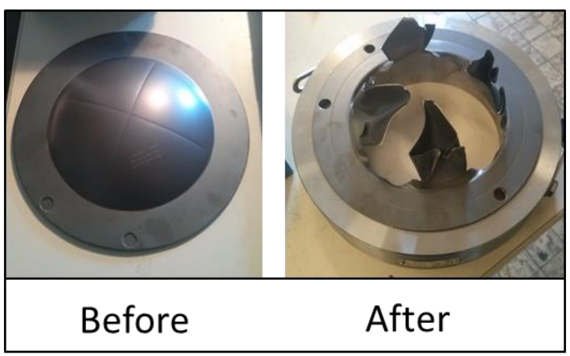
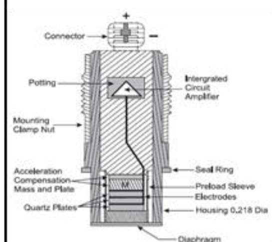
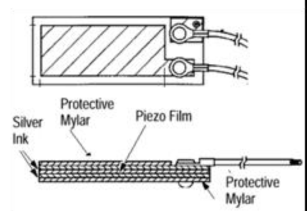
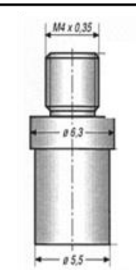


Fig4: Diaphragm

Sensors tested

	PCB 113A24	PVDF Prototype	PVDF Muller M60
	 	 	 
Pressure Range	0-70 bar	0-20 GPa	0-20 GPa
Sensitivity	0,2v/bar	5pC/bar	5pC/bar
Rise time	> 1us	<100 ns	60 ns

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Experiment Results

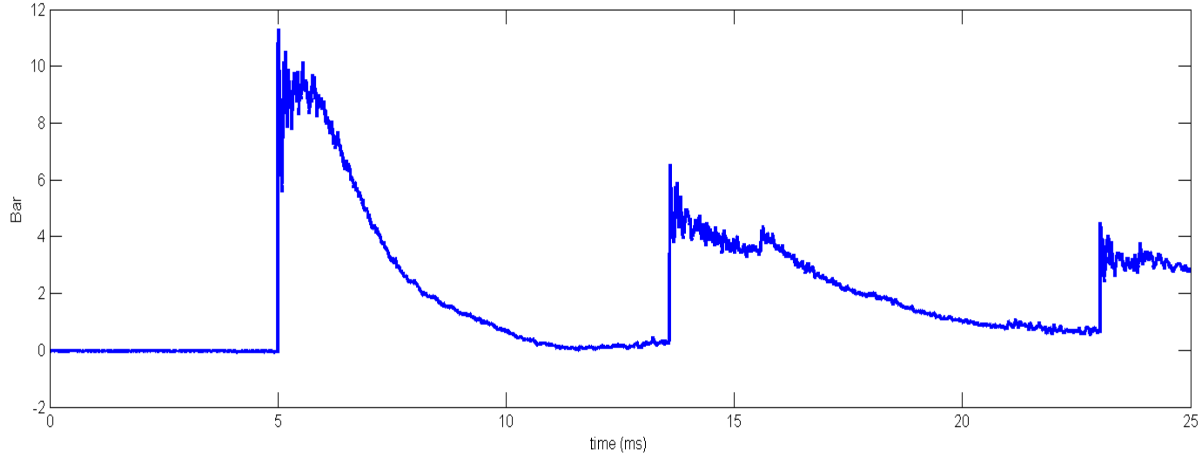


Fig1: PCB 113A24 sensor response

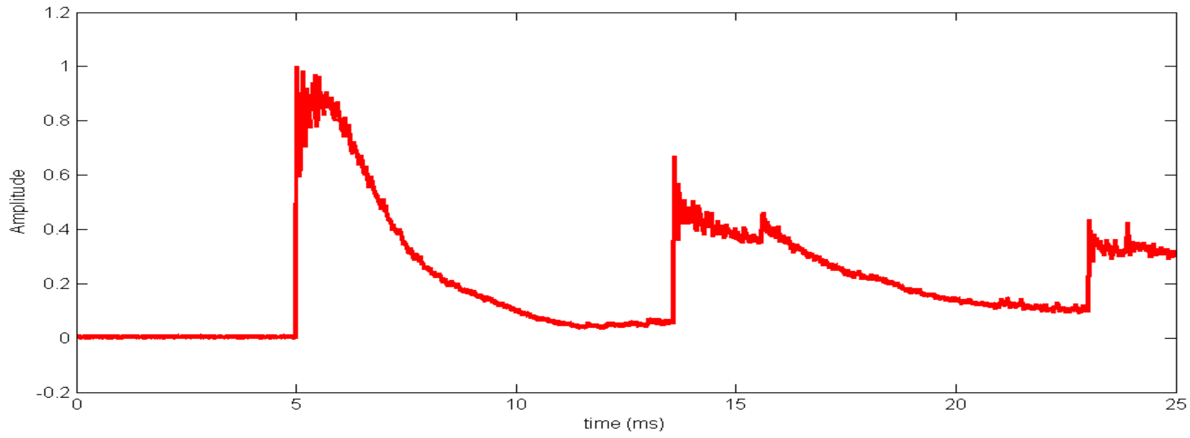
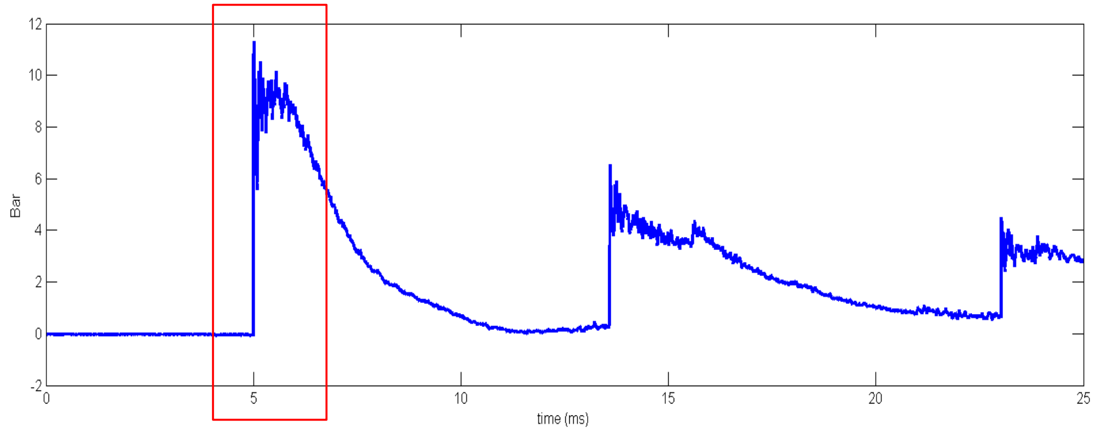


Fig2: PVDF sensor response

Experiment Results



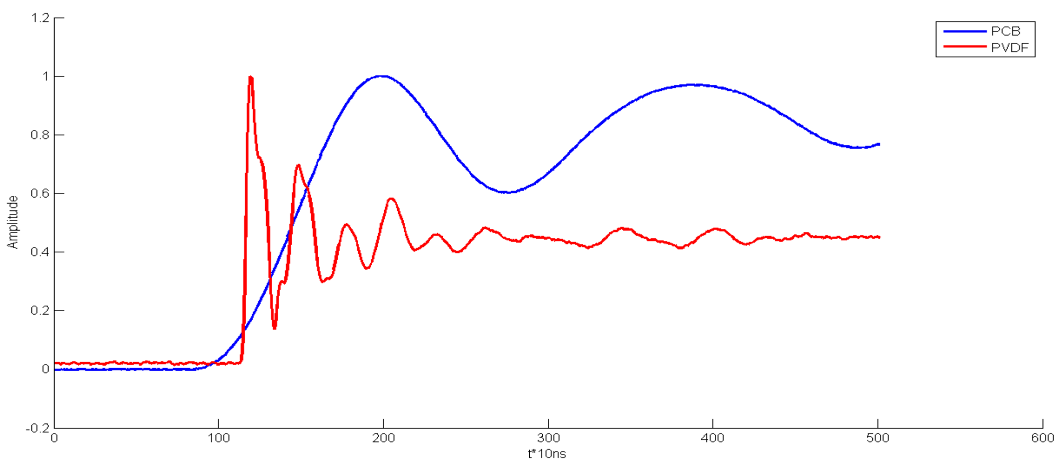
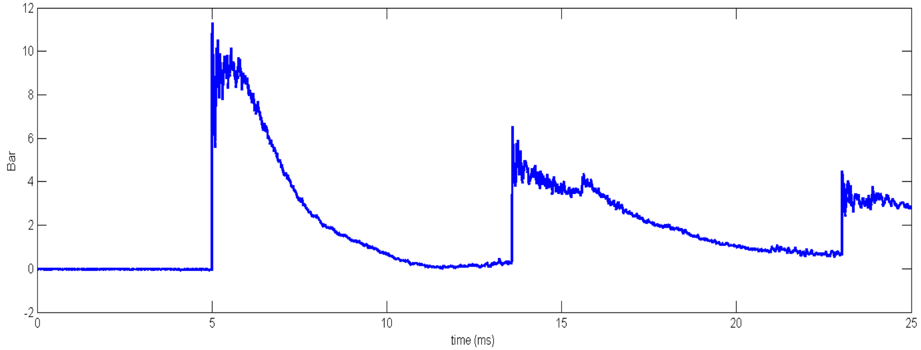
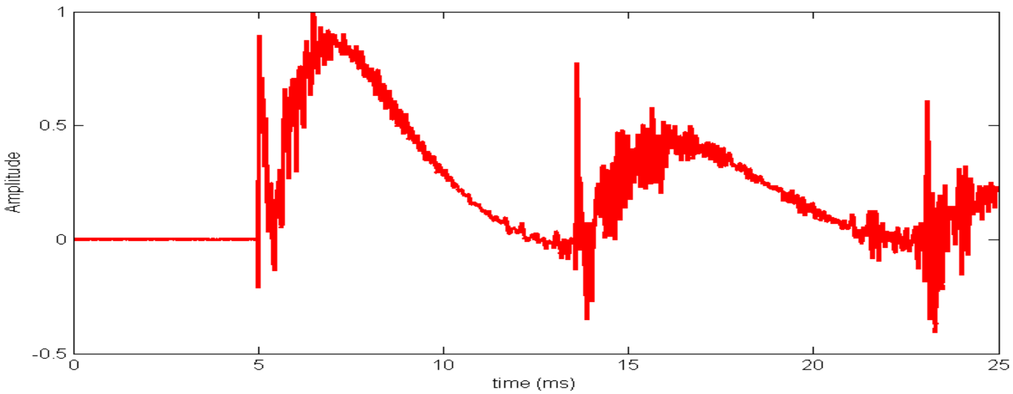


Fig2: Zoom on the first front

	Rise time
Pcb 113A24	1 us
PVDF Muller	100 ns

Experiment Results





- Noisy signal
- Structural vibrations

Conclusion and Perspectives

Conclusions :

- PVDF sensors have a good performances to sense fast dynamic signals
- Rise time under 100 ns has been recorded
- Packaging aspects are very important in order to optimize the sensor responses

Perspectives :

- Improve the packaging of the prototype sensor
- Reduce the vibration of the prototype sensor
- Develop a special conditioning electronic to improve the signal to noise ratio
- Develop special post processing program to get the best approximation of the real signal

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