



**DARPA Air-Coupled Acoustic Sensors Workshop**  
**August 24-25, 1999, Crystal City, VA**



# **Novel Parametric-effect MEMS Amplifiers/Transducers for Sonar Applications**

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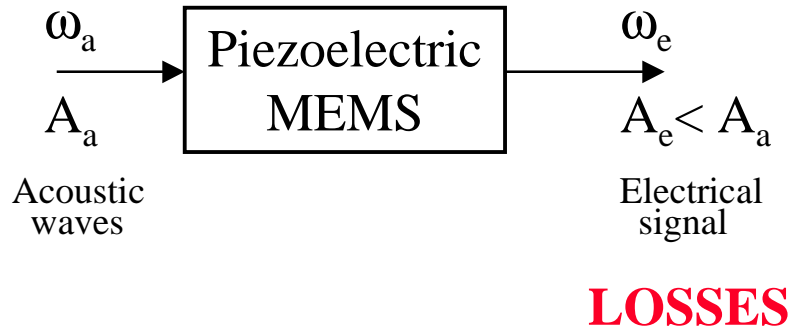
Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>24 AUG 1999</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Novel Parametric-effect MEMS Amplifier/Transducer</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>University of Michigan</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>DARPA, Air-Coupled Acoustic Microsensors Workshop held on August 24 and 25, 1999 in Crystal City, VA., The original document contains color images.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>UU</b>	18. NUMBER OF PAGES <b>4</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			



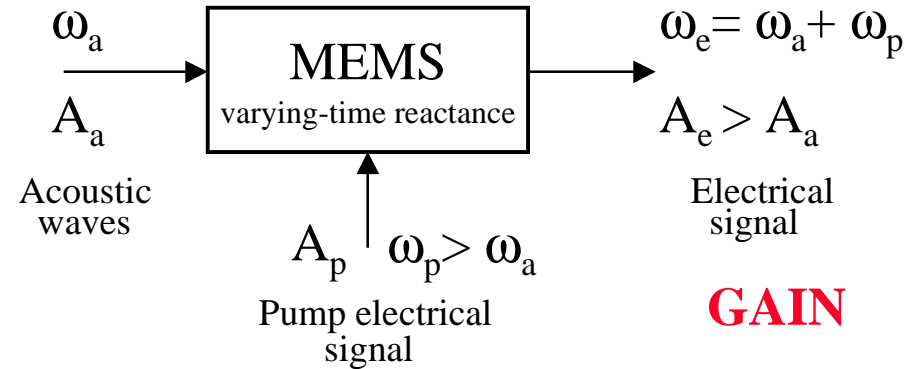
## Idea: Use Parametric Effects in MEMS



### Transducer



### Parametric Amplifier Transducer



First mechanical parametric amplifier using MEMS

- Advantages:
- gain at the transducer level
  - low-noise (no 1/f noise)
  - silicon technology: high integration, low cost
  - wide bandwidth (kHz - MHz)



## Parametric Effects



- have been largely used in **1960's**: up and down frequency conversion, amplification **at microwave frequencies**.
- are based on **time varying properties** of a capacitor or inductor (Manley-Rowe Equations).
- allow to **transfer power** from the pump frequency ( $\omega_p$ ) to the input signal frequency ( $\omega_s$ ) or to the up-conversion frequency ( $\omega_u$ )  $\Rightarrow$  **GAIN**.
- The source of power for a usual transducer amplifier is a **dc supply**,  
for a parametric amplifier: the **source of power is the pump electrical signal ( $\omega_p$ ), which is a higher frequency** than the input signal ( $\omega_s$ ) .



# Amplifiers / up-converters

## Gain - Bandwidth



**Time varying** capacitor:  $C(t) = C_0 + C_1 \cdot \cos(\omega_p t) + C_2 \cdot \cos(2\omega_p t) + \dots$  with  $C_1/C_0 = 0.5 - 1.0$

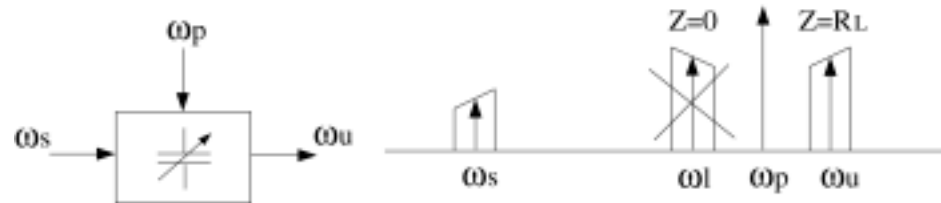
⇒ currents and voltages are generated at all **combination frequencies**:

$$f_{n,m} = n \cdot f_s \pm m \cdot f_p \quad (n, m = -\infty \dots \infty)$$

Practically, we will keep only certain combinations of frequencies.

Noninverting up-converter

$$f_u = f_p + f_s$$



Equivalent input conductance is positive

⇒ **Stable** amplifier and possible matching

Max. gain and bandwidth at matched conditions:

$$g_u = g_s = 2\pi C_1 \cdot \sqrt{f_s \cdot (f_p + f_s)}$$

Manley and Rowe:  $\frac{P_s}{f_s} + \frac{P_u}{f_u} = 0$

**Transducer and Power Gain:**  $\frac{P_u}{P_s} = \frac{f_p + f_s}{f_s} > 1$

**Bandwidth:**  $B = \frac{C_1}{C_0} \cdot \sqrt{2 \cdot f_s \cdot (f_p + f_s)}$