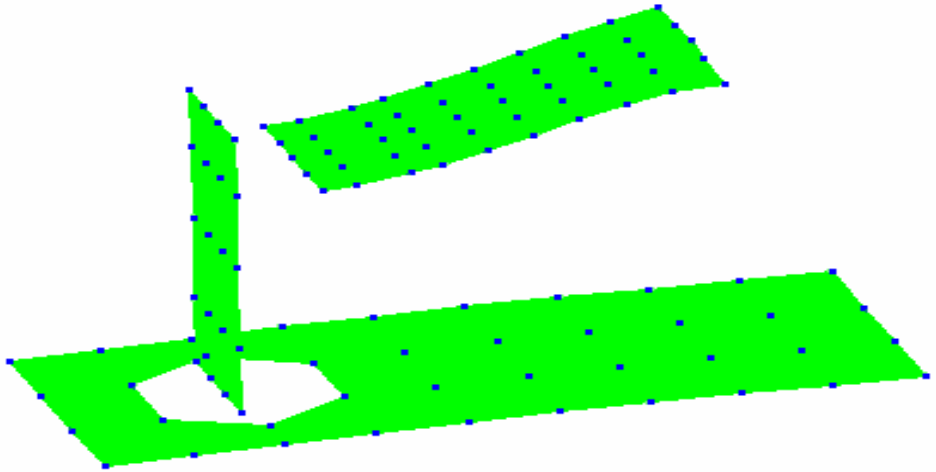
Modifying a Self-Sensing Circuit to Increase the Stability of Vibration Control

Eddie Simmers
Jeff Hodgkins
David Mascarenas

Mentors:
Gyuhae Park
Hoon Sohn



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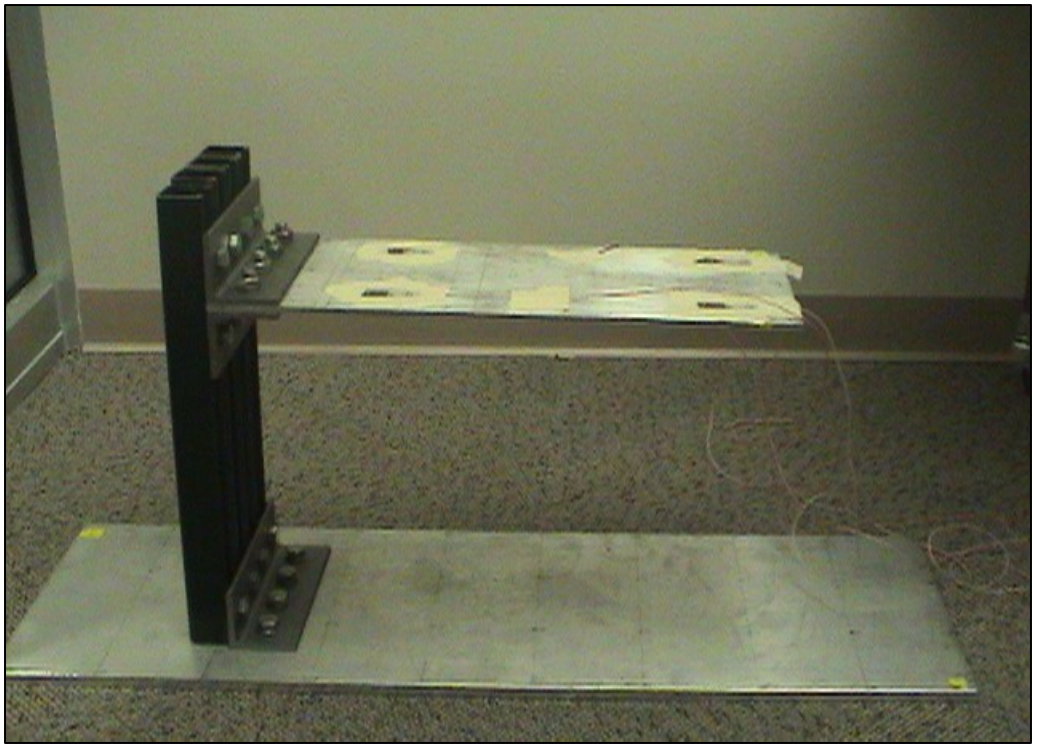

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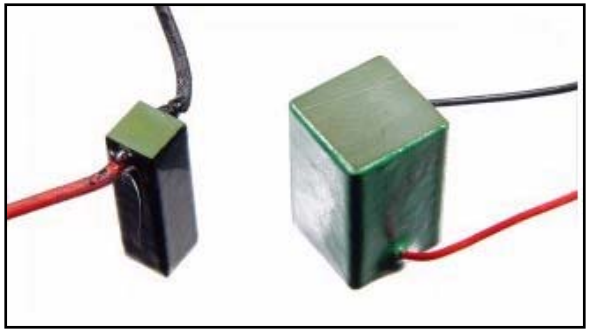
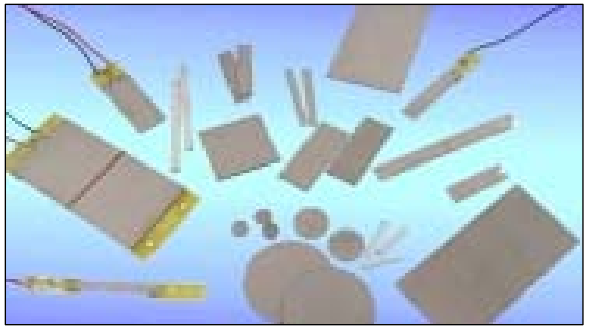
Piezoelectric materials (PZTs) have properties that make them attractive as sensors

Advantages	Challenges
Non-intrusive	PZT is brittle
Potential for self-diagnostic capabilities	High electric fields are required (0.5–2 MV/m)
High sensitivity to strain	Only low strains are obtainable



piezo.com



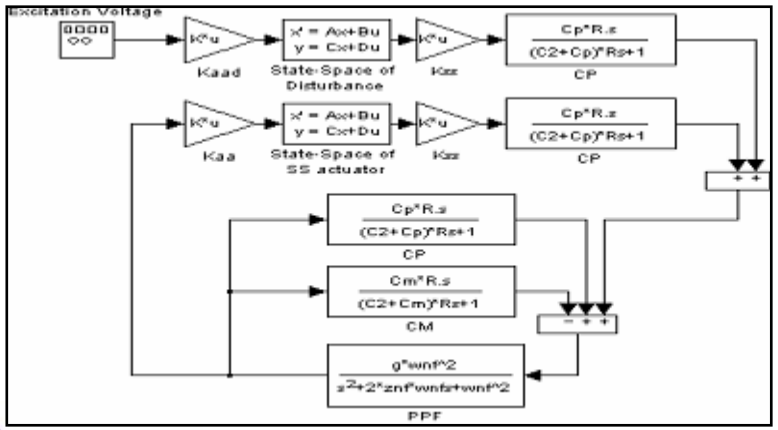
piezo.com

This talk will cover modifications made to the bridge circuit to increase control stability

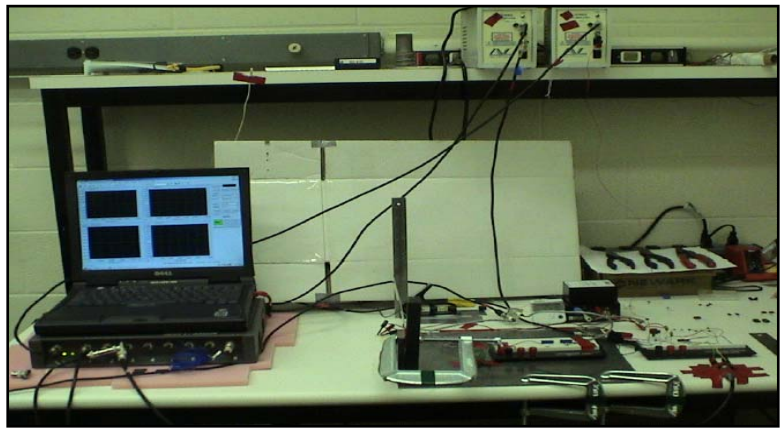
Analytical Modeling

$$A = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ -\omega_1^2 & 0 & 0 & 0 & -2\zeta\omega_1 & 0 & 0 & 0 \\ 0 & -\omega_2^2 & 0 & 0 & 0 & -2\zeta\omega_2 & 0 & 0 \\ 0 & 0 & -\omega_3^2 & 0 & 0 & 0 & -2\zeta\omega_3 & 0 \\ 0 & 0 & 0 & -\omega_4^2 & 0 & 0 & 0 & -2\zeta\omega_4 \end{bmatrix}$$

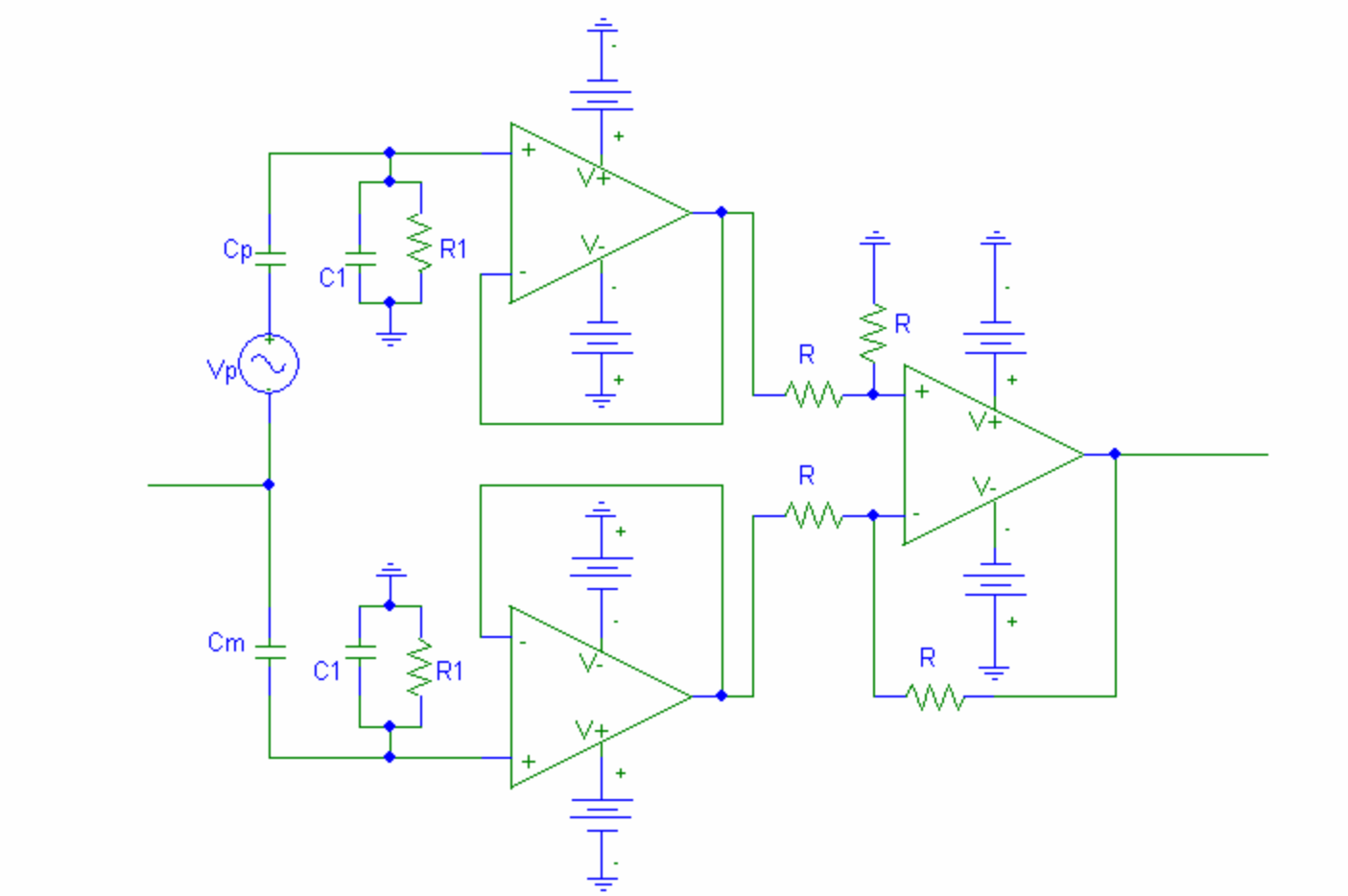
Analytical Simulation



Experimental Verification



The piezo-beam, self-sensing bridge, and feedback control were modeled analytically



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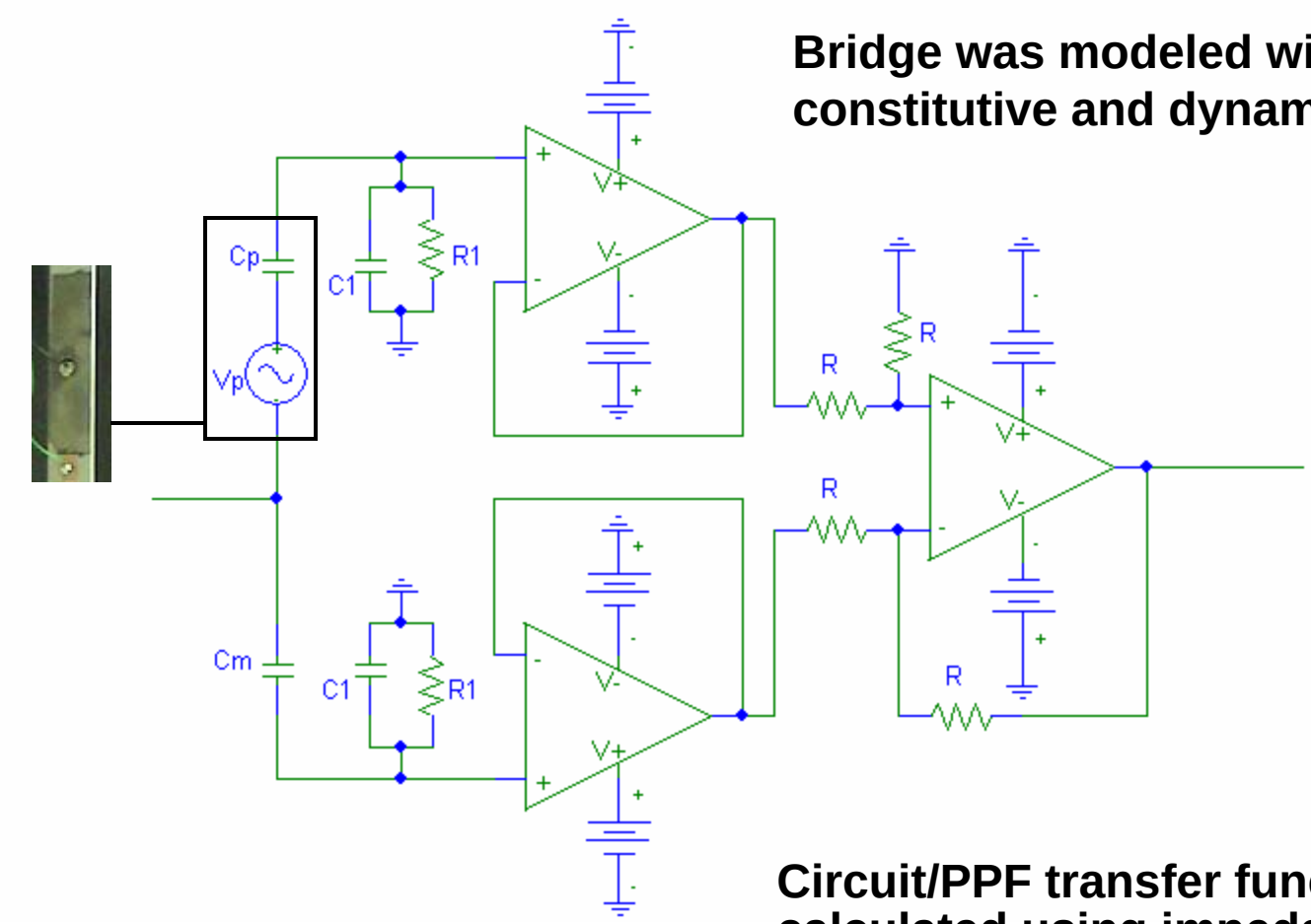

Bridge was modeled with piezoelectric constitutive and dynamic beam equations

Circuit/PPF transfer functions were calculated using impedance

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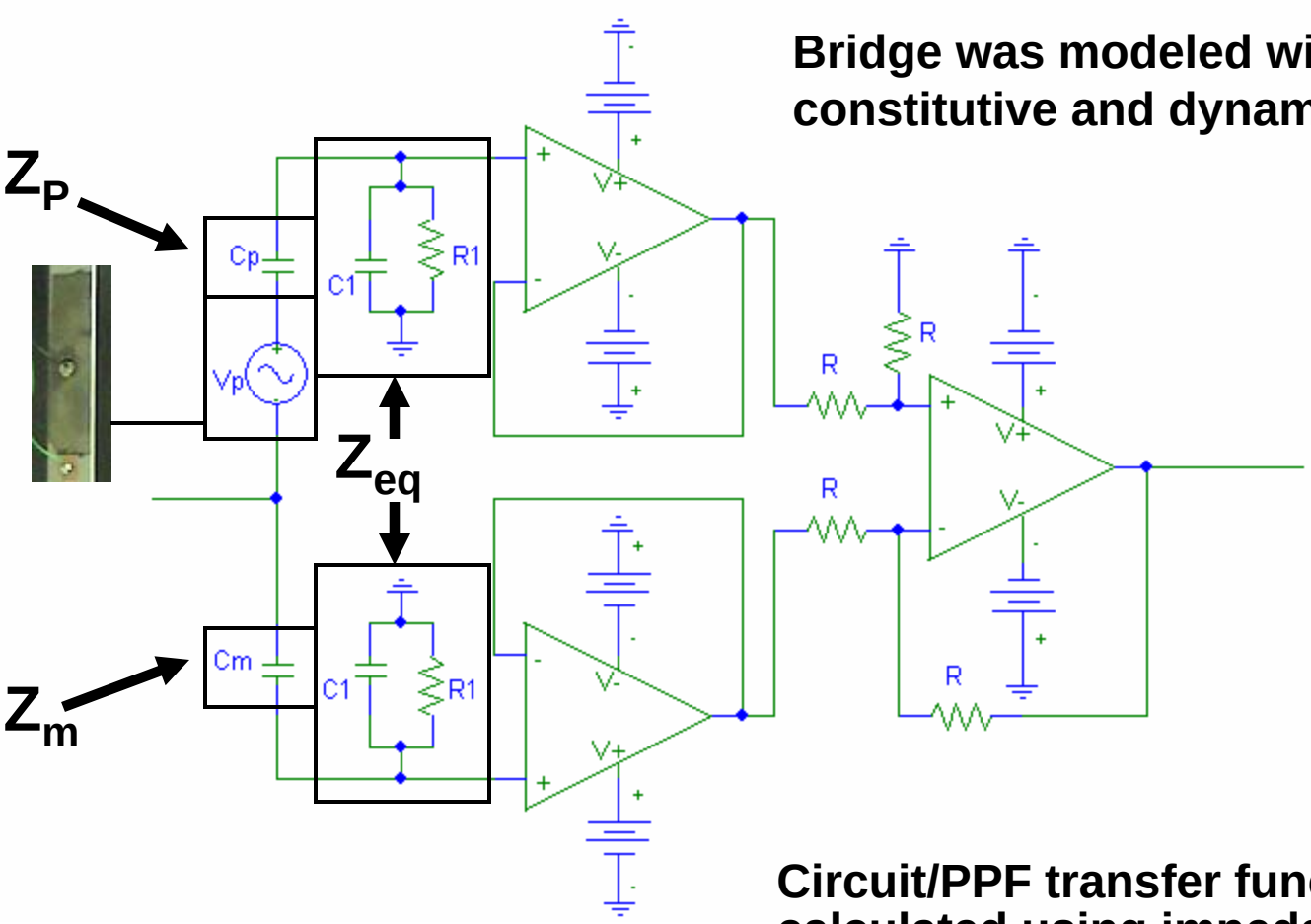

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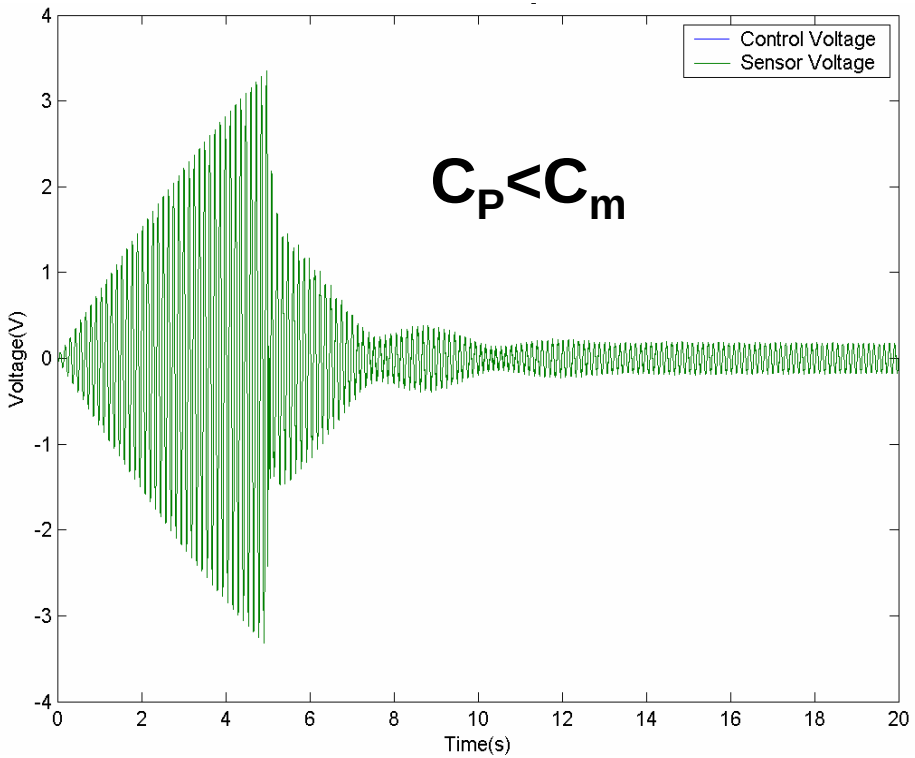
A simulation was developed to identify how C_P and C_m related to stability



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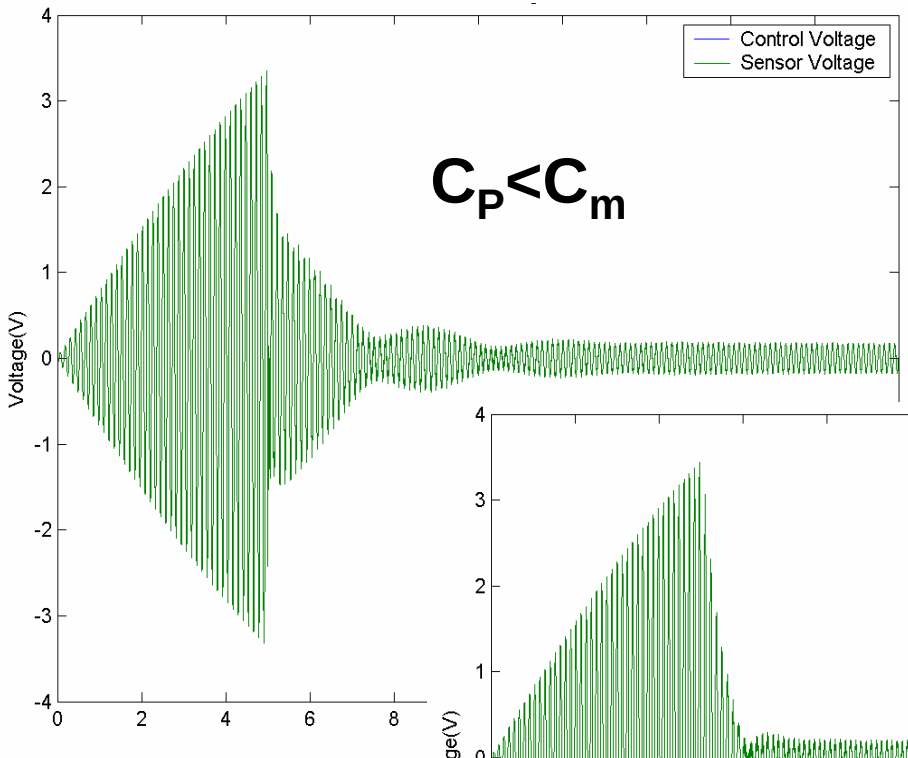

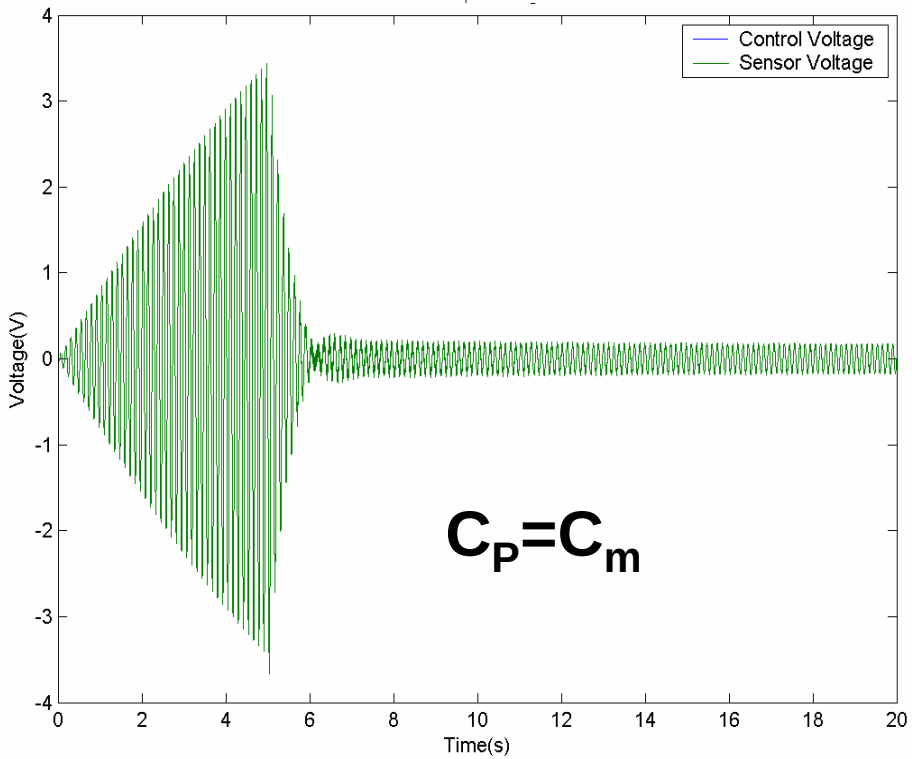

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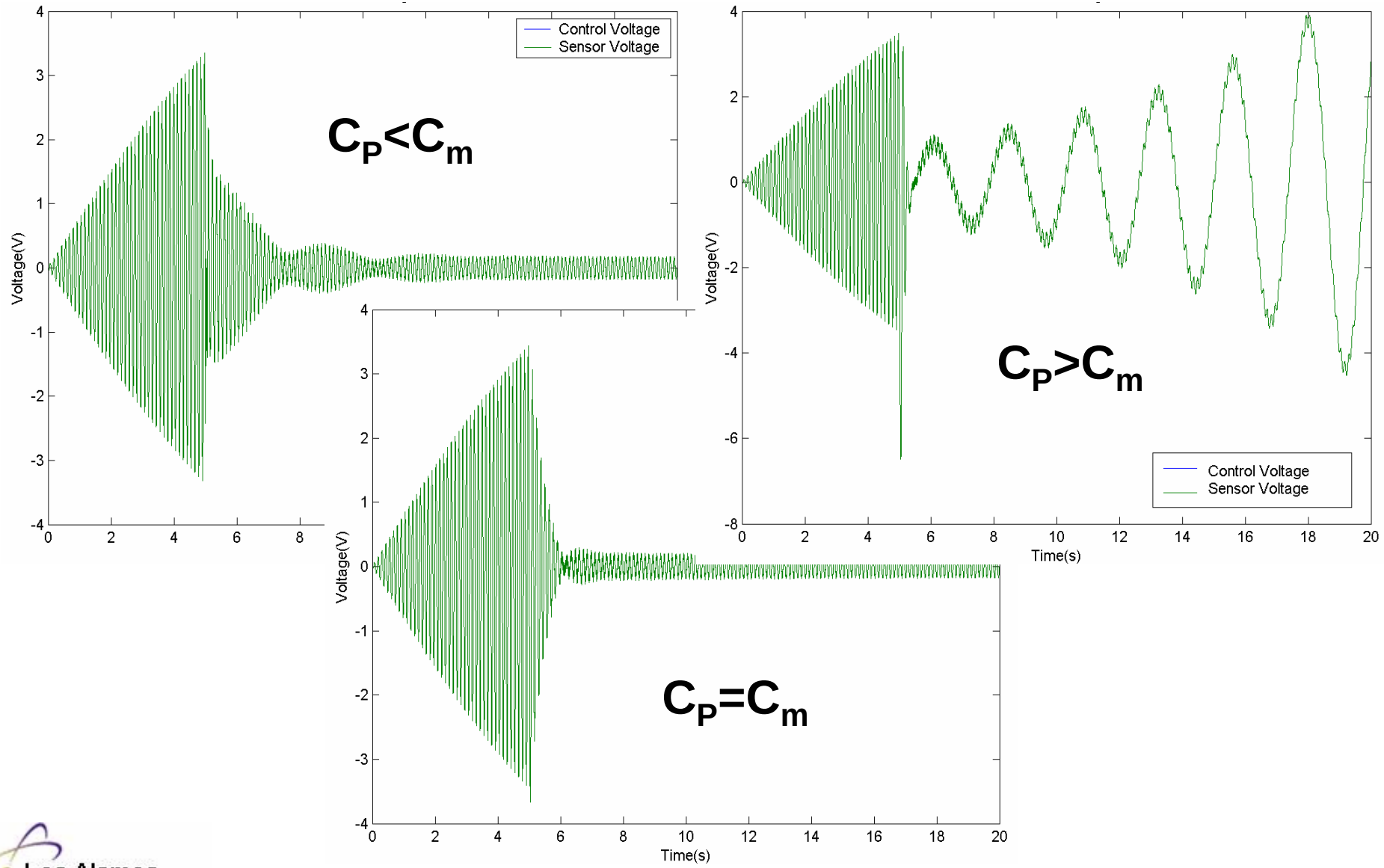

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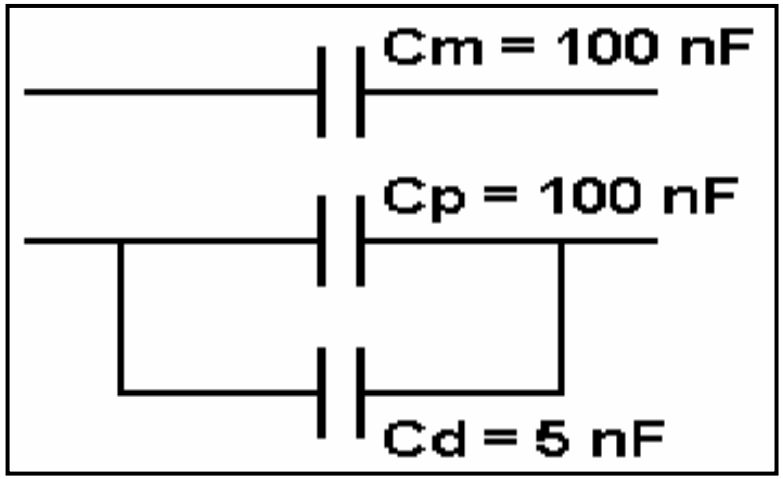
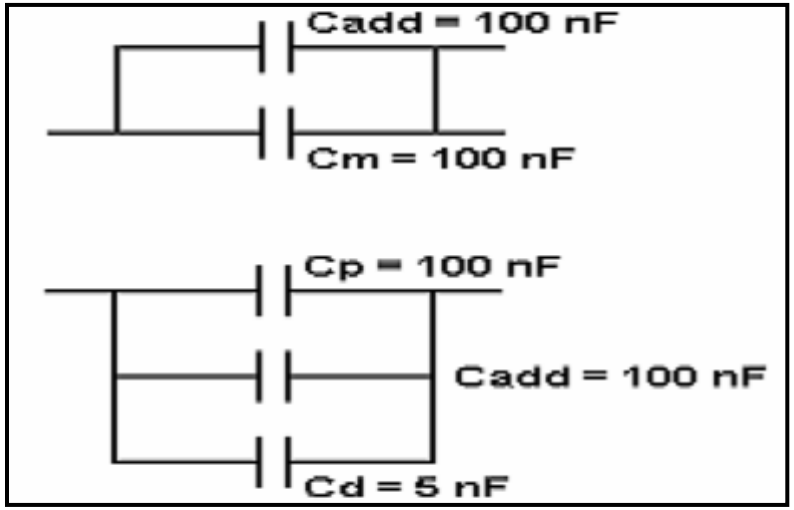
Our concept for improving the stability of the system was based on minimizing percent mismatch

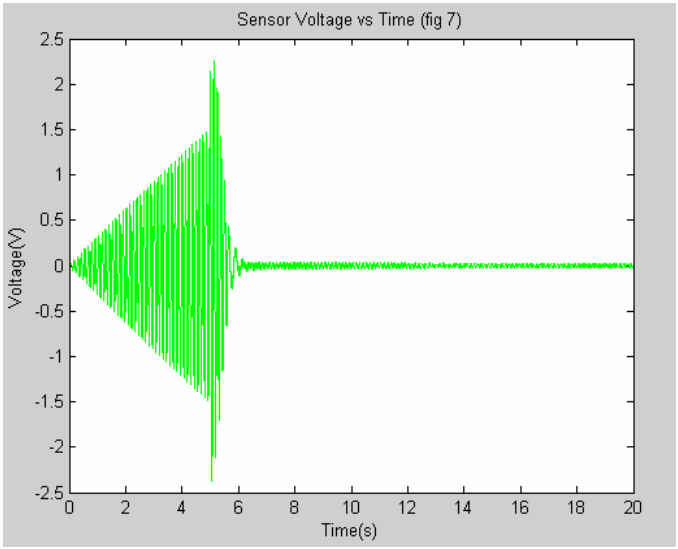
No added capacitor case:
5% mismatch



Added capacitor in parallel:
2.5% mismatch



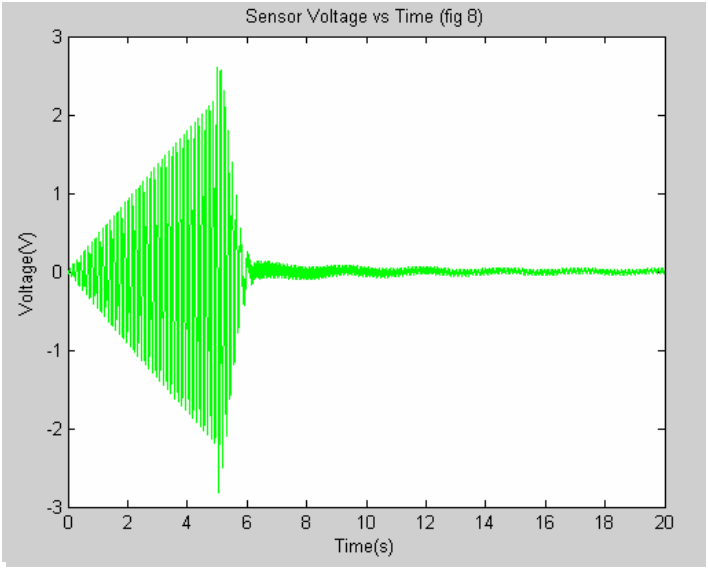
At a 9% temperature change, C_{add} is stable



Series add

Stable

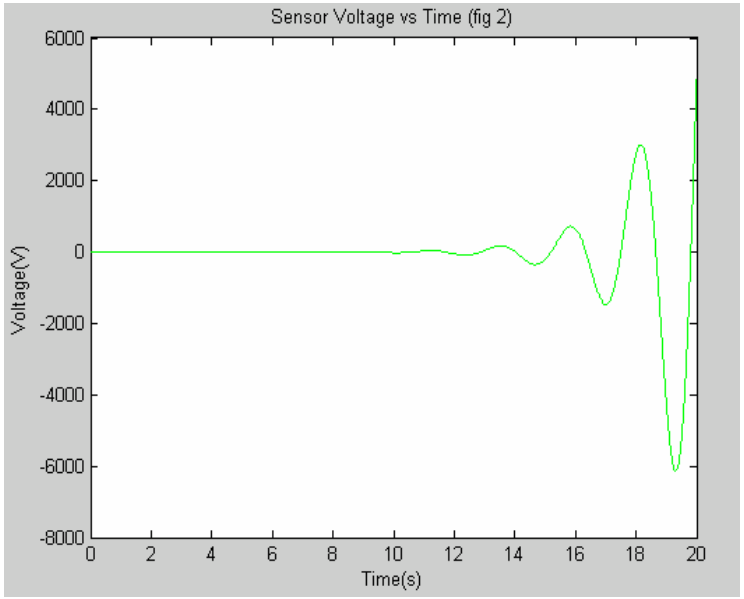
t_s=1.4s



Parallel add

Stable

t_s=1.4s



No Add

Unstable

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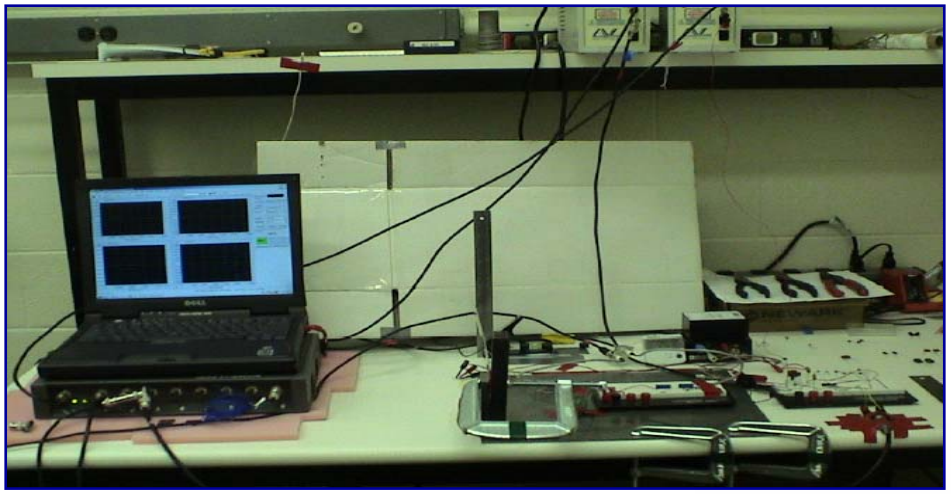
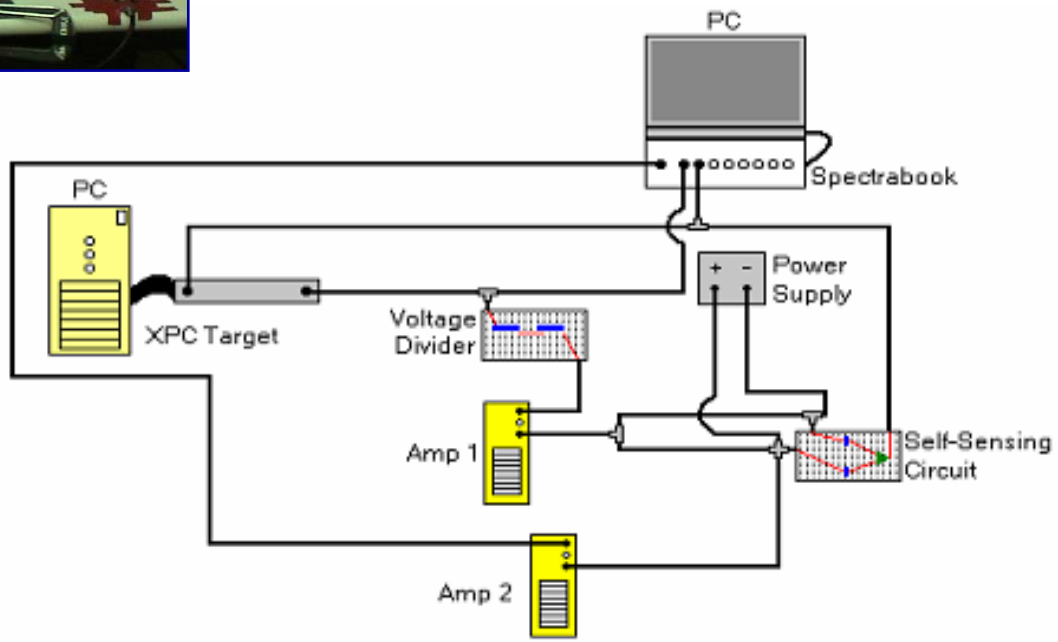
The simulation results were verified experimentally by using an aluminum cantilever beam





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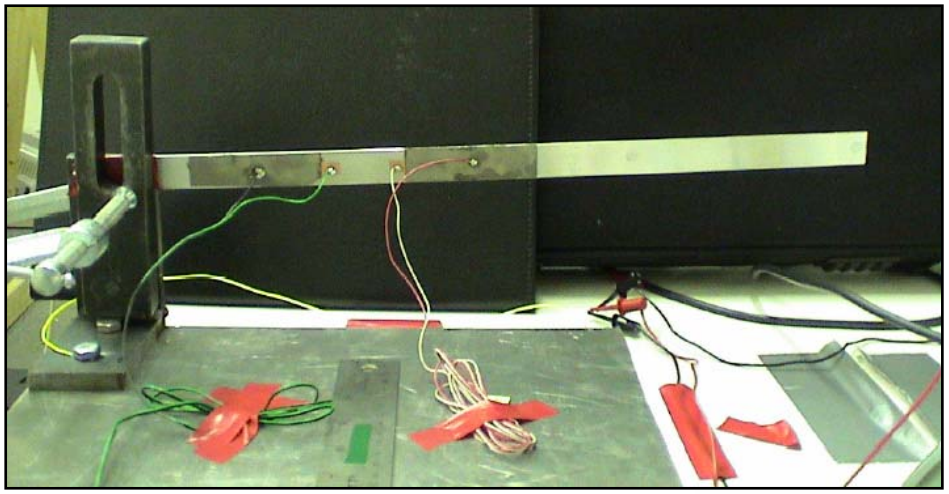
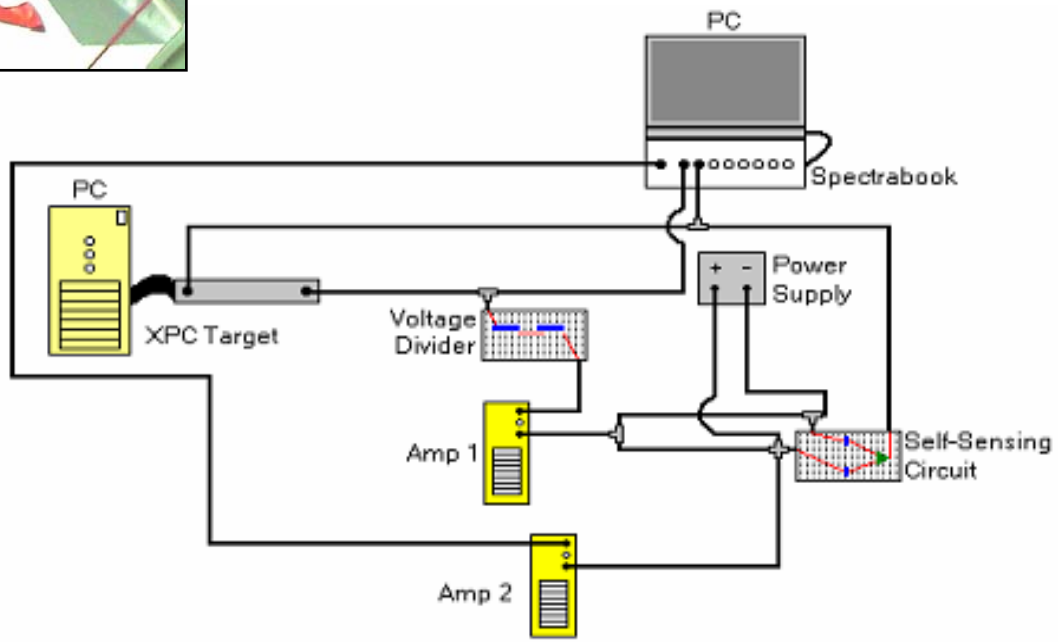
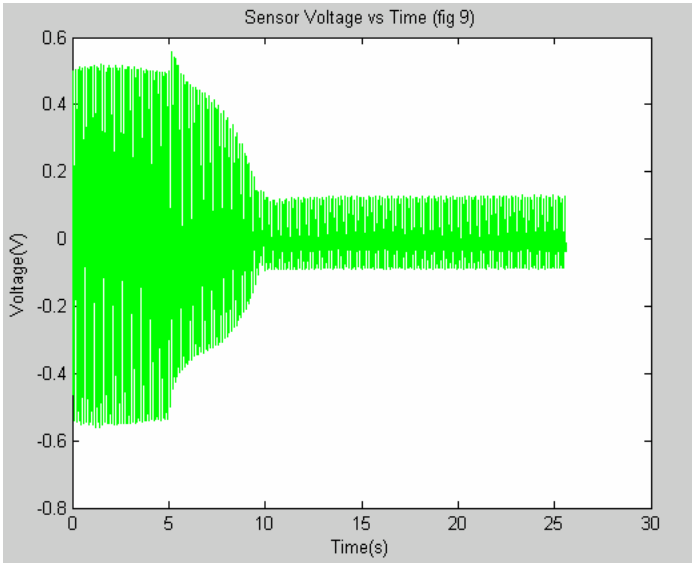




For a 4 nF disturbance, C_{add} creates stability



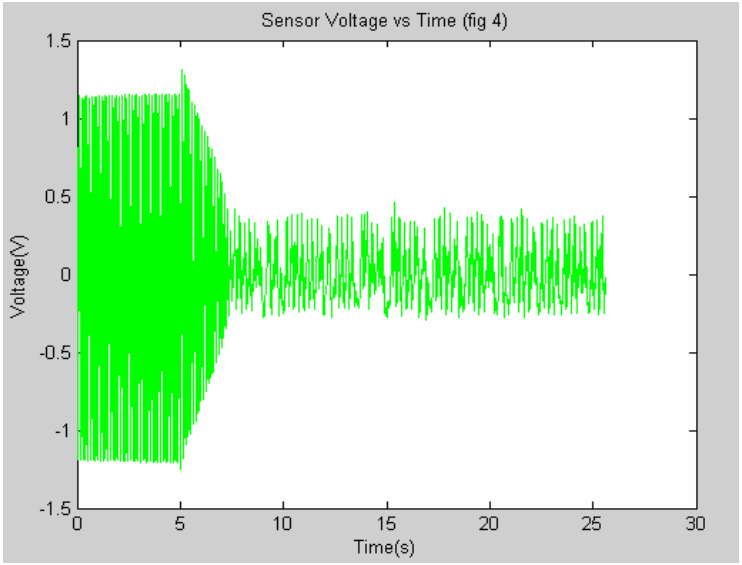
Series add

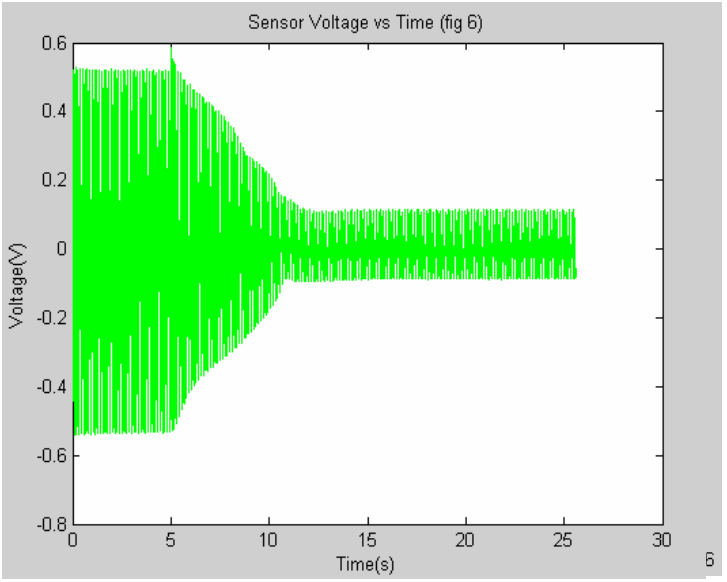
Stable

t_s = 5.03s

No add

Unstable





Parallel add

Stable

t_s = 6.08s

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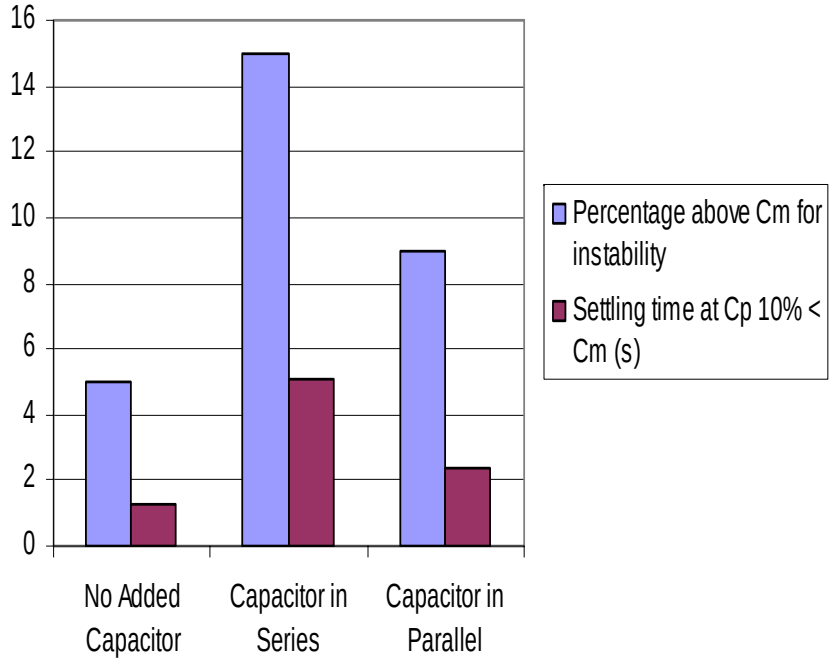
In summary, we quantified dynamic characteristics of the self-sensing actuation for the first time

Two new design schemes have increased control stability

Schemes can become more effective, but at the cost of increased power

Both new design schemes were validated experimentally



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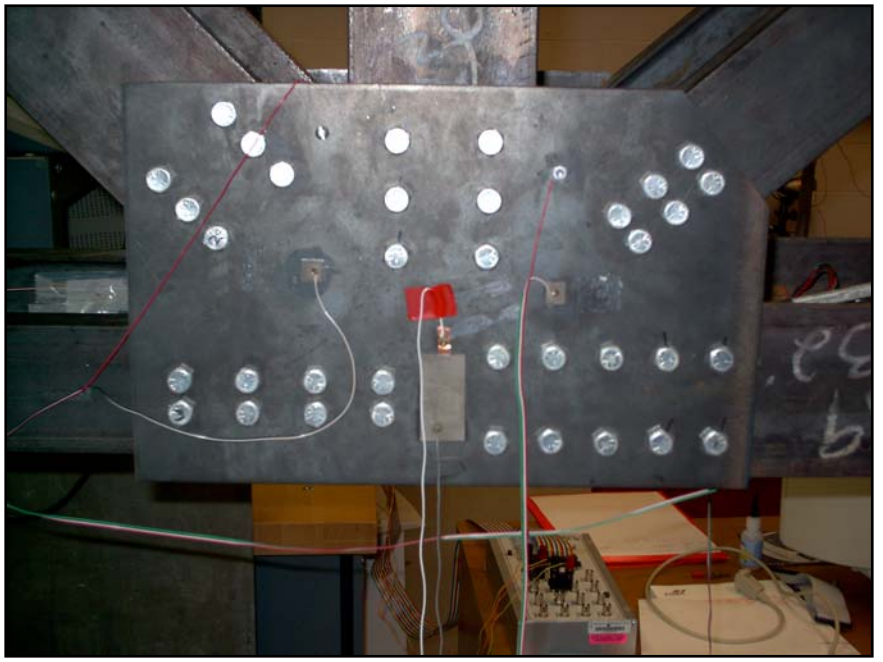

Questions?