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

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Jeff Hodgkins
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Mentors:
Gyuhae Park
Hoon Sohn

Dynamics Summer School
Los Alamos, New Mexico
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Piezoelectric materials (PZTs) have properties that make them attractive as sensors.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-intrusive</td>
<td>PZT is brittle</td>
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<td>Potential for self-diagnostic capabilities</td>
<td>High electric fields are required (0.5–2 MV/m)</td>
</tr>
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<td>Only low strains are obtainable</td>
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Challenges:
- PZT is brittle
- High electric fields are required (0.5–2 MV/m)
- Only low strains are obtainable

Advantages:
- Non-intrusive
- Potential for self-diagnostic capabilities
- High sensitivity to strain

Images:
- piezo.com
This talk will cover modifications made to the bridge circuit to increase control stability.

**Analytical Modeling**

\[
A = \begin{bmatrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
\end{bmatrix}
\]

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

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

- $C_P < C_m$
- $C_P = C_m$
- $C_P > C_m$
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, $C_{\text{add}}$ is stable

**Series add**

Stable

$t_s = 1.4s$

**Parallel add**

Stable

$t_s = 1.4s$

**No Add**

Unstable
The simulation results were verified experimentally by using an aluminum cantilever beam.
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For a 4 nF disturbance, $C_{\text{add}}$ creates stability.

Series add
Stable
$t_s = 5.03s$

No add
Unstable

Parallel add
Stable
$t_s = 6.08s$
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.

![Bar chart showing percentage above Cm for instability and settling time at Cp 10% < Cm (s)]
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Questions?