Towards software-based methods for steady and precise oscillation control at kilohertz frequencies

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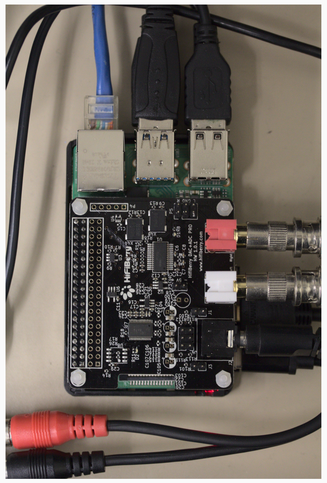
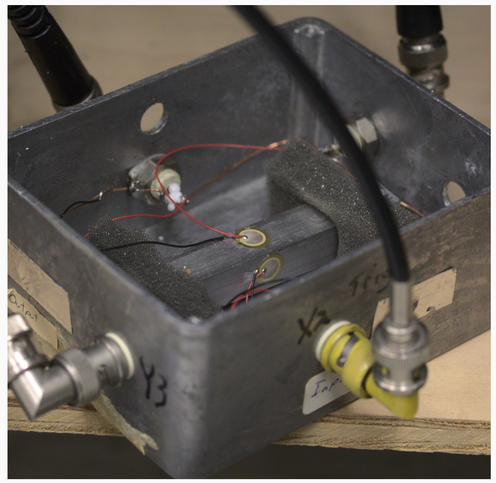
Introduction

Oscillators resembling Non-Hermitian and *PT*-symmetric systems are of interest in electronics for the potential to apply their diverse behaviors as filters.[1] Active manipulation with piezoelectric transducers allows us to gain control over the equations of motion for these oscillations.

Instrumentation setup

We used a Raspberry Pi 4 with realtime kernel patches, with a Hifiberry DAC+ADC Pro sound card. Four piezoelectric transducers were fixed on the center of four sides on a small aluminum bar; four stereo audio input and output jacks are connected to each of the sides to measure and control the oscillation in x and y axes. Photos of the Pi (left) and oscillator setup (right) are below.





Mathematical description

We can control the complex frequency of oscillation ω by adjusting gain parameters, shown below with respect to the natural frequency ω_0:

$$\omega = \frac{ib}{2m} \pm \omega_0 \sqrt{1 - \frac{b^2}{4mk} \pm \frac{\sqrt{G_{xy} G_{yx}}}{k}}$$

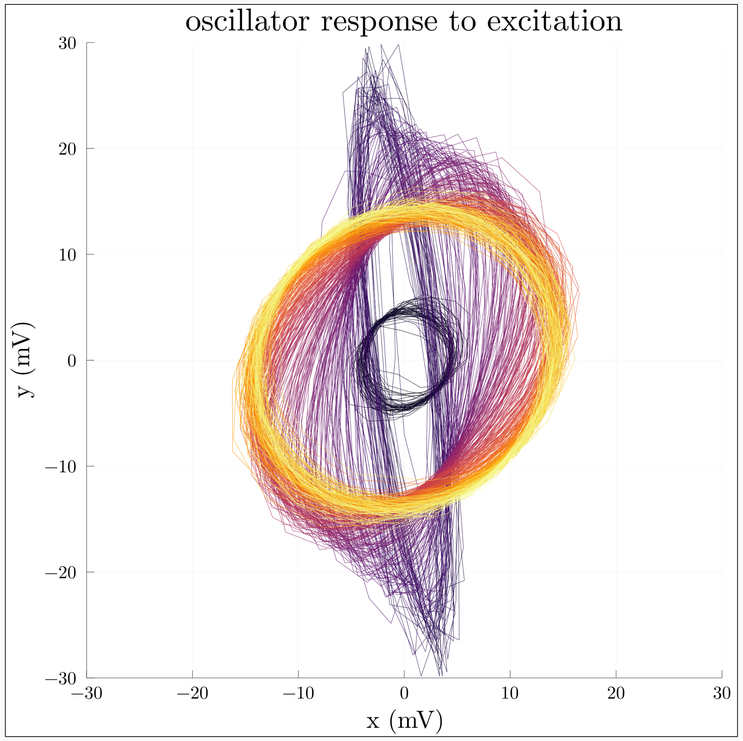
In the case that both gains are equal in magnitude, then circular rotation is obtained by setting them to opposite signs, whereas a standing wave will form when they are of the same sign.

Results

While system latency is on the order of tens of cycles, we have precise control, in mod 2π, over the phase delay feedback through buffer resizing and sub-sample interpolation. We have sustained undamped oscillations on the order of many seconds once the phases and gains are tuned, and then set constant. The system remains undamped even when perturbed.

Shown to the right is a 30 ms capture of the oscillator sustaining a small amplitude (black), then being excited by a hammer (purple), then decaying to its natural mode while retaining a high amplitude (yellow).

All data shown were recorded from the Raspberry Pi while simultaneously maintaining the feedback loop.



References

1. J. Schindler, et al., "*PT*-Symmetric Electronics," *J. Phys. A: Math. Theor.* 45, no. 44 (Fall 2012): 9–10, https://doi.org/10.1088/1751-8113/45/44/444029.

source code:

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