The World Depends on Sensors and Controls

Piezo-Resistive High Speed Hydraulic Pressure Cycling

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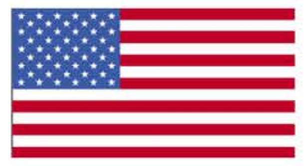
Sensata Technologies



Attleboro, USA

Abstract

The purpose of the project was to develop a high speed pressure cycler that enabled Sensata to cycle at frequencies in line with customer specification, on a manifold full of parts, and to develop a system that can hydraulically cycle sensors at or higher than the designed cutoff frequency with full control over wave input, frequency, and test duration.

Objectives

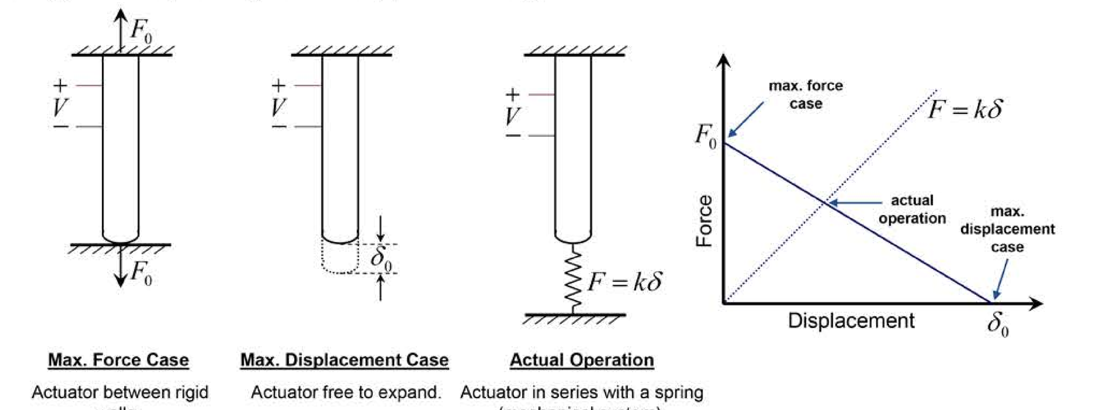
Background

- **History**

  The PR high speed pressure cycler was first developed by Vaibhaw Vishal, PhD, in 2008 for high speed pressure cycling of a single sensor, the system has not undergone significant revision since then.

- **Piezo-Resistive Cycler Fundamentals:**

  When electric voltage is applied to piezo-actuator it "tries to" expand/contract depending on the polarity of the applied voltage.



- **PR cycler set-up**

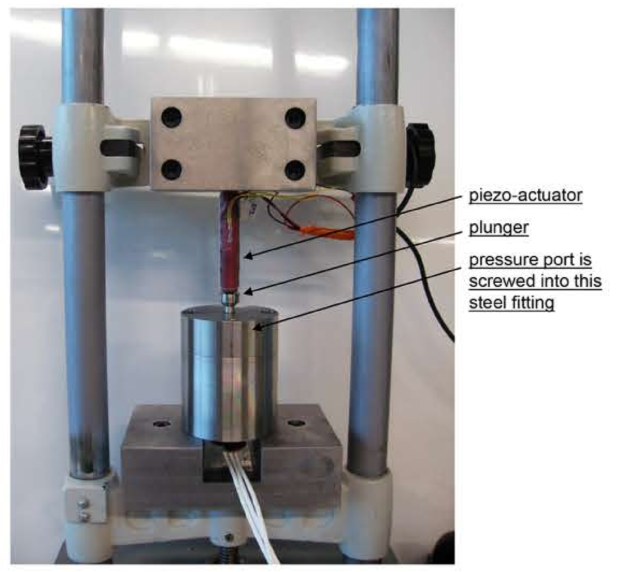


Figure: Picture of piezo-cycler

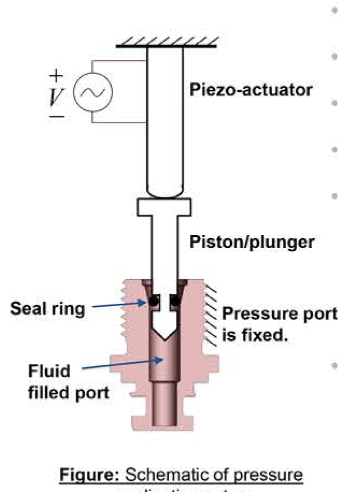


Figure: Schematic of pressure application setup

High frequency piezo-cycler

- Maximum speed = 800 Hz.
- Max pressure range = 120 bars.
- One part (max. 2) can be cycled at a time.
- As of now, not connected to any oven.
- Desired waveform such as sine-wave, square-wave, *etc.*, can be selected.

The primary component of this cycler is a piezo-electric actuator which works on the principle of reverse piezo-electric effect.

Above diagrams courtesy of Vaibaw Vishal, PhD

- **Limitations**
  - 1 sensor can be actuated at a time due to the small piston diameter and the consequent need for a low volume fluid cavity
  - Must bleed through the same hole as the piston which means you can burst the sensor, during the plunge bleeding
  - Cannot be placed in the oven due to the size of the supports
  - Cannot be used for long term testing due to the potential for fluid leakage

Short Pressure Cycling

- **Short Pressure Cycler, aka, PR Cycler 2.0**

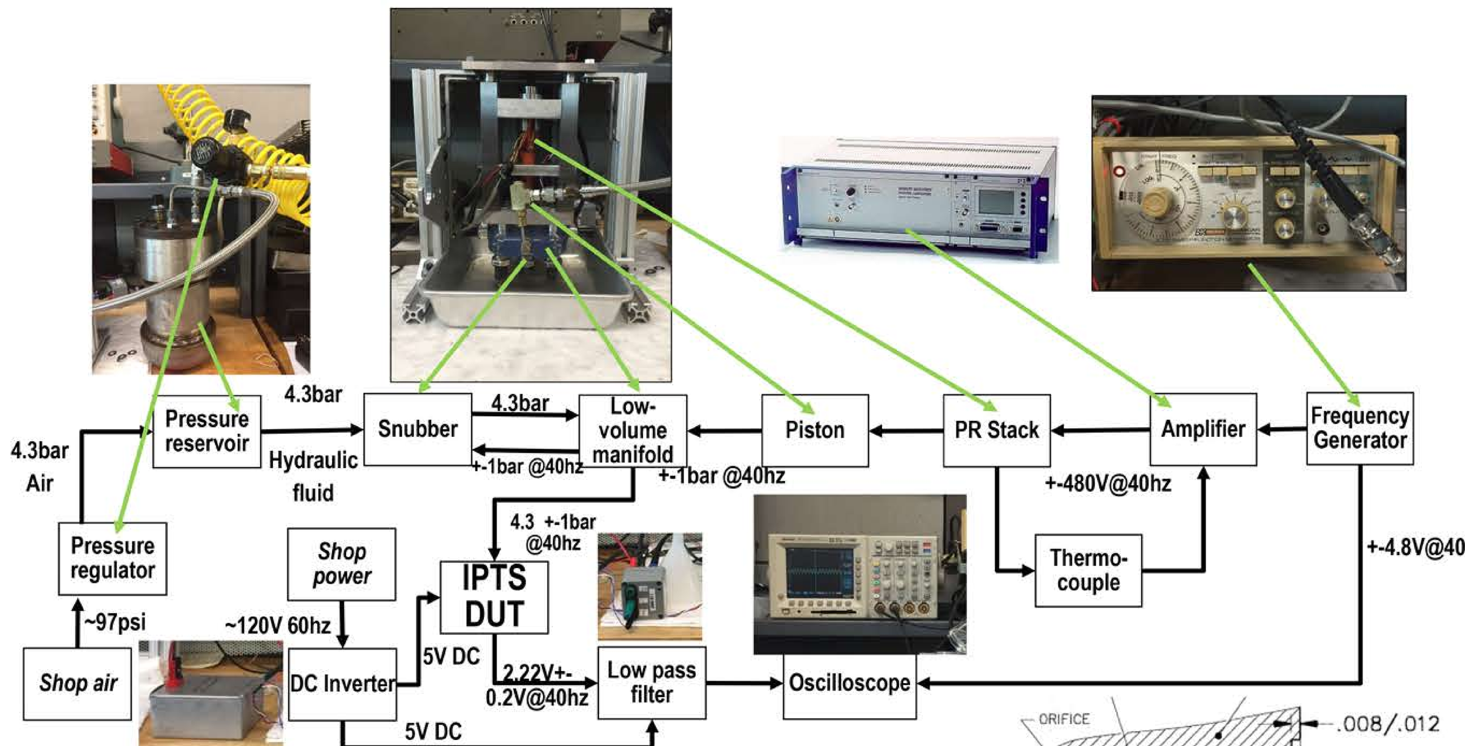
  In light of the shortcomings found in the PR cycler originally developed in 2008 there were a number of changes that would have to be made to improve the cycler.

- **Improvements**

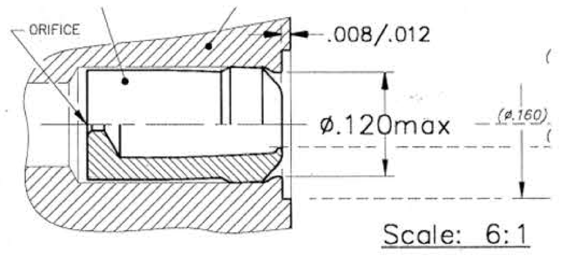
  Needed to cycle at least 12 parts, **increase piston diameter (9mm)**

  Must be low maintenance over a 4 month testing period, **either easily refillable pressure cavity or constant fluid ingress**

- **Network Diagram of PR Cycler 2.0**

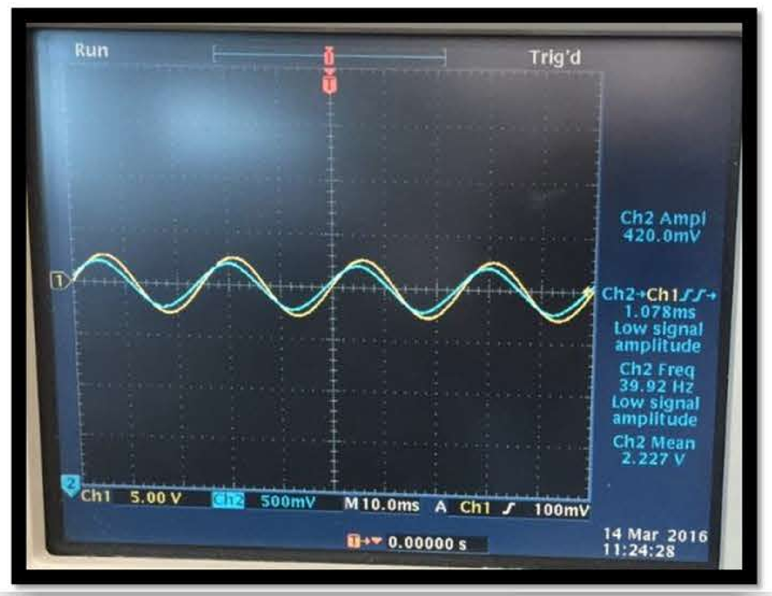


- **Pressure Accumulator + Snubber Function**
  - Hydraulic fluid constantly flows from pressure reservoir into manifold, acts as a low latency "check valve"



Pressure Reservoir	Snubber	System	Piezo Stack
+530kpa	+530kpa -50 sin(x)	$f(x) = 50\sin(x) + 530$kpa	+50 sin(x)kpa

- **Results**
  - Sensors output a 40hz wave acceptably with the required voltage levels, ~2.22V +- ~0.200mV
  - Latency from frequency generator to sensors fluctuates from 1ms - 1.8ms
    - Aggregate of all connections outlined in above network diagram suggests *very* fast sensor performance, and likely exceeding the 10ms T90 Step Response requirement
    - System can be used in the future for hydraulic step response testing
  - Max frequency tested: 320hz, ~10% amplitude drop-off



Frequency Response Characterization

- **PR Cycler 2.1**

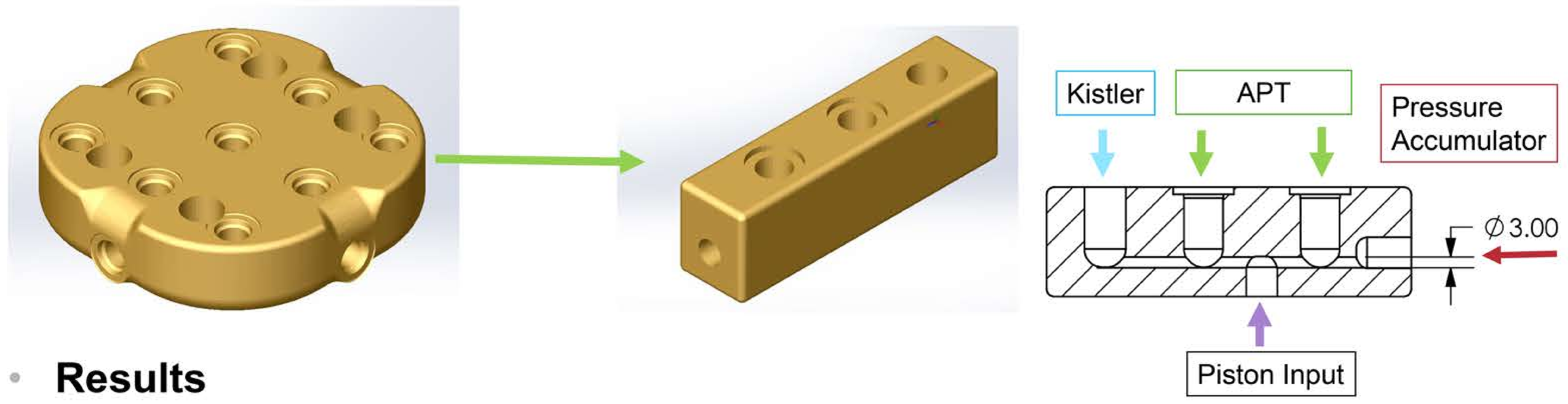
  The design for the short pressure cycler was ported to conduct high frequency pressure cycling on multiple sensors and a Kistler. Purpose of test set-up is to compare frequency response in Gen3 and Gen4 APT.

- **Requirements**

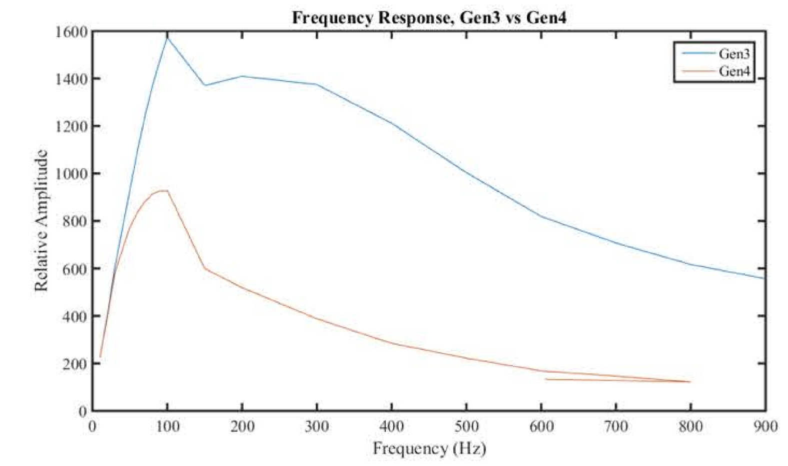
  Needs to cycle at a very high frequency with no pressure attenuation, **redesign manifold for minimal fluid volume**

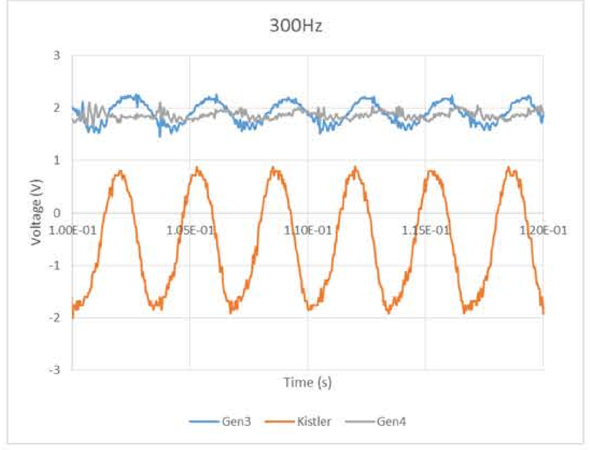
  Needs to incorporate control sensor capable of high frequency reading, **inclusion of Kistler**

- **Manifold revision**

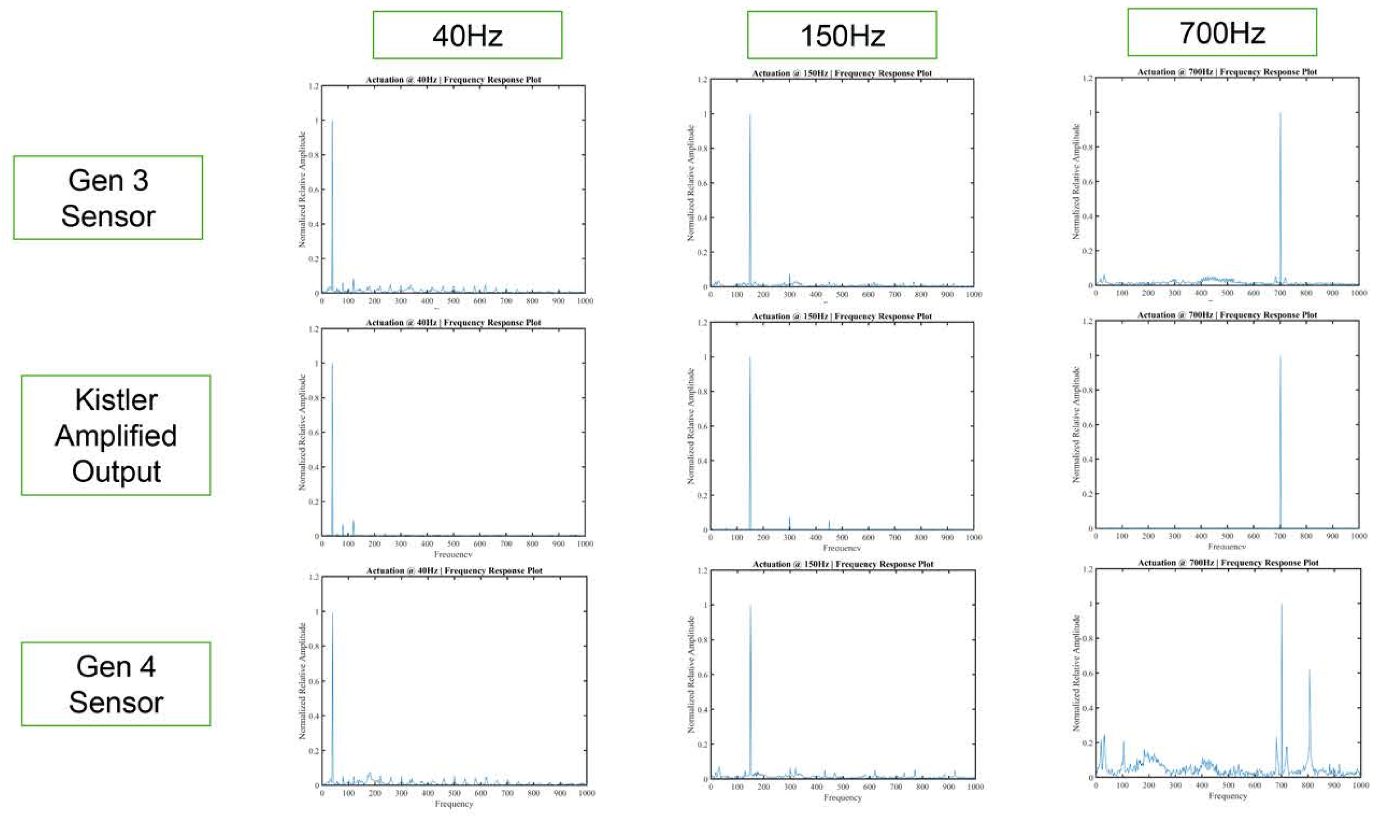


- **Results**
  - Stack repeatedly drove system at different input frequencies, example of 300hz output below
  - Cyclic output was readable and sensed by both Gen3 and Gen4 until 800hz, where Gen4 output significant non-input frequencies, seen below where Gen4 inflects at 800hz
  - Further evaluation shows that target amplitude output dropped for Gen4 ~80hz, and Gen4 >600hz





- **Fast Fourier Transform Plots at different input frequencies**



Acknowledgements & References

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