Multi-Convertor Configurable Simulator for Dynamic Radioisotope Power Systems

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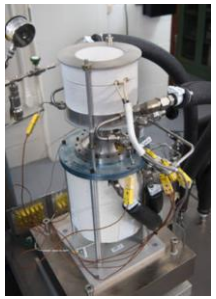
Outline

- Introduction: Multi-Convertor Configurable Simulator (MCCS)
- MCCS Design
- MCCS Test Results
- MCCS Summary

Sub-kW Free-Piston Stirling Convertors



Technology Demonstration Convertor (TDC)

Advanced Stirling Convertor (ASC)

Sunpower Robust Stirling Convertor (SRSC)

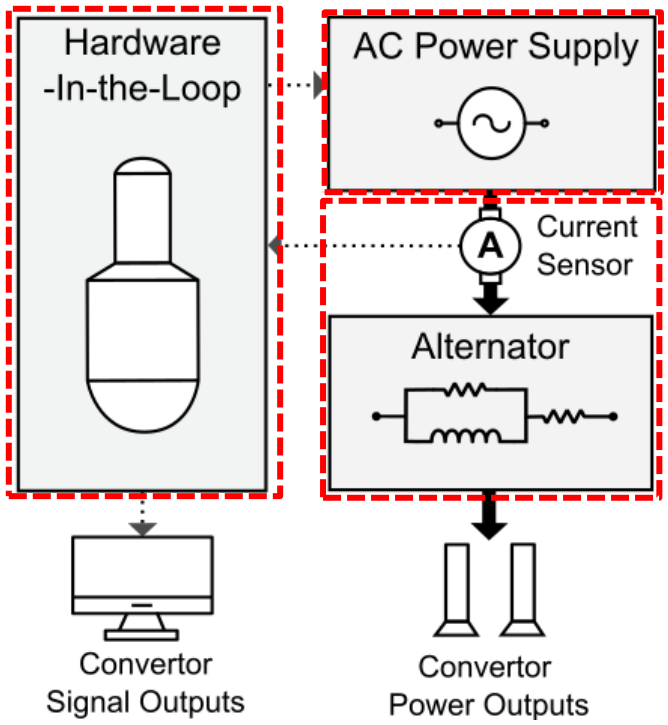
Flexure Isotope Stirling Convertor (FISC)

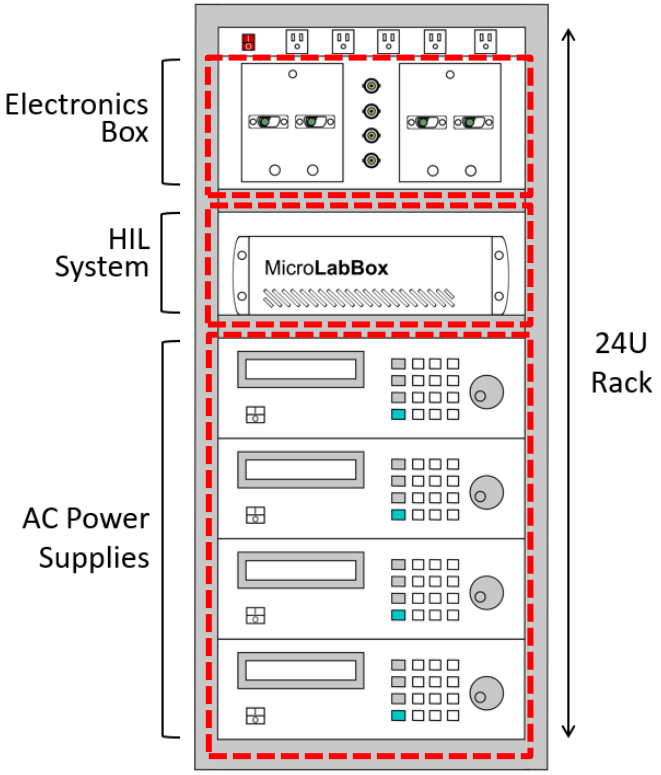
- High thermal to electrical energy conversion efficiency >20%
- Extended laboratory operation demonstrated for > 16yrs
- Piston controllers required for stable operation
  - Stirling convertors are valuable and heat-up time is long; simulator development is desirable for controller development
  - Multiple Stirling convertors are required to produce hundreds of watts for near future flight missions; state-of-the-art simulators can only simulate up to two Stirling convertors.
  - State-of-the-art simulators are limited to one specific type of Stirling convertors.

Solution:
Multi-Convertor Configurable Simulator (MCCS)

- Objectives
  - Simulates any free-piston Stirling convertors up to 1kW/convertor
  - Simulates up to four Stirling convertors (i.e., up to 4kW total)
  - Easily reconfigurable to different types Stirling convertors with minimum modifications
  - Accurate representation of Stirling convertors

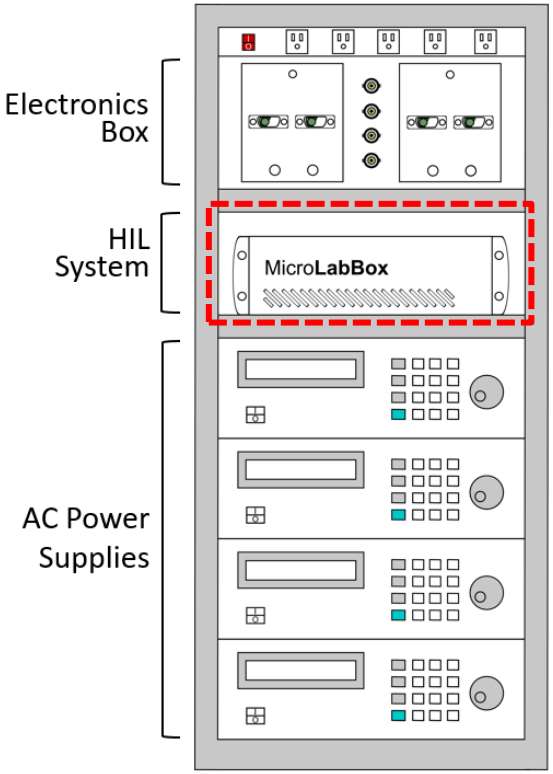
MCCS Design: How it works

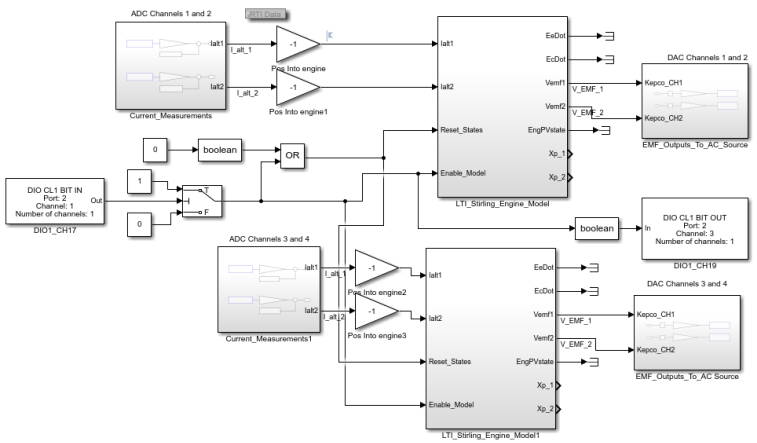


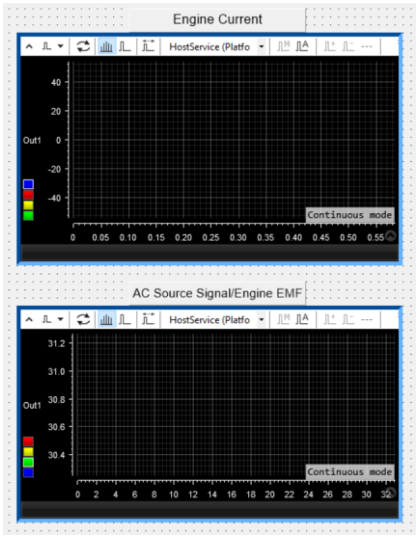


- Hardware-In-the-Loop (HIL) system
- Switched-mode AC power supplies
- Electronics box to simulate alternators and sense current through the alternators for feedback to the HIL system

MCCS Design: HIL System

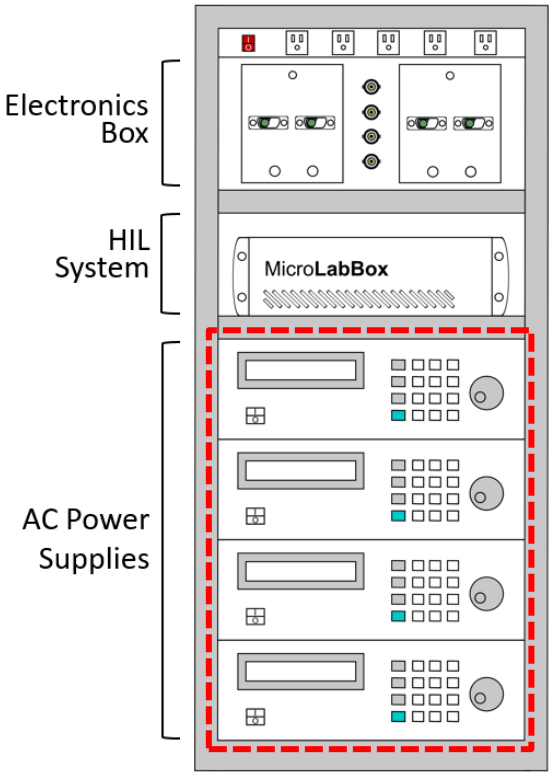




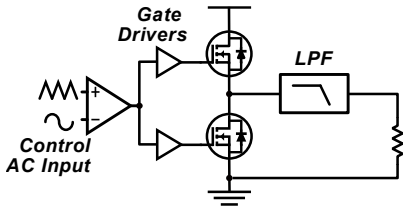


- Linearized Stirling convertor model programmed in the HIL system (dSpace MicroLabBox)
- Graphic User Interface (GUI) system makes the programming straightforward

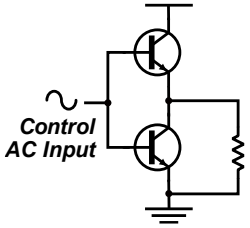
MCCS Design: AC Power Supplies



Class-D amplifier



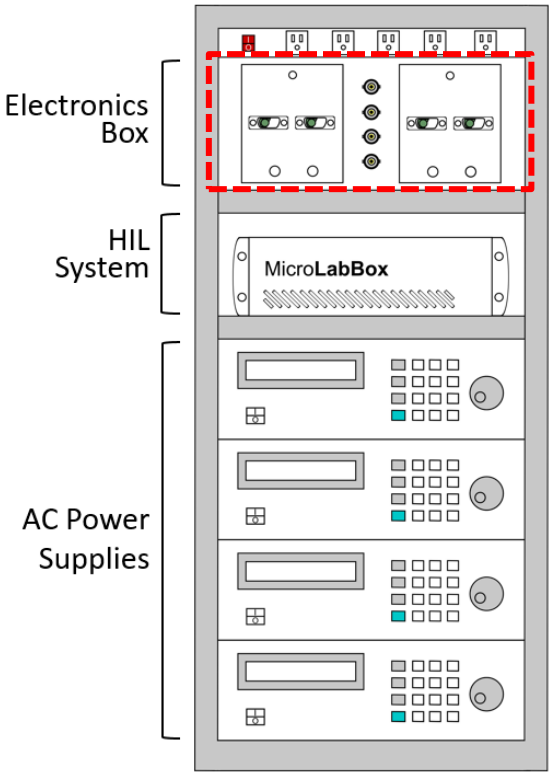
Class-AB amplifier

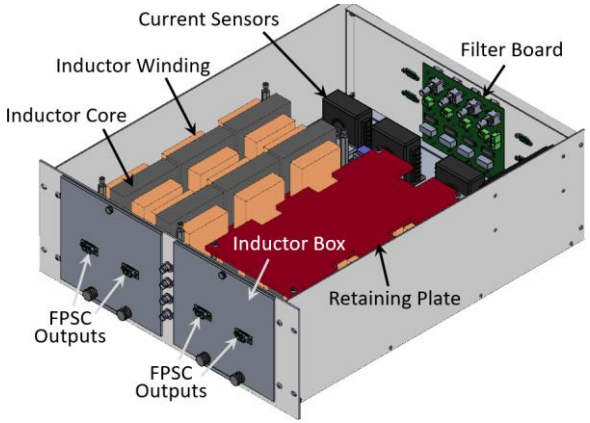


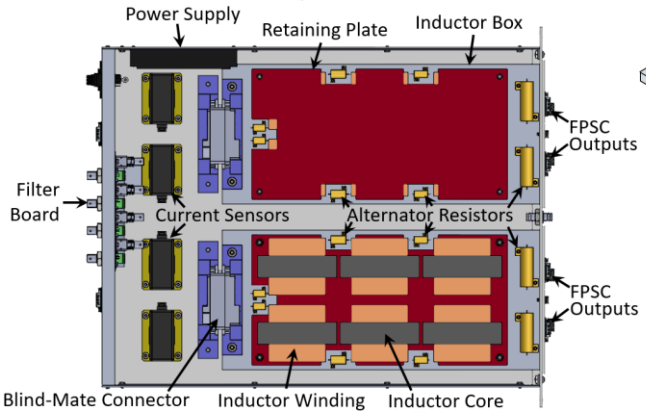
Switched-mode	Linear
Low output distortion	Very low output distortion
Moderately wide output bandwidth	Very wide output bandwidth
Moderate range for active output impedance control	Wide range of active output impedance control
Lower weight and smaller size	Higher weight and larger size
Ability to provide full current into loads without de-rating	Rated current varies depending on rated voltage due to linear amplification

- Switched-mode AC power supplies selected to enable simulation of different types of Stirling convertors
- Four AC power supplies used to simulate up to four Stirling convertors

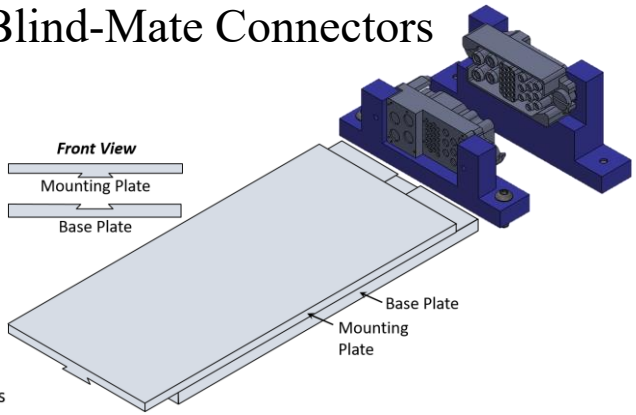
MCCS Design: Electronics Box





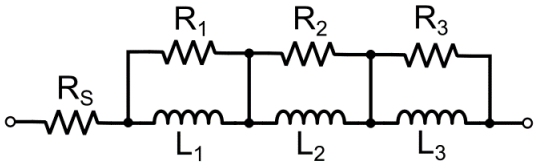


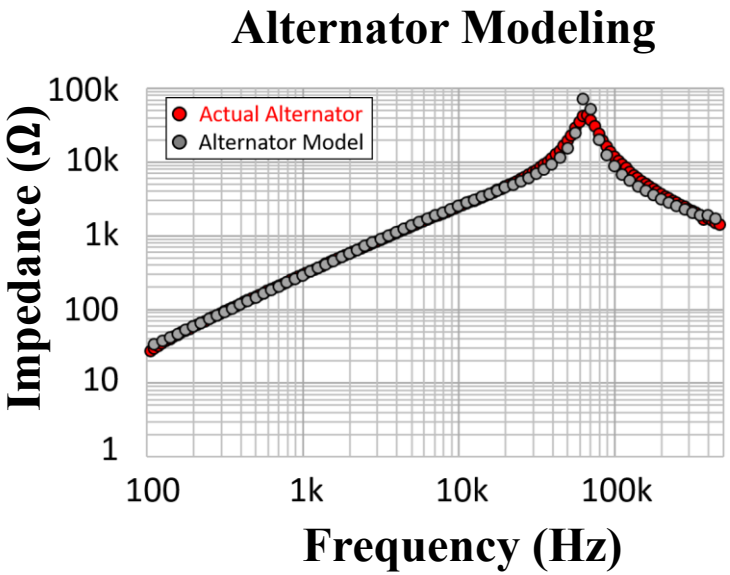
Inductor Box
Dove-Tail Slide &
Blind-Mate Connectors



- Electronics box contains inductor boxes, current sensors, and a filter board
- Inductor box is the only hardware to swap out to reconfigure to another type of Stirling convertor
  - Inductor box designed for easy swap-out using a dove-tail slide and blind-mate connectors

MCCS Design: FISC Example





- The MCCS configured to the Flexure Isotope Stirling Convertor (FISC)
  - A linearized model of the FISC was programmed in the HIL system.
  - An R-L network model was designed to represent the actual frequency response of the FISC alternator
  - Nothing else needs to be changed!

MCCS Test Results: FISC Example

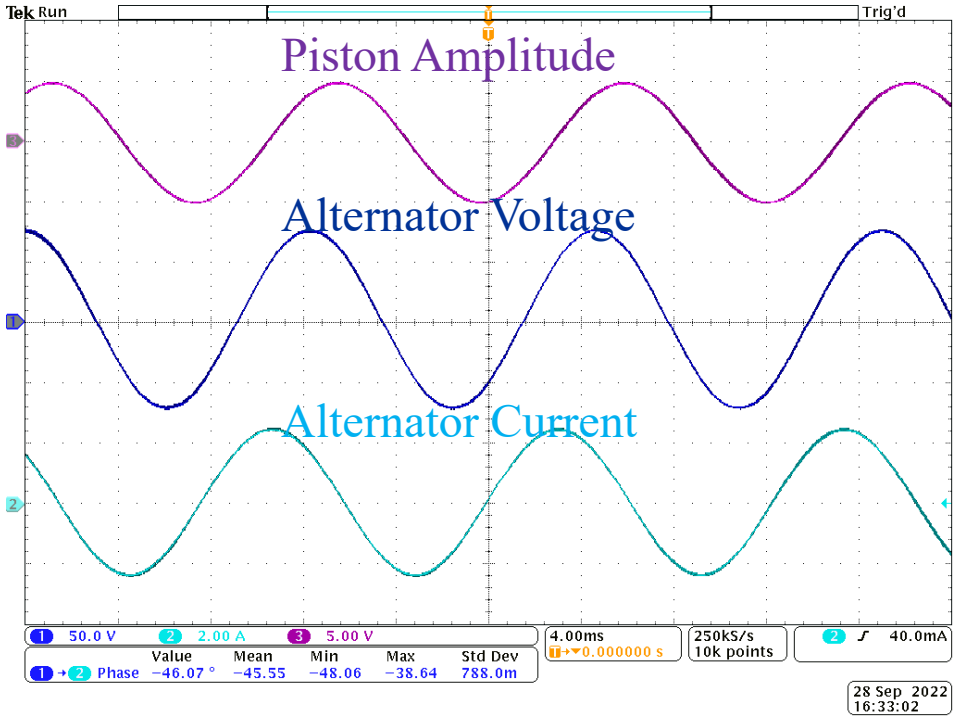


Table II. Comparisons between MCCS and FISC.

Parameter	FISC	MCCS
Alt. Voltage	52.3Vrms	52.4Vrms
Alt. Current	1.48Arms	1.67Arms
Alt. Power	59.7W	60.1W
Power Factor	0.78	0.68
Piston Amp.	4.9mm	5.0mm

- The MCCS matches FISC data very well.
- Small mismatch found in the power factor
  - This is due to some delays in the current sensor and the filter board.

Summary and Future Work

- Multi-Convertor Configurable Simulator (MCCS) was designed and developed
  - Simulates any low-power free-piston Stirling convertors
  - Simulates up to four Stirling convertors
  - Easily reconfigurable (only HIL system code and inductor boxes need to be reconfigured)
  - Results of the FISC example match the FISC test data
- MCCS is a great way to test controllers for Stirling convertors for near future flight missions.
  - Faster controller design iterations
  - No damage to valuable Stirling convertors
- Current sensor and filter board can be re-designed to improve the accuracy
- Building another MCCS unit is planned to simulate up to eight convertors simultaneously

Questions?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