Alternative Setup for Long-Duration Low-Duty-Cycle 600 °C Ambient Testing of SiC Integrated Circuits

By: Alain Izadnegahdar[*], Stephanie L. Booth[1], David J. Spry[1], and Philip G. Neudeck[1]

[*]*SAIC Inc*
5147 White Pine Drive
Brunswick, Ohio 44212 USA
Ph: 330-220-1031

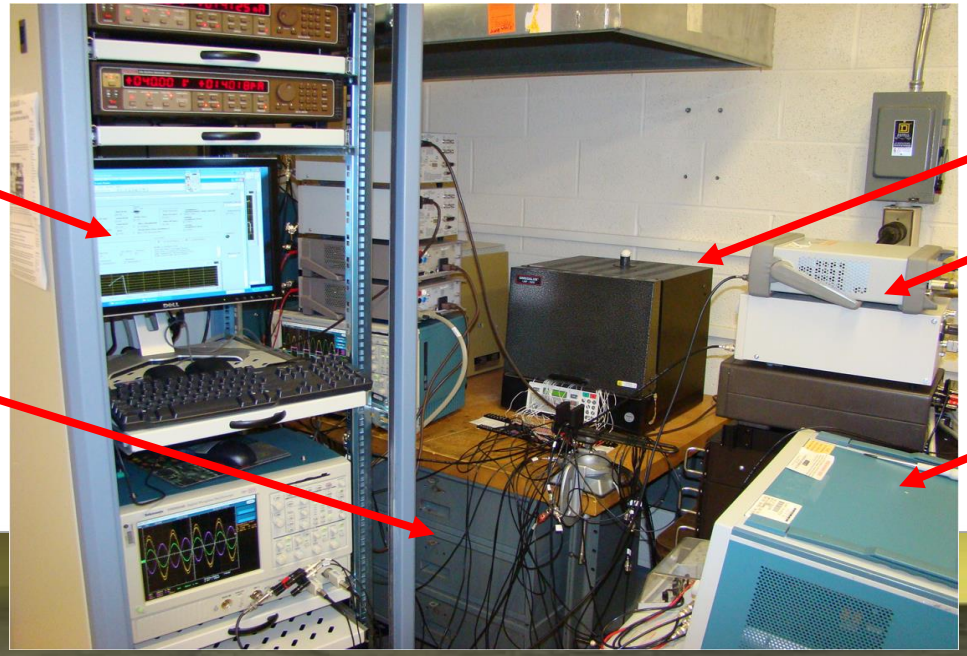
[1]*NASA Glenn Research Center*
21000 Brookpark Road
Cleveland, Ohio 44135 USA
Ph: 216-433-4000

Agenda

- Introduction
- Solution - Setup Overview
  - Compact Oven Overview
  - Testing Setup Overview
- Oven Enclosure Design and Testing
  - Mechanical Construction
  - Thermal Characterization
  - Oven Controller
- Measuring ICs in the Oven
- Conclusion

Introduction – The Problem

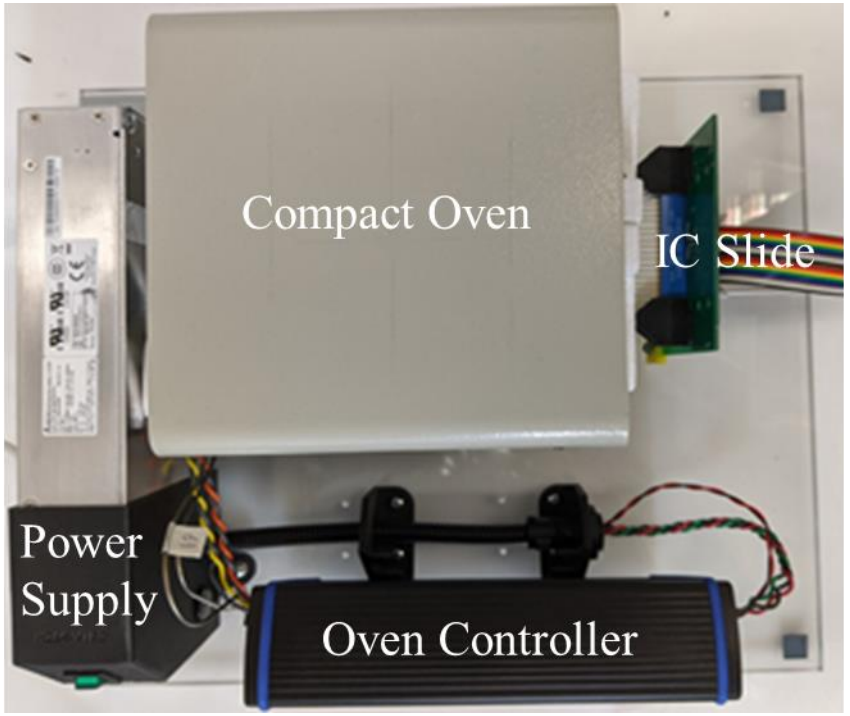
- On the surface of Venus, the average temperature is 460ºC
  - Requires specialized high temperature electronics (SiC)
  - Commercial off the shelf (COTS) ovens are physically large
  - Each SiC IC testing requires unique wiring and measuring



Solution – Compact Oven Overview

- Team designed and created a smaller oven that can be connected nicely with a NI PXI system

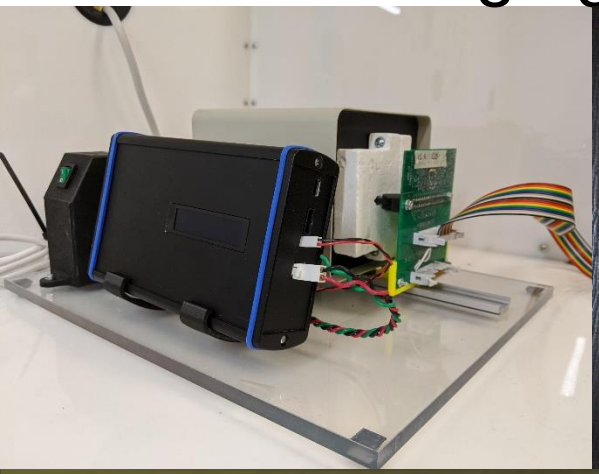
Old COTS Oven vs New Compact Oven



New Compact Oven Footprint

Solution – Testing Setup Overview

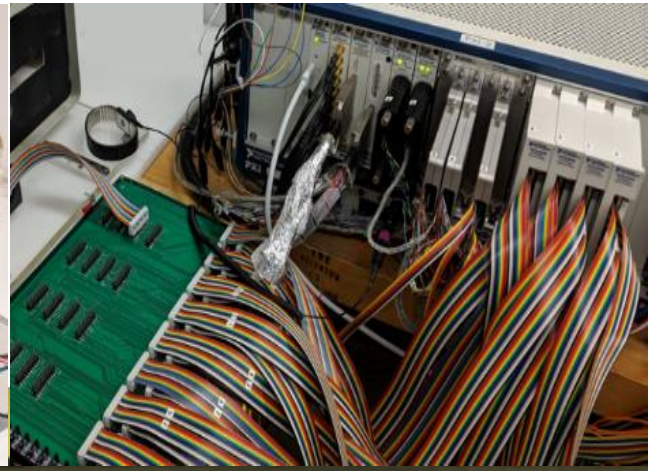
- Oven substrate board: houses the DUT, mounts to the fixture board, and slides into the oven
- Fixture board: reroutes the DUT connections to signals and power pins for the NI PXI system
- Breakout board: provides a way to test 32 ovens without changing any wiring



New Compact Oven

Oven substrate board

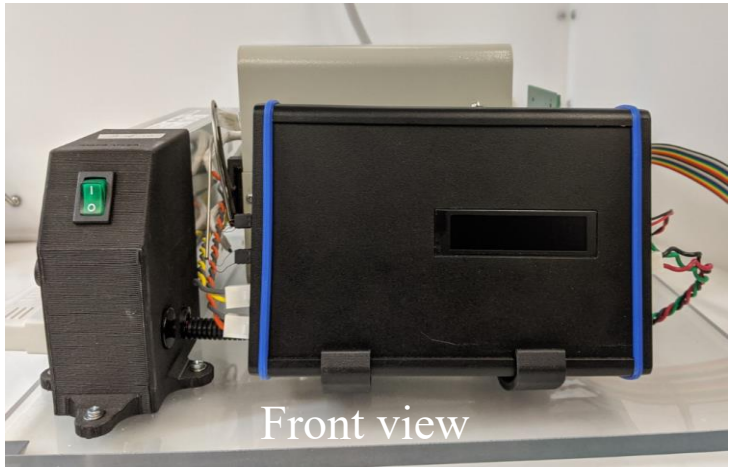
Fixture board

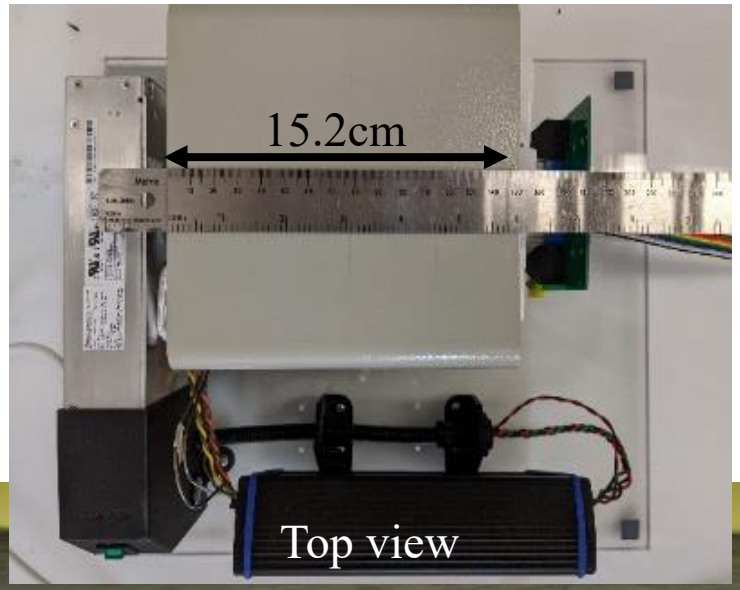


Breakout board to ovens and PXI matrix measurement unit

Oven – Mechanical Construction

- Compact COTS empty metal box
  - 15.2 x 15.2 x 12.7 cm
- Oven electronics are physically separated
- Within frame
  - Custom ceramic heater cavity assembly
  - 2 types of high temperature insulation
    - Hard 1 ½ inch thick
    - Soft ½ inch thick

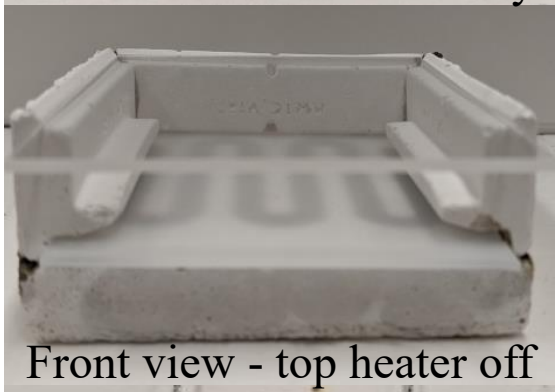


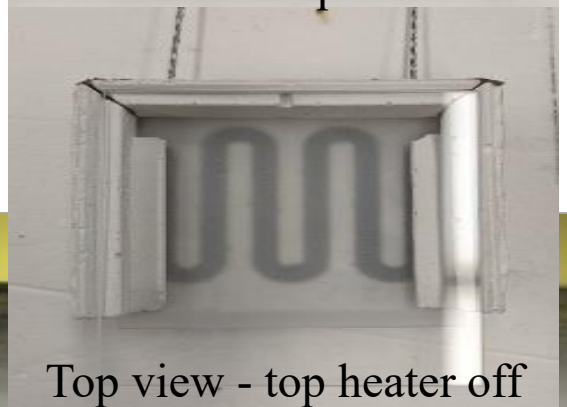


Oven – Mechanical Construction Cont.

- Custom ceramic heater cavity is Silicon Oxide based
- The Custom ceramic heater cavity assembly contains:
  - Custom ceramic heater cavity
  - 2 COTS quartz plates
    - Either polished or unpolished
  - 2 COTS high temperature heating coils


Front view - full assembly

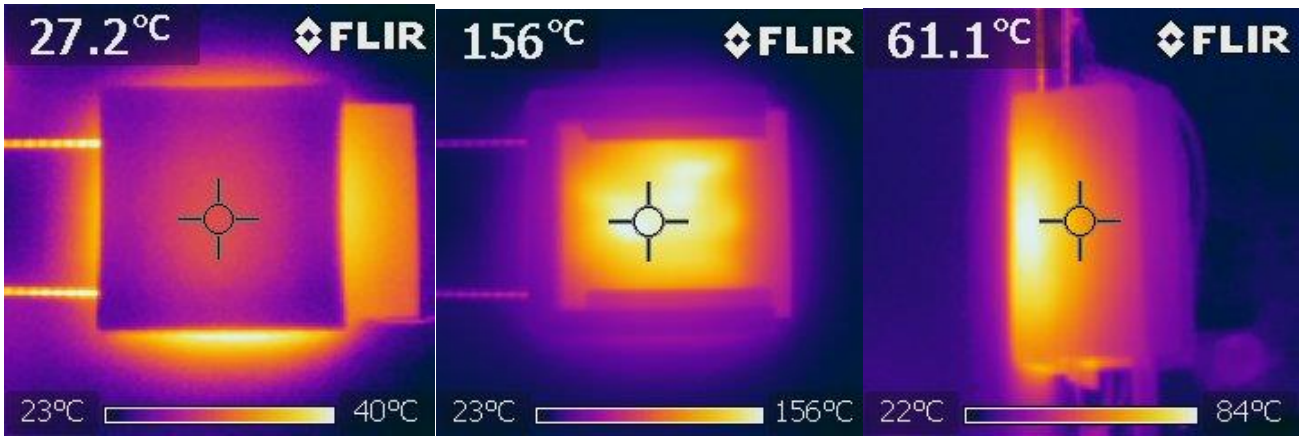

Front view - top heater off


Top view - top heater off

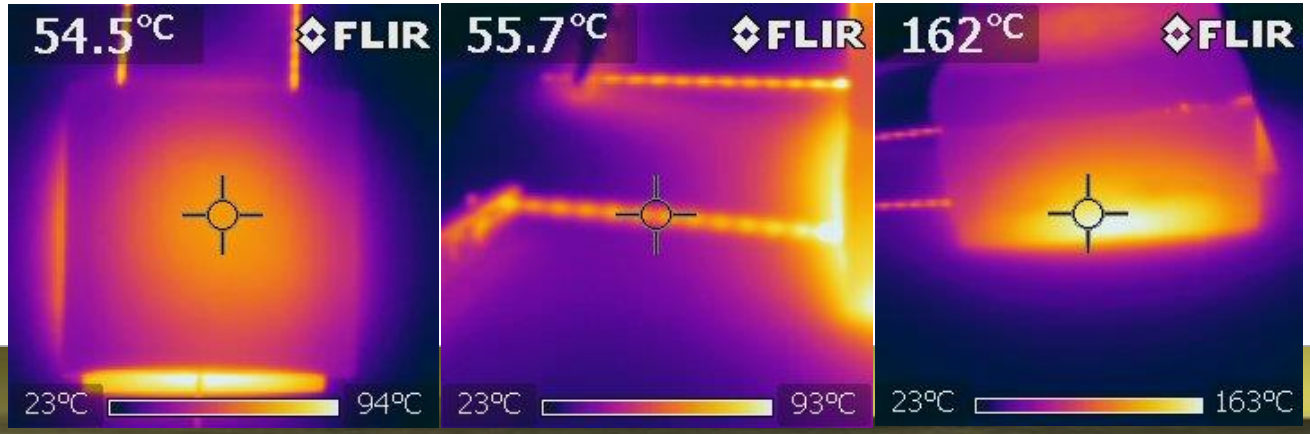
Custom ceramic heater construction process:

3D print → RTV Silicon Mold → Silicon Oxide Ceramic

Oven – Thermal Characterization

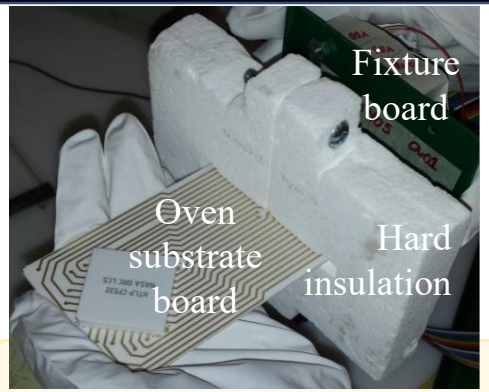


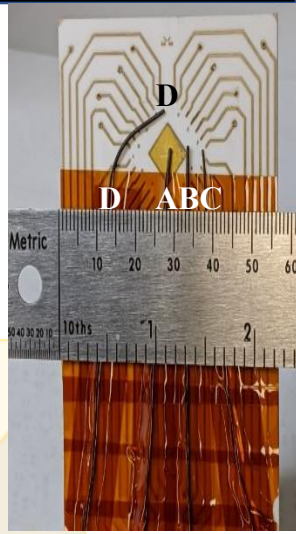
At 150°C:	Top Ceramic on	Bottom Quartz	Side with Top On
At 500°C:	Top Ceramic on	Coil Leads	Side with Top On

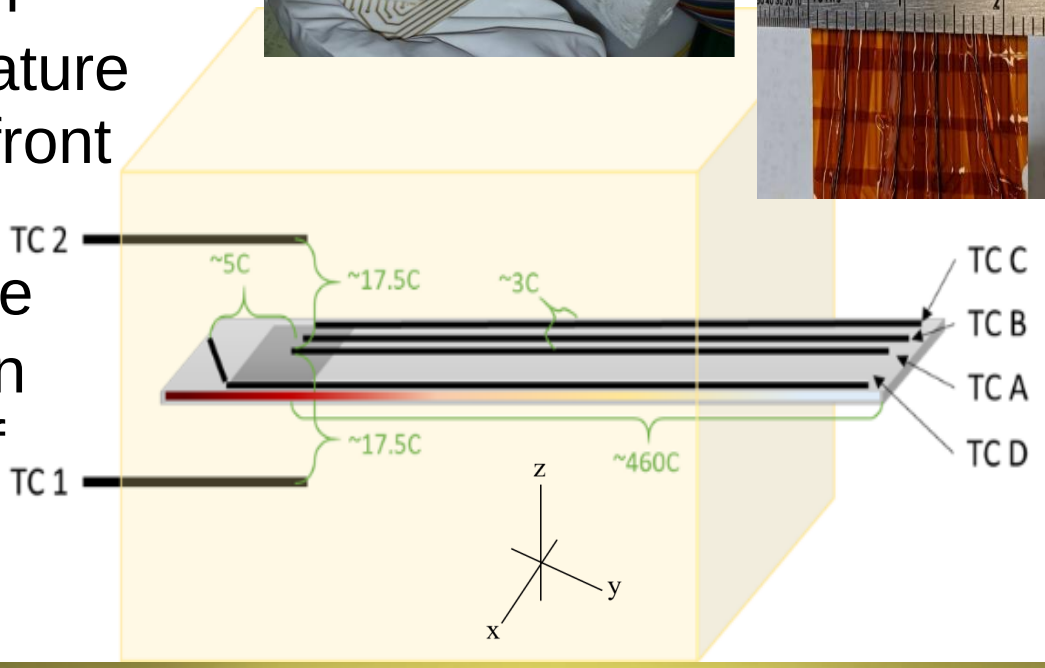


Oven – Thermal Characterization Cont.

- Oven tested up to 600°C
- Few findings for low error:
  - Oven substrate board needs to be pushed all the way in
  - Use the hard high temperature insulation to close off the front of the oven
  - Be mindful of the ramp rate
  - Oven heating configuration provides different levels of power.

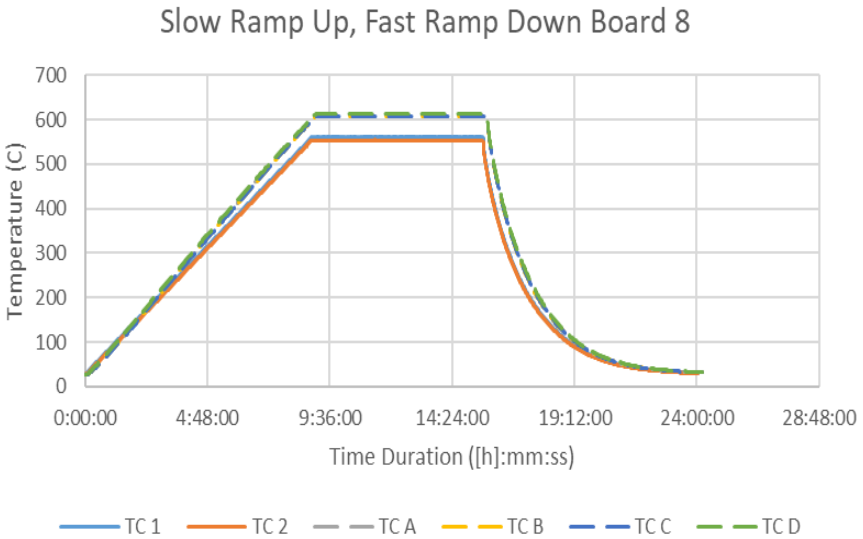


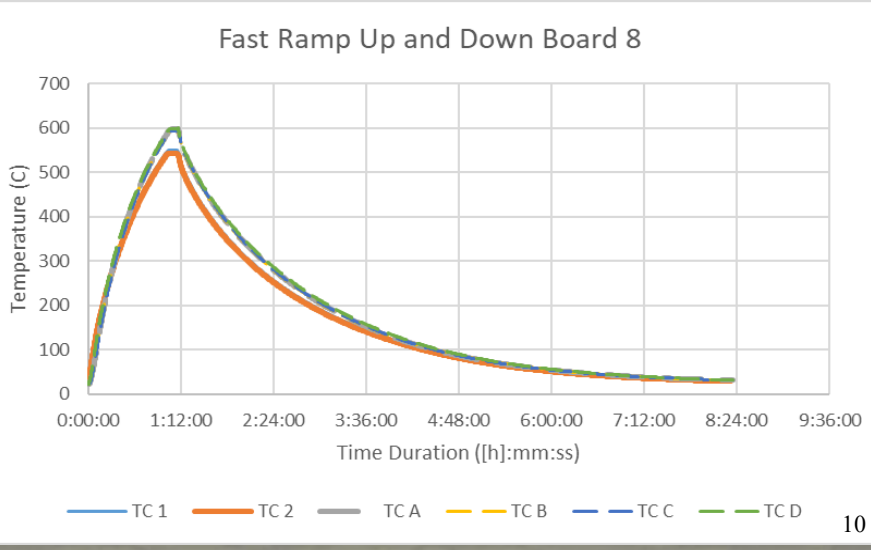




Oven – Thermal Characterization Cont.

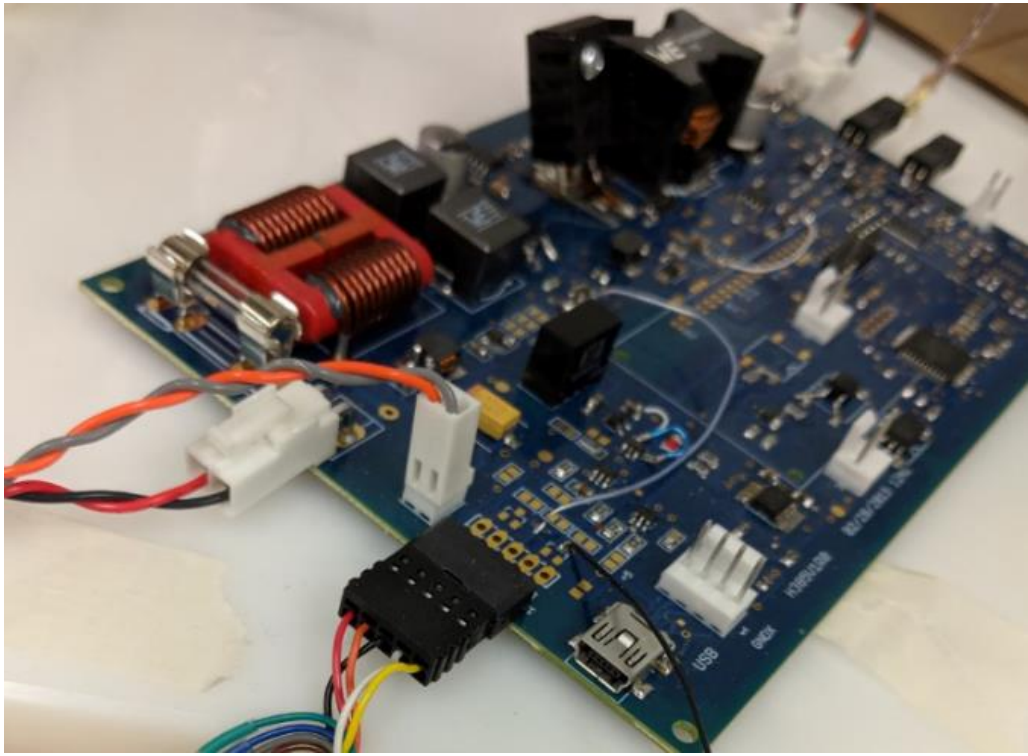
- <5 °C variance with oven substrate board pushed fully in
  - isolating both top and bottom heater
- TC1 and TC2 see less heat than the substrate
- Oven heat was unable to keep up with the ramp rate for the fast ramp up





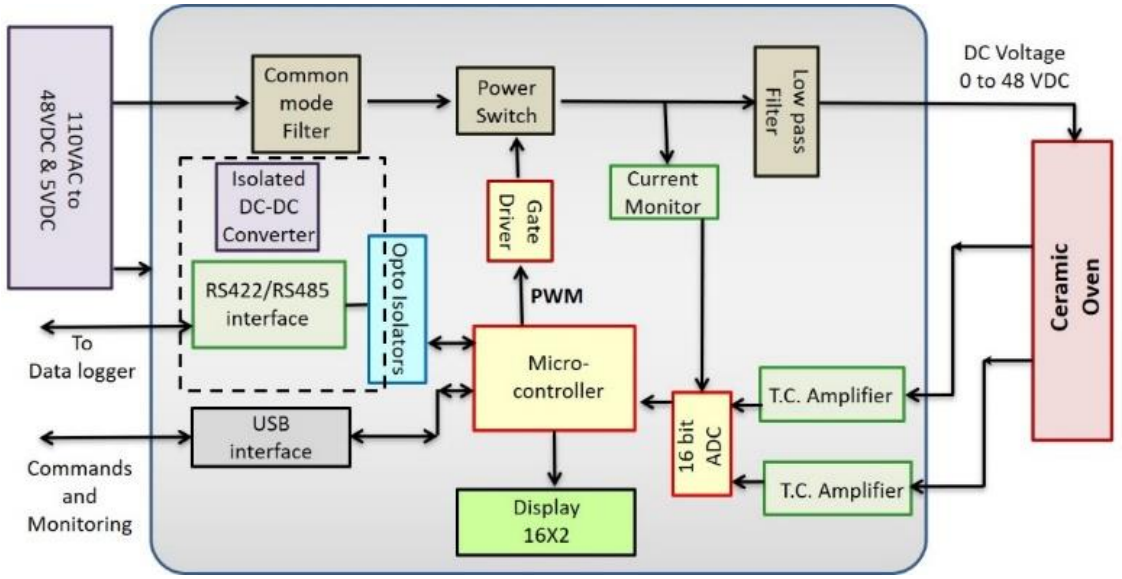
Oven – Controller

- Basic characteristics:
  - DC powered
  - Programmable
  - Separates the power between:
    - Control
    - Oven heating
  - Able to network ovens together



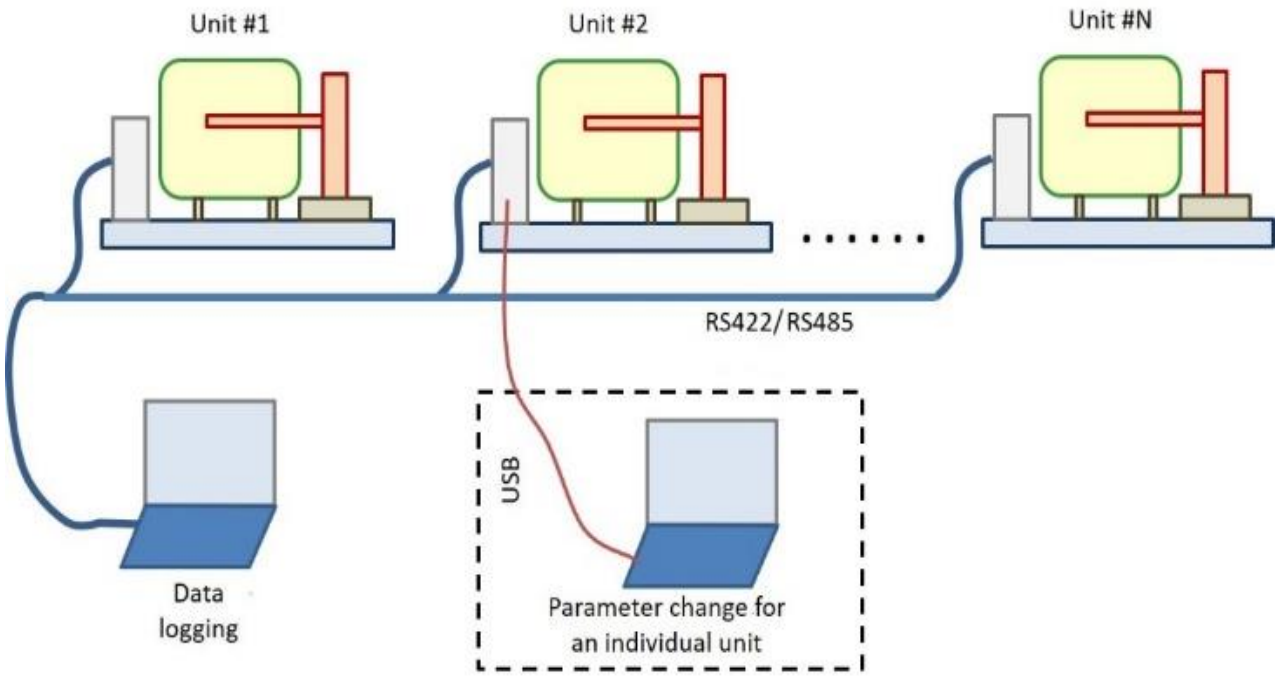
Oven – Controller Cont.

- Details of the controller:
  - Controls oven target temperature and oven ramp rate independently
  - Supplies up to 400 Watts
    - 120 Watts typical
  - 48V line to heat ovens
  - 5V line for control



Block diagram of oven controller

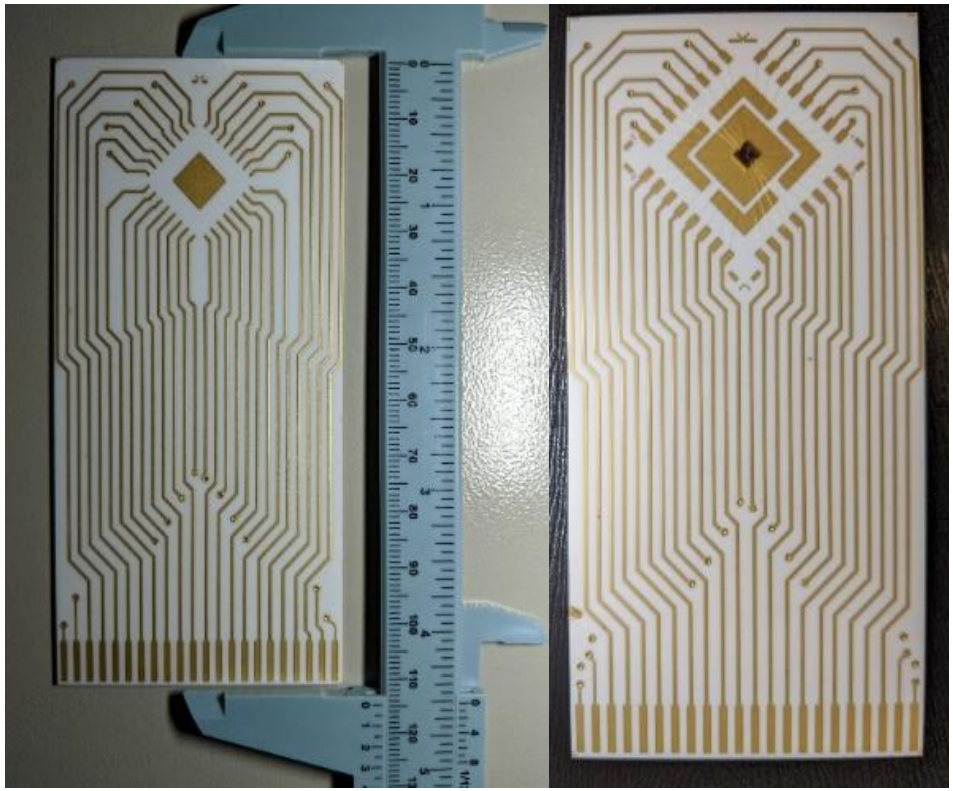
Oven – Controller Cont.



Using a second communication port, the ovens can be networked together and controlled by typing in the oven's specific identification number.

Measuring ICs in the Ovens

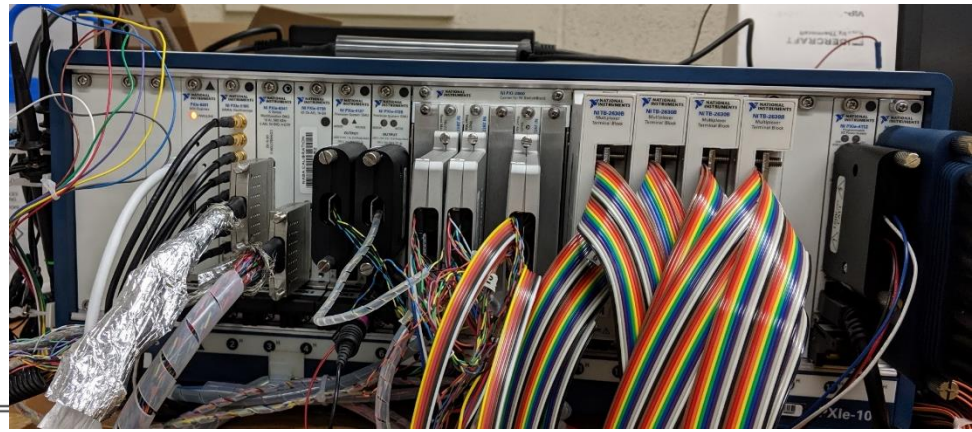
- Ceramic package resides on a movable 11.43 cm long Al_2O_3 substrate.
- Able to connect package via wire bonding
- Substrate dissipates the heat enough to connect to a room temperature connector
- This board connects to a NI PXI system for unique IC testing



Measuring ICs in the Ovens Cont.

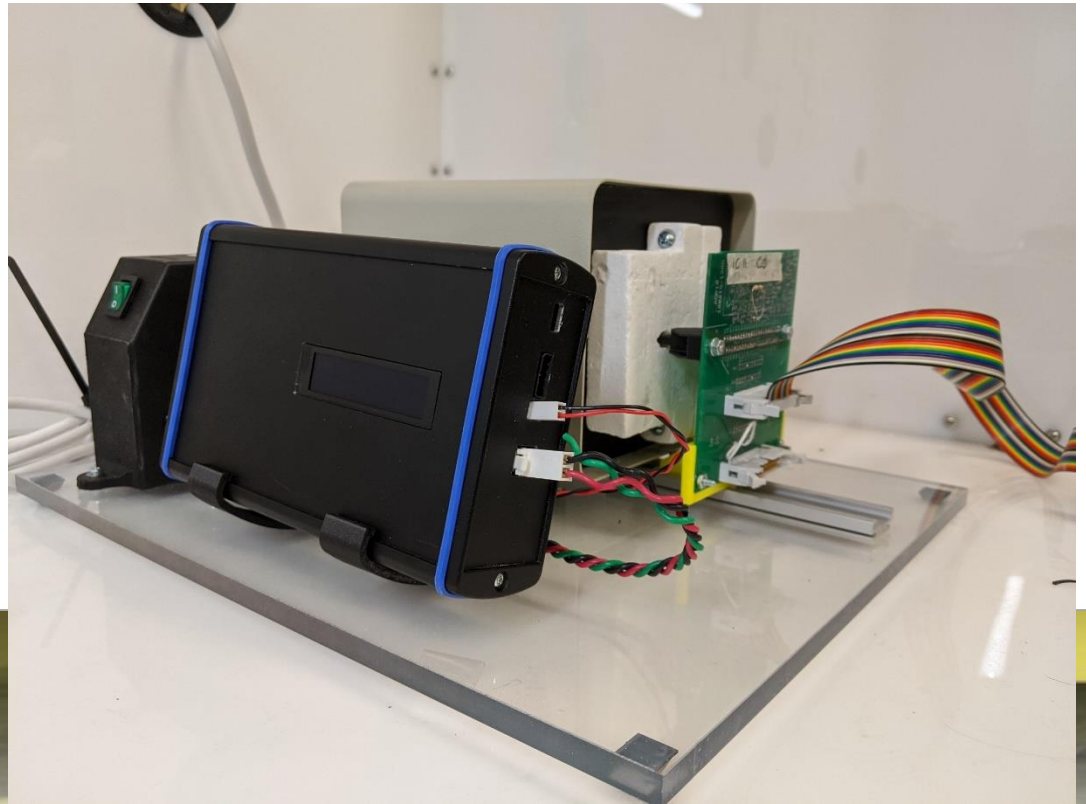
PXI system details

- Switching
  - Reed Relays
  - NI SwitchBlock
- Measuring
  - Oscilloscopes
  - Analog Inputs
  - SMU
- Sourcing
  - SMU
  - DC Power
  - Analog Outputs



Conclusion

- Achieved a smaller footprint of high temperature ovens
- Achieved a scalable testing rig
- Ceramic heating block can reach up to 600C



Questions?