Heaters and Temp Sensors Production & Testing Plan

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August 19, 2024

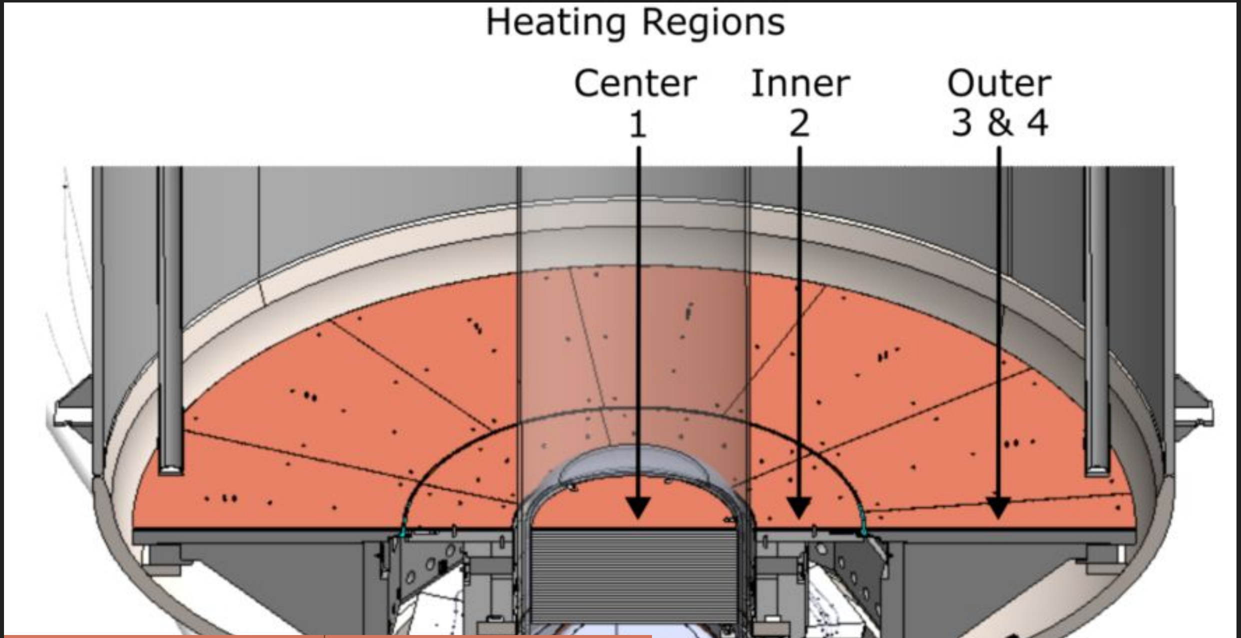
PICO

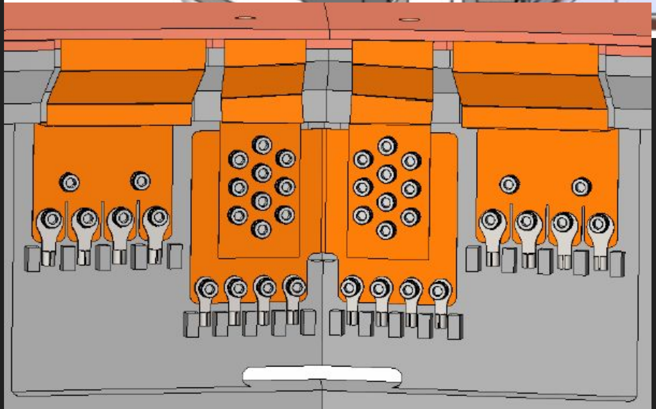
UNIVERSITY OF ALBERTA

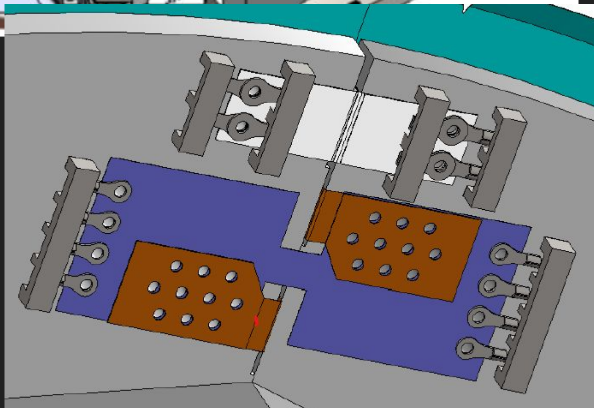
Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

Flexible Printed Circuit Boards

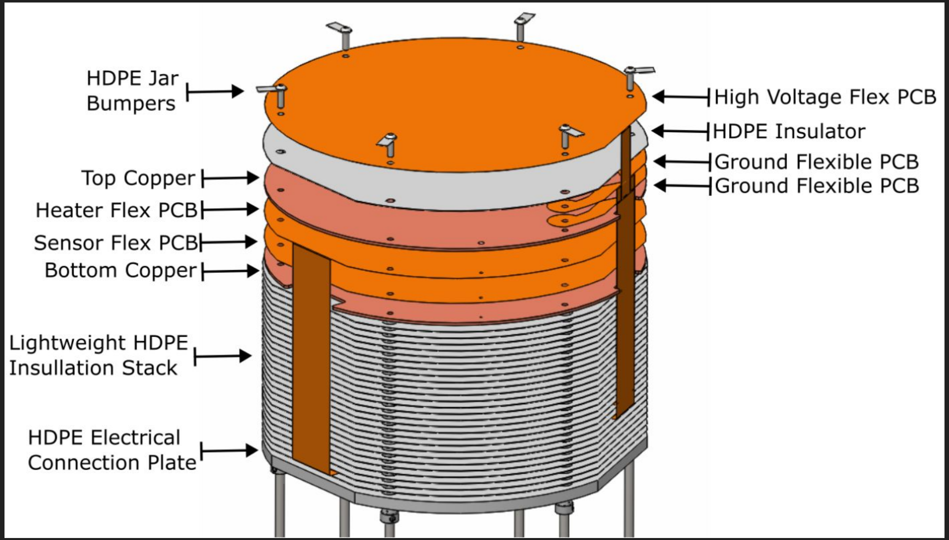
- Outer
  - Heaters
  - Sensors
    - 1-Wire Connector
    - RTD Connectors
- Inner
  - Heaters
  - Sensors
    - 1-Wire Connector
    - RTD Connectors
- Center
  - Heaters
  - Sensors

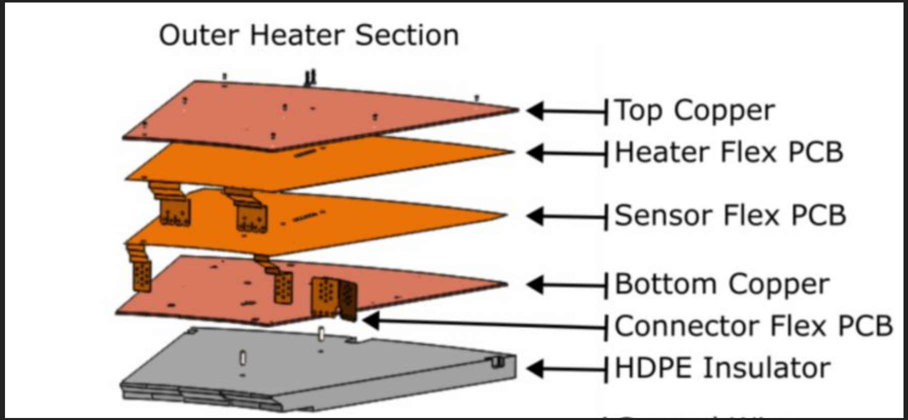


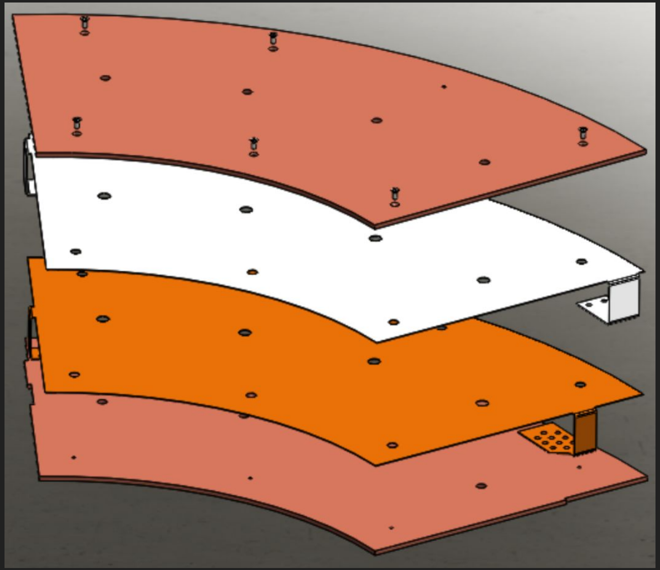




PCBs At A Glance







Production Steps

Heater and Connector PCBs:

- Comprised of nothing other than the PCB
- No additional components
- No soldering required

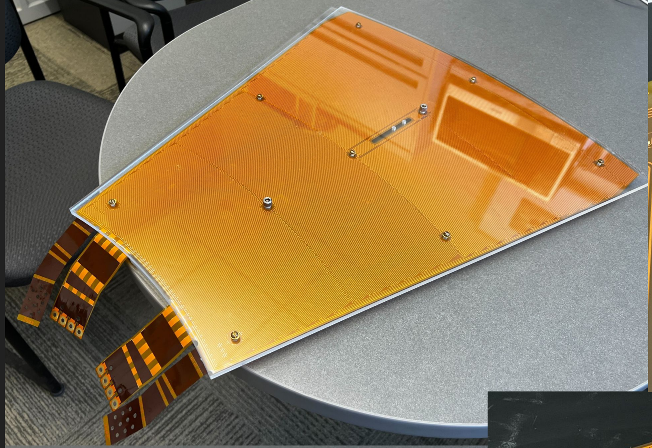
Sensor PCBs:

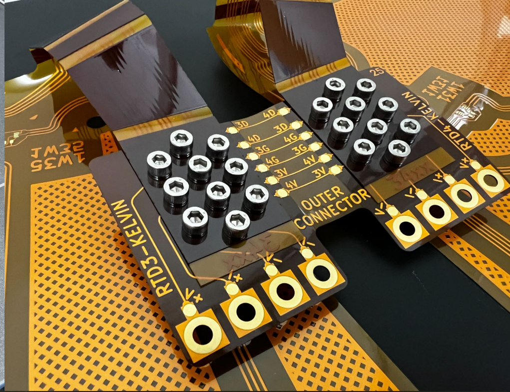
- Require components to be soldered
  - 1-Wire Temperature Sensors
  - Decoupling Capacitors
  - PT100 RTDs
- Will be assembled by Michael Rangen at University of Alberta
  - Radon Free Room
  - Hot Air Rework Tool
- Components procured
- Approved lead-free solder paste procured

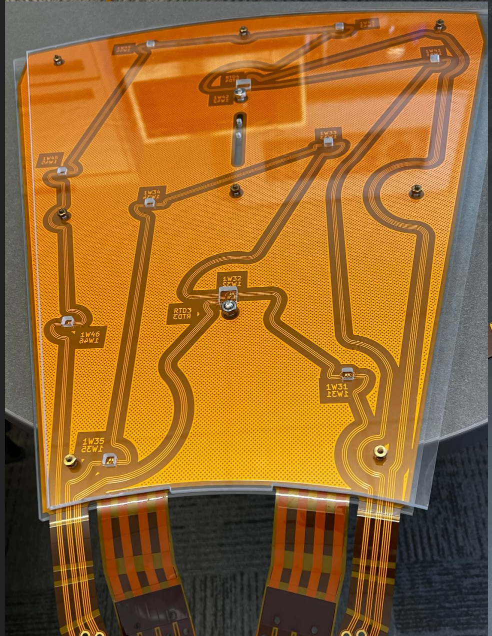
Production Status

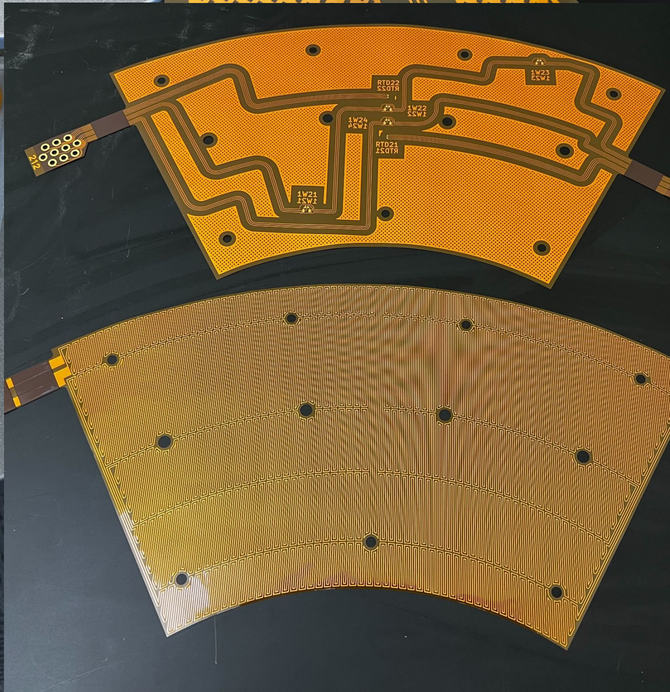
Flexible PCBs:

- Outer
  - Heaters at UofA
  - Sensors at UofA but not soldered
  - Connectors at UofA
- Inner
  - Heaters at UofA
  - Sensors at UofA but not soldered
  - Connectors at UofA
- Center
  - Heater is designed not ordered
  - Sensor is partially designed
  - HV is designed not ordered



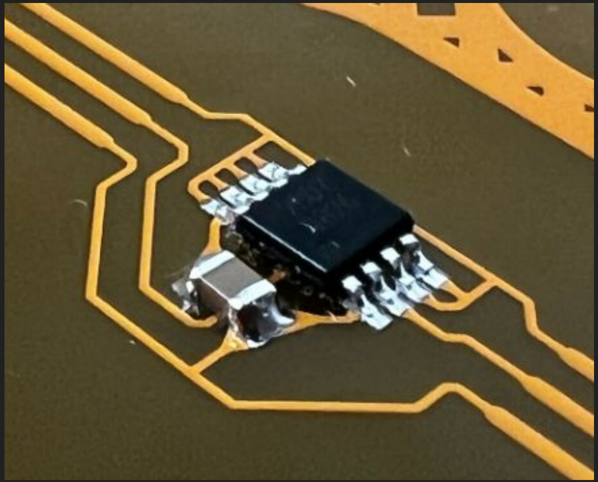


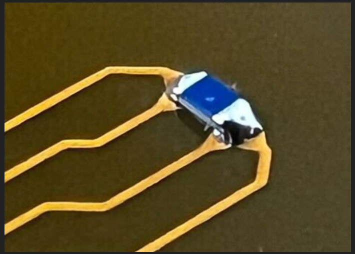




Sensor Components

- 1-Wire
  - Capacitor
    - Kemet C0805X105K8RAC7210
  - Sensor IC
    - Texas Instruments TMP1826DGKR
- PT100 RTD
  - Platinum Resistance Temperature Detector
  - Vishay PTS060301B100RP100





Testing Steps

Heater and Connector PCBs:

- 4-Wire Kelvin Meter Resistance Measurements
  - The resistance is temperature dependant, on the same magnitude as the RTDs so temperature should recorded and remain constant during testing

Sensor PCBs:

- PCB Continuity Test
- 1-Wire Temperature Sensors
  - Identify and record sensor addresses
  - Read Temperatures from each sensor
  - Calibrate each IC using on board RTDs while board is submerged in an oil bath
  - All completed sensor PCBs should be wired up and the entire sensor network tested together
- Decoupling Capacitors
  - Check for shorts
  - RLC tweezer meter to catch less obvious issues
- PT100 RTDs
  - MAX31865 RTD amplifier with SPI interface

Resistance Measurements

- Aqeeb J Ahmed (UofA Summer Student) has recorded the resistance of the heating elements in each outer heater PCBs using a 4-Wire Kelvin meter.
- Measurements from May 27, 2024
- Inner heaters are ready to be measured

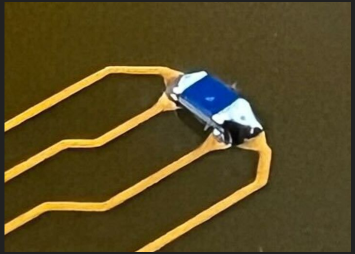
Heater	3A [ohm]	3B [ohm]	4A [ohm]	4B [ohm]	1W temperature at measurement [C]	temperature at measurement [C]
1	39.91	39.99	39.47	39.43	21.63	21.5
2	39.94	40.02	39.5	39.47	21.69	21.54
3	41.72	41.8	41.14	41.1	21.69	21.6
4	40.66	40.74	40.13	40.1	21.69	21.65
5	41.48	41.55	41.89	40.85	21.69	21.66
6	41.65	41.71	41.02	40.98	21.75	21.69
7	39.91	39.98	39.49	39.45	21.75	21.69
8	39.91	39.98	39.92	39.88	21.75	21.7
9	39.88	39.96	39.44	39.4	21.75	21.75
10	39.75	39.82	39.8	39.76	21.8	21.75
11	39.88	39.95	39.41	39.37	21.81	21.76
12	39.97	40.03	39.46	39.42	21.81	21.8
13	41.44	41.51	40.9	40.86	21.81	21.83
14	39.94	40.02	39.5	39.47	21.88	21.8
15	41.34	41.42	41.3	41.25	21.88	21.8
16	40.71	40.77	40.14	40.1	21.88	21.81
17	41.36	41.46	40.89	40.85	21.88	21.85
18	41.51	41.59	40.88	40.84	21.88	21.84
19	39.99	40.08	39.52	39.49	21.94	21.83
20	39.95	40.02	39.49	39.45	21.94	21.83
21	40.68	40.75	40.16	40.12	21.94	21.86
22	40.72	40.79	40.17	40.13	21.94	21.85
Stats						
Mean	40.55909091	40.63363636	40.16454545	40.08045455	21.80818182	21.745
Median	40.325	40.41	40.025	39.99	21.81	21.78
Standard deviation	0.7250675442	0.7258134711	0.7560909952	0.6707882873	0.09673903844	0.1039574089
Variance	0.5257229437	0.5268051948	0.5716735931	0.4499569264	0.009358441558	0.01080714286

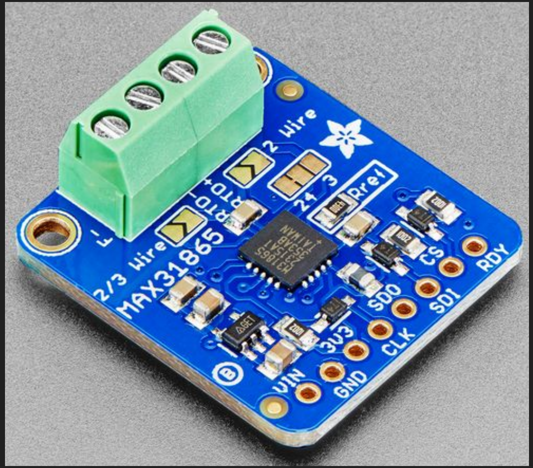
COLOUR SCALE IS BY THE COLUMN

Detector	Part #
I2C	BME280
1 wire [1W]	TMP1826DGKR
Fluke multimeter	8846A

RTD Testing

- MAX31865
- Adafruit has a convenient breakout board
- Libraries are already written
- Breakout board procured and at UofA, hasn't been tested yet.





General Description

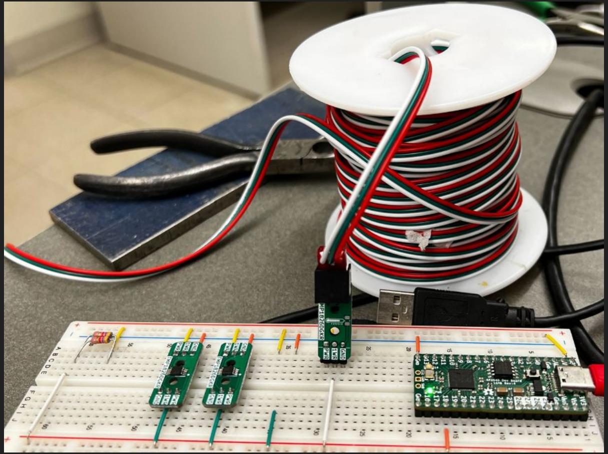
The MAX31865 is an easy-to-use resistance-to-digital converter optimized for platinum resistance temperature detectors (RTDs). An external resistor sets the sensitivity for the RTD being used and a precision delta-sigma ADC converts the ratio of the RTD resistance to the reference resistance into digital form. The MAX31865's inputs are protected against overvoltage faults as large as ±45V. Programmable detection of RTD and cable open and short conditions is included.

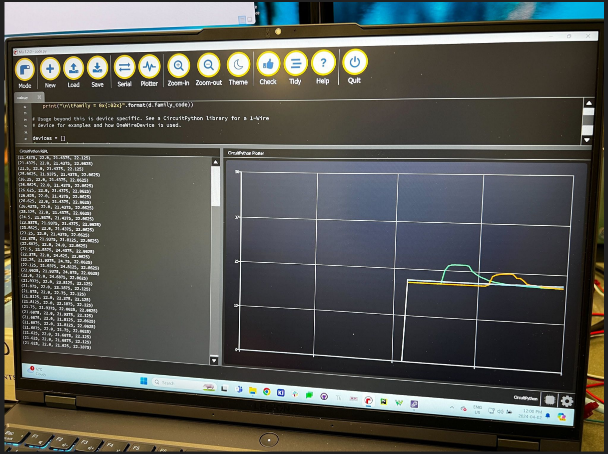
Applications

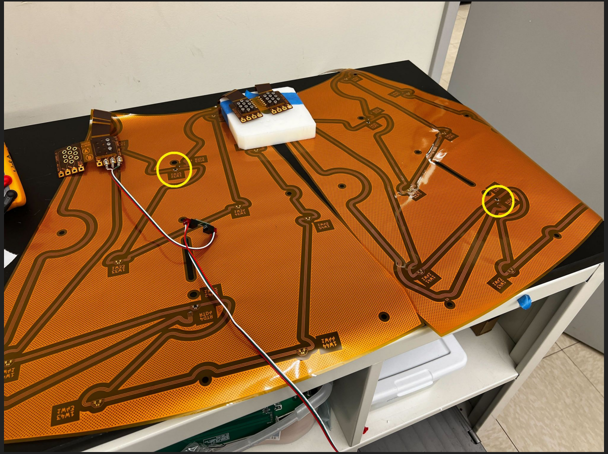
- Industrial Equipment
- Medical Equipment
- Instrumentation

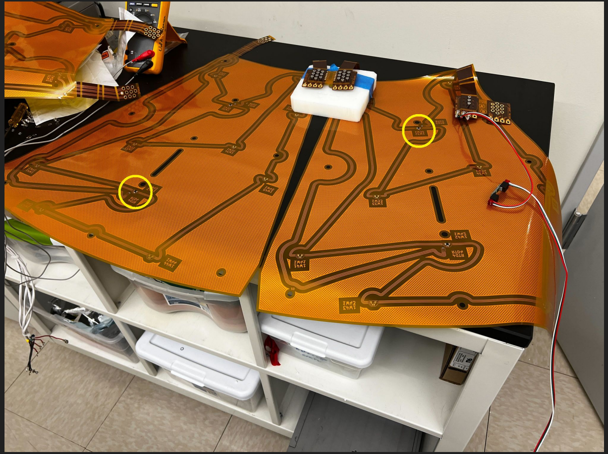
Outer Sensor 1-Wire & Connector Board Test

- Preliminary testing shows no issues with the outer sensor board and sensor connector board designs.
- Successfully communicated to sensors on both 1-Wire busses through 100 feet of spooled 3-conductor cable using an RP2040 microcontroller running a modified Circuit Python 1-Wire library.



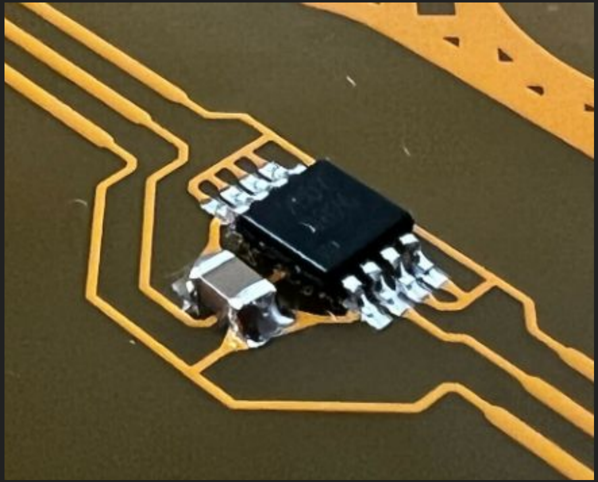






1-Wire Calibration

- https://www.ti.com/lit/ds/symlink/tmp1826.pdf
- Current interface is an RP2040 running a modified Circuit Python Library



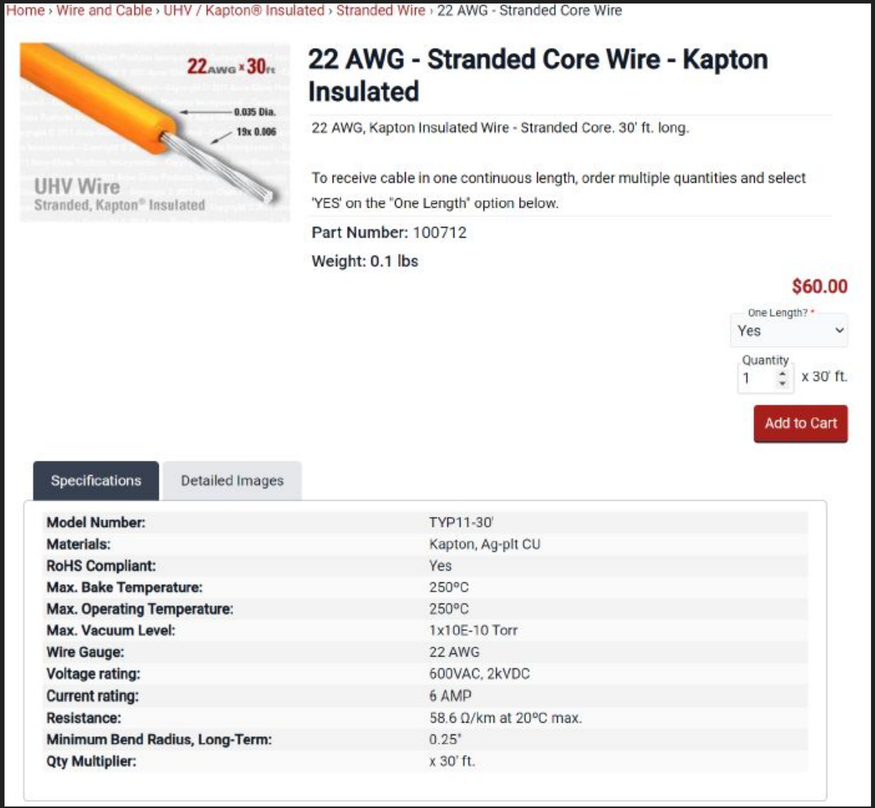
9.3.5 Temperature Offset

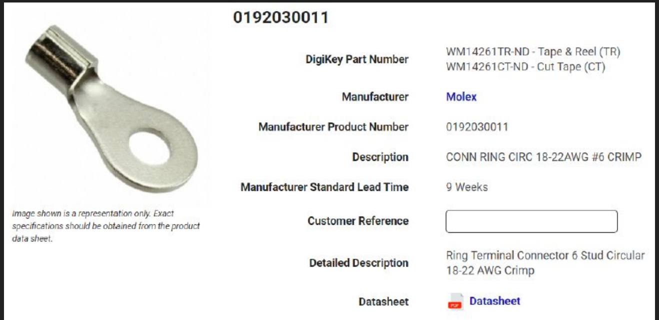
The temperature offset has the same format as the temperature result and is stored in the temperature offset registers.

The device, after every temperature conversion, applies the offset value before the temperature is stored in the temperature result register. The host write to the offset register can be stored in the configuration EEPROM of the device, which removes the overhead for the host to reprogram the value or reapply in software at every power up. The offset features allow the device to achieve better accuracy at the temperature range for the application by performing a single point calibration.

Additional Calibration Work To Be Done

- A temperature controlled tank of oil for calibrating the temperature sensors
  - Sous Vide Immersion Circulator?
- 3D printed spacers and rods for alignment and separation of PCBs to allow flow between PCBs during test
- A 3D printed jig to simplify the electrical connections during calibration/tests
- A function for writing to the temperature offset registers of the 1-wire devices will be need to be added to the library
- Electrical wire have not been ordered
- Ring crimps have not been ordered





Additional Heater Work To Be Done 1/3

- Wiring harnesses for inside the detector need to be built based on lengths provided by Badru Celil's 3D models
- Electrical wire has not been ordered
- Ring Crimps have not been ordered

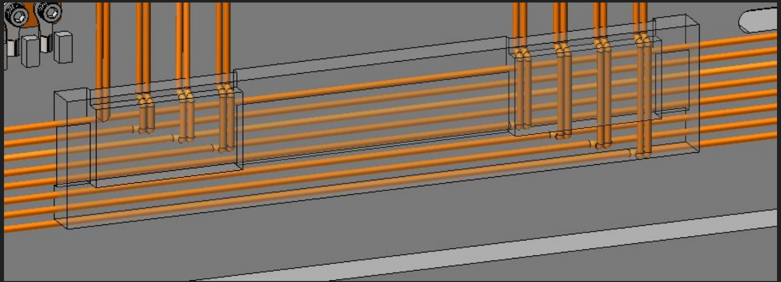
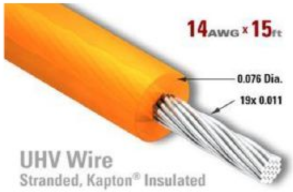


Image shown is a representation only. Exact specifications should be obtained from the product data sheet.

0192030048

DigiKey Part Number	WM19882TR-ND - Tape & Reel (TR) WM19882CT-ND - Cut Tape (CT)
Manufacturer	Molex
Manufacturer Product Number	0192030048
Description	CONN RING CIRC 14-16AWG #6 CRIMP
Manufacturer Standard Lead Time	33 Weeks
Customer Reference	
Detailed Description	Ring Terminal Connector 6 Stud Circular 14-16 AWG Crimp
Datasheet	Datasheet

Home › Wire and Cable › UHV / Kapton® Insulated › Stranded Wire › 14 AWG - Stranded Core Wire



14 AWG - Stranded Core Wire - Kapton Insulated

14 AWG, Kapton Insulated Wire. 15' ft. long.

To receive cable in one continuous length, order multiple quantities and select 'YES' on the "One Length" option below.

Part Number: 100715

Weight: 0.25 lbs

$131.00

One Length? * Yes

Quantity 1 x 15' ft.

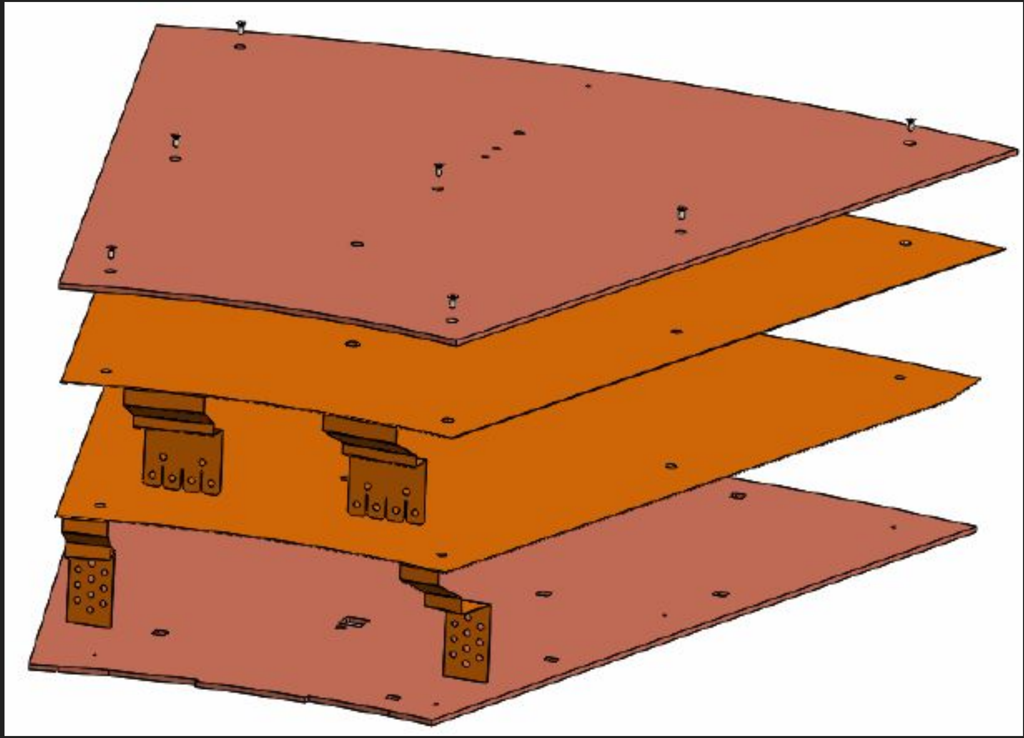
Add to Cart

Specifications | Detailed Images

Model Number:	TYP14-15'
Materials:	Kapton, Ag-plt CU
RoHS Compliant:	Yes
Max. Bake Temperature:	250°C
Max. Operating Temperature:	250°C
Max. Vacuum Level:	1x10E-10 Torr
Wire Gauge:	14 AWG
Voltage rating:	600VAC, 2kVDC
Current rating:	16 AMP
Resistance:	11.4 Ω/km at 20°C max.
Minimum Bend Radius, Long-Term:	0.48"
Qty Multiplier:	x 15' ft.

Additional Heater Work To Be Done 2/3

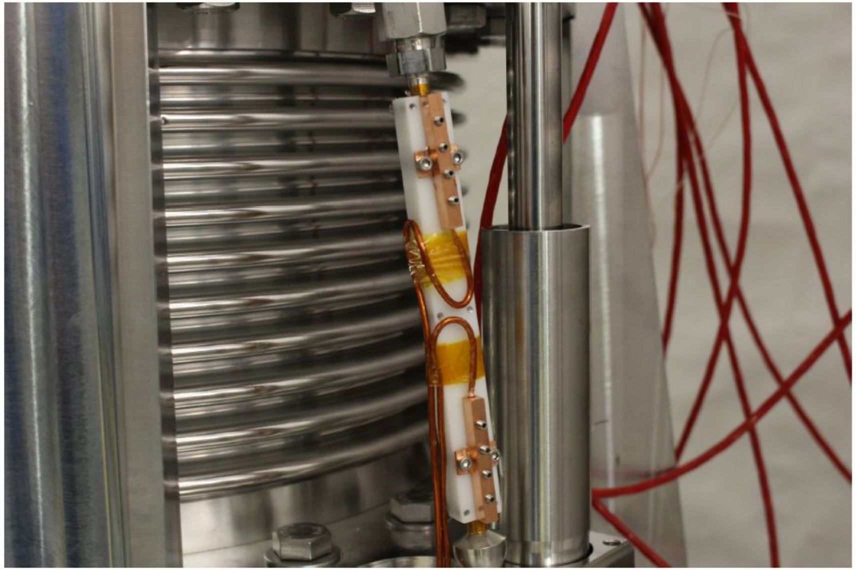
- Copper plates need to be machined
- Cleaning, sealing, & shipping of copper sandwich assemblies needs some thought



Additional Heater Work To Be Done 3/3

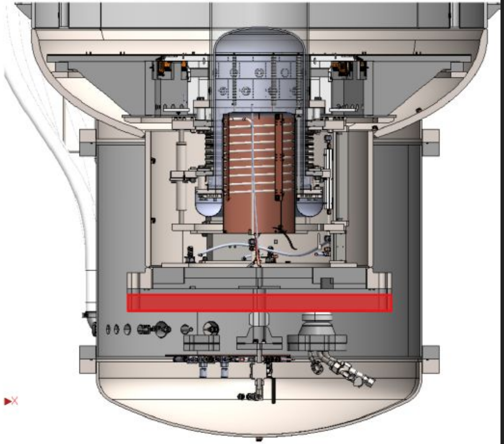
1.6 Freon Heater

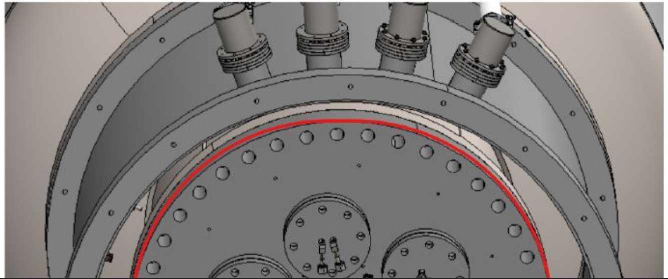
A freon heater similar to PICO-40L's will be designed for PICO-500. The heater consists of a straight section of steel pipe, insulated with kapton tape, wrapped in nichrome heater wire, clamped with HDPE blocks. Connections to it are made via terminal blocks machined from copper. The design is scaled from ¼" in PICO-40L to ½" in PICO-500.



1.7 Flange Heater

The flange may need to be heated in order to prevent its elastomer o-ring from dropping below -25°C. An insulating layer of Polyimide or HDPE will be used to prevent the Nichrome wire from shorting to the grounded flange, and an outer protective layer of HDPE will be used to secure and protect the flange heater. A machined copper terminal block, similar to the freon heater's, will be used for making electrical connections.





Questions?