LIGHTLY-SPACE-RATED PRESSURE SENSOR

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PROBLEM STATEMENT

NEED: A pressure sensor for short-term, small-satellite missions.

AUTOMOTIVE SENSORS:
- Compact
- Cheap
- Unreliable in Space

SPACE SENSORS:
- Space Rated
- Expensive
- Bulky

SOLUTION:
Design a sensor to bridge the gap between these two mature technologies to supply the emerging small-satellite market.

DESIGN OBJECTIVES

- Space-Rated
- Low Mass
- High accuracy within design pressures and temperatures
- Compact Size
- Low Cost

OPERATING REQUIREMENTS

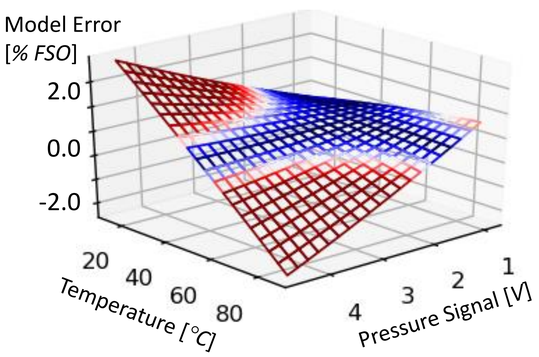
PRESSURE	vacuum	35bar
TEMPERATURE	-20°C	100°C
ACCURACY	Up to 0.8% Full-Scale Error	

DESIGN STRATEGY

Constraint: Use an **off-the-shelf sense cell**

Problem: Sense cell is **highly sensitive** to changing temperature, not perfectly linear with pressure

Uncompensated Sense Cell Response Error



Plan: Incorporate **second-order signal compensation** to account for nonlinearities

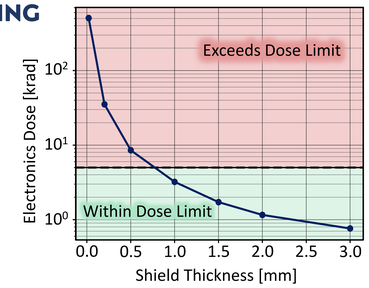
ENCLOSURE DESIGN

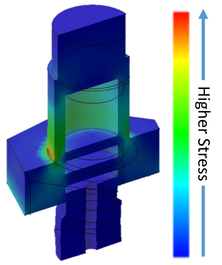
RADIATION SHIELDING

Goal: Protect electronics from **ionizing radiation**

Method: Simulate irradiation of chip through thin wall of varying **materials and thicknesses**

Result: Iron shield with **thickness 0.6mm** baselined for design environment





VIBRATION RESISTANCE

Goal: Design sensor to **withstand launch vibrations**

Method: Simulate vibration and determine **sensitivity of stresses** to various factors

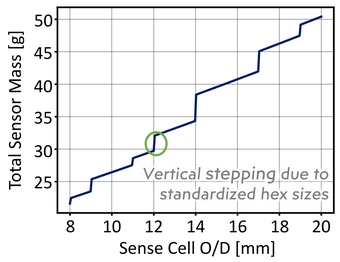
Result: Response **most sensitive to height**; not expected to cause failure

MASS OPTIMIZATION

Goal: Optimize sensor geometry to **reduce mass**

Method: Compute mass of **various configurations** of outer diameter & hex size

Result: Best **sensor diameter** and **hex size** identified



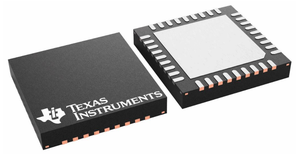
ELECTRONICS DESIGN

SIGNAL PROCESSING CIRCUIT

Goal: Design a circuit to **amplify, compensate and transmit** signal

Method: Evaluate commercial signal processing chips for **accuracy, programmability and size**

Result: **Eight-component** circuit



BOARD LAYOUT

Goal: Constrain signal processing circuit in a robust, **minimal package**

Method: Evaluate constraint and layout options for withstanding **shock load, assembly process and size**

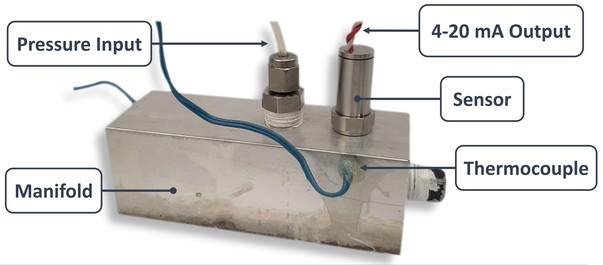
Result: **Two-piece** PCB assembly

TEST DESIGN

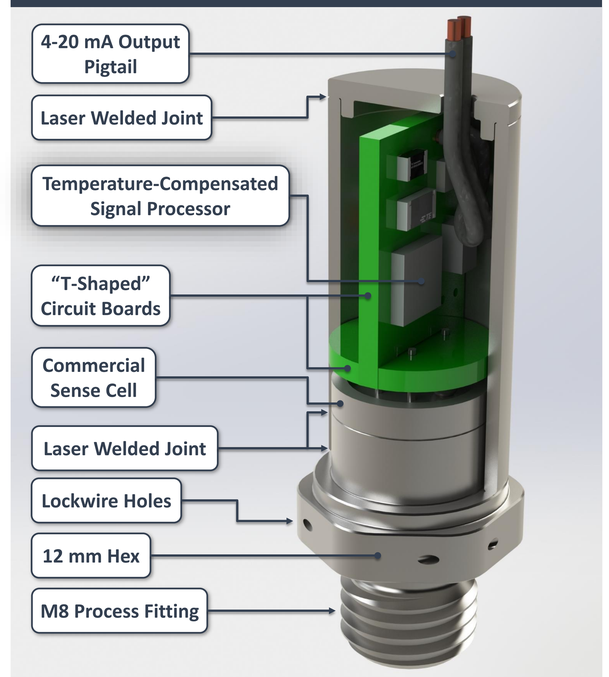
Goal:
- Compare **sense cell options**
- Validate sealing method
- Validate prototype **accuracy**

Method:
Supply pressure to prototypes at various temperatures

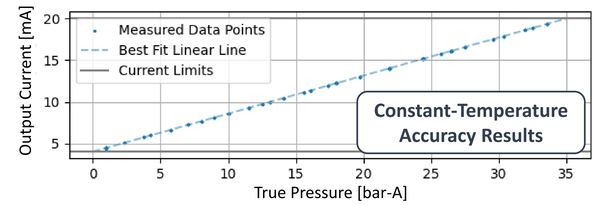
Results:
- Sense cell selected from results
- Meets accuracy requirement at **constant temperature**
- Sealing method validated
- Inaccuracies at **low temperature** (-15 °C)



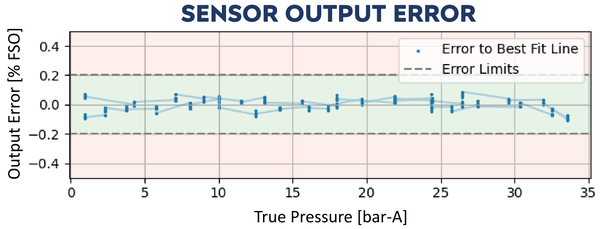
RECCOMEDED DESIGN



CALIBRATED SENSOR RESPONSE CURVE

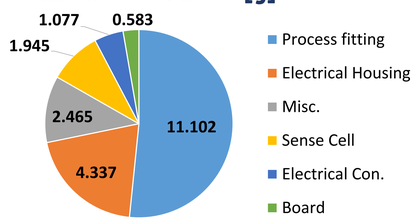


SENSOR OUTPUT ERROR

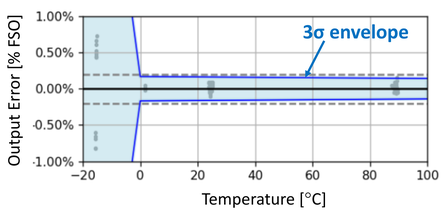


RESULTS

MASS BREAKDOWN [g]



SENSOR ERROR ENVELOPE



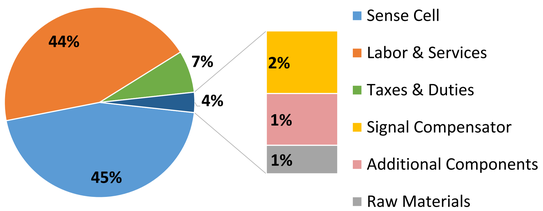
DETERMINISTIC FEATURES

Sense cell element
- Drives accuracy and minimum diameter

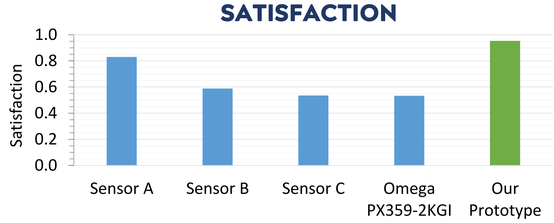
Signal-processing chip
- Drives PCBA components, accuracy, and size minimum diameter

Process and Electrical Fittings
- Drives interface and considerable system mass

COST BREAKDOWN



SATISFACTION



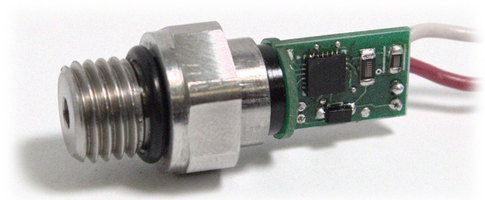
CONCLUSIONS

Satisfied Requirements

- ✓ Signal output $4 - 20\ mA$
- ✓ Pressure range $0 - 35\ bar\text{-}A$
- ✓ Radiation environment $75\ krad$
- ✓ Isothermal error $< \pm 0.15\ \%FSO$
- ✓ Total mass $< 40g$
- ✓ Total volume $< 6mL$
- ✓ Input voltage range $9 - 35\ Vdc$

Areas for Improvement

- Resolve self-heating of signal compensation chip by:
  - Improving thermal uniformity
  - Adding external RTD
- Eliminate low temperature hysteresis
- Implement laser welding process
- Optimize circuit design for manufacturing



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