American Semiconductor®
Reliably Thin Electronics

8th Advanced Technology Workshop on **Advanced Packaging for Medical Microelectronics**

iMAPS

The Need for Standards in Flexible & Printed Electronics

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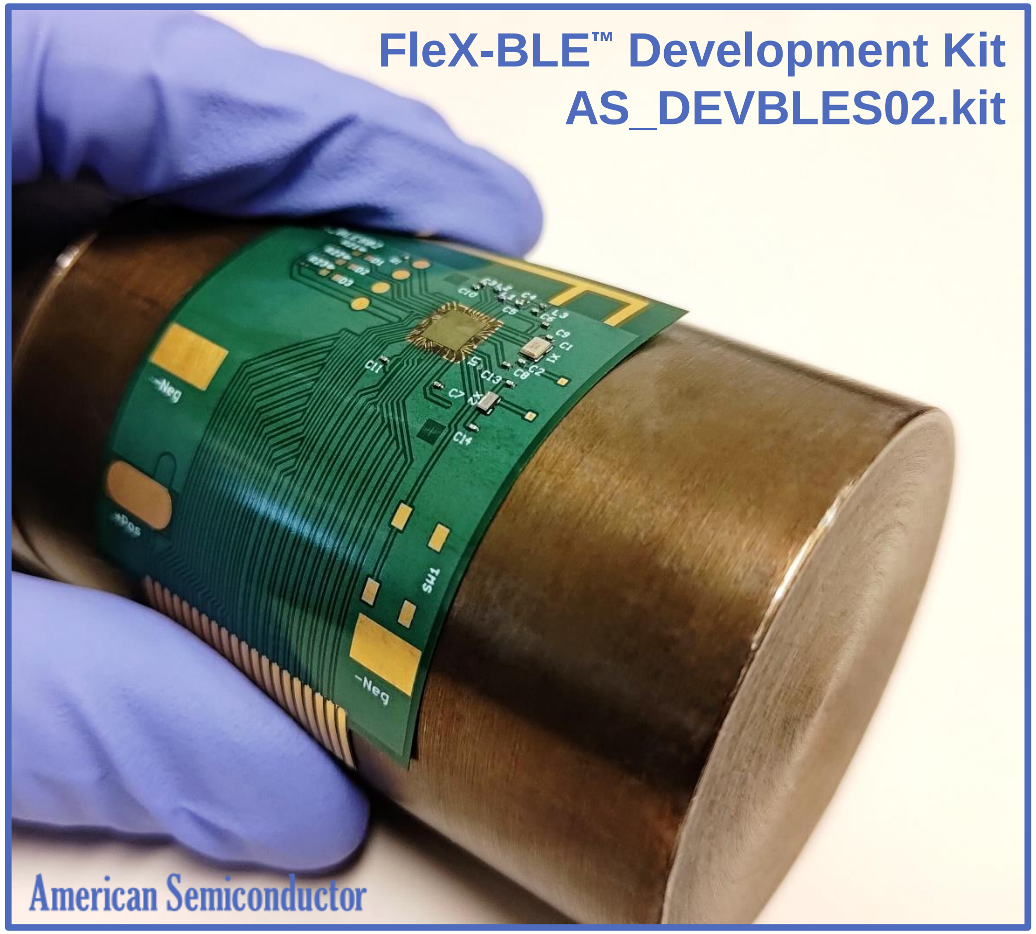
New Packaging Requires New Test Methods

- Flexible microelectronic systems are being introduced for wearables, implants, drug delivery, human-machine interfaces, rapid diagnostics and more.
- These novel medical devices rely on leading-edge thin and flexible microelectronics, but are they reliable?
- Bending, Twisting and Stretching are new requirements that are not typical of standard microelectronic systems.
- Development of test methods, systems and reporting of new reliability data for flexible medical electronics is needed to support this new technology



FHE Reliability Test Procedures

- ASI's pioneering work to create FHE test methods started in 2016 under contract with AFRL
- Since 2016, ASI has continued to develop and advance FHE device characterization and reliability

Initial FHE Reliability Tests

Test	Conditions	ASI Procedure	References
High Temp Life	125°C	ASI TEST008	ISO 10373-1; JESD22-A108
Low Temp Life	-25°C	ASI TEST009	JESD22-A108
ESD	HBM and/or CDM	ASI TEST010	ANSI-ESDA-JEDEC_JS-001 & JS-002
Static Radius of Curvature	Concave/Convex Bend	ASI TEST003	ASTM D522-93a; ISO 10373-1; ISO 7816
Dynamic Radius of Curvature	Concave/Convex Bend	ASI TEST005	ASTM D522-93a; ISO 10373-1; ISO 7816
Axial Torsion	Twist Test	ASI TEST006	ISO 10373-1; ISO 7816
SEM Inspection	Post SoP Conversion	ASI TEST007	MIL-STD-883: M2018
Data Retention	150°C, non-biased	ASI TEST009	JESD22-A117; JESD-A103

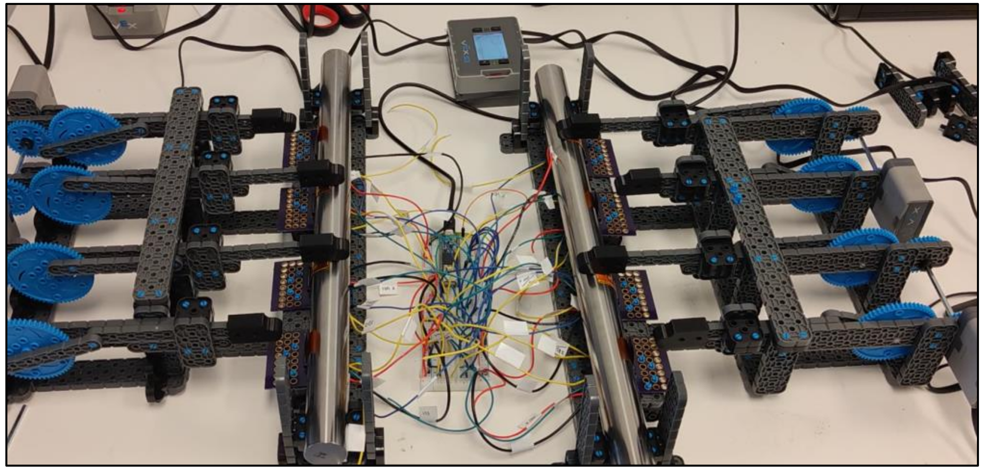
This work sponsored in part by the Air Force Research Laboratory AFRL/RX

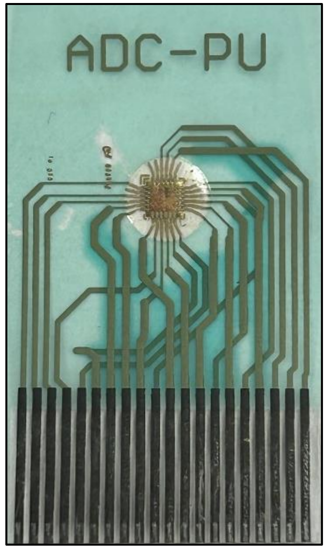
New 2020 Tests
Temperature-humidity-bias (THB 85/85) JESD22-A101
HAST JESD22-A110
Low Temp JEDEC22-A119

Still Needed
Temp Cycling
Other??

Current State of FHE Testing

- Test methods for FHE circuits are not commonly defined
- We lack industry standards involving flexible electronics testing methods or metrics
- Most manufacturers have resorted to an array of “home built” testing solutions
  - Test fixture designs
  - Test coupon designs (for data collection during mechanical deformation)
  - Testing conditions (duration, electrical bias, environmental conditions, etc.)
- As a result, results are often difficult to correlate between organizations
  - Adds complexity in conveying performance metrics between development teams or industry partners
  - Difficult to benchmark results with technology adopters and customers

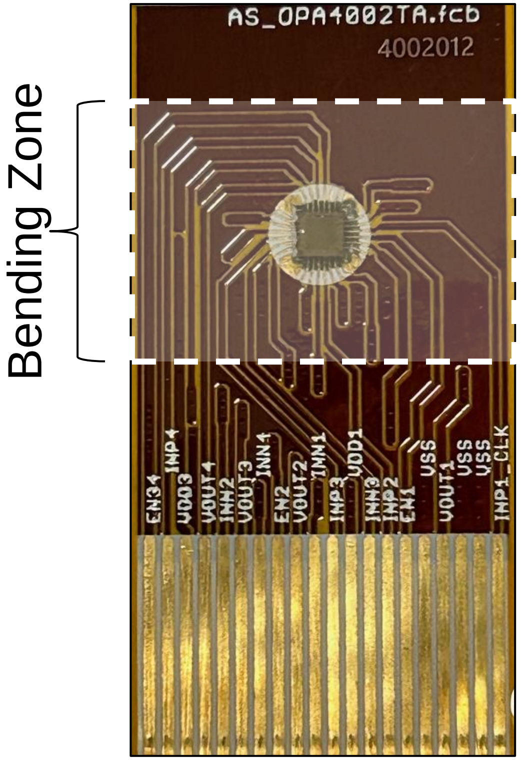

ASI Home Built Radius of Curvature Tester



ASI Test Coupon

Test Coupon Design

- In situations where electrical data needs to be collected during mechanical deformation (bend, torsion, etc.), test coupons are required to incorporate all necessary components for device function
  - Silicon die
  - Rigid or flexible passive elements
  - Connections for bias power or I/O signals
- Development of a viable coupon layout is often challenging
  - FCB material selection
    - Are materials under test representative of final product?
    - Impact of mixed interconnect materials (ACA, solder, etc.)
  - Trace layout symmetry
    - Trace routing can form local areas of non-uniform rigidity that can alter deformation
    - Uniformity is critical in the flex zone (area of deformation)
  - Size and orientation of rigid passive components
    - May need to establish holdout regions to avoid flex zone



Sample ASI Coupon w/Flex Die

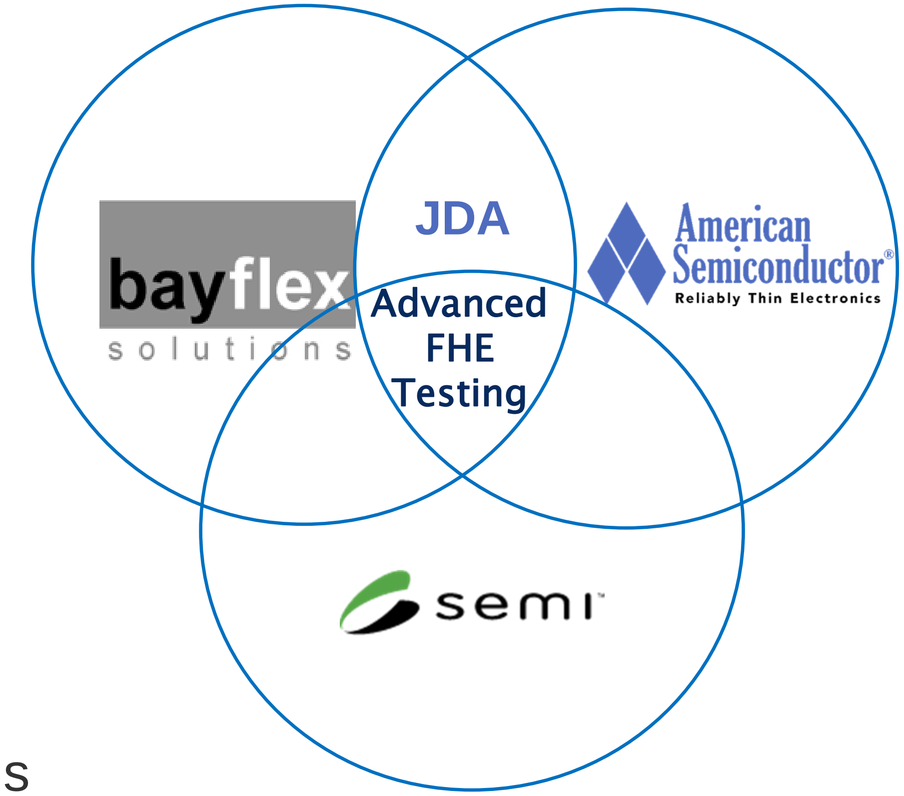
ASI & Bayflex/Yuasa (JDA) & SEMI collaboration

- American Semiconductor and Bayflex Solutions are working together to develop flex testing equipment and methodologies that can be universally adopted across the industry
  - Joint development of standard test method and apparatus for chip-on-flex RoC and torsion

- Equipment development
  - Universal sample mounting
  - Method for electrical connection (in-situ bias device operation)
  - Mechanical design to isolate targeted axis of motion
  - Compatible mini-environments for temp, humidity, etc.

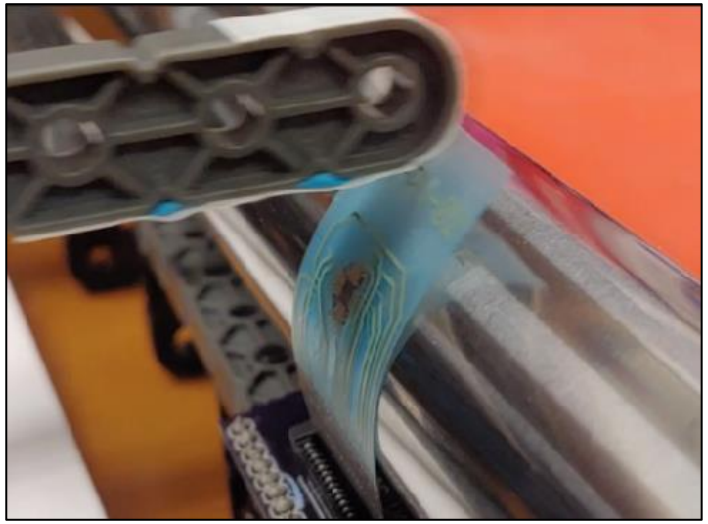
- Method development
  - Flexure direction and amplitude
  - Test coupon design
  - Targeted cycle counts
  - Acceptable cycle rates

- ASI/Bayflex collaboration with SEMI to create NIST standards

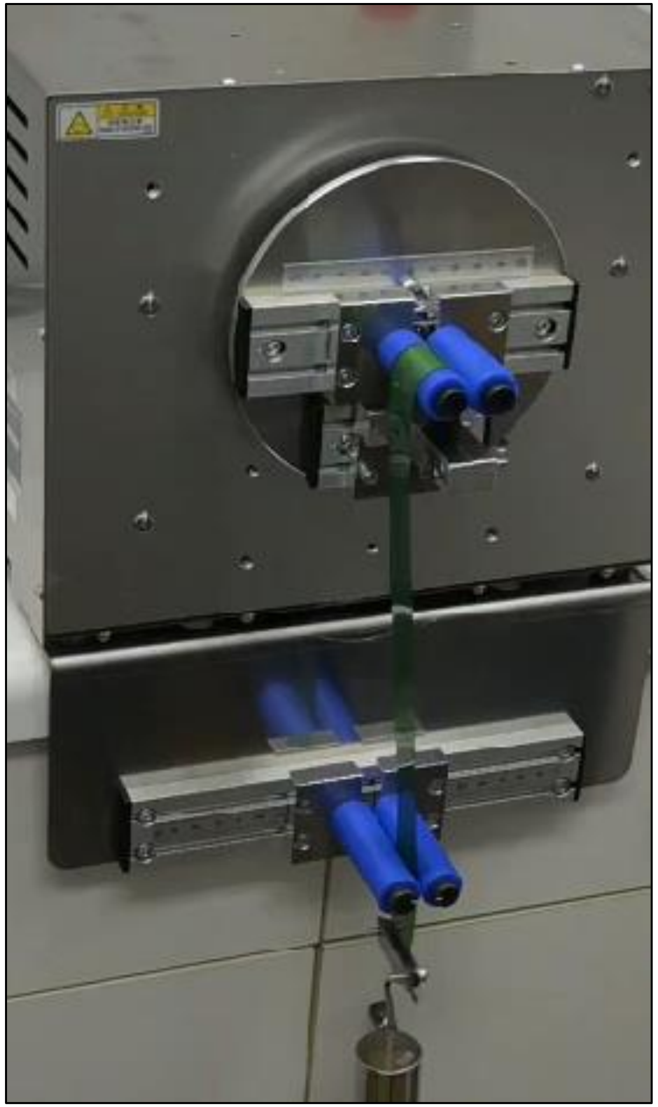


Bend/RoC Endurance Test Systems

- The overall goal is to settle on industry recognized test methods
  - Develop purpose-built test system designs that are accepted industry-wide
    - Standard design can be built internally, or purchased from equipment supplier
  - Establish testing services which are available for low-volume users
- Bend, or Radius of Curvature (RoC), Testing
  - Interchangeable bending radius mandrels
  - Programmable bend angles and speed
  - Single or Dual direction bend configuration
  - Capable of electrical connection for in-situ bias and data collection



Current ASI ROC Endurance Test



Bayflex/ASI ROC Endurance Test

Torsion Endurance Testing

- Torsion (Twist) Testing
  - Programmable twist angles and speed
  - Capable of electrical connection for in-situ bias and data collection
  - Importance of test coupon design compatibility with robotics
    - Shape of coupon is critical to achieving 2-axis deformation at the point of interest
    - Test fixture needs to allow coupon to float perpendicular to rotation axis to prevent addition of a stretch component

Current ASI Torsion Endurance Test

Bayflex Torsion Endurance Test

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Flexible Electronics Test Data

iMAPS

Static RoC Testing

- SoP-TM Test Chip, no coupon
- Manual conformance to RoC mandrel

Dynamic Bend Test

- ASI TEST005 derived from ASTM D522-93a
- Chips mounted on flex coupons of PET or PI
- Robotic cycling at specific (RoC) for bend and release in concave and convex orientation
- Test: 10mm RoC, 10,000 cycles

SoP-TM Mechanical Reliability

Test	Concave	Convex	
ASI TEST003 10mm, 10,000 cycles	PASS	PASS	SoP- TM, ACA FC on PET
Static RoC 12 mm	PASS	PASS	SoP-TM only
Static RoC 10 mm	PASS	PASS	SoP-TM only
Static RoC 8 mm	PASS	PASS	SoP-TM only
Static RoC 7 mm	PASS	PASS	SoP-TM only
Static RoC 6 mm	PASS	PASS	SoP-TM only
Static RoC 5 mm	PASS	PASS	SoP-TM only
Static RoC 4 mm	PASS	PASS	SoP-TM only
Static RoC 3 mm	PASS	PASS	SoP-TM only
Static RoC 2.5 mm	PASS	PASS	SoP-TM only
Static RoC 2 mm	PASS	PASS	SoP-TM only
Static RoC 1.5 mm	Cracked	Cracked	SoP-TM only

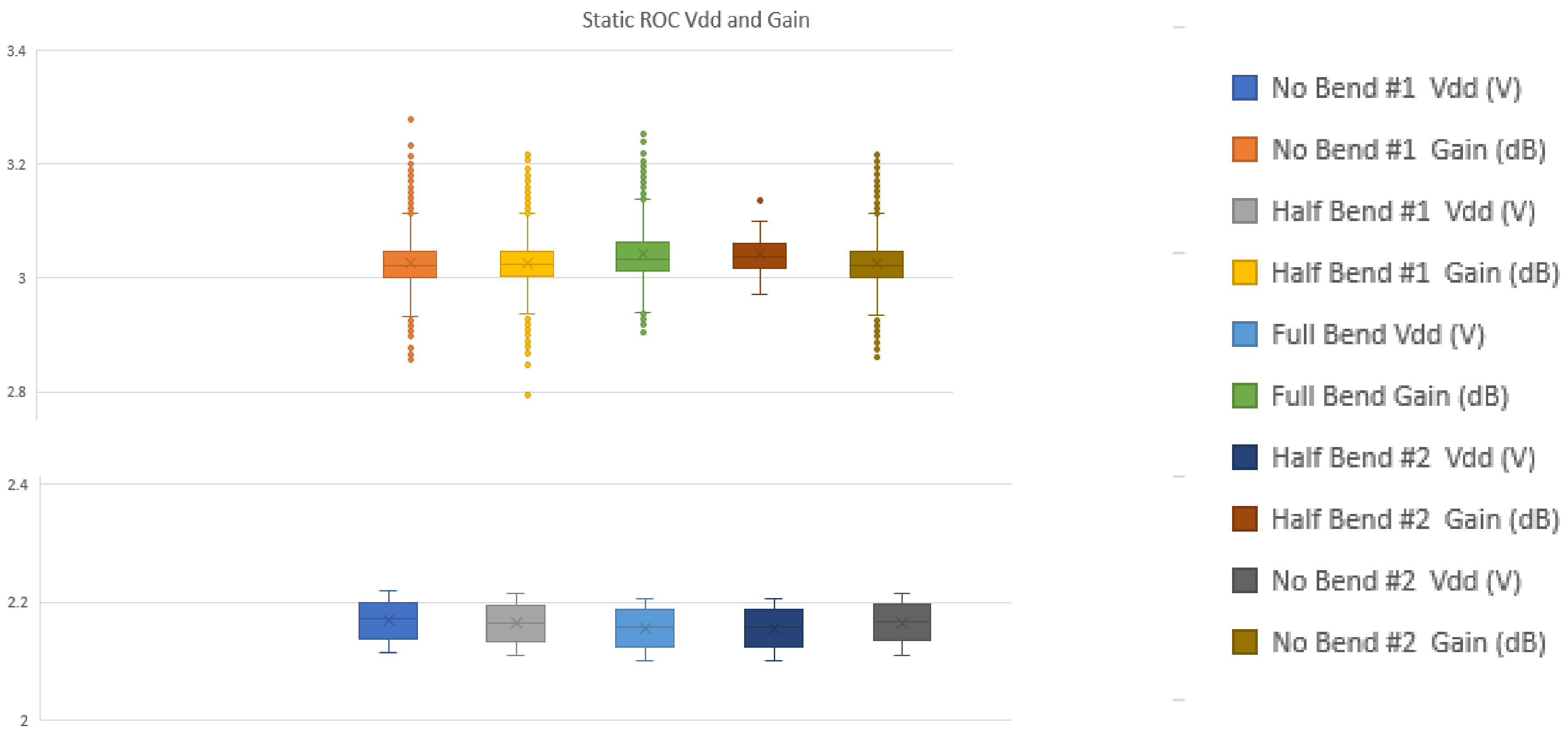
SoP-TM ETST vs Stress Summary Statistics

Box Plot

AS_OPA4002
Static test results for 15mm RoC

Gain (dB)

Vdd (V)



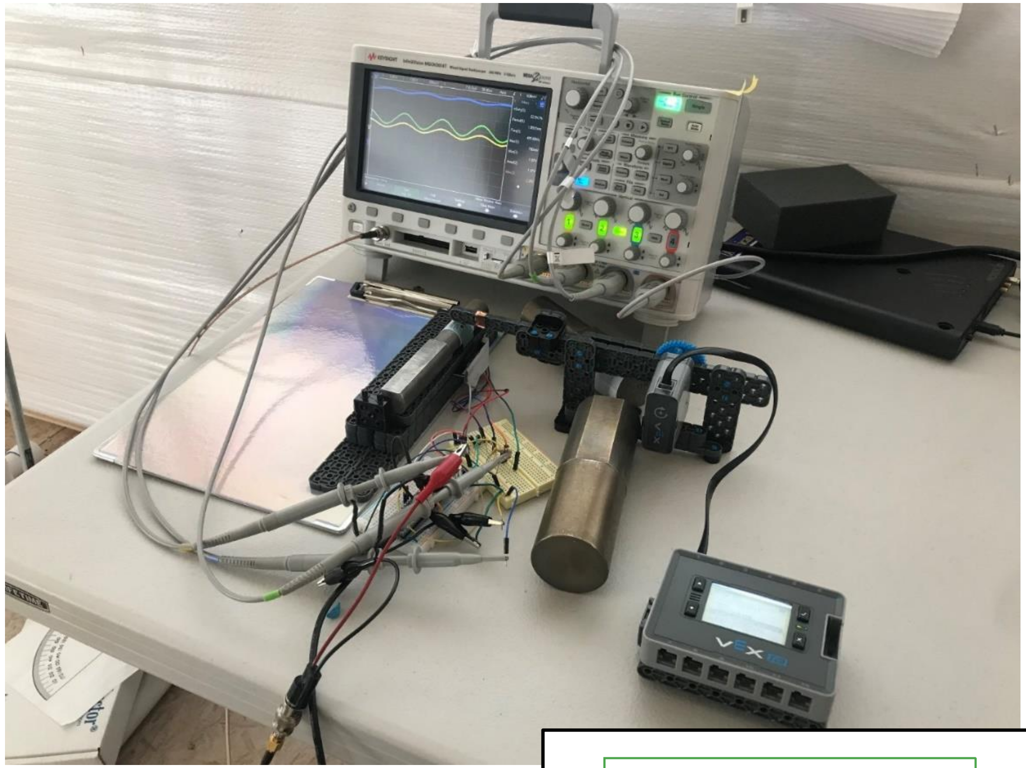
- Static RoC OpAmp test used sample **after 10k concave + 10k convex cycles at 10mm RoC**
- Vdd difference between no bend and full bend only 0.013V
- Gain difference between no bend and full bend only 0.016dB

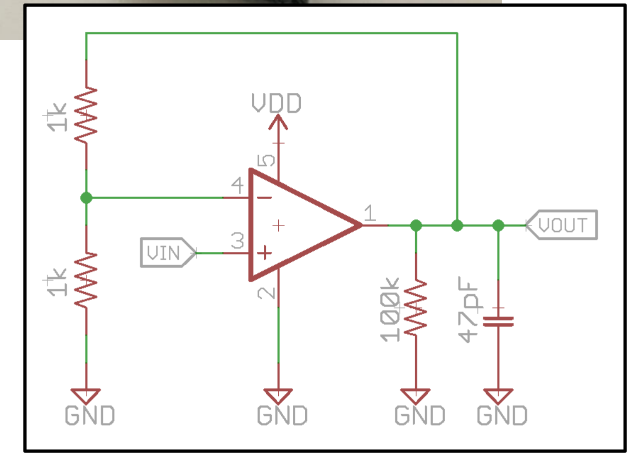
AS_OPA4002 Dynamic RoC – ASI TEST005

ASI Procedure: TEST005

- Dynamic bend testing
  - 10mm ROC
  - 10k cycles in each bend direction (concave/convex) for 20k total cycles

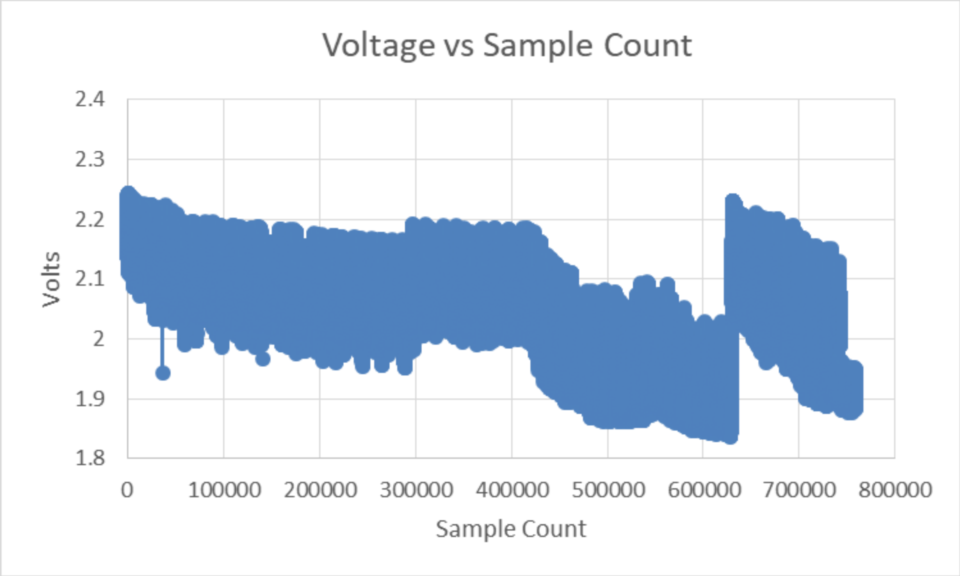
- Keysight Infinivision MSOX3024T Mixed Signal Oscilloscope
- Vex Robotics Kit
- 10mm Mandrel
- Teensy 3.4 (MCU)
- Custom Data Collection Software
- 3.3V LM317 Circuit
- OPA4002 configured as a non-inverting ~3dB amplifier

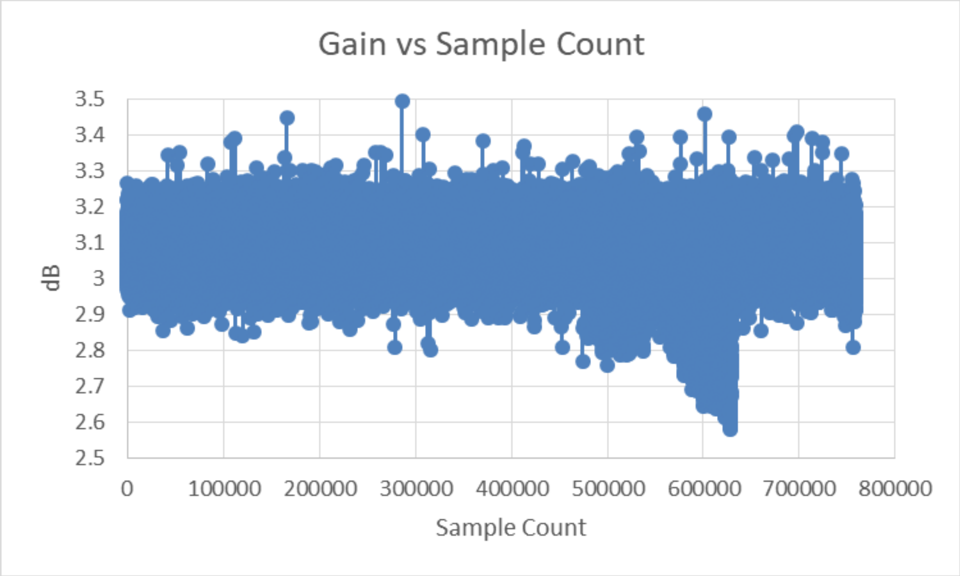




Dynamic Concave Bend Test 15-20k

- Vdd
  - Average: 2.04V
  - Minimum: 1.83V
  - Maximum: 2.24V
  - Std. Dev.: 88.1mV
- Gain
  - Average: 3.06dB
  - Minimum: 2.57dB
  - Maximum: 3.49dB
  - Std. Dev.: 0.0528dB
- Gain continued to hold relatively constant except for times of extreme Voltage drop





Call to Action

- Call to Action:
  - FHE Test Standards need user input
  - Working group formation is in-progress
  - If you are interested in participating, please contact Randy Parker for more information

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Thank You

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