Measurement and Validation of Suspension Loads on Formula SAE Car Using Micro-Measurements Strain Gages

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The 2018 SC Racing FSAE team and our car.

The task for this project was to build a circuit that can measure strain quantitatively on the suspension of the car while it is running using Micro-Measurements® strain gages. This data will allow the team to determine where on the suspension we can shave as much semi-sprung (hybrid) mass from the vehicle, in turn improving vehicle dynamics.

Company/Institute: University of Southern California, USC Racing, Formula SAE

Industry/Application Area: Automotive / Load distribution

Product Used:

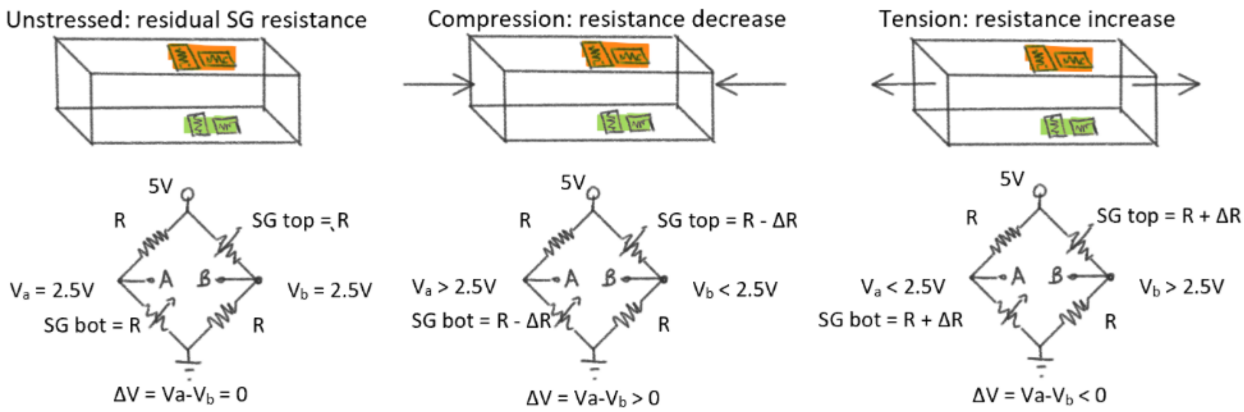
- Tee Rosette Strain Gages: CEA-06-120FZ-120
- Application Kit: GAK-2-200
- Protective Coating: 3145 RTV Silicone Rubber (3 oz)

The Challenge

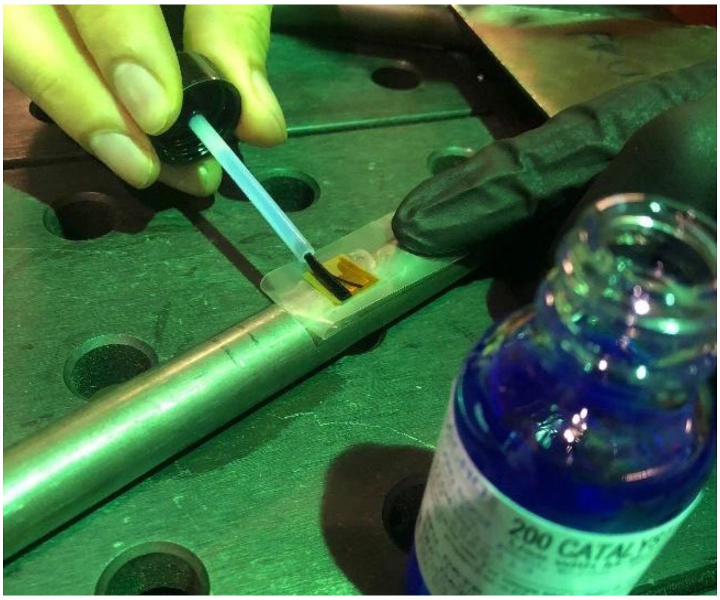
The biggest goal every year for USC Racing is to reduce weight without compromising structural rigidity and integrity. Downsizing suspension components such as A-arms and pushrods reduces unsprung mass, which in turn significantly improves performance. We needed a way to measure strain and load distributions in order to safely downsize our suspension components. Knowing the load on each individual component of our suspension will give us a major advantage when we compete in Lincoln, Nebraska.

The Solution

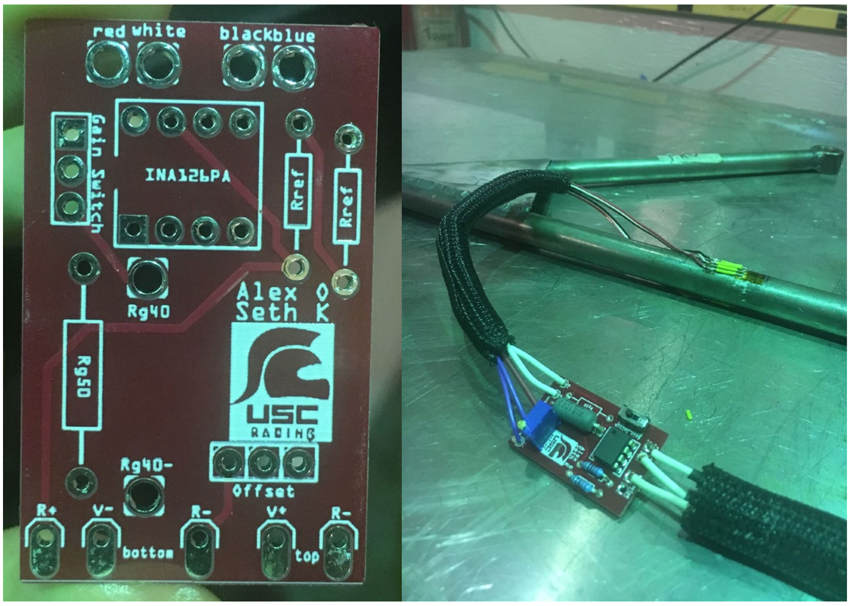
We went with a half-bridge setup using Micro-Measurements® strain gages. This configuration allows readings for axial stress while minimizing bending readings. Since the gages are on opposite sides of the signal node, the voltage at the node on both branches will either increase or decrease the same amount. The other resistances on the bridge consist of unstressed gages on a tee-rosette strain gage. The switch to tee-rosettes was inspired by the issue caused by temperature's effect on readings. The unstressed gages will also increase and decrease in resistance due to the temperature of the specimen or the ambient temperature along with the active gages, maintaining a balanced bridge in the unstressed state within operating temperatures of the gages.



The applications kit provided us with more than enough material to bond the strain gages and complete our design. This kit covers numerous applications for strain gages such as bonding, cleaning, protecting, wiring, and more. The Micro-Measurements® team also provided plenty of videos and resources for bonding gages and soldering wires onto them. The gages supplied to us by the Micro-Measurements® team were high quality, and were much simpler to bond and solder onto. This greatly decreases chances of installation errors compared to our previous gages we were working with.



The strain gages were then wired to a printed circuit board designed in-house. Our PCB allowed us to convert a change in resistance into a reliable 0V - 5V reading. We can set the offset voltage, change the amplification ratio, and balance the bridge all in the PCB. We can now route all wiring and cover the PCB, and start recording data into our DAQ.

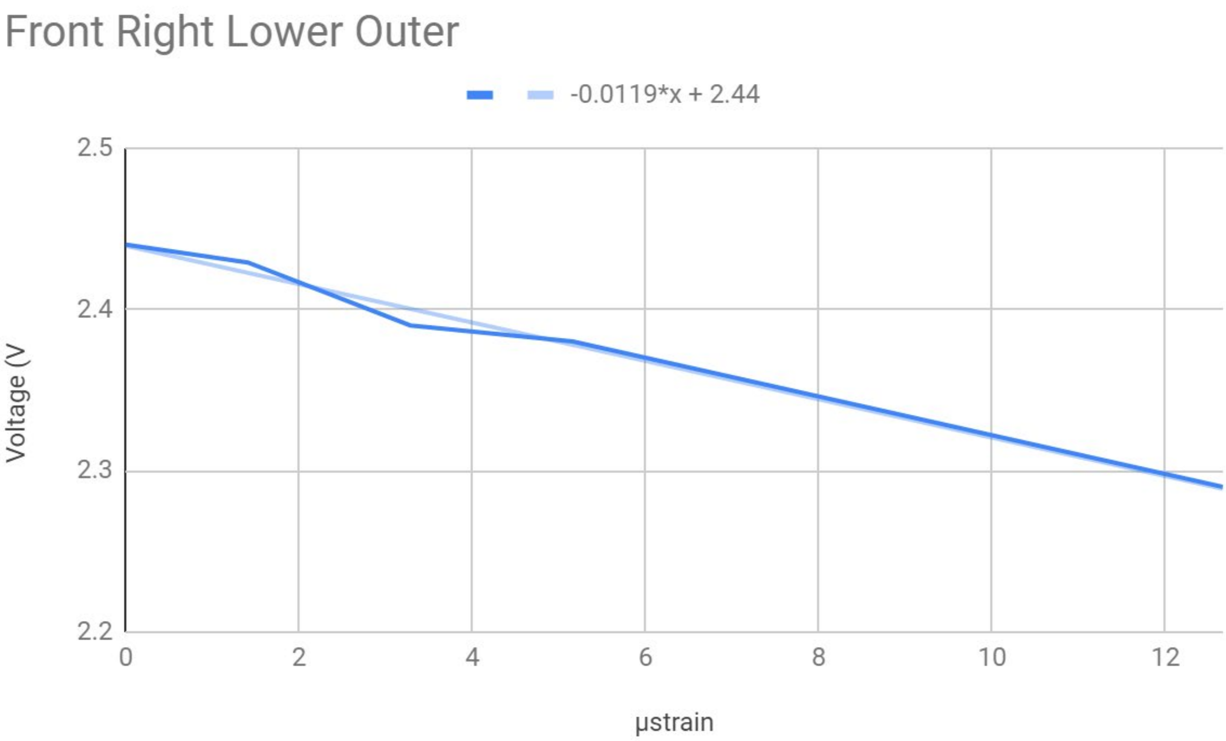


Our final PCB design. The PCB was covered in a heat shrink so no metal contacts would short.

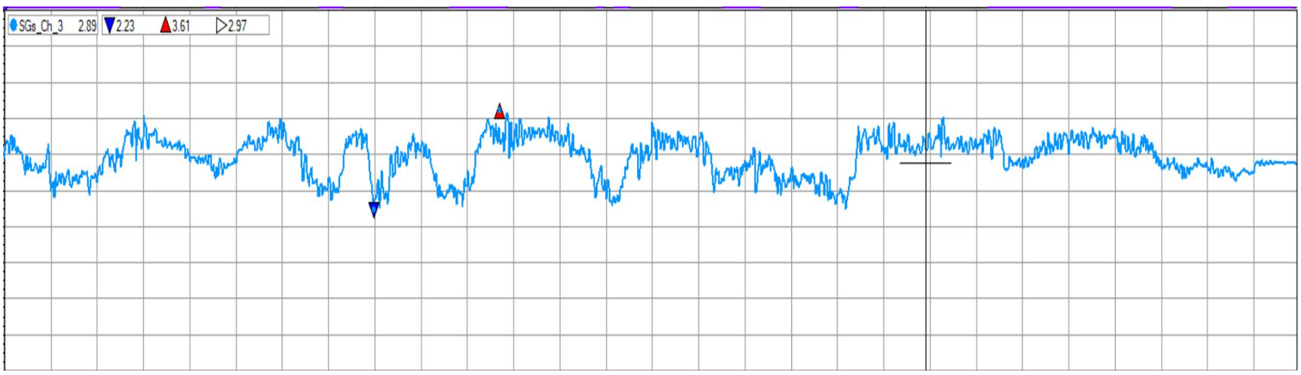
The User Explains

Calibration of each circuit is essential to maintaining the integrity of the data since each circuit is different in its tolerances and gage alignment with the direction of force. Thus, the circuit's excitation when experiencing a load must be validated using known weights.

Example calibration curve taken from calibration of one circuit on the front right lower A-arm:



At this point, the car is driven simulating the skid pad test with the strain gages logging data, and then we go through all the runs to find the largest (realistic) peaks on each component. Then, we must use the linear relationship between voltage and strain determined by calibration to get the values shown below. Here are some examples below:



	A-arm: Front Right Upper - Outer	A-arm: Front Right Lower - Inner A-arm	FR anti-roll bar	A-arm: Rear Right Upper - Outer
Peak Compression Run 1 (lbf):	165.17	236.623	26.53	175.5
Peak Tension Run 1 (lbf):	105.92	104.93	28.57	157.14
Peak Stress Run 1 (MPa):		48.507715		
Peak Compression Run 4 (lbf):	80.79	213.99	61.22	
Peak Tension Run 4 (lbf):	96.94	104.94	185.71	
Peak Stress Run 1 (MPa):		43.86795		
Peak Compression Run 3 (lbf):	93.35	195.47	18.38	
Peak Tension Run 3 (lbf):	75.40	98.77	20.41	
Peak Stress Run 1 (MPa):		40.07135		

“With Micro-Measurements® tee-rosette strain gages, we were able to determine that the stress on suspension components of our design is well below the yield strength threshold, thus allowing data to validate the hypothesis to reduce the size of suspension members.”

Acknowledgement:

Formula SAE caters to students the opportunity to learn and apply knowledge to a complex problem. Each member plays an integral role in pulling together individual projects into a race car, consequently, each project is essential to the success in this endeavor. In order to succeed, these engineers must effectively work together, communicating to the team the ins and outs of each individual project, and remain committed to the project. SAE brings a type of education that is unattainable in lectures -- a real-world experience. Our team would like to thank the Micro-Measurements® team for their generous donation and instructional support. This made possible a project that would allow our team to take real-time physical data on our vehicle to improve the next iteration.

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