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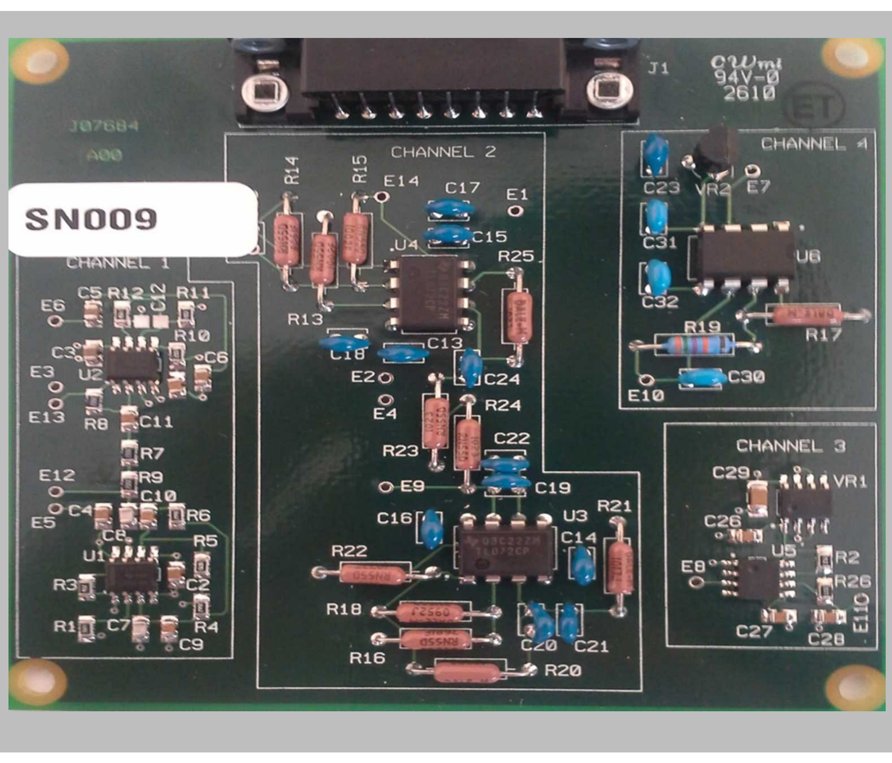

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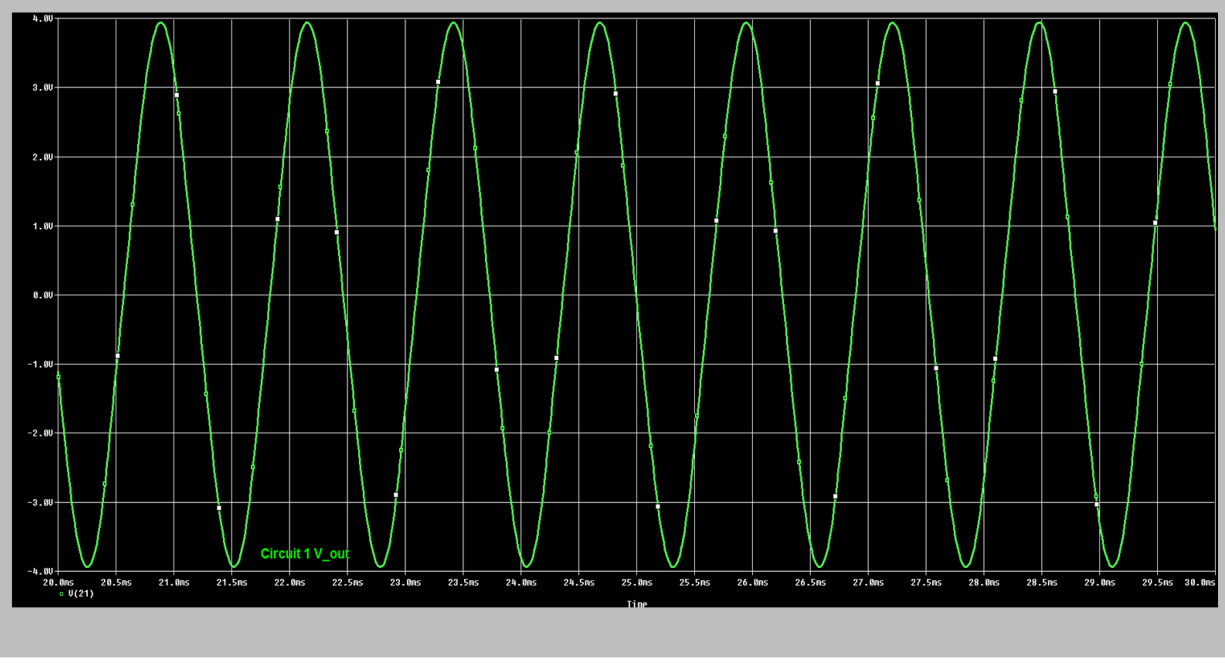

SPICE Circuit Modeling to Locate Failures on a Printed Circuit Board

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Abstract

Electrical circuits are often operated in severe mechanical environments and can fail due to structural vulnerability. The purpose of this project, as part of a larger project to construct novel failure models for components in vibration environments, is to create and verify models of four separate function generator circuits using SPICE software, then insert 'failures' into the model and note the corresponding output. Comparison of the circuit output of intentionally broken models with measured output from circuit boards tested to failure allows us to pinpoint the circuit element(s) where the failure occurred. Knowing not only the time until failure but also the location of that failure allows for a more accurate failure model.

Introduction

The goal of the WSEAT Vibration Experiment is to obtain failure models of function generator boards under vibrations testing. Initially, 16 identical printed circuit boards were placed on electrodynamic shakers, instrumented with accelerometers and strain gages, then shaken until 'failure'. These PCBs contain four separate function generators: two sinusoidal outputs, using operational amplifier oscillators, and two square wave outputs, using 555 timer chips. Currently, the failure models for the circuits depend on cumulative dissipated structural energy as calculated through an equivalent reduced-order structural model. The current failure models for the WSEAT test boards can be fine-tuned by pinpointing exactly where in the circuit the failure occurred.

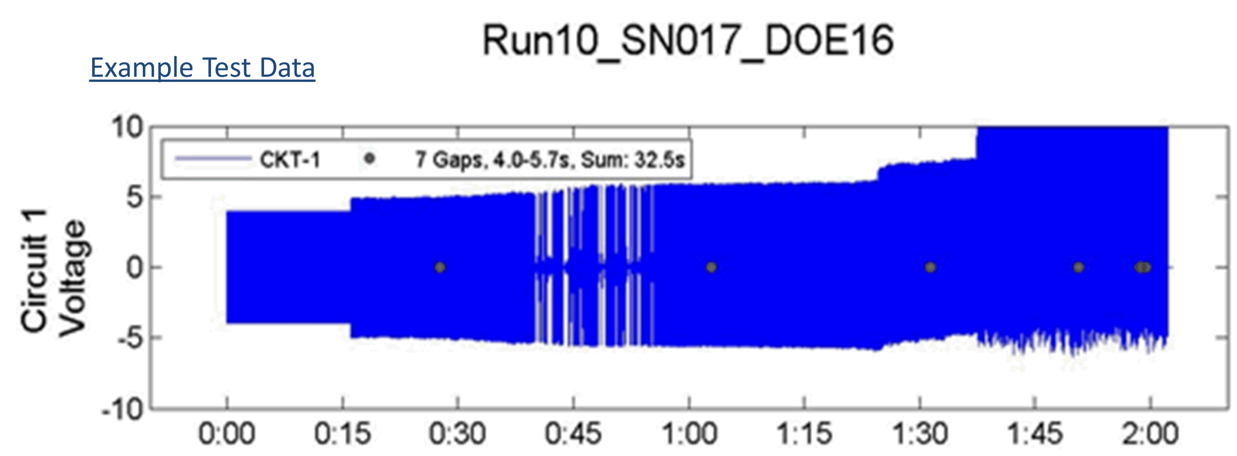
The purpose of this project is to create and verify models of these function generator circuits using SPICE (Simulation Program with Integrated Circuit Emphasis) software then introduce failures to the model. The models were verified using both Sandia National Laboratories' Xyce and PSpice and checked against measured circuit output data from 16 copies of the test board. Many failures simply result in trivial outputs (0V DC for example), but some result in unique output waveforms. Understanding the contributions of each element in the circuit, as well as how the circuit may fail and what that failure looks like, gives valuable information. When compared with the actual circuit's failed waveform, this data helps pin point the location of the device failure and in some cases reveals the circuit element that failed first.

Benefit of Modeling Approach

The test boards were exposed to vibration environments for periods of time that went well past the first failure – in many cases three or more failures were noted in the output. The goal of this research is to find failed models whose outputs we can use as 'signatures' to compare to the actual data.

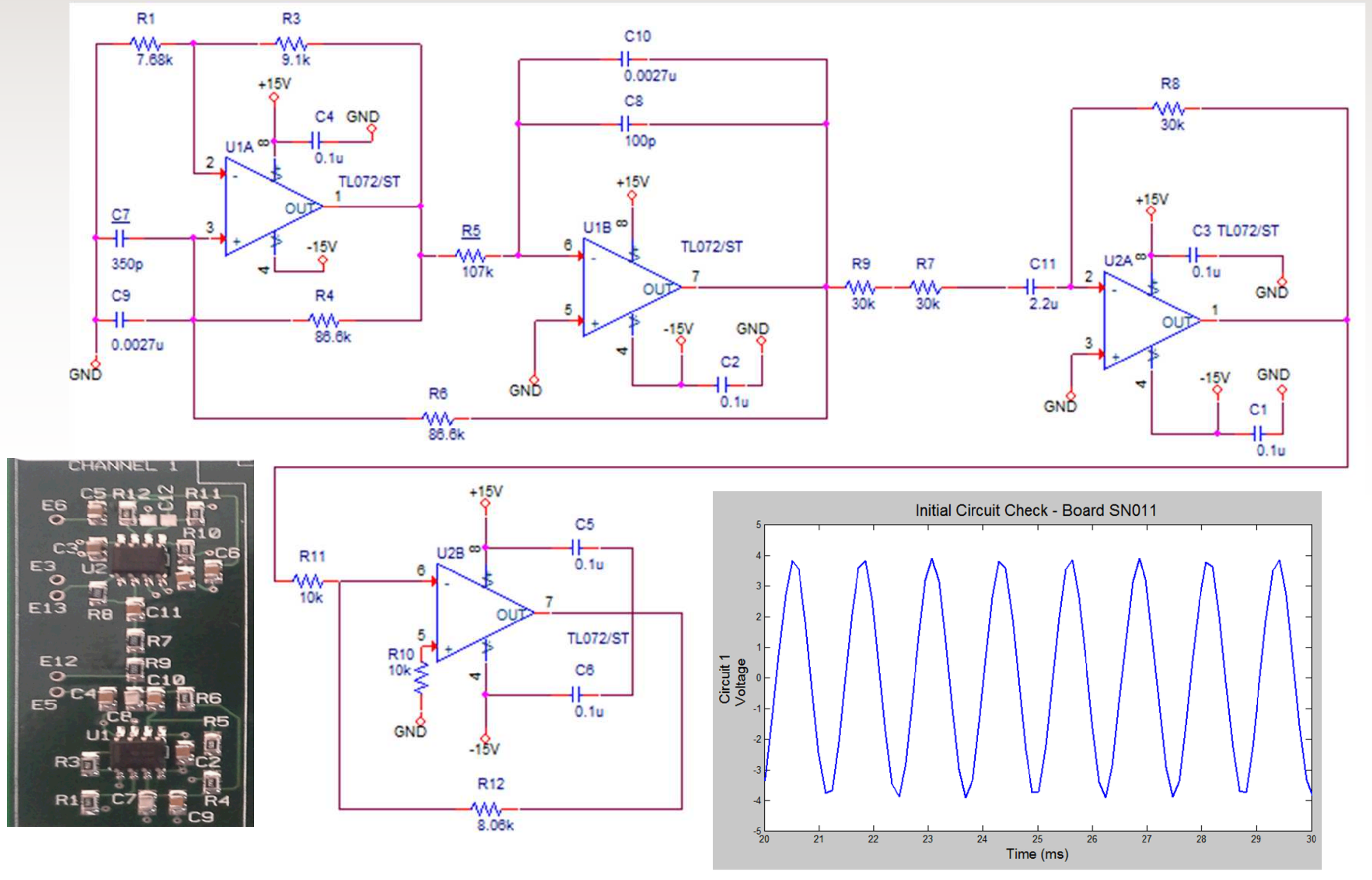
For example, if turning element X of circuit 1 into an open circuit causes the amplitude to increase by a factor of 1.5 and circuit 1 of test board 17 shows a failure at ~15m of amplitude modulation close to 1.5x the normal amplitude, then perhaps element X being open is the 'signature' we can assign to that failure

Example Test Data



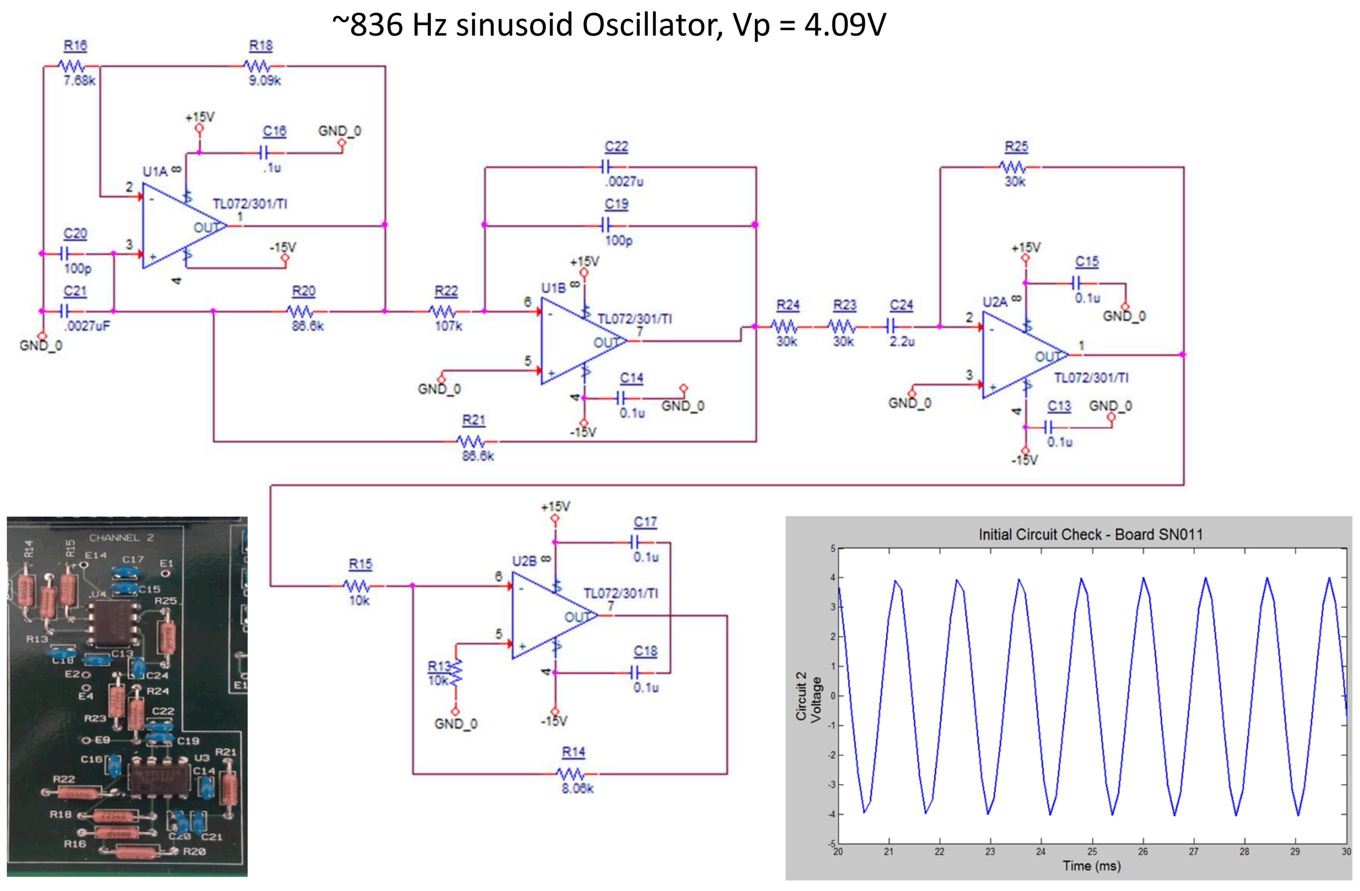
Circuit 1

~793 Hz sinusoid Oscillator, Vp = 3.94 V



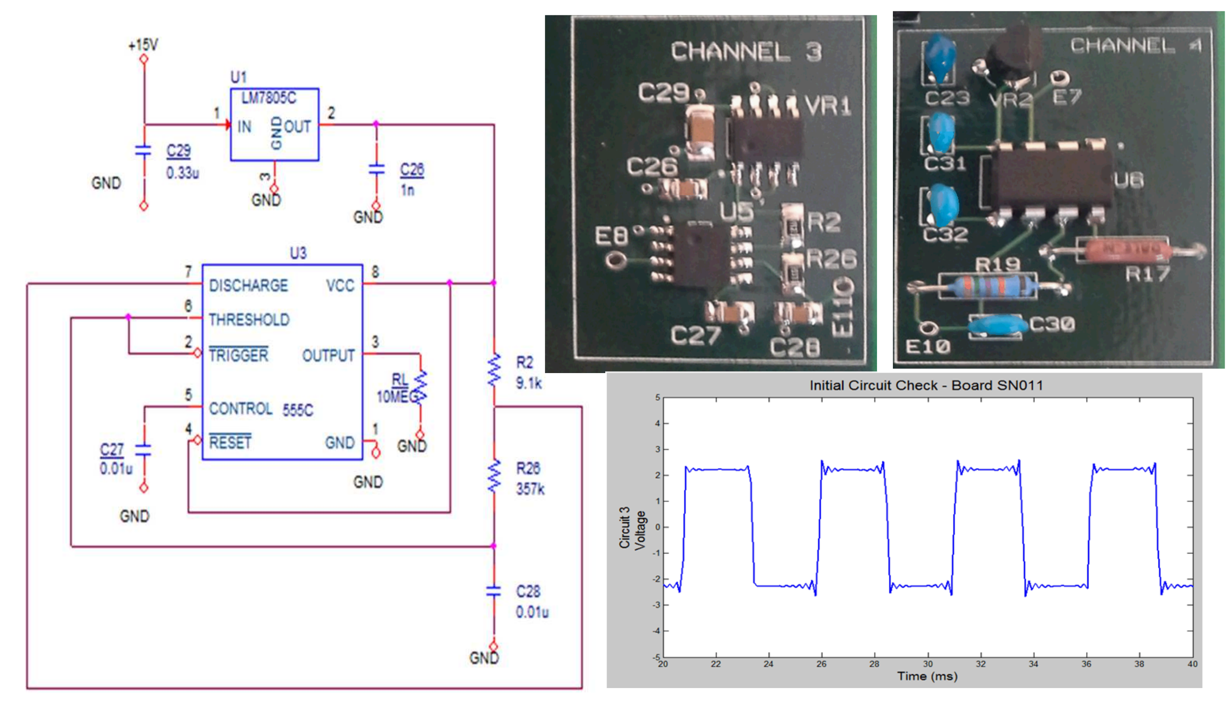
Circuit 2

~836 Hz sinusoid Oscillator, Vp = 4.09V



Circuits 3 and 4

~200 Hz square wave



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Circuit 1 In Depth

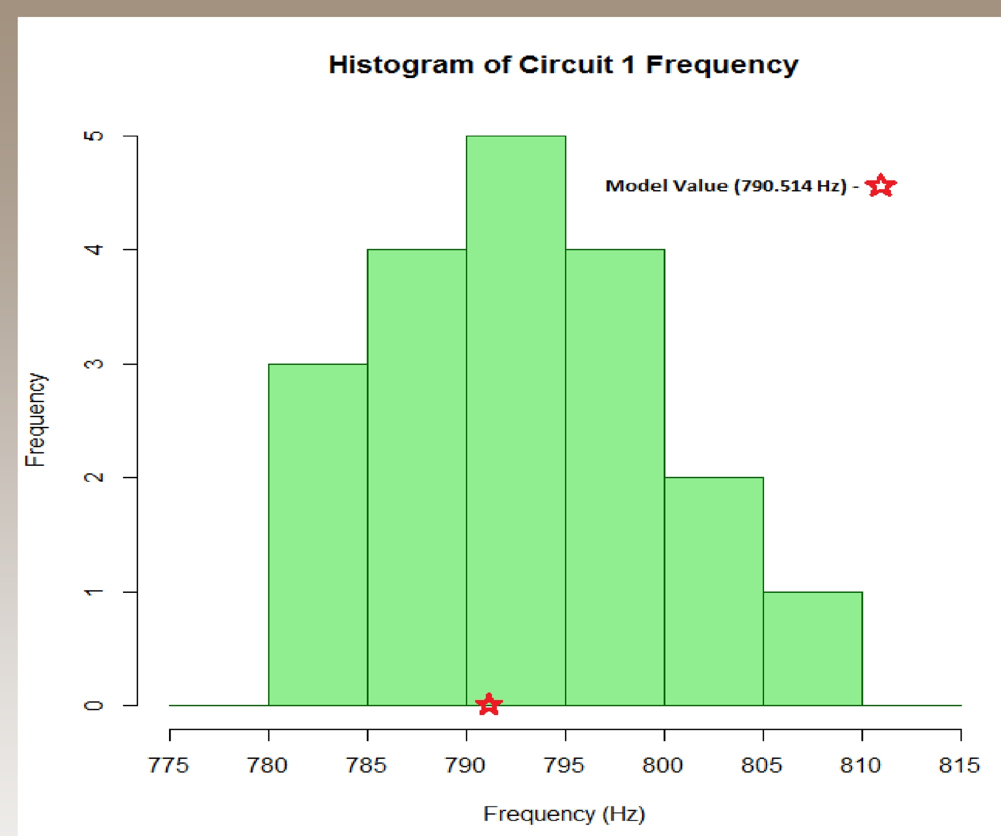
Methods

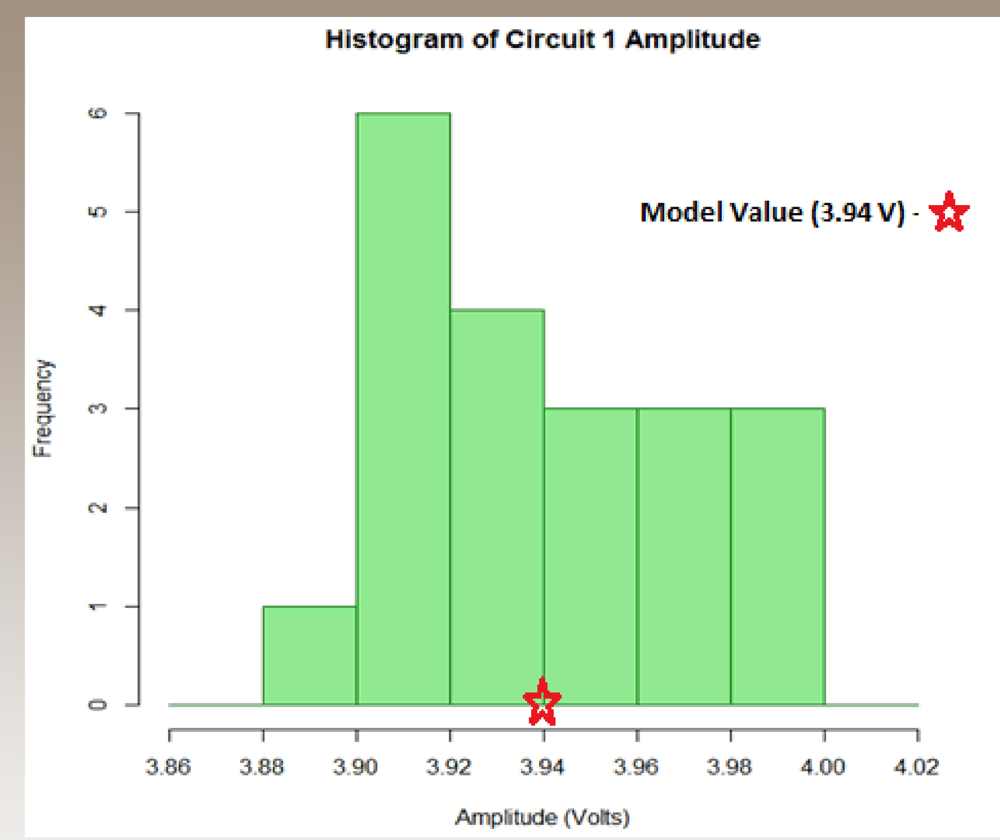
Methods:

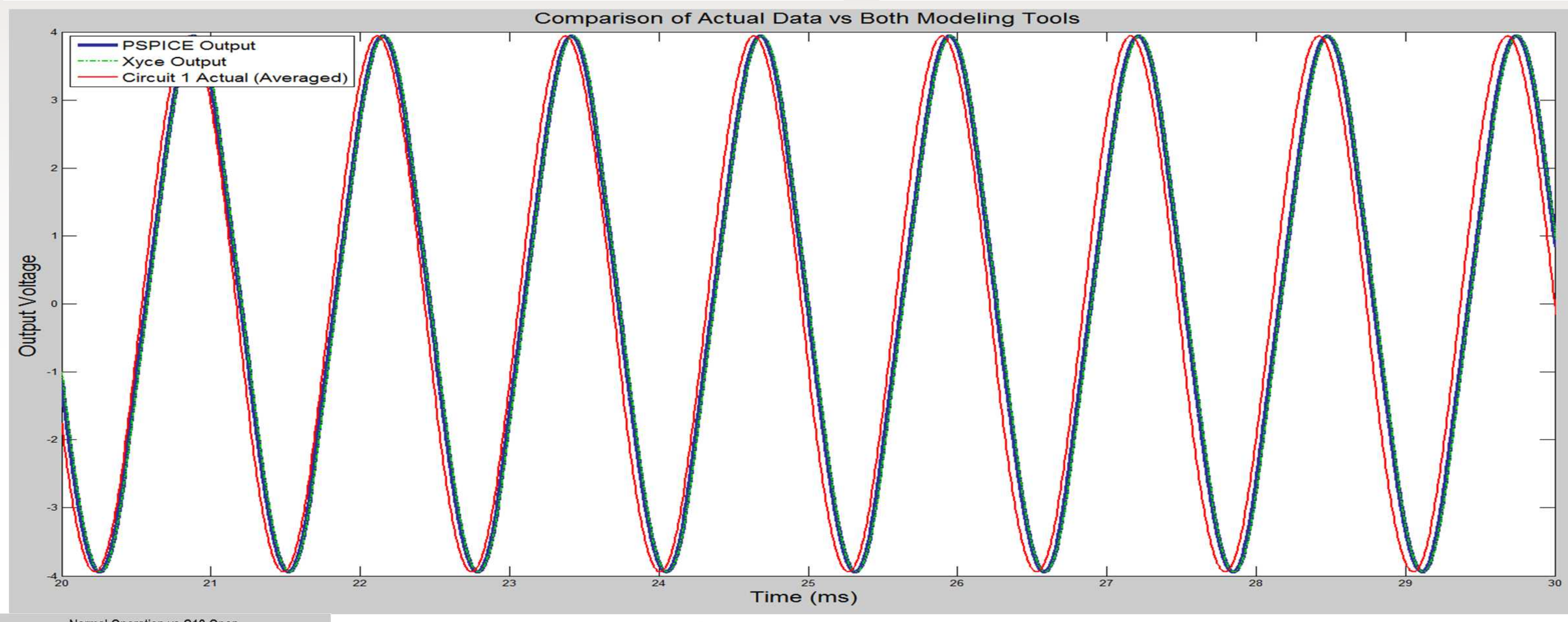
- Using the data from initial circuit characterization, sample statistics: frequency and amplitude, were calculated for each board
- A SPICE netlist for the circuit 1 oscillator was coded and tested using both Xyce and PSPICE. The results from both simulations were then compared to the average of the sample of test boards.
- Failures were then introduced to the SPICE model in the form of:
  - Opening and shorting each passive element in circuit
  - Breaking connections to pins of op-amp IC chips (V+, V-, in+, in-, output)
- Parameter sweeps of resistors and capacitors critical for circuit functionality were conducted to determine the contribution of each respective element
- After modeling failures, the actual boards were probed with a Multimeter to test the integrity of each element and determine if an element or connection had failed

Materials:

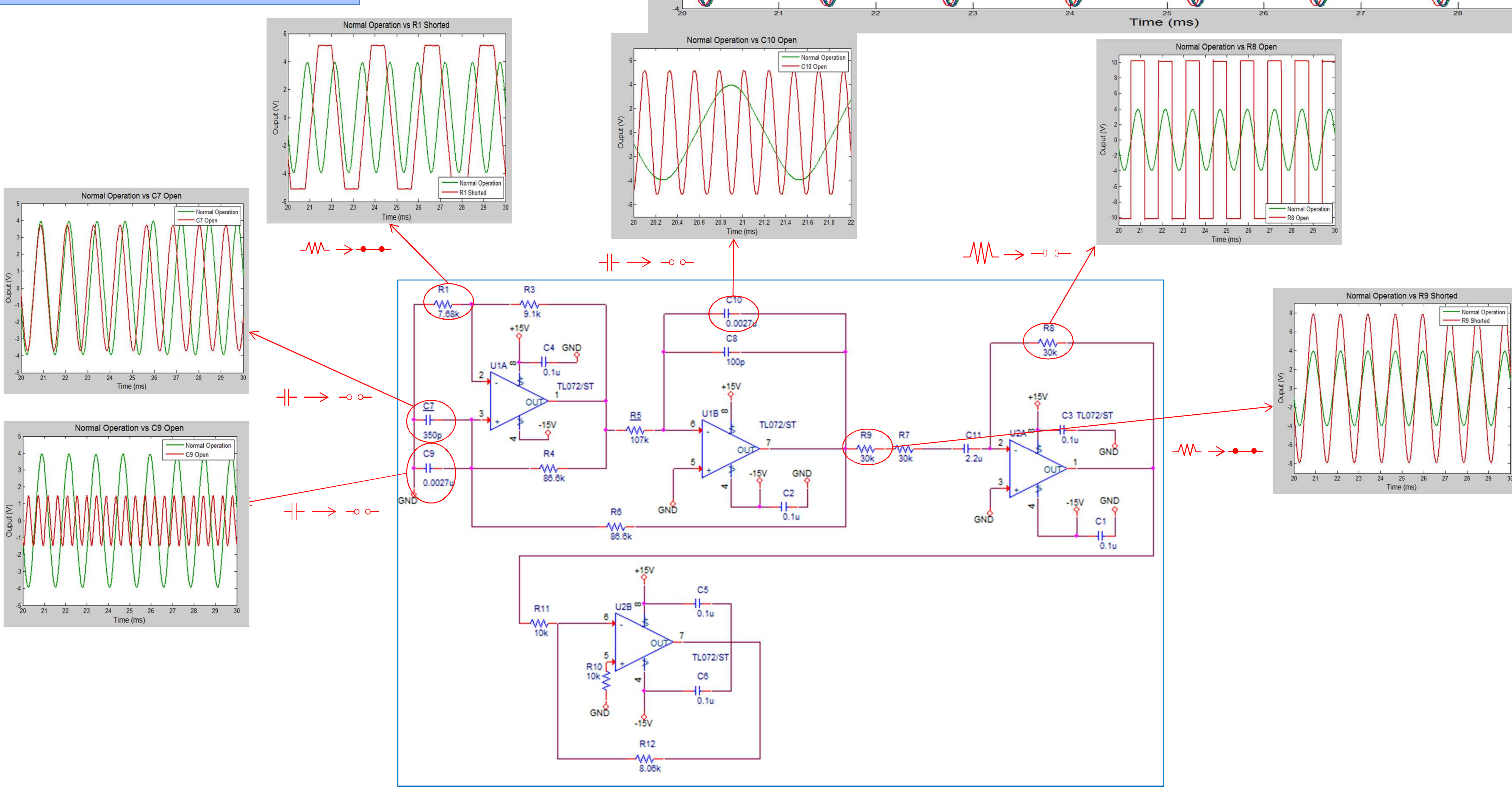
- Cadence OrCad/Pspice analog circuit simulator
- SNL Xyce analog circuit simulator
- MATLAB and Excel (for data analysis)
- Fluke 87-5 Digital Multimeter







Failure Modeling Results



List of Elements		
Critical (Output = 0V)		[red]
Critical (Output ≠ 0V)		[gray]
Not Critical		[black]
	Shorted	Open
Element		
R1	[gray]	[red]
R3	[red]	[gray]
R4	[red]	[red]
R5	[gray]	[red]
R6	[red]	[gray]
R9	[gray]	[red]
R7	[gray]	[red]
R8	[red]	[gray]
R11	[gray]	[red]
R10	[red]	[red]
R12	[red]	[gray]
C9	[red]	[gray]
C7	[red]	[gray]
C4	[red]	[black]
C8	[red]	[gray]
C10	[red]	[gray]
C2	[red]	[black]
C11	[black]	[red]
C1	[red]	[black]
C3	[red]	[black]
C5	[black]	[black]
C6	[black]	[black]

Results

The goal of this research is find where the failures happened on the actual board. The modeling approach has allowed us to view failed outputs and hypothesize what caused the failure but we cannot know for sure until working with the actual test boards.

After probing the boards with a Multimeter and finding compromised elements or solder joints on various circuits, we have been able to assign locations of failure to a few boards. This, in conjunction with the data on failed models, has allowed us to pinpoint which element caused the failure. When complete, this research project will yield valuable information about where the failures are located on each of the 16 boards tested to failure in vibration environments.

Future Research

At this point the modeling portion of the research is almost complete. More complicated failures other than a single element are currently being modeled. The next steps in the research are:

1. Analyze waveforms of circuits that failed under testing and compare to models
2. Probe each failed circuit while unpowered using a Multi-meter and check for continuity at connections and integrity of elements
3. Using an oscilloscope, probe each failed circuit while powered. Knowing the signal at each node of the working model and directly comparing that with each node of the failed circuit seen on the oscilloscope will pinpoint exactly where the failure occurred.

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