Self-Sustained (Wien Bridge) Oscillator – Experiment Guide 29 July 2021

This is the procedural portion of the instructions of the nonlinear oscillator / Wien Bridge oscillator experiment. See also the Jupyter notebook

Wien_Bridge_Oscillator_Theory_v9_4.ipynb

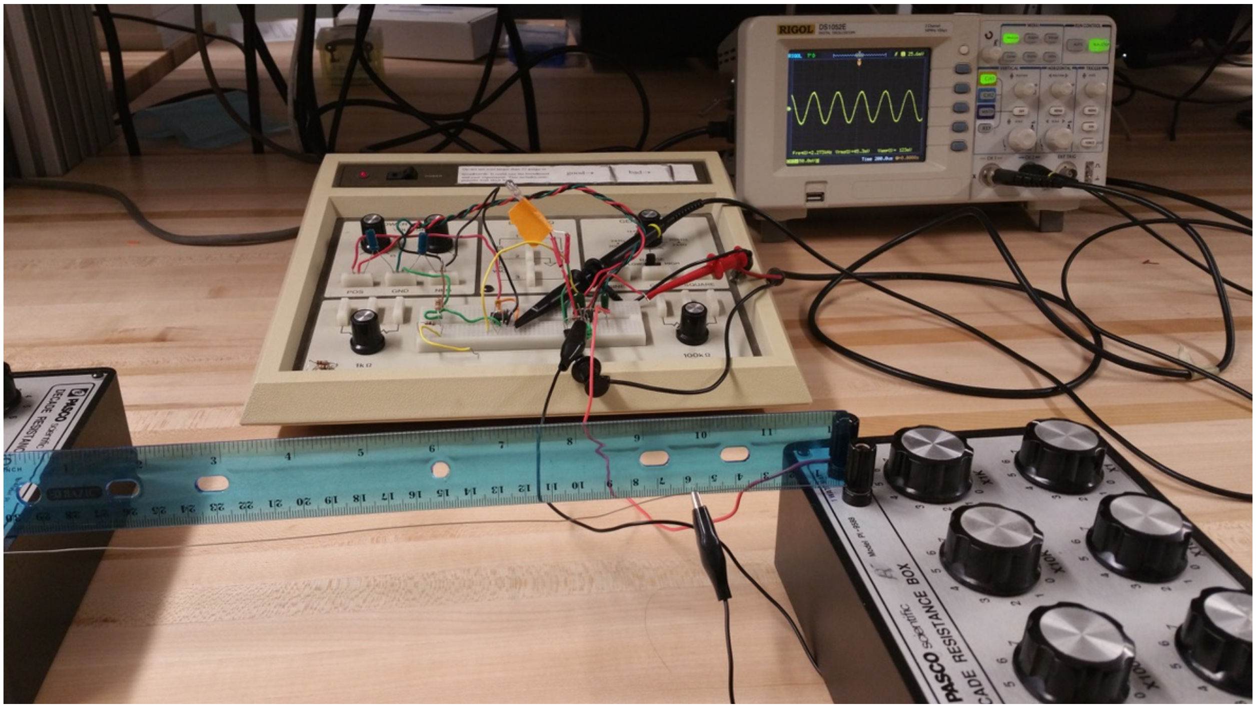
for a thorough discussion of the theory with accompanying numerical simulations

Laboratory Pre-Requisites
(1) Building and Evaluating Inverting and Non-Inverting Amplifiers using an Op-Amp
(2) Performing analog mathematical operations with Op-Amps

Instrumentation Co-Requisite
(1) Operation and features of a Rigol 50MHz oscilloscope

Conceptual Pre-Requisites / Co-Requisites
(1) Complex representation of oscillator signals
(2) Complex electrical impedance of passive circuit components
(3) Combining impedances of series and parallel passive components
(4) Time-domain analysis of RC-circuits
(5) Kirkhoff's Laws for analyzing multi-path circuits
(6) Mathematical solutions for the behavior of a damped simple harmonic oscillator

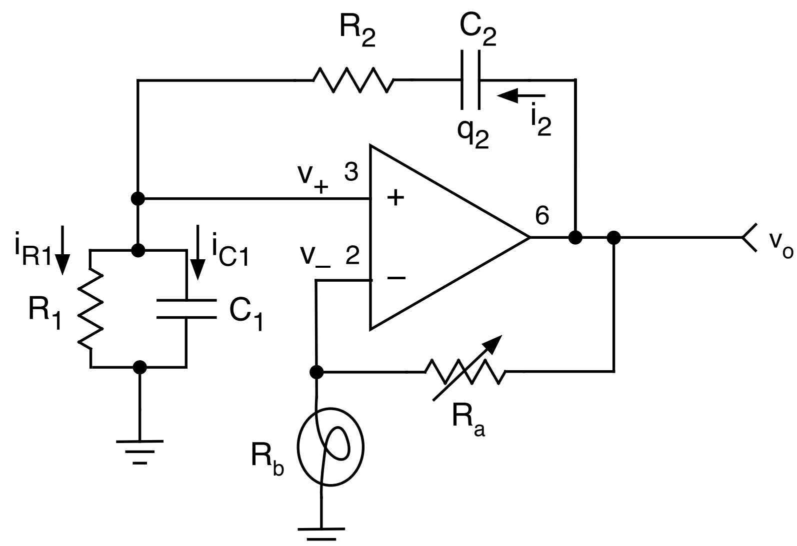
Experiment setup



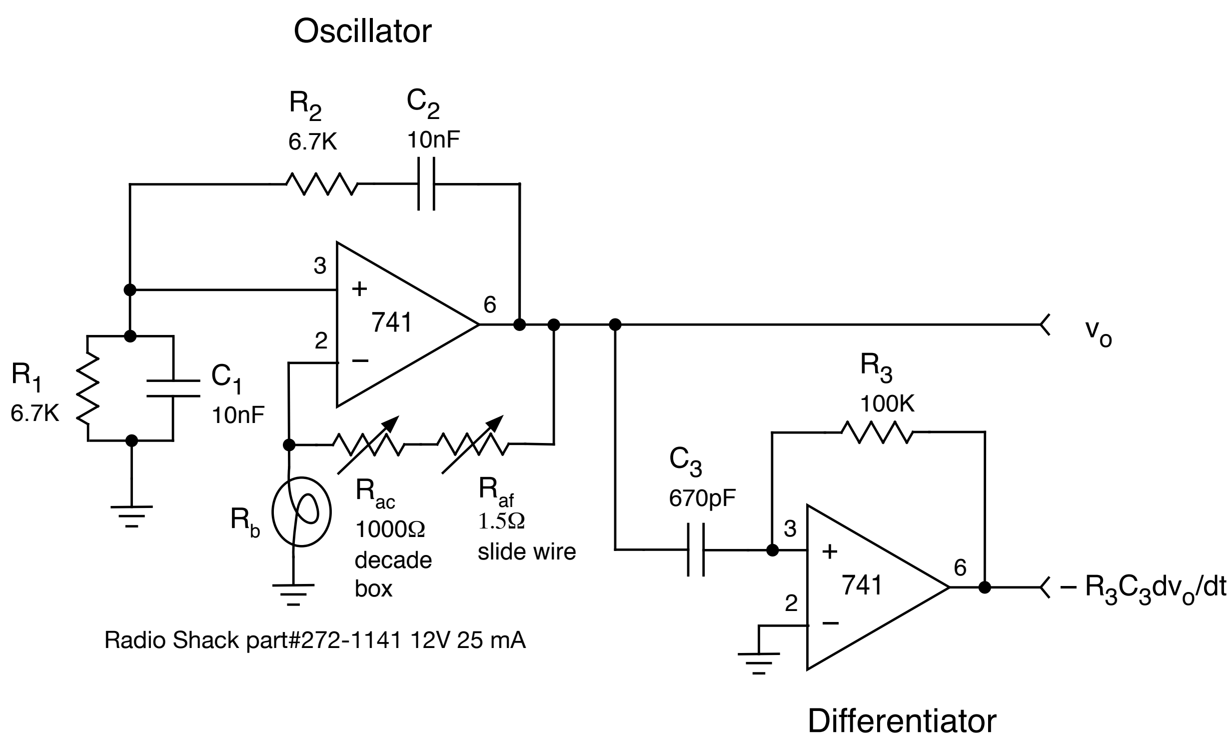
Equipment

Solderless prototyping module with built-in power supplies adjustable to ± 12 volt
  Or Solderless breadboard and ± 12 volt power supplies
Various lengths of solid 22-gauge wire for breadboard connections
Two 741 op amps (or near equivalent)
Two 6.7k resistors
Two 10 nF mica capacitors (do not use ceramic capacitors)
One decade box with up to 1000 ohm range
  Or variable potentiometer with ten-turn dial
Slide-wire variable resistor with >1 ohm dynamic range, e.g. 40 cm of 22-gauge nichrome wire
  And/or 0.1 ohm steps on decade resistance box
Tungsten filament light bulb 12 volt 25 mA (RadioShack part 272-1141 or equivalent)
  https://www.radioshack.com/products/radioshack-12v-25ma-miniature-lamps
  Possible near substitutes:
  JKL part number 2174 incandescent lam lamp (Digikey part 289-1216-ND)
  https://www.digikey.com/en/products/detail/jkl-components-corp/2174/1553133
  Visual Communications Company part number 7219 incandescent lamp (Digikey CM7219-ND)
  https://www.digikey.com/en/products/detail/visual-communications-company-vcc/7219/242927
One 100k resistor
One 670 pF capacitor
Digital multimeter, capacitance meter, digital oscilloscope (e.g. Rigol 1052), ruler

Circuit Diagram – Basic Wien Bridge Oscillator



Circuit Diagram – Wien Bridge Oscillator and Differentiator



Experimental Procedure

A Circuit Component Evaluation

Start with a pre-built circuit

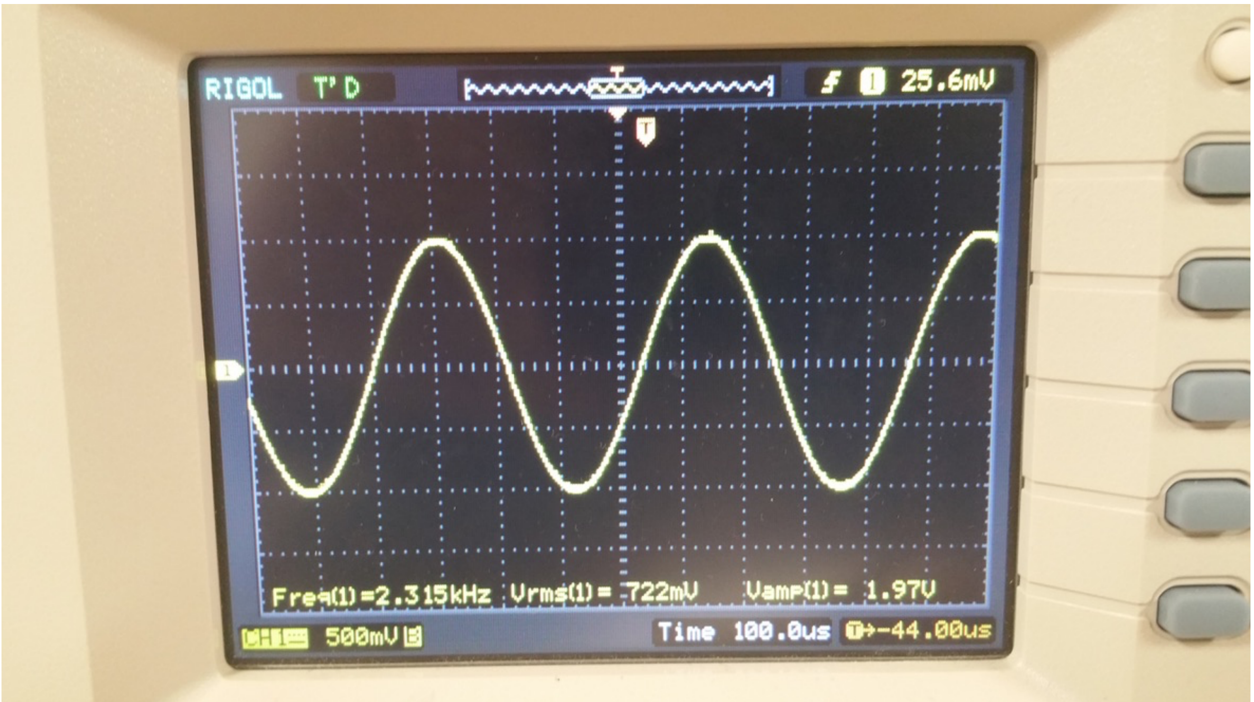
(1) Pull, measure, and replace each component of the circuit.

(2) Predict the frequency.

(3) Measure the light bulb resistance directly and in series with measured 100 ohm, 220 ohm, 470 ohm resistors. Extrapolate if necessary to a “zero-current” value of the lightbulb resistance.

(4) Predict the gain resistance R_a needed for signal onset.

B Finding the gain needed for onset of oscillation and then obtain a 1V amplitude sine wave



Connect an oscilloscope to the circuit output (pin 6)

(1) Apply power. Adjust the power supply knobs to give +12.00 and -12.00 (±0.05V)

(2) Find the value of the gain decade resistance value that first yields oscillation. Using the measured "cold" lightbulb resistance value, determine the onset gain. How does it compare to the predicted value?

(3) Adjust the gain decade box to achieve a 1V amplitude (2V peak to peak) sine wave.

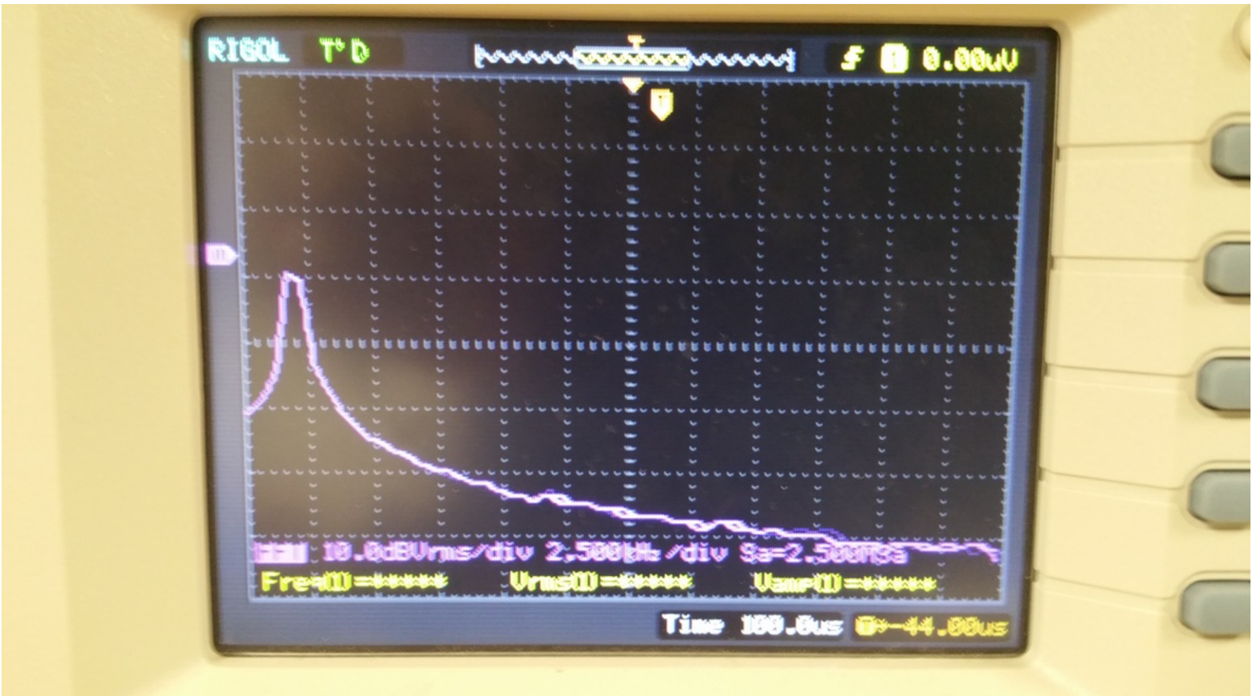
(4) Measure the frequency
(a) by working out the period from the oscilloscope trace
(b) by using the digital scope's internal measurement function
Comment on the comparison to your predicted value

(5) Obtain the various oscilloscope amplitude measures. Quantitatively demonstrate how the measures are compatible.

(6) Take a photograph of the screen display including both the voltage-versus-time trace, two types of amplitude measure (rms and peak-to-peak), and a frequency measure.

(7) Offload a signal sample using a USB drive. (After lab time) Plot the data using a Python script.

C Spectrum analysis



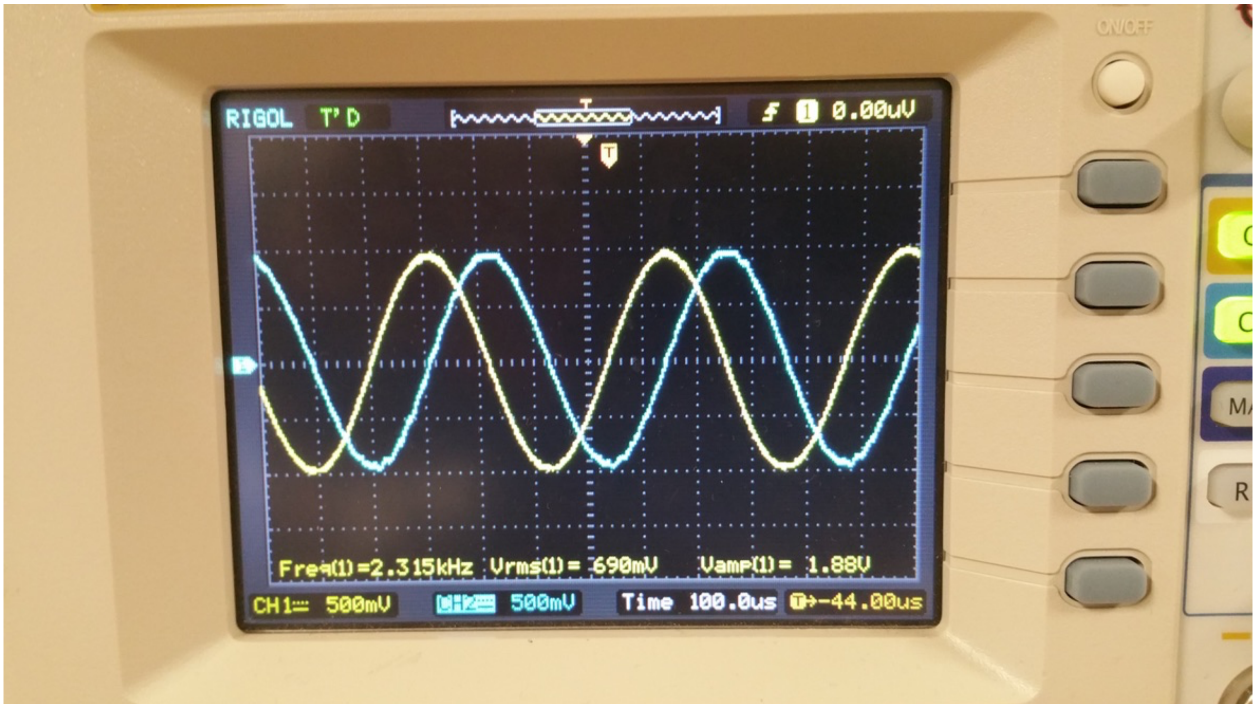
(1) Use the oscilloscope as a spectrum analy zer to evaluate the signal power spectrum. Comment on the contents of the spectrum. Are there harmonics?

(2) Take a photograph of the oscilloscope display.

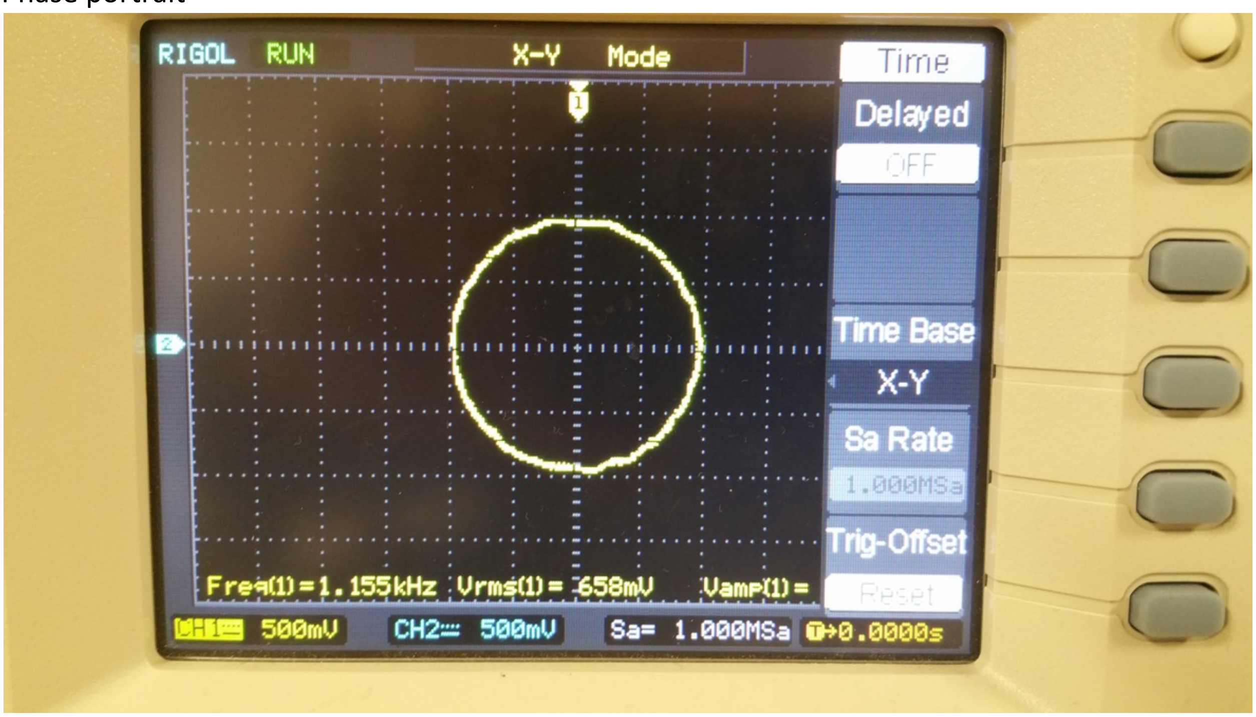
(3) Offload the spectrum data using a USB drive. (After lab time) Plot the data using a Python script.

D Phase Portrait Representation

Signal and differentiated signal



Phase portrait



(1) Pull and measure the components for the differentiator circuit.

Predict the signal output amplitude and phase relation to the signal input.

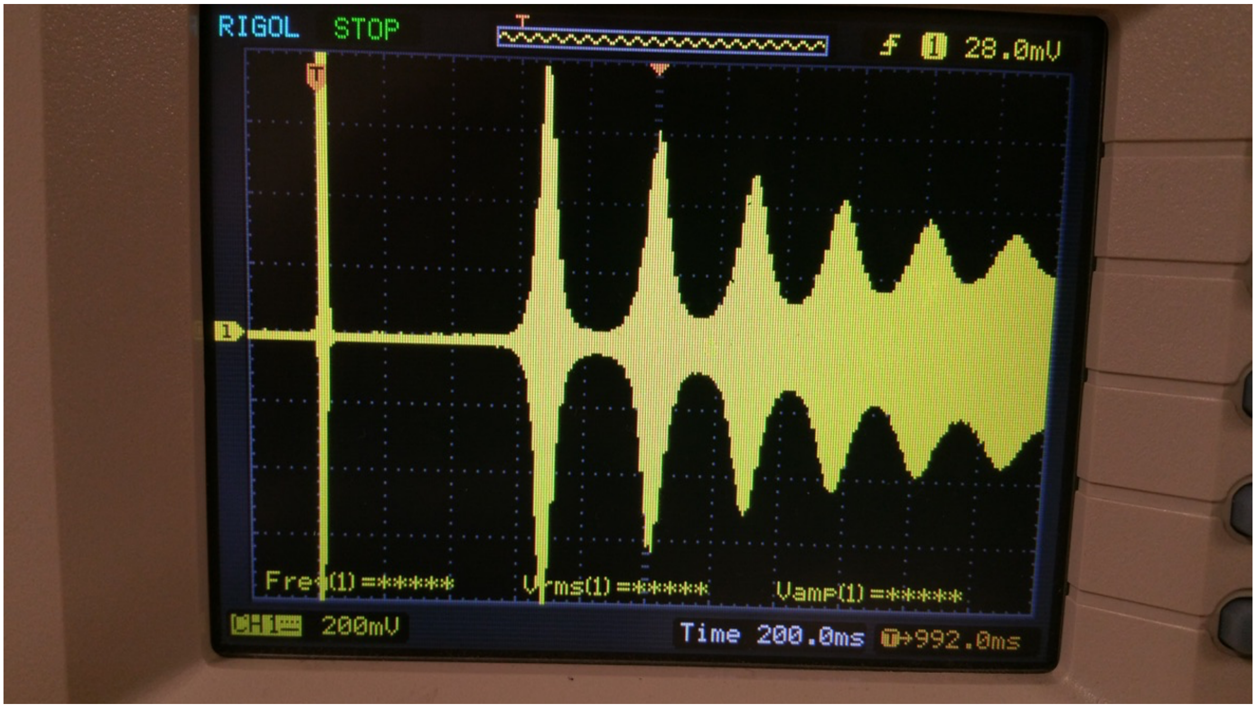
(2) Pass the output signal through the differentiator circuit. Set up a two-channel trace on the oscilloscope: Channel 1 is oscillator output and Channel 2 is differentiator output.

(3) Measure the signals and relative phase using two channels on the oscilloscopes and the internal amplitude functions. Take a photo of the screen display.

(4) and set up an XY trace on the oscilloscope. Obtain a phase portrait of the oscillation. Take a photograph of the screen display.

(5) Offload the two-channel data using a USB drive. (After lab time) Plot the data using a Python script.

E Threshold Behavior: Squegging



(1) Adjust the decade box value to just below onset

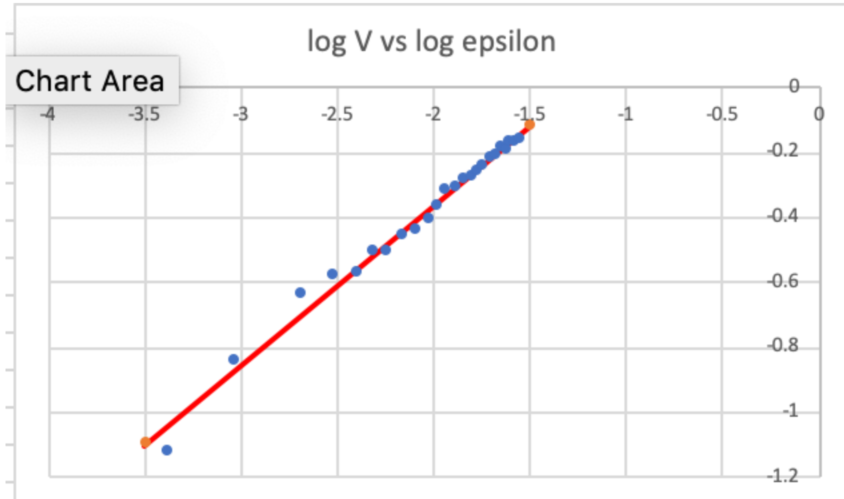
(2) Switch the decade resistance up by 10 ohms. You should see the signal wobble and then stabilize. Turn the time base to very long (e.g. 0.5 second per division). Switch the decade box down 10 ohm and then back up 1 ohm. You should see the envelope of the squegging.

(3) Capture a squegging trace using a single shot trace.
NEED TO WORK OUT A TRIGGERING PROTOCOL
Take a photograph of the oscilloscope screen. Download the trace using the USB drive.

(4) Turn the gain down to below threshold. Obtain a squegging trace for each 1 ohm increment up to 10 ohms in the gain setting. Photograph the screen and download the trace each time.

(5) Measure the time between spacing between squegging peaks.

F Threshold Behavior: Investigating Amplitude Growth



(1) Dismount the nichrome slide wire and measure its resistance across a measured length. Determine the resistance per unit length in milliohms per mm. Measure the diameter of the slide wire and calculate its resistivity. How does this compare to published values for type 80 nichrome wire?

(2) Set up the slide wire potentiometer in series with the decade box. Adjust the decade box to just below onset (within 1 ohm). (Alternatively: use a decade box with 0.1 ohm steps)

(3) Find the slide wire distance where onset just occurs. Do this several times over a half hour to determine repeatability. Come from below and above onset: are the results the same within uncertainty? (Alternatively: if available, adjust the 0.1 ohm steps of the decade box to obtain onset.)

(4) Set the slide wire just below onset. Now advance the slide wire in 30 roughly 1cm increments, recording the amplitude using rms measures. Create a table: slide wire position and rms amplitude.

(5) Write down a formula for how you will calculate epsilon (the dimensionless threshold parameter) from the slide wire position, slide wire resistance per unit length, decade box resistance, and light bulb cold resistance.

(6) Convert your table to epsilon and sine wave amplitude.

(7) Plot amplitude versus epsilon.

(8) Create a table of log10 (epsilon) and log10(amplitude). Plot log10(amplitude) versus log10(epsilon).

(9) Do a linear least-squares fit to obtain slope and intercept. Be sure to include uncertainties in the outcome values.

(10) Interpret the slope in terms of a fundamental model for the Wien Bridge oscillator near onset.

(11) Interpret the intercept in terms of a fundamental model for the Wien Bridge oscillator near onset.

G Amplitude over a wide range of gains

(1) With the slide wire and decade box set to just achieve a signal, measure the starting amplitude.

(2) Increment the decade box in 1 ohm steps, then 10 ohm steps, and then 100 ohm steps until the signal shows signs of saturation (leveling off at the extremes). Create a table of gain resistance and rms amplitude.

(3) Record a photograph of the saturated signal.

(4) Explain why saturation is occurring.

(5) Convert data to epsilon and sine wave amplitude.

(6) Plot amplitude versus epsilon.

(7) Plot amplitude versus epsilon.

(8) Create a table of log10 (epsilon) and log10(amplitude. Plot log10(amplitude) versus log10(epsilon).

(9) Do a linear least-squares fit to obtain slope and intercept. Be sure to include uncertainties in the outcome values.

(10) Comment on how the slope compares to the value obtained near onset.

(11) Recompute slope for different numbers of data points. Plot slope versus maximum epsilon. Is there an asymptote for small values of max-epsilon?