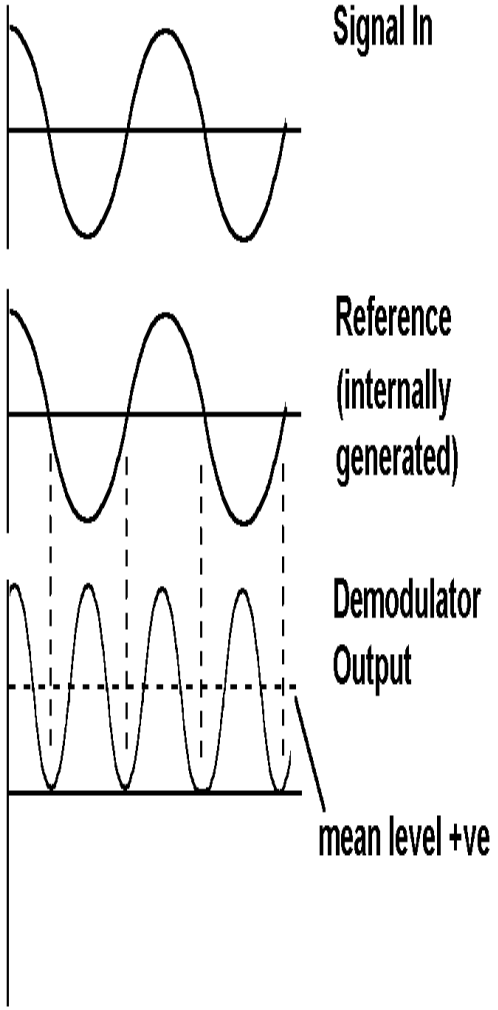
# How to make a Lock-in Amplifier

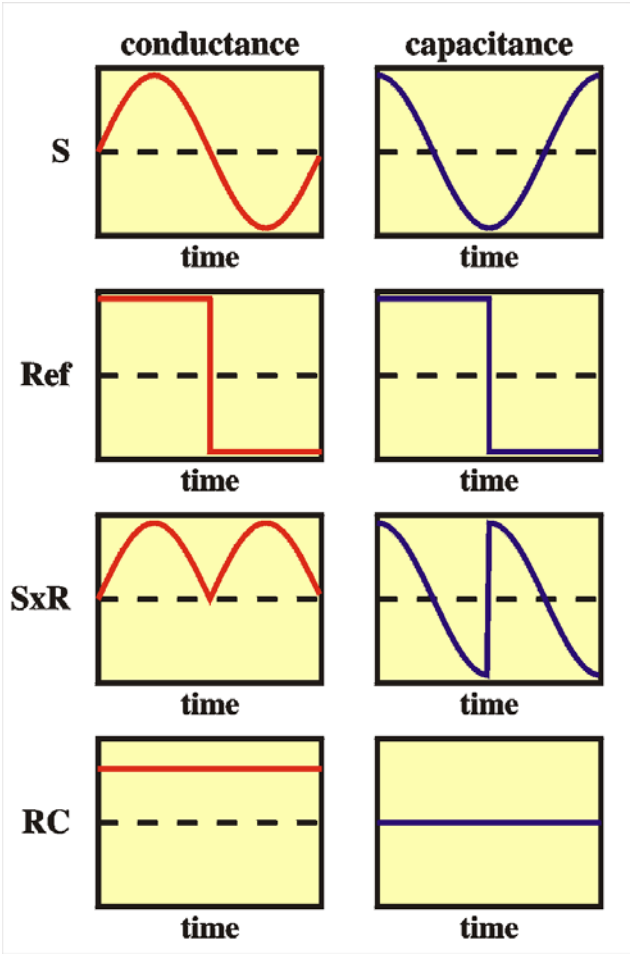
By Sultan Abdul Wadood

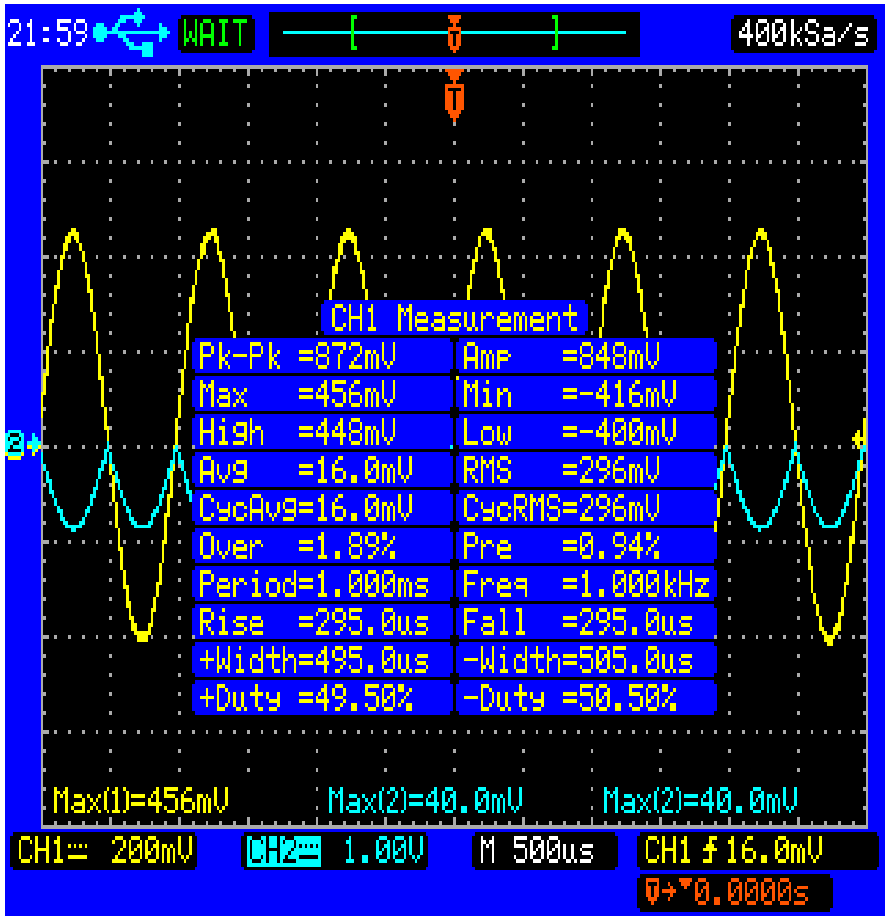
# Introduction

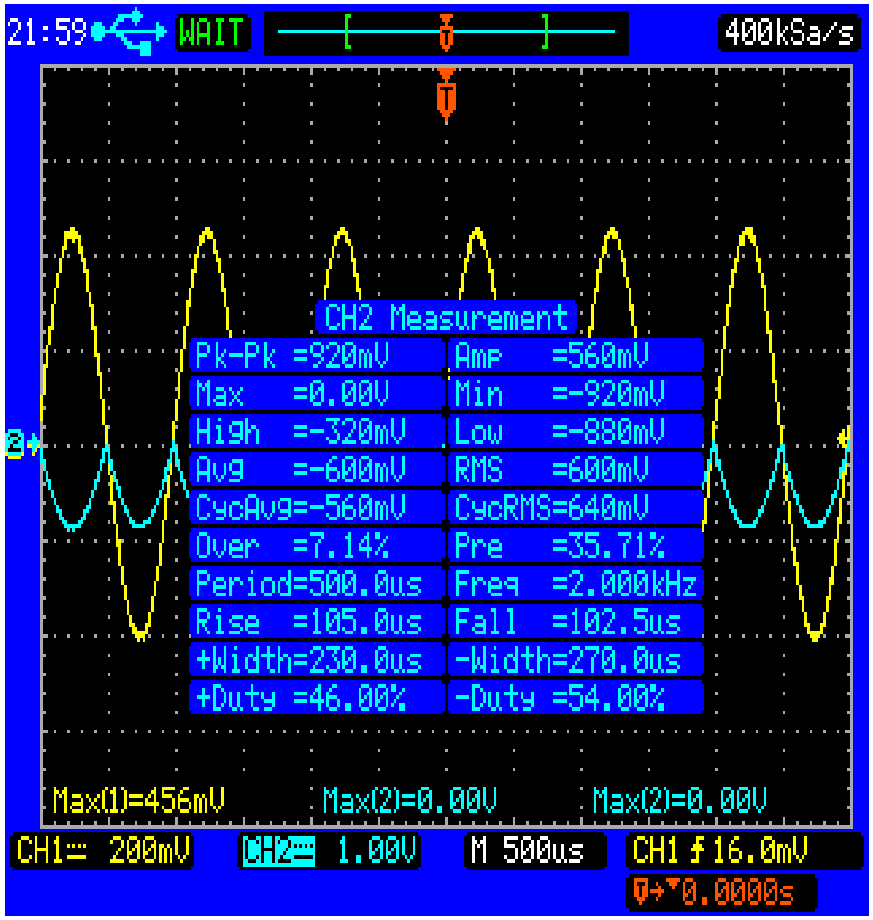
- Used to recover a small signal buried in a large noise
- Uses phase sensitive detection

# Phase Sensitive Detection




21:59
WAIT
400kSa/s
CH1 Measurement
Pk-Pk =872mV
Amp =848mV
Max =456mV
Min =-416mV
High =448mV
Low =-400mV
Avg =16.0mV
RMS =296mV
CycAvg=16.0mV
CycRMS=296mV
Over =1.89%
Pre =0.94%
Period=1.000ms
Freq =1.000kHz
Rise =295.0us
Fall =295.0us
+Width=495.0us
-Width=505.0us
+Duty =49.50%
-Duty =50.50%
Max(1)=456mV
Max(2)=40.0mV
Max(2)=40.0mV
CH1 200mV
1.00V
M 500us
CH1 f 16.0mV
0.0000s


21:59
WAIT
400kSa/s
CH2 Measurement
Pk-Pk =920mV
Amp =560mV
Max =0.00V
Min =-920mV
High =-320mV
Low =-880mV
Avg =-600mV
RMS =600mV
CycAvg=-560mV
CycRMS=640mV
Over =7.14%
Pre =35.71%
Period=500.0us
Freq =2.000kHz
Rise =105.0us
Fall =102.5us
+Width=230.0us
-Width=270.0us
+Duty =46.00%
-Duty =54.00%
Max(1)=456mV
Max(2)=0.00V
Max(2)=0.00V
CH1 200mV
1.00V
M 500us
CH1 f 16.0mV
0.0000s

- Mixer and Multiplier
- Product of two sinusoids(f1 and f2) is a signal containing two parts:

$$A\sin(\alpha t+\varphi 1)*B\sin(\beta t+\varphi 2)=\frac{AB}{2}\left(\cos(\alpha-\beta)+(\varphi 1-\varphi 2)\right)-\left(\cos(\alpha+\beta)+(\varphi 1+\varphi 2)\right)$$

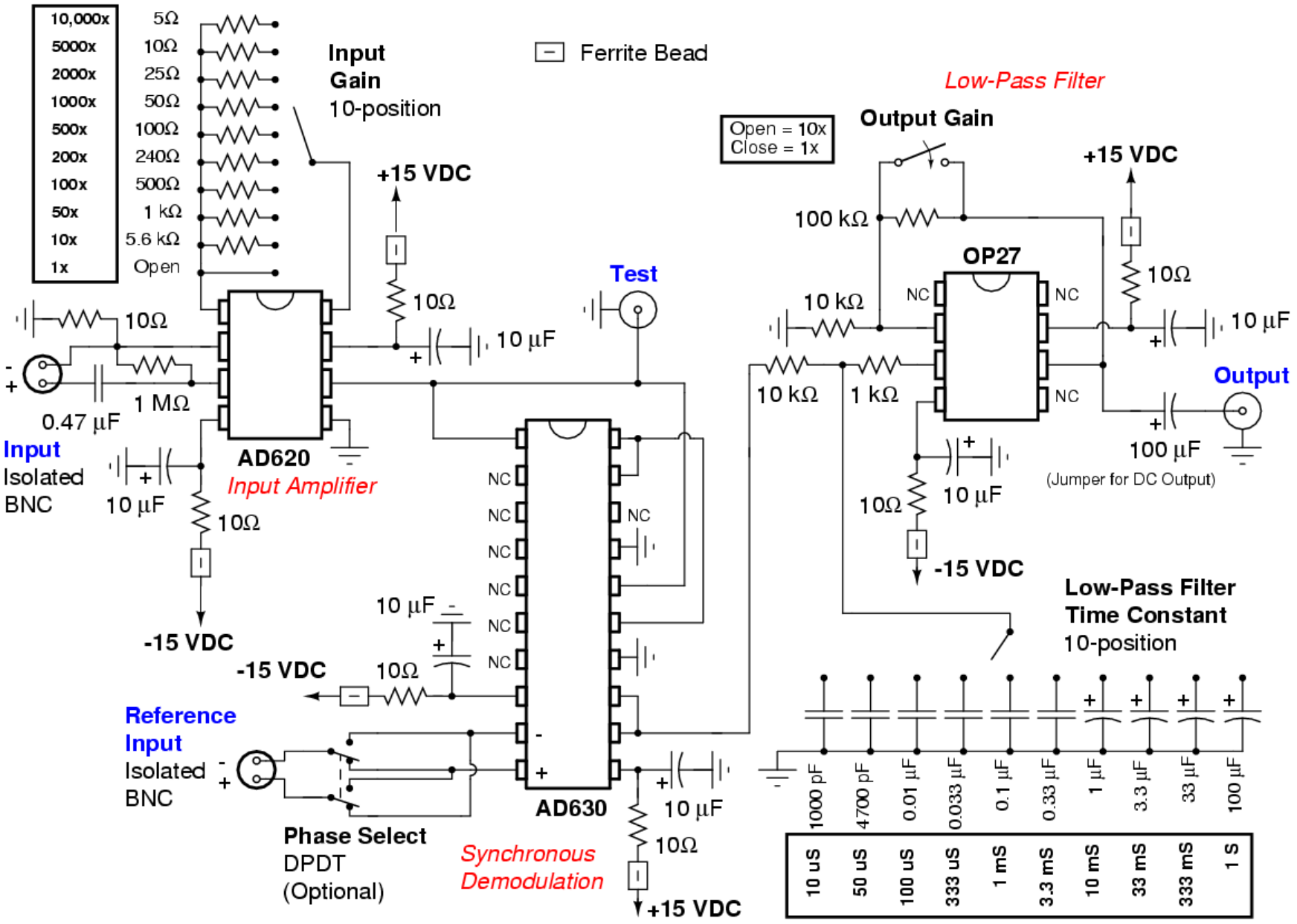
- A mixer, instead multiplies the incoming signal with a square wave.(like AD630).

# Home Brew Lock-in Amplifier

- Four Parts:

1. Input Amplifier (AD620)
2. Mixer (AD630)
3. Low Pass Filter (Single Pole)
4. Output Amplifier (OP 27)

# Lock-In Amplifier



# Noise and Other Terms

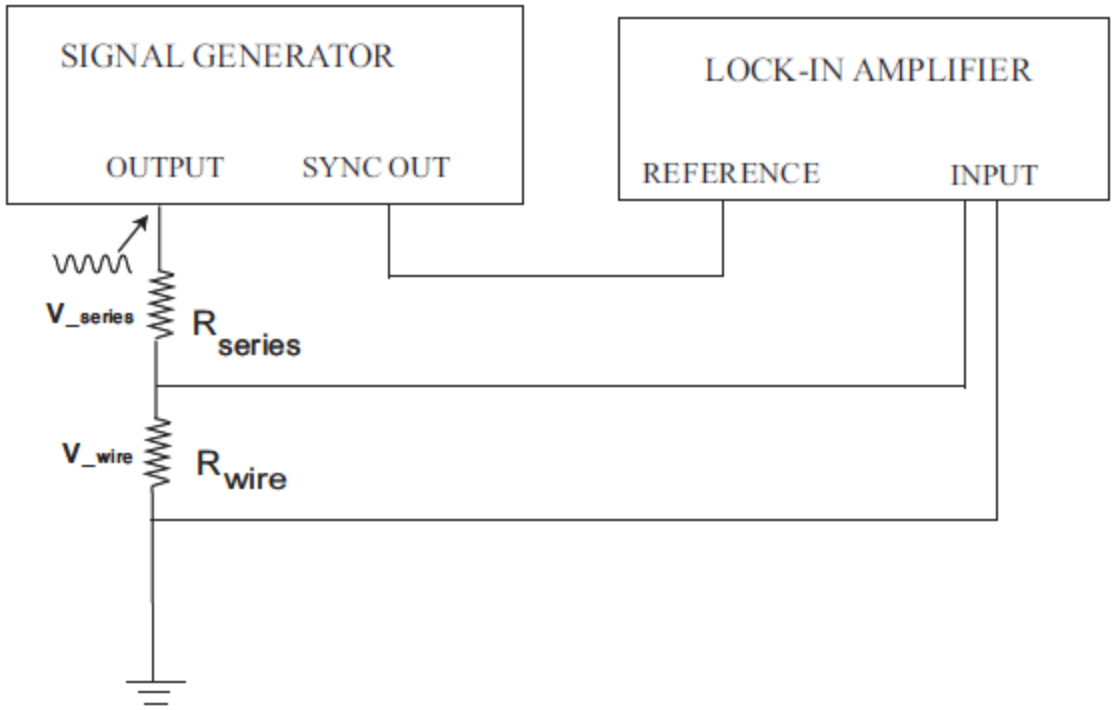
- Many types of noise but we have restricted ourselves to White Noise and 1/f noise.
- Inherent Worst noise figure of 75.83µV.
- Dynamic Reserve= Ratio of Overload level of noise to full scale input signal
- SNR:Signal to Noise Ratio

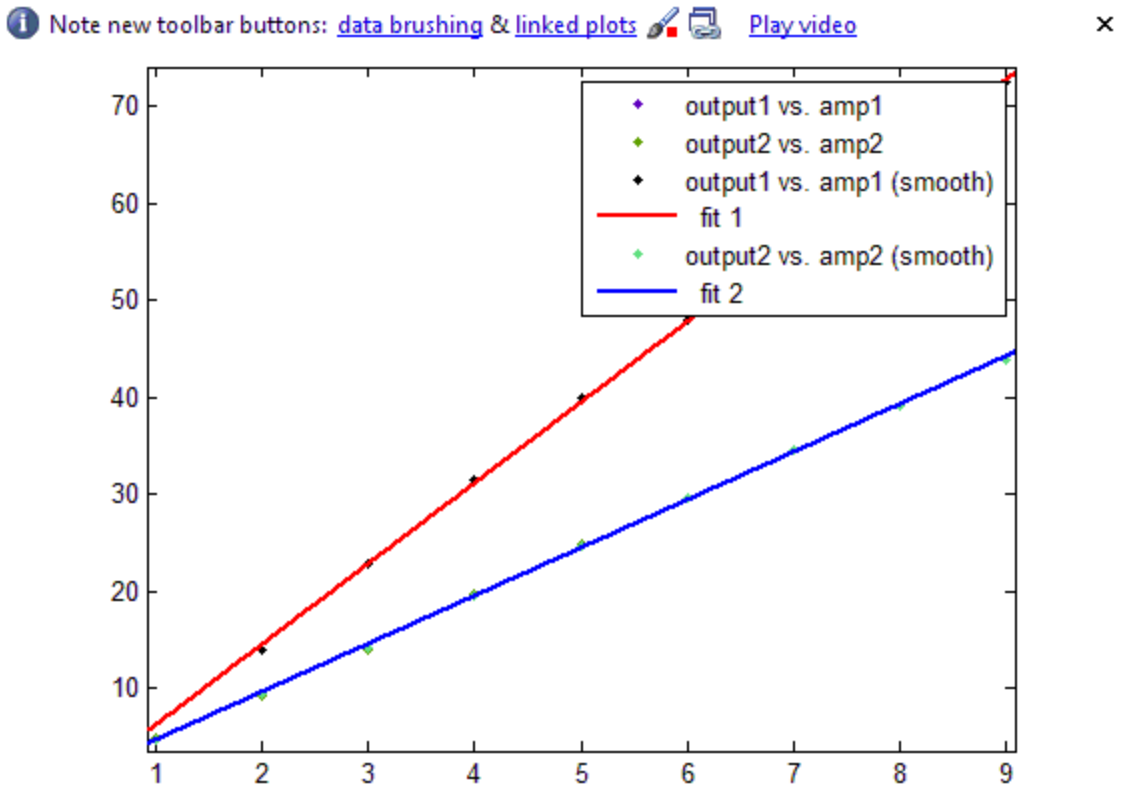
# Experiment and Testing

- Signal Recovery:
- SNR =40-60dB(Signal of 10mv(amp) and Noise of 1V-10V(amp)

  60% of the signal is recovered.(4.2mV)
- Fourier Series and Beats

- Measurement of resistance of a wire



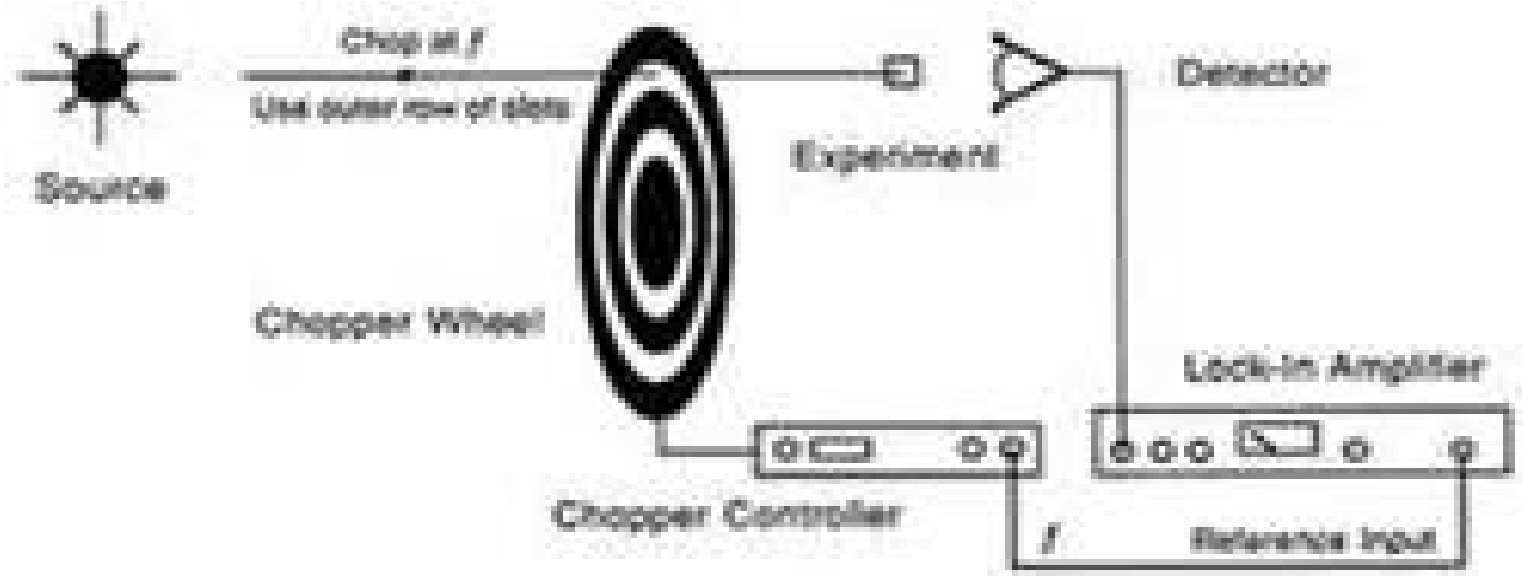



Y-axis: Voltage drop across wire in mV.

X-axis: Amplitude of Source

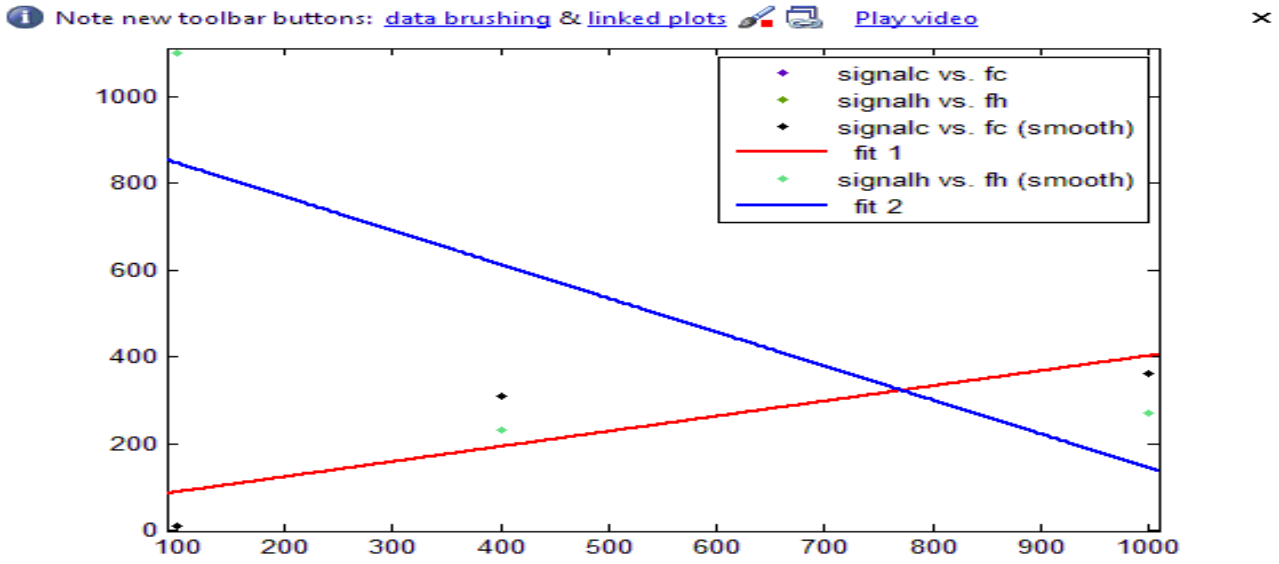
- Commercial:22.3mOhm
- Homebrew:14m Ohm
- Erroneous Results.

- Optical Chopper Experiment:




Single Beam Experiment

# Good results at higher frequencies. A deeper look into the experiment.




Y-axis: Signal rms in mV.
X-axis: Chop Frequency

# Results

- Large Deviation from the Commercial Lock-ins.
- Cursory measurements to be avoided.
- Further Testing required.
- Improvements like PLL, dual phase,phase shifter etc. can be made.

# Acknowledgements


- Dr Sabieh
- Sir Wasif
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- Mr. Yousaf
- Mr. Ali
- All Physlab staff