ELECTRONIC FEEDBACK SYSTEM FOR STABILIZATION OF FIBER INTERFEROMETER

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Abstract— When a constant laser light passes through the fiber interferometer we expect the constant output intensity but due to temperature fluctuations and mechanical vibrations the phase of the light passing in one of the arms changes with respect to another and we get the drift in the output voltage. Conventionally lock-in amplifiers are used but they are expensive and complex. Hence, we have designed an electronic feedback system to compensate the drift in the output voltage.

Keywords—Feedback, frequency, Noise, VCO.

I. INTRODUCTION

The basic aim is to stabilize the output intensity of Interferometer. When the light passes through the Interferometer through one of the input end, there should be constant output intensity but due to temperature drift and mechanical vibrations we get fluctuations/drift at the output voltage. Hence our aim is to minimize the fluctuations by the use of electronic feedback system.

In this documentation we have simulated and shown that how the feedback system can stabilize the output variations.

II. PRINCIPLE AND CONFIGURATION

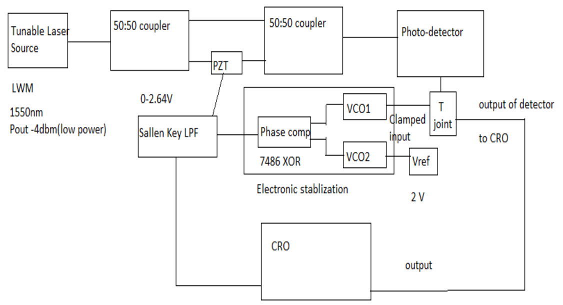


Fig.1. Configuration of stabilization of Interferometers

The above diagram shows the electronic feedback system for the stabilization of the interferometer. The feedback system consists of two VCO's, a phase comparator and a low pass filter whose output when given to Piezo-electric transducer (PZT) changes the length of the fiber to compensate for fluctuations.

When the laser light passes through the input end, we get the intensity fluctuations at the output end and when given to photo-detector will produce voltage fluctuations which we take as our error signal. This error signal is given to one of the VCO's which generates the frequency (f0) and we give a constant reference voltage to second VCO which also generates the frequency (fr) and now these are compared by the phase comparator for the phase variations and as we know the phase variations would have occurred because of the drift hence an error signal is generated whose envelope is taken by the low pass filter of suitable cut off frequency. This signal is given to PZT which changes the length of the fiber to compensate for the phase variations to cancel out the fluctuations. We get the maximum phase variation from the PZT when the output of the filter is more which in turn depends on the output frequency f0 of VCO1 which in turn depends on the error signal.

III. SIMULATION USING MATLAB-SIMULINK

A. Sinusoidal Noise

The simulation for the electronic feedback system has been done to show that the feedback system can compensate for the fluctuations at the output of interferometer to get a constant DC output of one of the port of it.

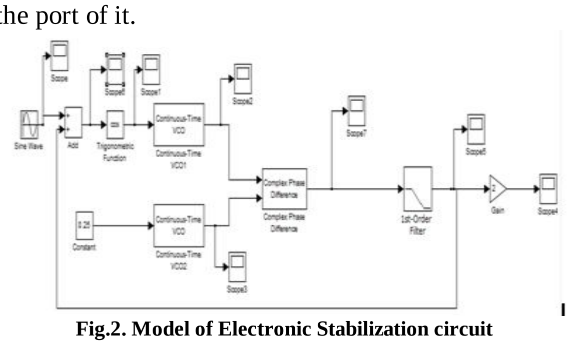


Fig.2. Model of Electronic Stabilization circuit

The above model shows the simulated implementation of the feedback circuit. In this let us assume the output variations of the interferometer be sinusoidal i.e. let the fluctuations be sinusoidal (amp: 0.4 V and Freq: 0.16 Hz) in nature. Now our aim is to produce a signal which is exactly opposite to it so that when fed back it could cancel the fluctuations to get the constant output signal. So initially the input sine wave is given to the cosine block. Here the cosine block represents the dependency of the fluctuations on the cosine function when given to the photo-detector. We know that the photo-detector only sees the power hence the variation of the phase will be visible inside the cosine function. Now these variations are given to the VCO (center freq: 40Hz and output amplitude 0.5V) which produces the frequency according to the input voltage. Also we take the reference constant voltage of 0.25V and give it to other VCO (center freq:40Hz and output voltage 0.5V) to produce frequency according to voltage.

These frequency variations are given to phase comparator block which compares the phase difference between the two frequency signals. After that the signal is given to the Low pass filter which is a 1st order filter of time constant 5*10^-2 (R: 10K and C 5pF). The low pass filter computes the envelope of the output of the phase comparator block and produces a signal which is opposite to the error signal and is given back to the input and now when added produce a constant signal which is the compensated output. The output of the filter is given to the amplifier of gain 2 to produce the voltage from 0-4V which is required to produce the phase change for PZT by pi. Hence we get a constant output from scope6.
The simulation results are shown below:-

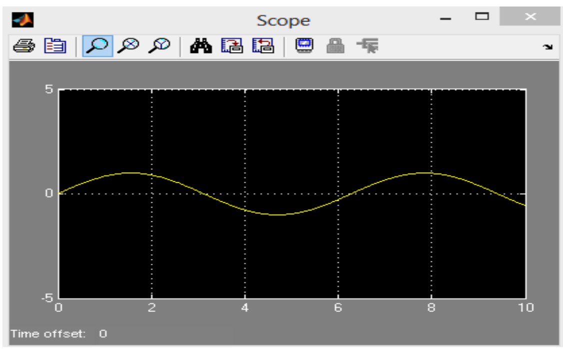


Fig.3. Sine wave fluctuation with amp 0.4 V and freq 0.16Hz

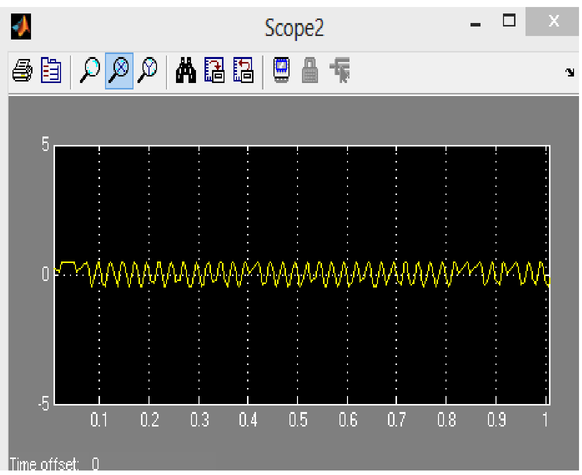


Fig.4. Vco1 output for input fluctuations (center frequency 40Hz and output amp 0.5V)

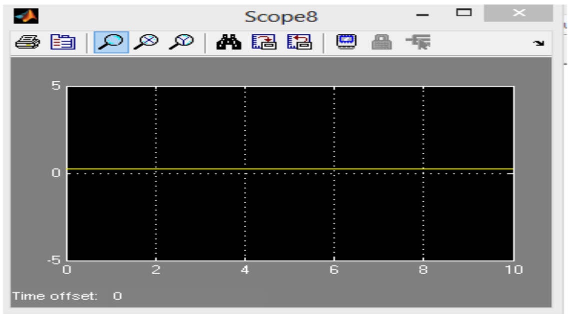


Fig.5. Scope 8: Reference voltage 0.25V

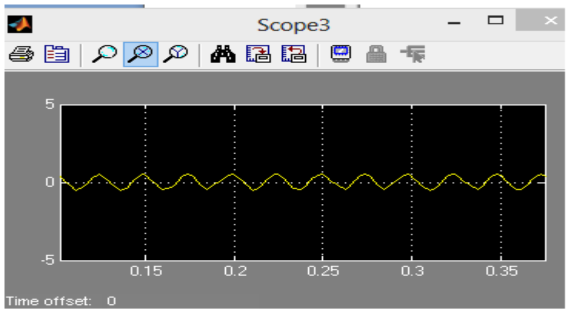


Fig.6. Scope 3: VCO 2 output(of same freq and sensitivity)

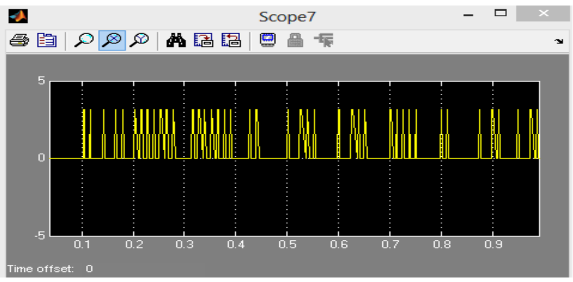
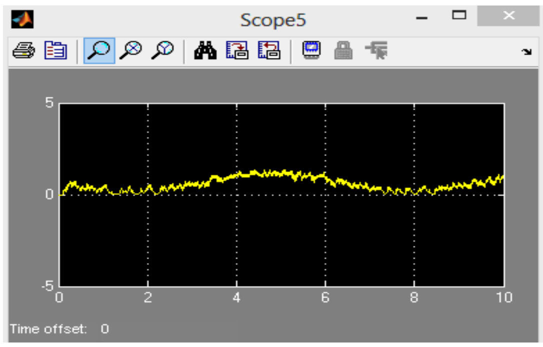


Fig.7. Output of the phase detector showing the difference in the phases of both the VCO output frequency signals.



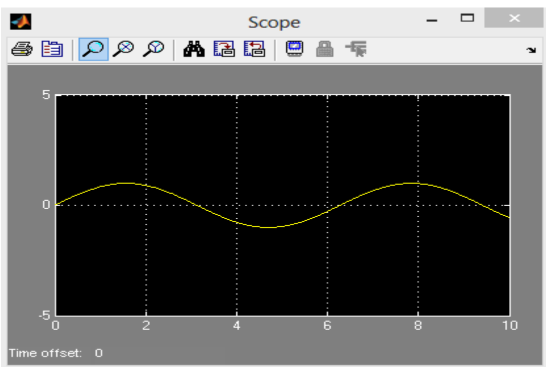


Fig.8. Scope 5: Low pass filter output producing a signal opposite to the error sine wave signal (Scope) to be fed back to produce the constant output signal.

From this we get that our feedback system has generated a feedback signal which is exactly opposite to that of the variation hence when added would compensate for the variations.

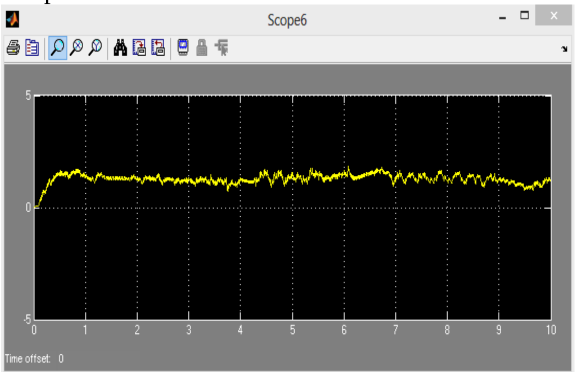


Fig.9. Scope 6:- it shows the constant output signal i.e. compensated signal

Hence the simulation shows that we have compensated for the phase variations in the input signal.

B. Gaussian noise

As the noise is random now we use a Gaussian noise generator as a source and examine how our stabilization circuit works.

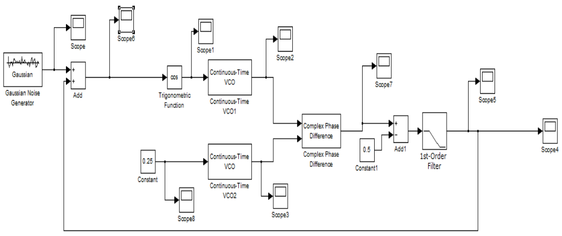


Fig.10. The circuit with Gaussian noise of 0 mean and variance 0.4 with initial seed 41 and sample time 1 sec

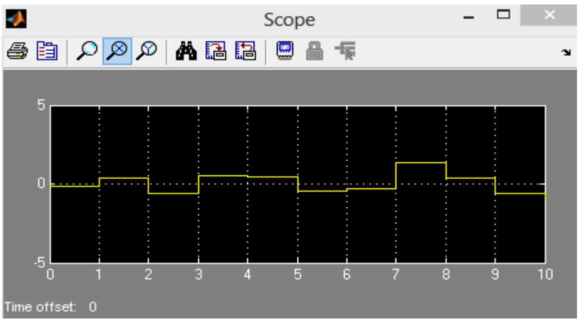


Fig.11. Gaussian noise

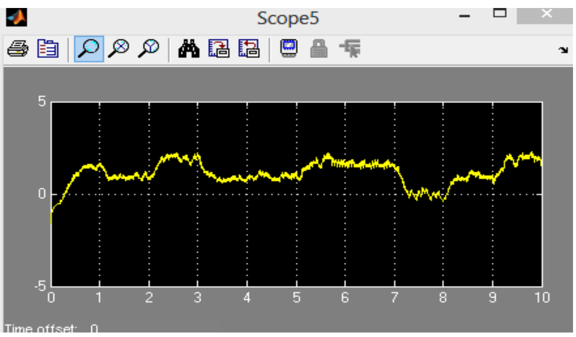


Fig.12. Output of low pass filter opposite to that of the noise.

This is fed back to the input and when added with the input variation produces the constant output voltage.

Fig.13. The constant output of the circuit.

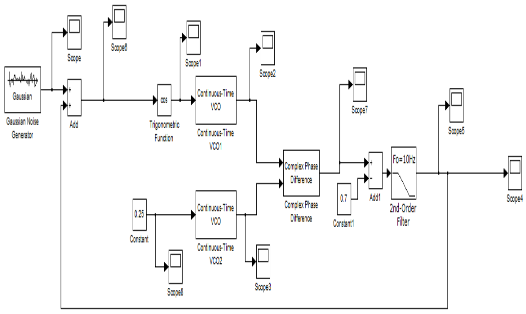


Fig.14. In the above circuit we took a 2nd order low pass filter with a cut off freq of 10Hz.

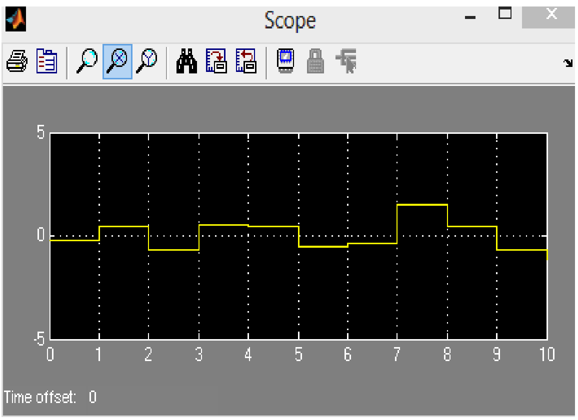


Fig. 15 Input, which is Gaussian noise of mean 0 and variance 0.4

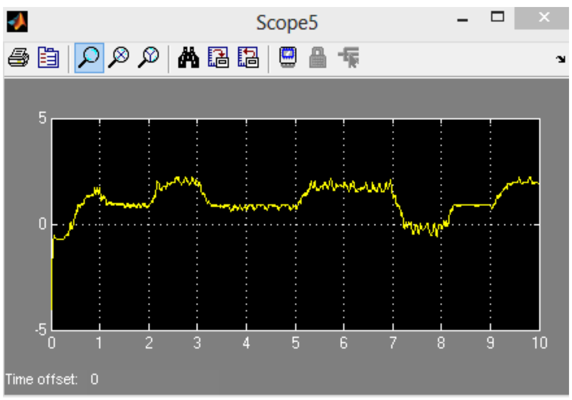


Fig.16. Output of the second order filter which is opposite to that of input and more stable than the output of first order filter.

Fig.17. Stable output of the circuit.

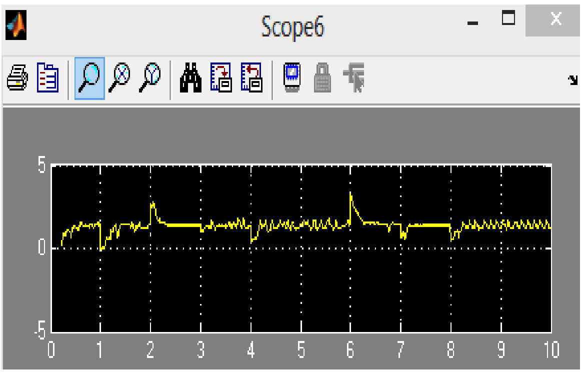


Fig.18. Lesser the variance more stable is the output.

C. Intermediate Noise

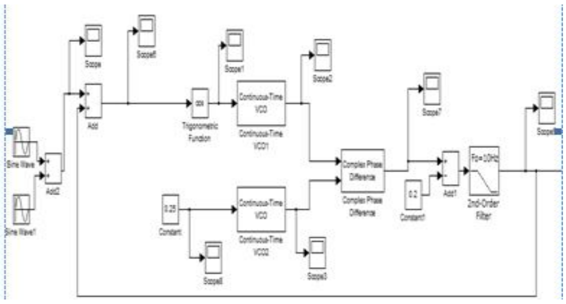


Fig.19. Two sine waves of different frequencies.

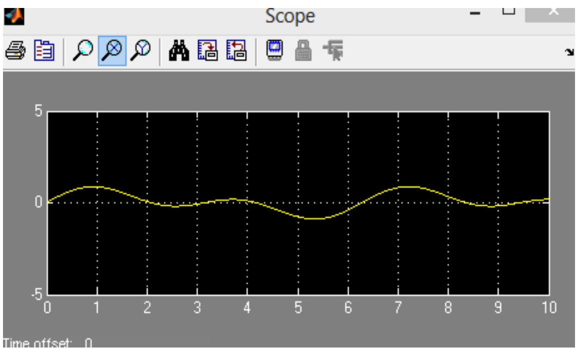


Fig.20. Initial input variation

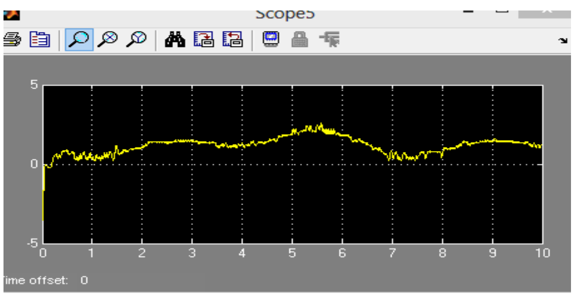


Fig.21. Output of the low pass filter.

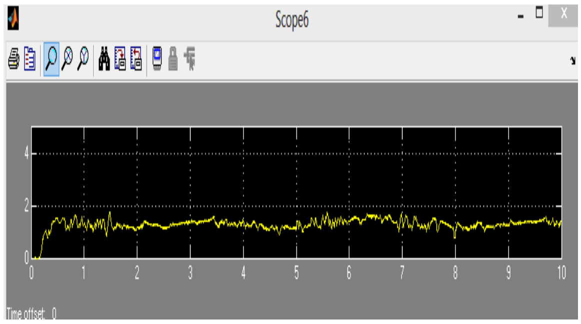


Fig.22. Output stabilized signal.

IV. PRACTICAL IMPLEMENTATION:-

We characterized **VCO** output for different center frequencies and then saw its response for various input voltages.
In the datasheet for VCO PLL CD04HC4046A we found that for proper operation of VCO the resistance should be within 3k to 300k and capacitance should be greater than 40pf.
For the operation to be little fast we kept the center frequency as 50Hz with resistance of 3.2K and capacitance 1uf.

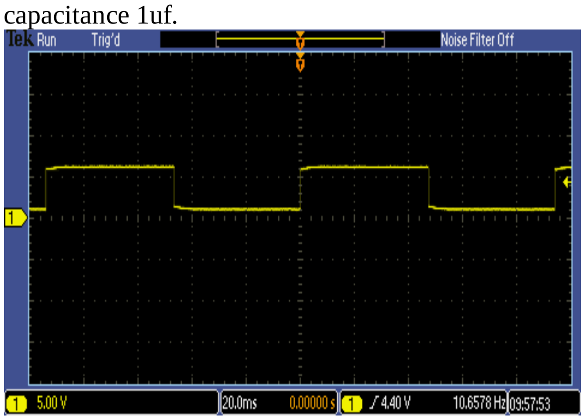


Fig.23. VCO output frequency for input 0.8 volts.

It is the minimum voltage at which VCO starts varying the frequency based on the input voltage.

We kept the frequency at 40 hz with voltage 1.8 volts.

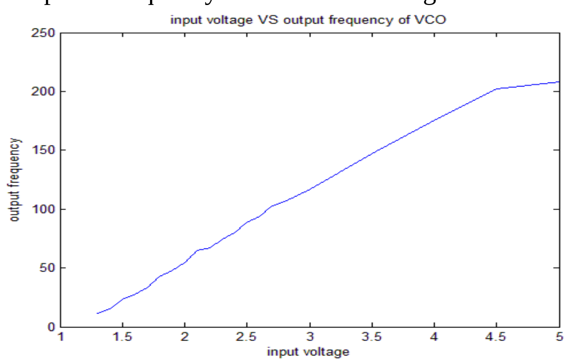


Fig.24. Above graph is without the use of clamper circuit for input voltage VS output frequency.

Then we used **the TUNABLE laser source of 1550nm from LWM** and saw the steady drift in the output voltage.

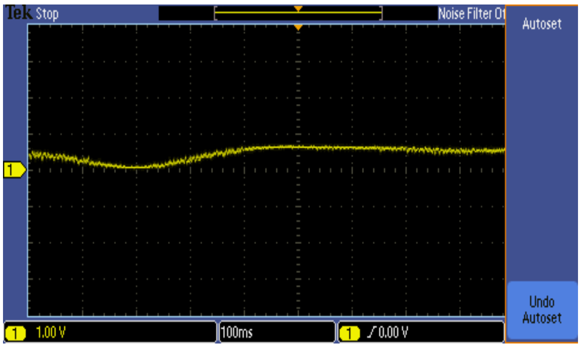
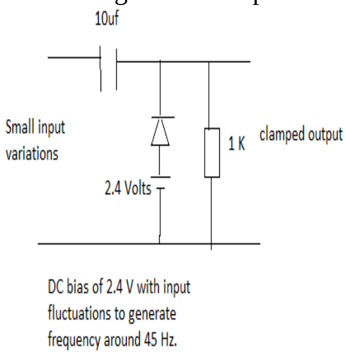


Fig.25. The drift in Laser output.

The above figure shows the small drift in the output of the laser. But since the drift is in millivolt range WE used the clamp circuit to clamp the variation to 2.5 Volts so that it may vary around 45 Hz which would result in fast
operation and tracking could take place.



FFig.26. Clamper circuit which clamps the input variations to vary around 2.4 volts.

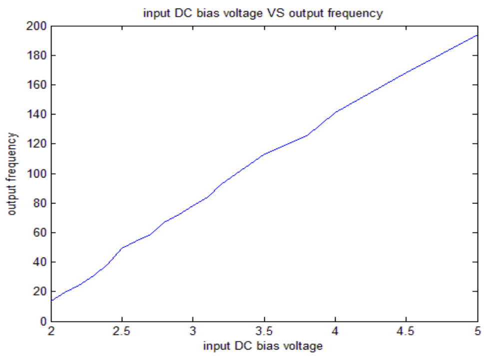


Fig.27. Above graph shows when we use the clamper circuit the minimum input voltage required to produce the same output frequency as in case without the clamper circuit increases.

1. The final circuit connection is as shown bel

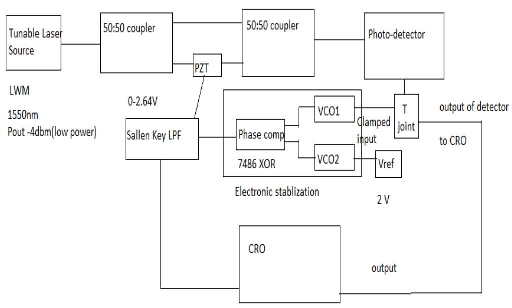


Fig.28. The overall block diagram of the circuit

In the above diagram the input from the TLS is given to 50:50 coupler and then split into two. Here Piezo is connected to one end for phase shift. Then another 50:50 coupler recombines the waves. The output then goes to the photo-detector producing the power. The output of the photo-detector has drift due to environment disturbances. This output since being small is clamped to 2.4 volts and given to one VCO of center frequency 45 Hz and another VCO is given a constant reference voltage of 2.4V. Then the output frequencies are given to phase comparator (XOR 7486) which gives the difference frequency signal whose envelope is detected by Sallen Key LPF with cut-off frequency of 8.76Hz. This produces the signal with voltage range 0-2.6 volts and is given to PZT to produce the phase change according to the voltage given.

Hence the output drift from the photo detector should decrease and we should get the constant **output**.

The following image shows the **output from the photo-detector** when the circuit is operating. The following images contain **the output of Photo-detector and the Sallen Key filter for different time scales.**

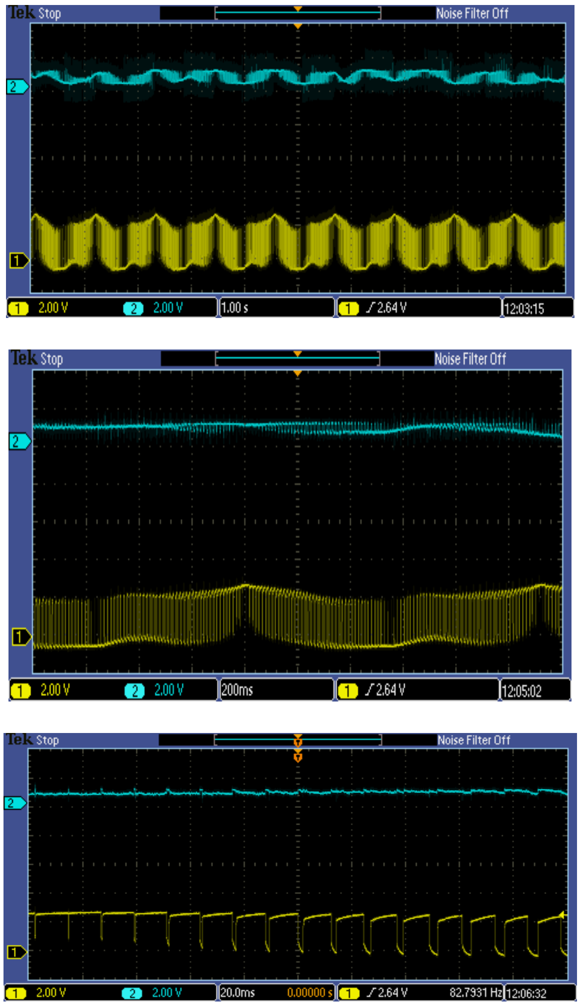


Fig.29. Channel 1 Low Pass Filter Output for different time scales (Yellow colour) Channel 2 Photo detector output (Blue colour)

Sallen Key Low Pass Filter has been used as it has very high attenuation in the stop band.

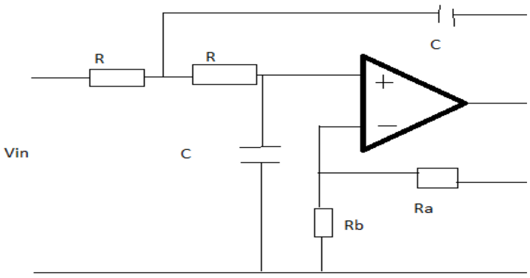


Fig.30. Sallen Key filter.

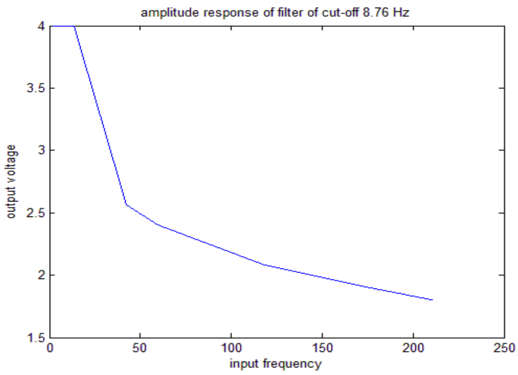


Fig.31. Above graph shows the amplitude response of the Sallen key filter for cutoff 8.76 Hz. PIEZO-ELECTRIC TRANSDUCER

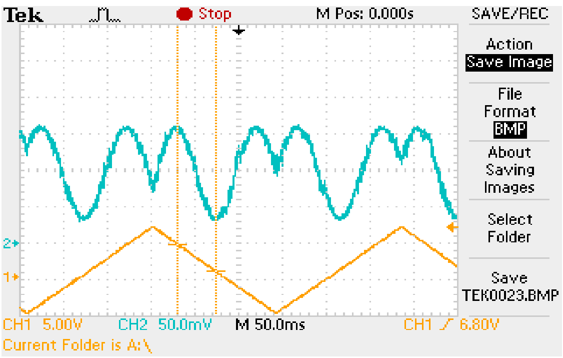


Fig.32. PZT having phase change from 0-pi for 0-3.6 volts

Also we tried with 1st order LPF with cut-off 15hz and output voltage varying from 0- 3.6 Volts to produce the change in phase of Piezo from 0-pi.

RESULTS

The output was as follows:-

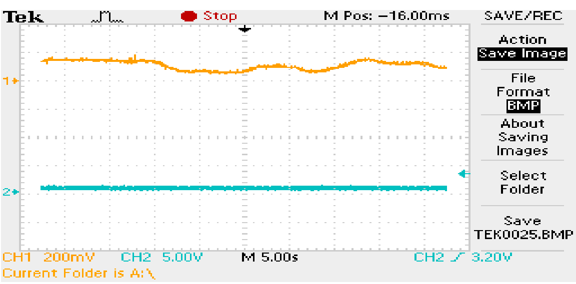


Fig.33
CH2: input fluctuations
CH1: LPF output

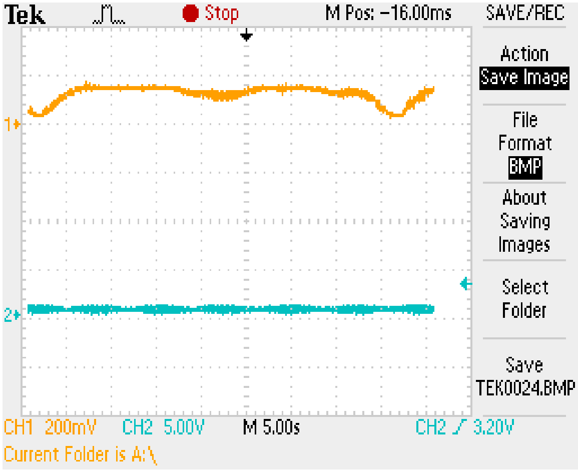


Fig.34. CH2: output voltage at different time-scale of the stabilized signal.

V. FINAL SET-UP PHOTOGRAPH

CONCLUSION

Hence we were able to design the electronic feedback circuit which was able to stabilize the laser source for 3.6 sec. This may not appear much but since light has very large bandwidth is enough to allow large mega bits of data to pass. Hence we could implement it in designing optical gates in which stabilization is extremely important to check for bit errors. Hence in the end we were able to design a cost effective means to stabilize the fiber interferometers.

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