October 2012

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Recommended Citation

Bhushan, Gaurav; Rangoonwala, Adnan; Khan, Aalim; and Bhowmick, Shomnath (2012) "Oscillation control electronics for a Quartz Tuning Fork Atomic Force Microscope (AFM)," *International Journal of Electronics and Electrical Engineering*: Vol. 1 : Iss. 2 , Article 15.

DOI: 10.47893/IJEEE.2012.1029

Available at: <https://www.interscience.in/ijeee/vol1/iss2/15>

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Oscillation control electronics for a Quartz Tuning Fork Atomic Force Microscope (AFM)

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Abstract:

This paper presents oscillation control electronics for Frequency Modulation Atomic Force Microscope (FM-AFM). It presents a Phase Locked Loop circuit performing the function of Frequency Control and its complete analysis.

Keywords- Phase Locked Loop, Frequency Modulation, resonance, resolution, frequency control.

I. INTRODUCTION

Atomic force microscopy (AFM) is a technique to obtain surface profile images and other information from a wide variety of samples, at extremely high (nanometer) resolution. It is based on detection of atomic forces by a nanometric tip attached to a micro cantilever. Frequency modulation (FM) AFM is the most recent and advanced operation method.

In FM AFM, micro cantilever is excited at mechanical resonance and tip surface interaction modifies resonance frequency and amplitude. Electronic system is used to sense the change and apply feedback. Commercially available systems are complex and costly. Quartz tuning fork is a replacement to micro- cantilevers, is simple as it gets rid of optics and is inexpensive. The immediate objective of this research project is to develop low cost electronics for quartz tuning fork AFM. We have very stringent requirements for the electronics - stability of 0.1 Hz/°C, resolution 0.01Hz in a bandwidth of 100 Hz. This summer electronics has been analyzed, developed and various experiments were performed to characterize. The major part of electronics revolves around Phase Locked Loop (PLL) IC NE/SE 567 which performs the basic function of frequency control in combination with a phase shifter. We will present performance data of the electronics and discuss its merits and limitations.

II. APPLICATIONS

Image the non-conducting surfaces, in biosciences help in DNA and RNA analysis, Proteins and peptides, Cellular membranes. Cell biologists used AFM's to study the dynamic behavior of living and fixed cells such as red and white blood cells, bacteria, platelets, cardiac myocytes. The high technology industries used AFM in semiconductors, data storage and advanced optical devices. AFM plays a critical role in many high technology products such as cameras, video recorders, and flat panel displays.

Fig. 1 Cancer Cells 78 x 78 microns.

IV. EXPERIMENTAL RESULTS

Fig. 2 Electronics for use in Frequency Modulation Mode Quartz tuning fork AFM

III. FM-AFM

Fig. 2 shows Frequency Modulation Atomic Force Microscopy (FM AFM) method of operation. As shown in Fig. 2, Phase Locked Loop (PLL) performs the function of frequency control. In FM-AFM, the cantilever stays close to the sample all the times, and has much smaller oscillation amplitude [4]. FM-AFM (noncontact AFM) is more sensitive to small oscillations of the cantilever, so may be operated in close contact (almost touching). FM-AFM, unlike the other AFM techniques can obtain true atomic resolution images. AM-AFM is typically used for tapping mode - where the tip actually taps the sample during each oscillation. While in the other mode i.e. FM-AFM the cantilever tip and sample interactions are more sensitive and we can obtain much better resolution compared to AM mode. A phase-locked loop or phase lock loop (PLL) is a control system that tries to generate an output signal whose phase is related to the phase of the input "reference" signal. This circuit compares the phase of the input signal with the phase of the signal derived from its output oscillator and adjusts the frequency of its oscillator to keep the phases matched. The signal from the phase detector is used to control the oscillator in a feedback loop.

PLL is obtained using an IC NE/SE 567 that works on low frequency ranges (0.1 Hz-500 KHz) and center frequency can be set by doing minimal adjustments. For atomic resolution phase difference of 90° is needed which gives you maximum sensitivity. AFM is able to trace any changes in resonant frequency and that is sensed by the Phase change happening at Phase Detector output of the PLL.

Fig. 3 Input and Output Waveform in locked condition for a Quartz Tuning Fork AFM system.

Fig.4 Power Spectrum Waveform (obtained using LAB VIEW program) of Phase Detector Output for Atomic Force Microscope

V. STABILITY ANALYSIS

For the PLL system, it's a 2nd order system and it is very much important to find out the stability of the system under various conditions and for which various experiments were carried out. From mathematical calculations, it can be shown that,

$$\frac{\Delta\theta}{f_i}(DC) = \frac{1}{K_p K_v}$$

VI. EXPERIMENTAL RESULT

As $(\Delta\theta/\delta)$ gives $1/K_p \cdot K_v$ so, $1/K_p K_v = 6.3$ which gives $K_p K_v$ as approx. $= 5.7 \cdot 10^4$ (order of 10^4).

VII. PLL SYSTEM TRANSFER FUNCTION

The transfer function experiment was performed by feeding frequency modulated input and by observing the frequency shifted output at PLL. Graph shown below shows amplitude and phase plot for a range of frequencies.

Transfer Function hence obtained using different MATLAB functions was,

TABLE I
ACTUAL FIGURES

Requirements	Expected	Obtained
Lock Range	1 KHz	4-5 KHz
Phase Shift	180°	180°
Center Frequency set Range	10-35 KHz	10-50 KHz
Resolution of Locked Frequency	0.1 Hz	0.2-0.5 Hz
Frequency, temperature drifts	0.1 Hz/°C	2 Hz/°C

VIII. CONCLUSIONS

Overall, the design of the FM-AFM provides a solid framework for the development of AFM. Center frequency can be set to various values by just adjusting R_1 . System is able to lock on for a range of frequencies. Set Point can be easily set to 90° using the Phase shifter present thus ensuring maximum sensitivity. Resolution of phase detector output observed upto around 0.2-0.5 Hz confirming the setup can work fairly well with FM-AFM.

ACKNOWLEDGEMENT

I would like to thank Adnan Rangoonwala, Sunitha R for helpful discussion, Ashwin Lal and his team at i2n Technologies for their valuable support and encouragement.

REFERENCES

- [1] Horowitz and Hill: The Art of electronics, Cambridge University Press; 2 Edition. 2010.
- [2] Malvino Bates: Electronic Principles, McGraw-Hill/Higher Education, 7 Edition. 2007.
- [3] Robert F. Coughlin, Frederick F. Driscoll: Operational Amplifiers and Linear Integrated Circuits, Prentice Hall, Edition; 6 Edition. 2000.
- [4] F. J. Giessibl, Appl. Phys. Lett. **76**, 1470 (2000).
- [5] T.R. Albrecht, P. Grutter, D. Horne, and D. Rugar, J. Appl. Phys. **69**, 668 (1991).