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Design and Development of Vibration Monitoring System

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Abstract
In this paper we present the method adopted to design and develop a vibration monitoring system. This system can be used to detect, identify and analyzethe amplitudes and frequencies of vibrationsthrough a sound card commonly embedded in any computer; by processing and analyzing in LabVIEW/ MATLAB. It is cost effective, compact, portable and accurate compared to instruments available in the commercial market and is also free of most of their constraints.

Keyword: Vibration monitoring, soundcard, LabVIEW, MATLAB

1. Introduction
Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. Vibrations give information about the overall functionality of any electronic, mechanical machinery. The parameters (frequency and amplitude) of vibration can be a factor to measure the performance of an electrical machine, mechanical motor, to estimate life time of a bridge, building etc.Hence there is need to develop a vibrationmonitoringsystem to ensure safe environmental conditions. There are many conventional instruments available to measure the levels of vibrations, but have limitations with the detection of low frequencyvibrations,cost and sensitivity. This paper discusses the method adopted to design and develop thevibration monitoring system which not only can detect the amplitude and frequency of vibrations but can also be used to measure from a remote location. Vibration analysis is done in LabVIEW/MATLAB using sound card which gives quick and accurate results.

2. Block Diagram and System Design
This section deals with the internal design and functioning of different blocks of the vibration monitoring system [1].

The detailsof the internal design and the principle used in the development of vibration monitoring system are elucidated to demonstrate that the system uses the principles of optoelectronics and communication. It comprises of a laser, photo-detector, transimpedance amplifier, modulation kit(signal modulation)and sound card (data acquisition). The light from laser is focused on a mirror which is placed on the vibrating platform (machine to be monitored). The reflected light from the mirror is made to fall on the detector in such a way that the received light falls partially on the active sensing area and partially on the outer perimeter of active sensing area of the photo detector leading to formation of fringes [2].

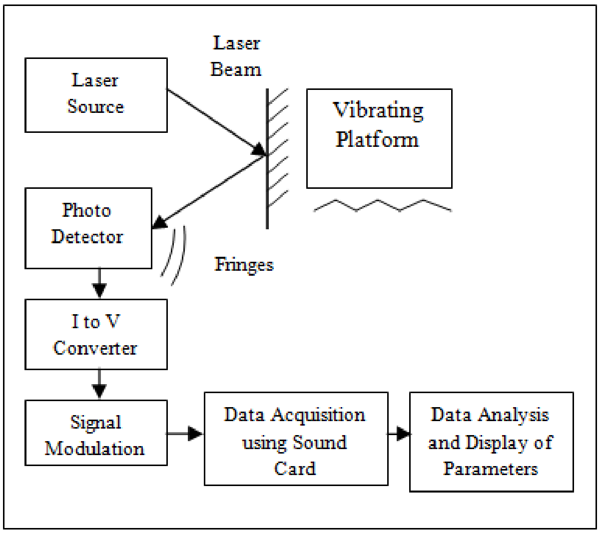

Fig. 1: Block Diagram of Vibration Monitoring System.

2.1 Transimpedance Amplifier
The Photo detector used gives a current output which is of low negative value.The transimpedance amplifier(IC µA741) is an inverting circuit which converts current to voltage with the help of a feedback resistor of value 330KΩ.

2.2 Signal Modulation
The vibration monitoring system is designed to detect frequencies from (0 to1KHz). Sound card which is used as a data acquisition medium to acquire vibrations has certain limitations. It accepts signals only within the audio range frequency (20 Hz-20 KHz) and the amplitude of the signal should be less than 500mV.The purpose of signal modulation block is to translate the frequency of vibrations to an audio range frequency by using modulation technique.Hence, the signal modulation block acts as an interface between the transimpedance amplifier and sound card. Two types of modulation techniques were used namely- Amplitude Modulation, FrequencyModulation. The modulation kit using Amplitude Modulation technique consists of a carrier generator, a modulator and an attenuator circuits. An ICICL8038 was used to generate a carrier signal of frequency 12.5 KHz, IC MC1496 was used for amplitude modulation purposes. On the other hand, modulation kit using Frequency Modulation technique consists of IC 8038 and µA741. Carrier generation, frequency modulation was possible with the help of IC 8038, attenuationby a potentiometer with µA741 acting as buffer.

2.3 Data Acquisition and Demodulation

Sound card is used as a medium to acquire data using LabVIEW which enables signal processing and analysis. Sound card is cheap and fast. On the other hand, USB-DAQ (USB 160-8FS) is expensive and needs separate configuration. Hence, Sound card is preferred as it reduces the cost of the entire system.

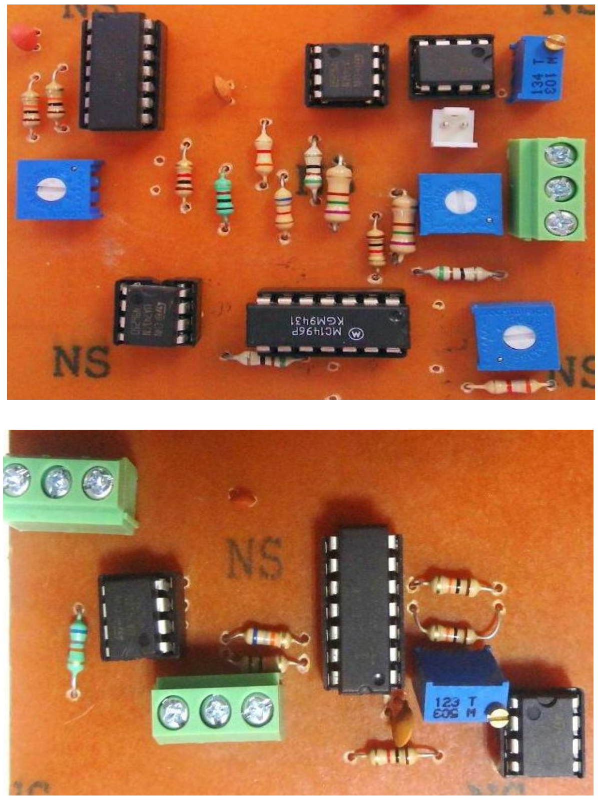

Fig. 2: PCB of AM and FM Circuits.

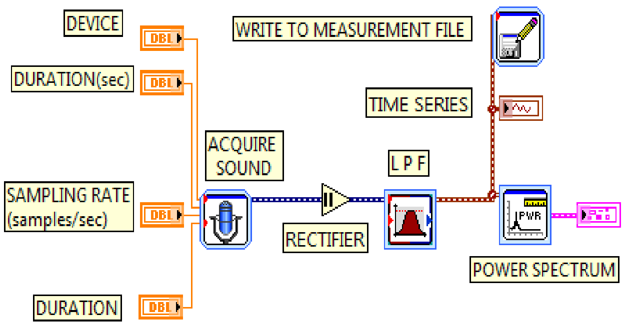

Fig. 3: Block Diagram of Demodulation Circuit in LabVIEW

Demodulation of Amplitude Modulated signal- Sound card takes modulated signal as input through a stereo jack, where the modulated signal undergoes demodulation in LabVIEW. Envelope Detection is the technique used to recover the original signal. The Virtual Instrument (VI) (Fig. 2b)is the module for demodulation.This VI can be created as .exe application usingAPPLICATION BUILDER tool available in LabVIEW [4].The ACQUIRE SOUND node present in the block diagram acquires data through sound card by adjusting various parameters like samplingrate (44100samples/sec), number of bits per channel(16).The combination of the rectifier and the low pass filter demodulates the input to sound card. The recovered signal's parameters (amplitude and frequency) are obtained using the SPECTRAL MEASUREMENTS option. The obtained waveforms can be viewed with the help of GRAPH node.

Demodulation of Frequency Modulated Signal- Sound card takes the frequency modulated signal as input using LabVIEW, later the processing and analysis is done in MATLAB. The signal is demodulated using MATLAB.

3. Experirimental Investigations

The vibrationswhich are nowavailable in the form of a modulated signal are acquired and analyzed using the sound card.Controlled tests were conducted using sound card and an USB-Data Acquisition System (DAQ). Testing with sound card was done by giving modulated signal whereas testing with USB-DAQ was done directly by giving the signal from the transimpedance amplifier. The test was performed bygiving signals (generated in MATLAB) of varying modes (single tone and multi tone) and frequencies to a speaker (vibrating platform). The method was as follows - single tone signal was varied from 0-1000 Hz in steps. These signals were processed and analyzed using LabVIEW. Similarly a spectral (multi tone) signal (song) was processed and analyzed using LabVIEW. Initially the experiment was conducted by first using sound card, later by USB-DAQ system which is an accepted standard LabVIEW which was converted to a single tone. The spectra of demodulated signal obtained using sound card and USB-DAQ werecompared with spectra of input signal to the speaker.

4. Results and Discussion

Figures (4-7) show the power spectra of a 10Hz single tone signal obtained using LabVIEW and MATLAB; figures (8-11) are the power spectra of a multi tone signal obtained by using LabVIEW and MATLAB. The first graph the 2 sets listed above represents the power spectrum of a test signal generated by method2. The second graph represents the power spectrum of the amplitude demodulated signal obtained using LabVIEW through sound card. The third graph represents the power spectrum of the frequency demodulated signal obtained using LabVIEW through sound card. The fourth graph represents the power spectrum of the vibrating input signal using USB-DAQ obtained from transimpedance amplifier. It is observed that the graph of a single tone signal of 10 Hz obtained using USB-DAQ has little resemblance with the other 3 graphs of same set. This proves that the vibration monitoring system is accurate to measuring even low frequencies. The conventional instruments need to be in contact with the vibrating platform, but in this case picking vibrations from a remote location is possible with the help of focusing laser light on mirror placed on the vibrating platform.

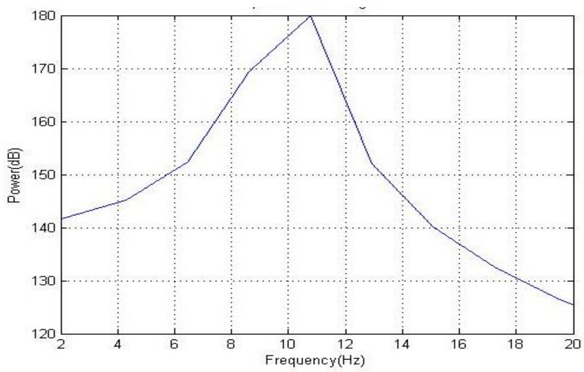

Fig. 4: Power spectrum of test signal of single tone frequency 10Hz.

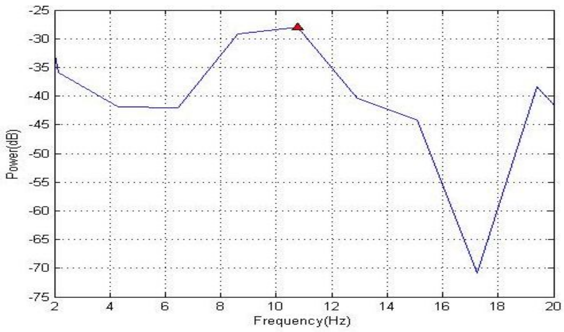

Fig. 5: Power spectrum of demodulated signal of AM for single tone frequency 10Hz observed using sound card.

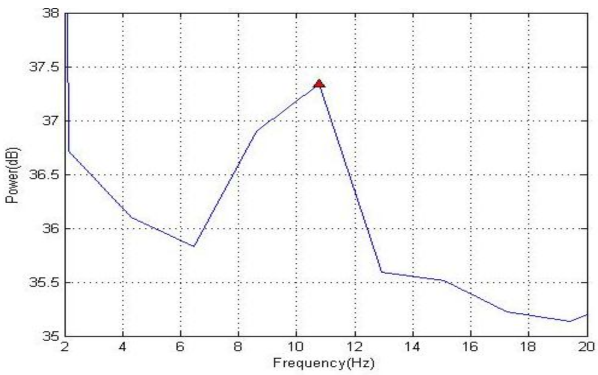

Fig. 6: Power spectrum of demodulated signal of FM for single tone frequency 10Hz observedusing sound card.

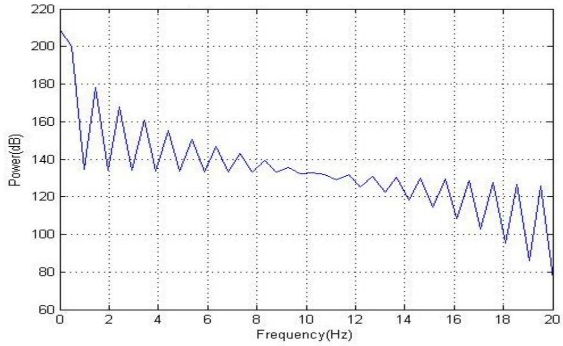

Fig. 7: Power spectrum of signal for single tone frequency 10Hz observed using USB-DAQ

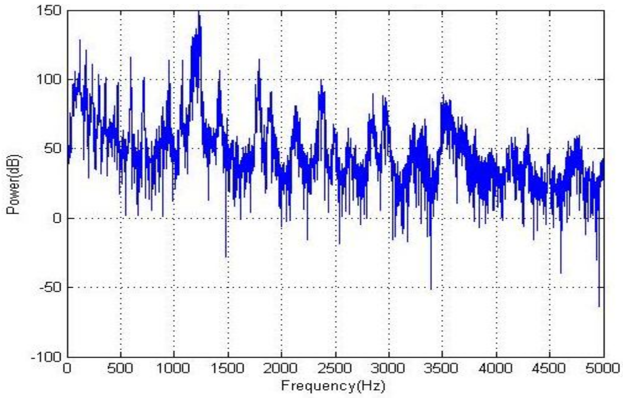

Fig. 8: Power spectrum of test signal of multi tone frequency.

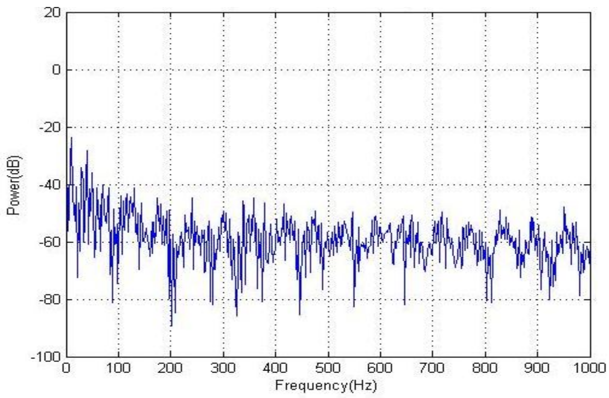

Fig. 9: Power spectrum of demodulated signal of AM for multi-tone frequency observed using sound card.

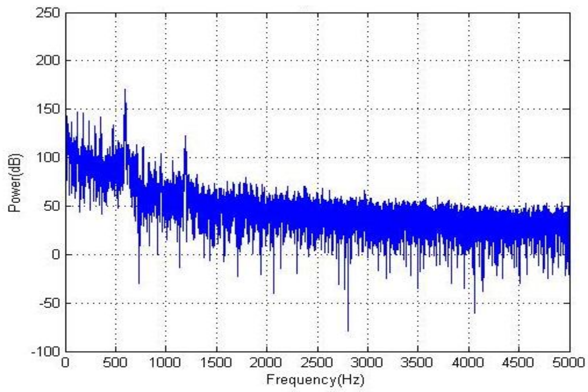

Fig. 10: Power spectrum of demodulated signal of FM for multi-tone frequency observed using sound card.

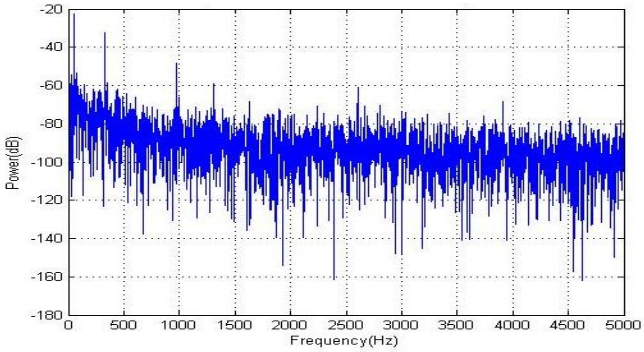

Fig. 11: Power spectrum of signal for multi-tone frequency observed using USB-DAQ

5. Conclusion

The results showed that this system is accurate and sensitive to all frequencies. Though there are many instruments available which are accurate, the developed system is cost effective, compact,and portable and can be used to measure vibrations from a remote location making it different from other conventional instruments. Thus, this low cost portable vibration monitoring system can be used for monitoring industrial machinery, bridges, buildingsand mechanical rotors.

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