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Contents

Volume 136
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Research Articles

Digital Sensors and Sensor Systems: Practical Design <i>Book Review</i>	I
Fast and Simple Measurement of Position Changes <i>White Paper, iC-Haus GmbH</i>	IV
A Novel Method of Linearizing Thermistor Characteristic Using Voltage Controlled Oscillator <i>Narayana K. V. L and Bhujanga Rao A.</i>	1
A Data Acquisition System Based on DSP for Mechanical Nanoscale Displacement Sensor <i>Yong Yu, Qian Wu, Hanyu Sun, Zhengwei Li and Yunjian Ge</i>	12
Modified AC Wheatstone Bridge Network for Accurate Measurement of Pressure Using Strain Gauge Type Pressure Sensor <i>Subrata Chattopadhyay, Mahuya Banerjee and Sagarika Pal</i>	25
Fingerprint Sensors: Liveness Detection Issue and Hardware based Solutions <i>Shahzad Memon, Nadarajah Manivannan, Azad Noor, Wamadeva Balachadran, Nikolaos V. Boulgouris</i>	35
Fiber Optic Vibration Sensor Using Pmma Fiber for Real Time Monitoring <i>P. Kishore, D. Dinakar , D. Sen Gupta, P. Saidi Reddy, M. Sai Shankar, K. Srimannarayana</i>	50
ARM Processor Based Multisensor System Design for the Measurement of Environmental Parameters <i>NarasimhaMurthy Yayavaram, Soundara Rajan, Vishnu Vardhan</i>	59
A Decoupling Algorithm Based on Homotopy Theory for 3-D Tactile Sensor Arrays <i>Junxiang Ding, Yunjian Ge, Yuan Wang, Zhachui Wang</i>	72
Digital Imaging and Piezo-dispenser Actuator in Automatic Flocculation Control <i>Jani Tomperi, Markus Honkanen, Pasi Kallio, Kauko Leiviskä, Pentti Saarenrinne, Iiris Joensuu, Marjatta Piironen</i>	83
An Embedded Web based Real Time Application for Remote Monitoring & Controlling of MST RADAR Transmitters <i>Nagabhushan Raju Konduru, Lakshmi Narayana Roshanna, Rajendra Prasad Thommundru, Chandrasekhar Reddy Devanna</i>	96
Advanced Oscilloscope Triggering Based on Signal Frequency <i>Shakeb A. Khan, Alka Nigam, A. K. Agarwala, Mini S. Thomas, T. Islam</i>	105
Pyramidal Traceability Hierarchy for Pressure Measurements and Calibrations at NIS- Egypt <i>A. A. Eltawil</i>	118

Fuzzy Logic Based Autonomous Traffic Control System <i>Muhammad Abbas, M. Saleem Khan, Nasir Ali and Syed Fazil</i>	132
Potential of Piezoelectric Sensors in Bio-signal Acquisition <i>Dipali Bansal</i>	147
Measurement and Analysis of Sodium in Vegetables Using ATmega16 Microcontroller Based Spectrophotometer <i>K. Muruganathan and P. Neelamegam</i>	158

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
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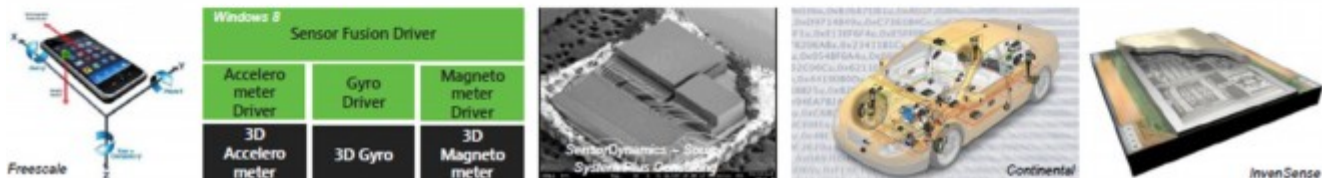
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Fiber Optic Vibration Sensor Using PMMA Fiber for Real Time Monitoring

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Abstract: A vibration sensor is realized using PMMA (Polymethyl Methacrylate) fiber optic probe as sensor. The probe consists of two fibers, one is transmitting fiber and the other is receiving fiber. In this technique the sensor is non-contact and do not perturb the source of vibration. A portable high performance NI-DAQPad6016 with LabVIEW software is used to interrogate the vibration. The amplitude resolution of the sensor is $1\mu\text{m}$ within the frequency range 1-300 Hz. The thermal effect on the sensitivity of sensor is minimal. The sensor is suitable for real time monitoring of low frequency vibration and is of low cost and portable. *Copyright © 2012 IFSA.*

Keywords: Data acquisition, Fiber optic probe, FFT (Fast Fourier transform), PMMA fiber, Vibration sensor.

1. Introduction

Vibration sensors are useful for monitoring the condition of rotating machinery, where overheating and excessive vibration results in breakdown [1]. Traditional magneto-electric vibration sensors and servo accelerometers have severe shortcomings when used to measure vibrations where low frequency components predominate. Mechanical and electrical vibration sensors need physical contact for the measurement. On the other hand optical sensor is used to measure low frequency vibrations and does not require any physical contact and do not perturb the source of vibration [2]. The optical fiber vibration sensors are divided into two types according to their working principle; they are: i) phase modulation type, and ii) intensity modulation type. The first type uses an interferometer such as Fabry Perot [3], Michelson or Mach-Zehnder [4], used in self-mixing [5] and Doppler vibrometry [6, 7] to

interrogate the phase shift caused by vibration. These methods are very high performance but they exhibit low stability and impose stringent mechanical requirements because the alignment is critical [8]. This approach is characterized by excellent performances but requires complex and expensive setups and not well suited to map the amplitude of vibration in several test points. Consequently, these have a limited practical use. The second one takes the advantage of change in intensity with the vibration using PMMA (Polymethyl Methacrylate) fiber optic sensor [9].

The absence of low-cost, stable and portable sensor for the detection of vibration of low frequency has led to this work. The sensor consists of a transmitting fiber and a receiving fiber. The core and cladding of these fibers are made up of PMMA and Fluorinated polymer respectively. The sensor consists of a LED as light source, a Transimpedance amplifier with a photo detector and a Data Acquisition system for real time monitoring of vibrations.

2. The Sensor Working Principle

The sensing head is made up of transmitting and receiving fibers which are bundled together in parallel (probe). According to the light intensity distribution function, the irradiance of emitted light from transmitter is expressed as

$$i(r, z) = \frac{2P_E}{\pi W^2(z)} \exp\left(\frac{-2r^2}{W^2(z)}\right), \quad (1)$$

where P_E is the optical power emitted by the transmitting fiber, r and z are the radial and longitudinal coordinates respectively and W is the beam radius which is also a function of z , given by

$$W(z) = W_0 \sqrt{1 + \left(\frac{z}{z_R}\right)^2}, \quad (2)$$

where, W_0 is the waist radius and $z_R = \sqrt{\frac{\pi W_0^2}{\lambda}}$ is the Rayleigh range are the important parameters in the Gaussian-Beam function. The intensity of light received by the receiving fiber from the reflector can be evaluated by integrating the irradiance $i(r, z)$ over the core area S_r of receiving fiber and is given by

$$P(z) = \int_{S_r} i(r, z) dS \quad (3)$$

The reflected light intensity collected by the receiving fiber depends on the separation between probe and the reflector. The modified form of Eq. (3) is given below.

$$P(z) = \frac{2P_E}{\pi W^2(z)} \int_{y=-R_r}^{R_r} \int_{x=m_1}^{m_2} \exp\left[\frac{-2(x^2 + y^2)}{W^2(z)}\right] dx dy \quad (4)$$

where $m_1 = R_r + R_t - \sqrt{R_r^2 - y^2}$ and $m_2 = R_r + R_t + \sqrt{R_r^2 - y^2}$, where R_t and R_r represents the core radius of transmitting and receiving fibers. The radial coordinate ' r ' is expressed as $\sqrt{x^2 + y^2}$ in Cartesian coordinate system [10, 11].

3. Experimental Setup

The schematic experimental setup of the vibration sensor is shown in Fig. 1. The fiber optic probe consists of two PMMA fibers of length 50 cm, diameter 1 mm (980/1000 μm core/ cladding diameter) and of Numerical Aperture 0.502 bundled together in parallel. The core and cladding refractive indices of the fibers are 1.492 and 1.405 respectively. One fiber of the probe acts as transmitting fiber and the other as receiving fiber. The PMMA fiber used is super ESKA SK-40, a high performance plastic optical fiber from ESKA Optical Fiber Division, Japan. The PMMA fiber has low attenuation in the visible red and the operating temperatures range from $-55\text{ }^{\circ}\text{C}$ to $70\text{ }^{\circ}\text{C}$. A commercial woofer (8 inch diameter) is used as vibrator to determine the response of the sensor at different frequencies.

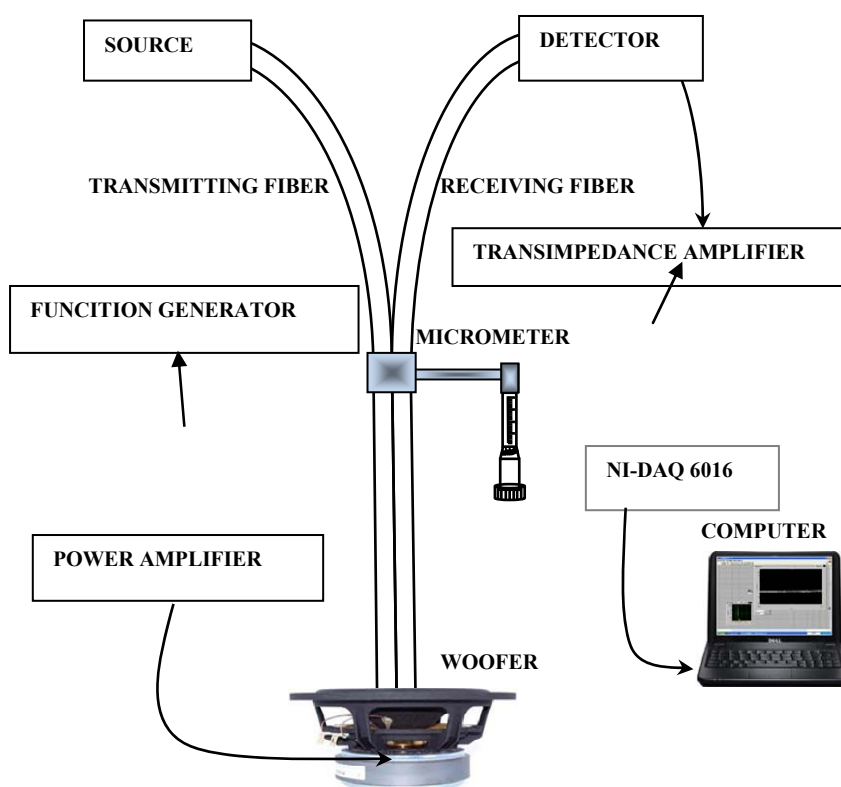


Fig. 1. Schematic experimental setup of PMMA fiber optic vibration sensor.

A thin plastic reflector (thickness $100\text{ }\mu\text{m}$) is glued at the center of the woofer to act as reflector. A Red LED IF-E96 from Industrial Fiber Optics Inc., is used as light source whose typical peak wavelength 660 nm is one of the optical transmission windows of the PMMA fiber. The LED is housed in a package specially meant for holding and for maximum coupling of light to a $1000\text{ }\mu\text{m}$ fiber. One end of a transmitting fiber is fixed to the housing of the LED. The frequency and amplitude of vibrations of the woofer is controlled through a Function Generator and Power Amplifier. A highly sensitive photodarlington transistor IF-D93, Industrial Fiber Optics housed in a "connector less" fiber package is used as detector. IF-D93 package features an Internal Micro-Lens and a precision-molded PBT housing to ensure efficient optical coupling with standard $1000\text{ }\mu\text{m}$ PMMA fiber. Optical response of detector extends from 400 nm to 1100 nm , making it compatible with a wide range of visible and near-infrared optical sources. One end of the Receiving fiber is fixed to the housing of the detector. The integrated design of the detector and LED are simple and cost-effective. The operating temperature range of the detector and LED is $-40\text{ }^{\circ}\text{C}$ to $85\text{ }^{\circ}\text{C}$. The detector is connected to a transimpedance amplifier designed using general purpose Op-Amp LM 741CN(improved performance over

industry standards within 0 °C -70 °C temperature range) to convert the modulated current signal into equivalent voltages as shown in Fig. 2. The Transimpedance gain of the amplifier is 10^6 V/A.

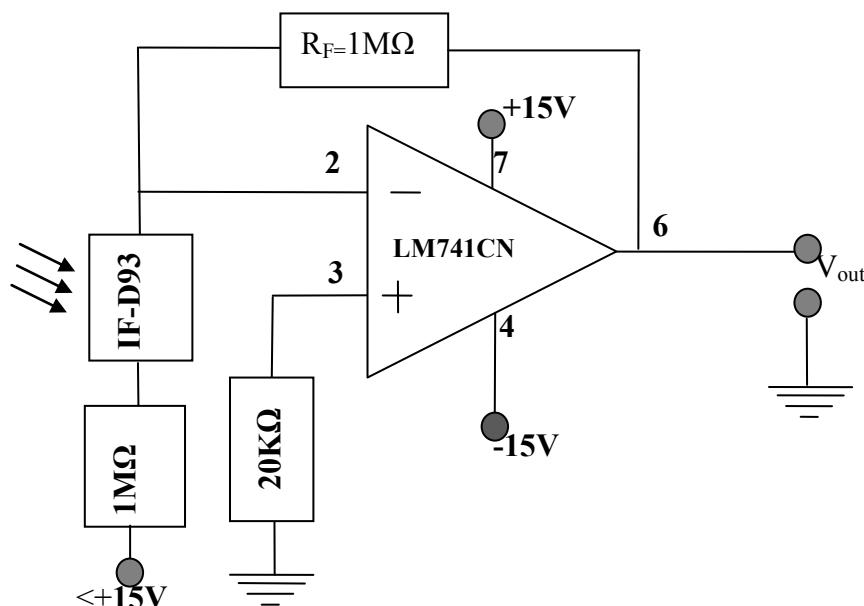


Fig. 2. Transimpedance amplifier to convert light into equivalent voltage.

A Portable High-Performance Multifunction Data Acquisition system from National instruments (NI-DAQPad-6016) with Plug-and-play USB connectivity for quick setup and a computer with LabVIEW software is incorporated for continuous monitoring of vibrations. It has 16 bit resolution, maximum sampling rate of 200 kS/s and maximum input signal range ± 10 V. It has 16 single ended or 8 differential analog software selectable input channels. The output of the transimpedance amplifier is connected to 'a0' and 'a1' ports for data acquisition. The Block diagram of the LabVIEW program for real time monitoring of vibrations is shown in Fig. 3. The DAQ Assistant control with NI-DAQmx multithreaded driver software provides ease of use, flexibility, and performance in multiple programming environments [12]. The data signal is smoothed by smoothing Filter and then saved to a notepad for the further analysis. The time domain data signal is converted into frequency domain signal by the FFT (Fast Fourier Transform). A while loop around the program is placed for continuous measurement.

4. Results and Discussion

4.1. Calibration of the Sensor

To calibrate the sensor the light from the LED is launched in to the transmitting fiber and after transmission the light is incident on the reflector embedded on the woofer. The reflected light received by the receiving fiber is coupled to the photo detector. The LED is biased by a well regulated power supply for constant output. The probe is displaced with the help of micrometer in steps of 50 μm from the reflector. The whole set up is mounted on a vibration free table (Newport). The response to the displacement of the sensor is measured using a multimeter (Protek MY69) connected to the output of the transimpedance amplifier. The Normalized output power to the displacement of the sensor from the reflector for 8000 μm dynamic range and the simulated results obtained using equation (4) are plotted in Fig. 4. The experimental and simulated results are in good agreement. The sensitivity of the front slope and back slope of the plot are found to be 0.009838 V/ μm and -0.002696 V/ μm over the linear

range of 400-1300 μm and 2000-4000 μm respectively. Linearity (R) is nearly equal to 1 for both front and back slopes. Front slope has relatively small measurable range but sensitivity is high over a small range and better for the measurement of amplitude of vibration in micro level.

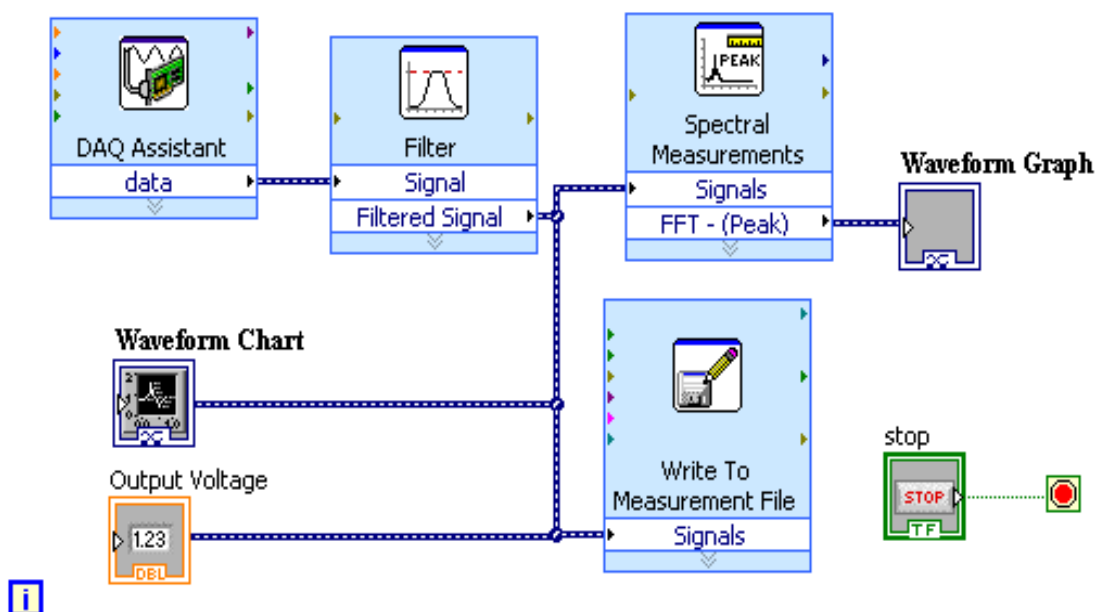


Fig. 3. Block diagram of LabVIEW program to monitor the vibration.

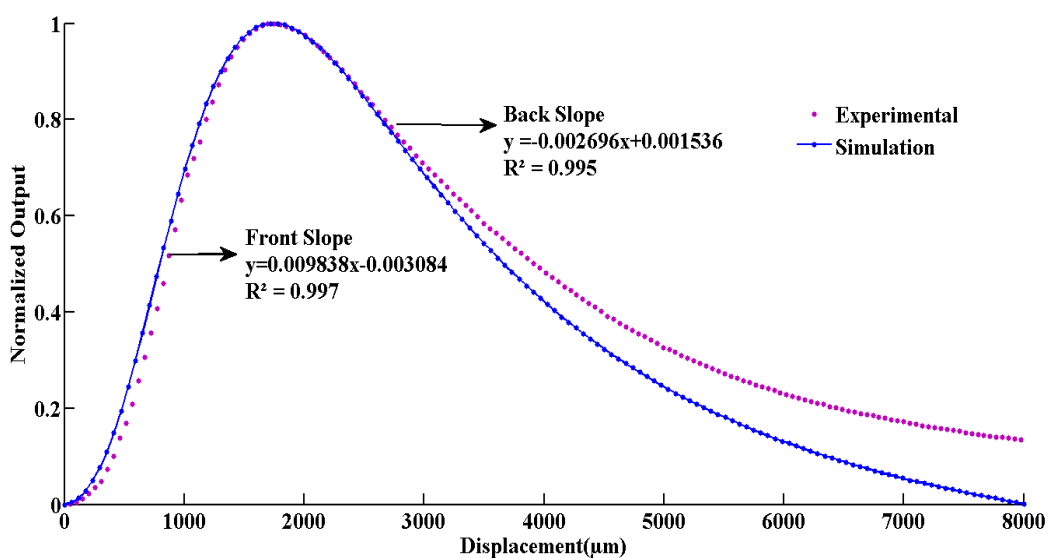


Fig. 4. Simulation and Experimental results of normalized optical output to the displacement.

4.2. Measurement of Vibration Amplitude

To determine the amplitude of vibration the probe is mounted normally to the reflector embedded on the center of the woofer. The initial position of the probe tip from the reflector is determined from the displacement response curve of the sensor (Fig. 4). The front slope is used for extremely small amplitude of vibration measurement. The probe is placed such that the detector output corresponds to the center of the linear region of the front slope at 850 μm . The output voltage from transimpedance amplifier is connected to the DAQPad. For higher sensitivity, front slope is used. Fig.5 shows the

Front Panel of the program display and it depicts the output voltage of the Transimpedance amplifier and the amplitude of vibration.

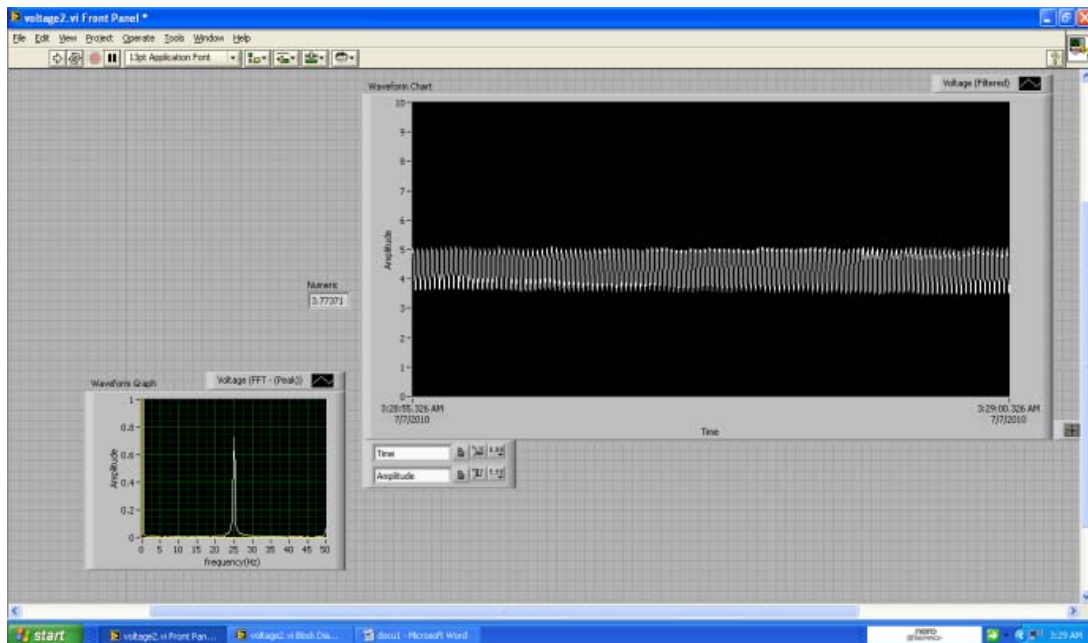


Fig. 5. Front panel of the LabVIEW program shows the 25 Hz output voltage signal and FFT.

The amplitude response of the sensor is plotted, by varying the driving voltage (0-140 mV) to the woofer at different frequencies from 10 to 60 Hz is shown in Fig. 6. The response is linear with the driving voltages. The peak voltage of the FFT(peak) is half of the amplitude (voltage) of the vibration. The front slope obtained from displacement sensor and output peak voltage of FFT(peak) gives the calibration of amplitude of vibration.

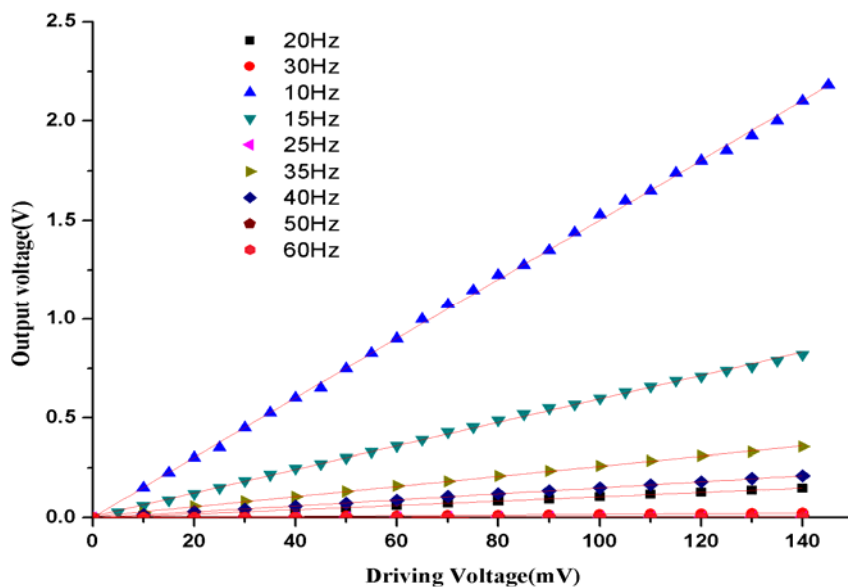


Fig. 6. The amplitude response of the sensor at different frequencies.

4.3. Frequency of Vibration

The frequency response of the sensor is obtained by recording the modulated signal from the receiving fiber using DAQSystem. The received signal is further processed and FFT (Fast Fourier Transform) is applied using LabVIEW software for the measurement of frequency of vibration. The measured frequency of vibration at 10, 40, 80 and 200 Hz are shown in Fig. 7. The frequency response of the sensor between the input frequency to the woofer and output frequency of the detected signal is shown in Fig. 8. The results show that the sensor has the capability of sensing maximum frequency of 300 Hz accurately. The can sense the frequency above 300 Hz with ± 2 Hz error. The experiment is repeated for testing the reliability of the system and the response of the system is consistent.

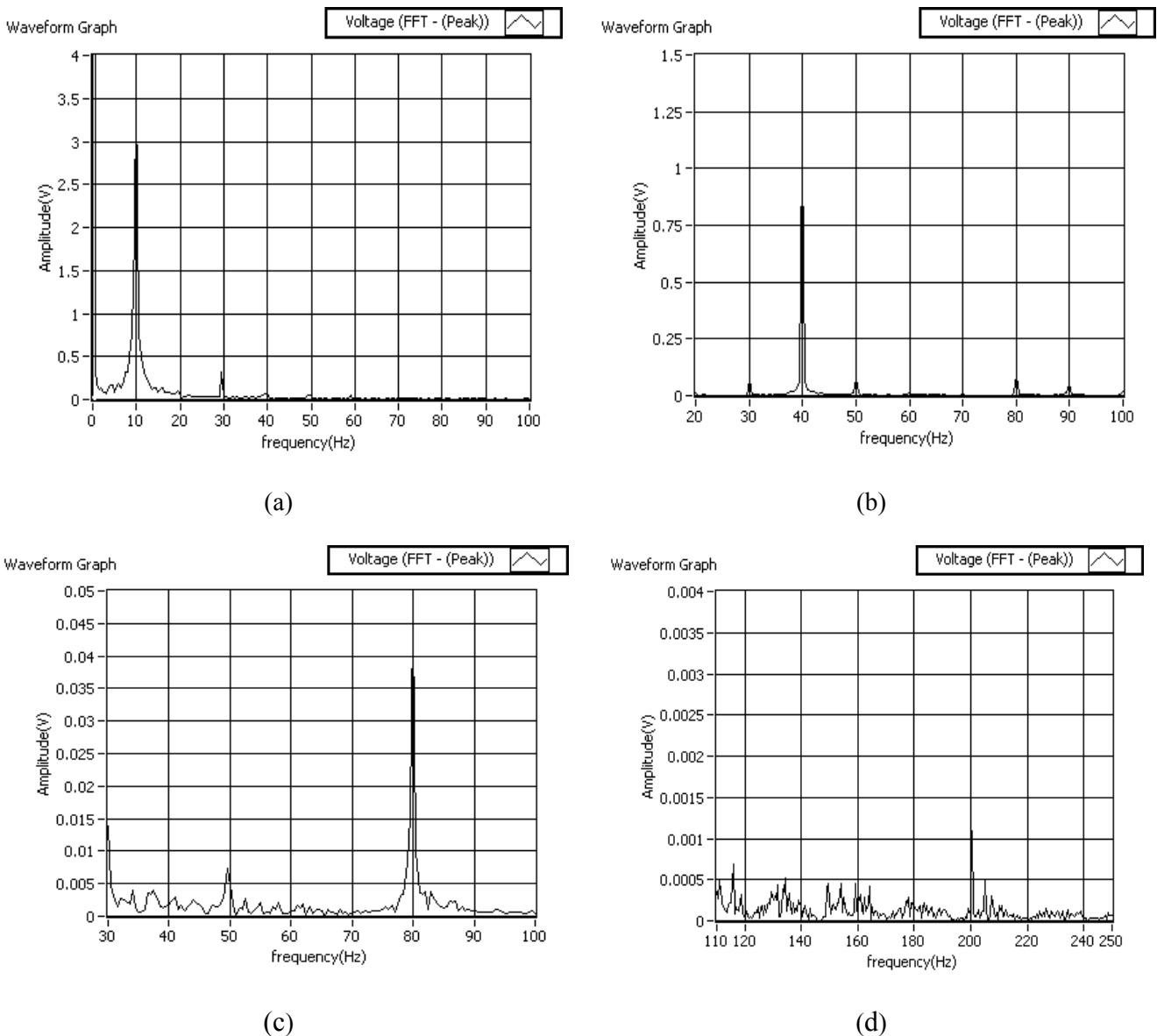


Fig. 7. FFT (peak) spectrum of the woofer at different frequencies (a) 10 Hz, (b) 40 Hz, (c) 80 Hz, (d) 200 Hz.

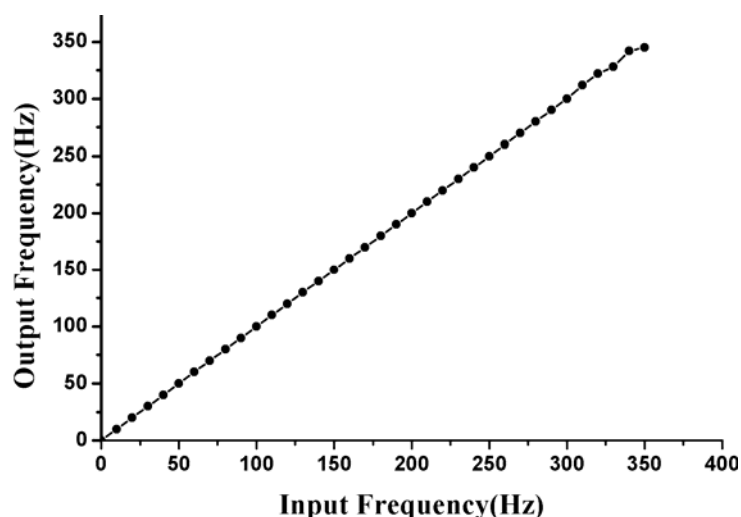


Fig. 8. The frequency response of the sensor.

The amplitude that is peak to peak output voltage of the detector and frequency (1-100Hz) response of the woofer is shown in Fig. 9. The result of this system is coinciding with the frequency response of the woofer and potentially high enough to measure low frequency of vibration. Front slope is suitable for the detection of smaller amplitudes than the back slope due to the higher sensitivity.

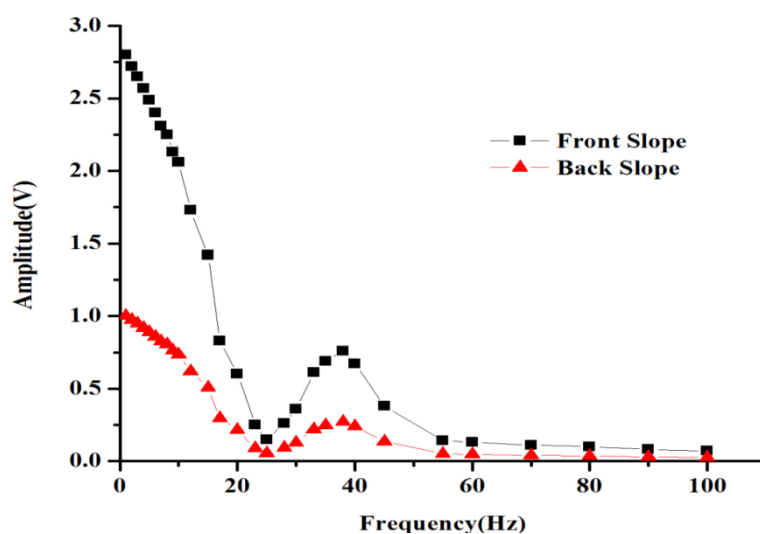


Fig. 9. Amplitude and frequency response of the woofer for the Front slope and Back slope.

5. Conclusions

A PMMA fiber sensor based on non-contact intensity modulation technique for the detection of low frequency vibrations has been demonstrated with amplitude resolution of $1\mu\text{m}$ within the frequency range 1Hz-300Hz. The working mechanism is based on displacement of reflector embedded on the vibrating surface from the sensor head. The measurement of frequency and amplitude of vibration is monitored using a woofer and is compared with applied known frequency for the real time monitoring of the system. The results show high sensitivity and good linearity and the sensor can be used for health monitoring of vibration parts of generator, compressor, Lathe machine, Milling machine etc., in industry. The sensitivity of the sensor is unaffected due to variation of temperature and humidity. The simple design of sensor head, portability and low-cost are the main advantage of this sensor.

References

- [1]. J. David Zook, William R. Herb, C. J. Bassett, Terry Stark, Jeff N. Schoess, Mark L. Wilson, Fiber-optic vibration sensor based on frequency modulation of Light-excited oscillators, *Sensors and Actuators*, 83, 2000, pp. 270–276.
- [2]. A. Buffa, G. Perrone, A. Vallan, A Plastic Optical Fiber Sensor for Vibration Measurements, in *Proceedings of the IEEE International Instrumentation and Measurement Technology Conference (I2MTC' 2008)*, Vancouver Island, Victoria, Canada, May 12-15, 2008.
- [3]. N. Sathitanon, and S. Pullteap, A Fiber Optic Interferometric Sensor for Dynamic Measurement, *International Journal of Computer Science and Engineering*, 2, 2, 2008, pp. 63-66.
- [4]. S. Donati, Electro- optical instrumentation: sensing and measuring with Lasers, *Prentice Hall*, Upper Saddle River, 2004.
- [5]. G. Giuliani, M. Norgia, S. Donati, T. Bosch, Laser diode self-mix in technique for sensing applications, *J. Opt. A: Pure Appl. Opt.*, Vol. 4, 2002, pp. S283-S294.
- [6]. P. Castellini, M. Martarelli, E. P. Tomasini, Laser Doppler Vibrometry: Development of advanced solutions answering to technology's needs, *Mechanical System and Signal Processing*, Vol. 20, 2006, pp. 1265-1285.
- [7]. A. Chijioke, J. Lawall, Laser Doppler vibrometer employing active Frequency feedback, *Appl. Opt.*, Vol. 47, 2008, pp. 4952-4958.
- [8]. J. Chang, Q. Wang, X. Zhang, D. Huo, L. Ma, X. Liu, T. Liu and C. Wang, A Fiber Bragg Grating Acceleration Sensor Interrogated by a DFB Laser Diode, *Laser Physics*, Vol. 19, No. 1, 2009, pp. 134–137.
- [9]. S. Binu, K. Kochunarayanan, V. P. Mahadevan Pillai, and N. Chandrasekaran, PMMA (Polymethyl Methacrylate) Fiber Optic Probe as a Noncontact Liquid Level Sensor, *Microwave and Optical Technology Letters*, Vol. 52, No. 9, 2010, pp. 2114-2118.
- [10]. Sulaiman Wadi Harun, H. Z. Yang, Moh Yasinand H. Ahmad, Theoretical and Experimental study on the Fiber Optic Displacement Sensor with two Receiving fibers, *Microwave and Optical Technology Letters*, Vol. 52, No. 2, February 2010.
- [11]. P. B. Buchade, A. D. Shaligram, Influence of fiber geometry on the performance of two-fiber displacement sensor, *Sensors and Actuators, A*, 136, 2007, pp. 199–204.
- [12]. NI web site (<http://www.ni.com>)

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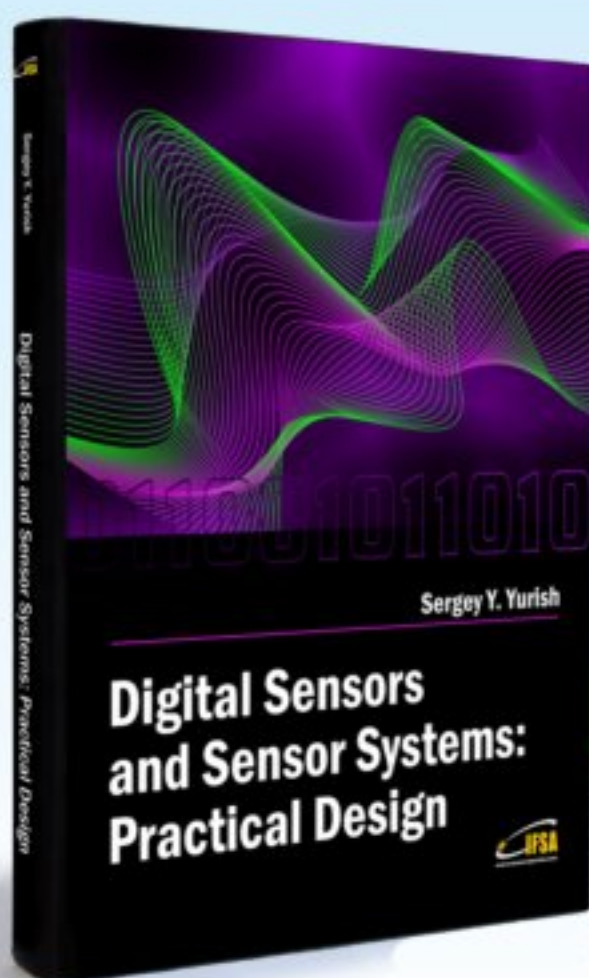
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