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Development of Highly Sensitive System for Measurement and Monitoring of Small Impacts

Priyanka Guin, Dibyendu Chatterjee, Arijit Roy

Abstract**—**Developing electronic system for detecting low energy impacts using open source hardware such as Arduino is challenging. A highly efficient loadcell is designed and fabricated. A commercial polyvinylidene fluoride (PVDF) piezoelectric film is used as primary sensor for sensing small impacts. Without modifying hardware, the Arduino board is configured by programming to capture the signal from the film sensor with a resolution better than 1.1 mV. By our system, impact energy as low as 1.8 μJ (corresponds to impact force of 39.9 mN) is reliably and monitored. In the linear zone, sensitivity of the system found to be as high as 20.7 kV/J or 3.3 V/N with a measurement frequency of 500 Hz. The various characteristics such as linearity, hysteresis, repeatability and spectrum analysis are discussed. After calibration, measurements of unknown impact energy and impact force are investigated and results are found to agree well.

Keywords**—**Arduino, impact energy, impact force, measurement system, PVDF film sensor.

I. Introduction

MEASUREMENT of low impact energy are of high importance in many fields such as instrumentation, bioengineering, aerospace, automation, ventilation, robotics, vibration and micro/nano manufacturing [1], [2]. The efficiency, flexibility and cost effectiveness are the main advantages of PVDF piezoelectric film sensors for versatile practical applications, especially in sensing dynamic mechanical impacts [3]-[12]. Recent applications of PVDF film sensor include microforce detection [3], impact energy detection [4]-[7], biomedical instrumentation [8], [9], material quality detection [10], dynamic stress detection [11], [12], pressure sensor [13] etc. Among these applications, detection of small impacts and corresponding energies are of the interest of present research and development.

Monitoring of events which create small impacts is challenging. Detection of small mechanical impacts by piezo-based sensor recently gains sufficient attraction [2], [4]-[7]. Most of these systems are developed to detect and monitor large impacts. For example, impacts created due to free fall of a mass of order of 20 gram from height of the order of 10 cm are reported [5]-[7]. In other words, impact energy of the order of 20 mJ is detected using PVDF piezoelectric film sensor [5]-[7]. Moreover, in energy harvesting applications using PVDF sensors, detection of impact energy of the order of 14.7 μJ is reported [14]. On the other hand, the capability of detecting smaller impacts (of the order of 10 μJ) by PVDF piezo-film is also reported [4]. In terms of impact force, the force in the range of 3-5 N is detected with good linearity using PVDF piezo-film sensor [3]. It is therefore required to develop an electronic system to detect very small impact energy (that creates minute mechanical signature), say for example of order of 10 μJ or less.

Arduino board is carrying many advantages in instrumentation. Arduino is a low cost and compact microcontroller board for making small computers that can sense more of the physical world than ordinary personal computer (PC). Arduino programmer kit consists of a built-in 10-bit ADC at the analog inputs which allows in the input to be divided into 1023 (=2^{10}–1) steps. The resolution of capturing analog signal by Arduino can be tuned to less than 5 mV by suitable programming.

In this paper, we have presented a very compact and cost-effective system for detecting low-impact mechanical energies. The system is integrated using Arduino board with a PVDF piezoelectric film sensor. In order to use the system without the help of a computer in real field, a LCD unit is used as data presentation element. A simple and efficient loadcell is fabricated (which holds the PVDF film sensor) to sense low mechanical impacts. Impact energy of the order of 1.8 μJ (or force of the order of 39.9 mN) is detected reliably. The mechanical impact energy is converted by the PVDF piezoelectric film into electrical signal. This electrical signal is captured with a resolution better than 1.1 mV. The various characteristics such as linearity, sensitivity, repeatability, hysteresis etc. are studied and presented in detail. Finally, an integrated system for measuring low unknown mechanical impact is demonstrated.

II. Experimental Setup

A. Mechanical Impact Creator

Commonly, an independent experiment is conducted to calibrate a measuring instrument. In order to calibrate or to estimate the sensitivity, we have created a system to generate small repetitive mechanical impacts. A small piece of steel ball (mass 18 mg, measured by a precision weighing machine Model: BSA224S-CW, Manufacturer: Sartorjus) is considered to fall freely under gravity to a beaker (made of glass). An electromagnet is used to release the steel ball from different heights. The beaker is placed on the sensor-fixture (Section II-B for details). The impact energy E_{imp} can be calculated as:

$$E_{imp} = mgh. \tag{1}$$

Priyanka Guin, Dibyendu Chatterjee, and Arijit Roy* are with the Department of Electronics, West Bengal State University, Barasat, Kolkata 700126, India (phone: +91-9051503636; e-mail: arijitroy@live.com).

where, ‘g’ is the acceleration due to gravity. Further discussion on the impact force estimation is presented in Section III-D.

B. The Sensor and Loadcell

In this work, we have used PVDF piezo film sensor SDT1-028K (manufactured by Measurement Specialties, USA) with capacitance of 2.6 nF as primary sensor. In most of the practical applications of PVDF piezo film sensor, a suitable loadcell or fixture is required to hold the sensor [4], [5], [8], [12], [15]. The nature of the fixture depends on the specific application [16], [17]. The sensitivity, noise and the range of the system is highly influenced by the fixture material and its design.

We have fabricated a fixture (shown in Fig. 1) in which the PVDF piezo-film is sandwiched between two plates [5], [7], [18]. The plates are fabricated from general purpose PCB (glass epoxy FR4 material, 1.6 mm thick, dot pitch: 2.54 mm, copper thickness: 35 µm). The size of each plate is 70×50 mm^2. The film sensor is placed between the plates and the plates are tightened by small nut-bolt pair at the four corners. The bolts are tightened in such a way that the direct contact between the plates is avoided. Thus, a simple and low-cost fixture is considered for our system.

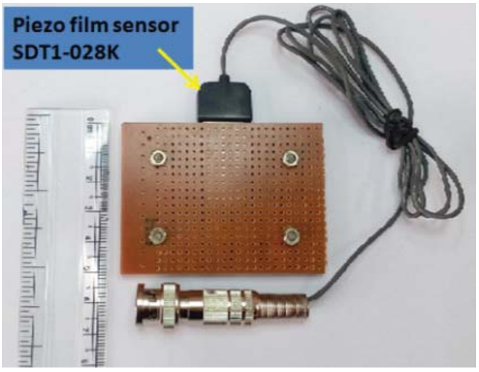


Fig. 1 Fabricated loadcell;Piezo-film sensor sandwiched between two PCB plates; A centimetre scale is provided to show the dimensions of the designed loadcell

The reasons behind the chosen material and design for loadcell are as follows: (i) We have used cost effective material to design the loadcell. (ii) The surfaces of the PCB plates are sufficiently rough, which allows deformation to the film sensor during the impact. If the sensor film is sandwiched between a pair of glass plates or between smoothened metallic plates such as copper and aluminium, the sensitivity of the system will decrease significantly [4], [5]. (iii) In the loadcell, soft materials like sponge, rubber etc. [5], [8], [9] are used as backstop material. On the other hand, the PCB plates are mechanically harder than these soft materials. The hardness of the PCB plates allows easiness while probing the loadcell in real applications. For example, our loadcell can be used to measure the impact of rain drop on soil up to a certain depth. In fact, our loadcell can be used for variety of applications with minimum modification. (iv) Due to the sandwich structure of our loadcell, the PVDF film sensor remains protected from the external hazards. (v) In addition to the above advantages, another advantage of our loadcell is that it is easy to assemble. Note that, the film sensor can easily be replaced by other one whenever required and such replacement is not possible for various types of reported loadcells employed in similar studies [5], [7], [8], [10], [12], [15], [17].

C. The Electronic System

The electronic circuitry is shown in Fig. 2. PVDF piezo-film is an active sensor and it is connected to ‘Piezo Film Lab Amplifier’ manufactured by measurement SPECIALTIES^{TM}, USA. The various parameters setting of the amplifier is shown in Fig. 2. For better performance of the sensor used in this work, the input impedance is kept at 1 GΩ. The amplifier operated in ‘voltage mode’, since the wire length from sensor to amplifier is less than a meter. Since we do not need to filter the sensor signal, the lower and upper cut-off frequency of the filter are kept at 0 Hz and 100 kHz respectively, without any pre-filtering gain. A post filtering gain of 40 dB is applied to the signal.

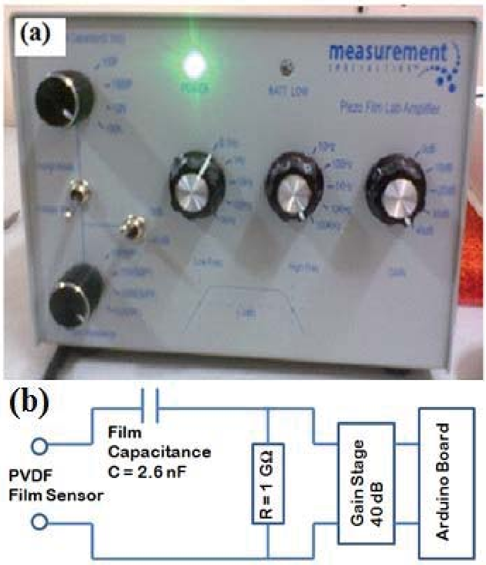


Fig. 2 (a) Piezo film lab amplifier; (b) Circuit diagram schematic for our system

The output from the amplifier is connected to the Arduino board (UNO R3) for further processing and to display the results on a LCD (as shown in Fig. 3). It is to be noted here that we have obtained zero output voltage in the absence of any impact event. Thus, the noise level is extremely small (below 1.1 mV in magnitude), which in turn eliminates the necessity of signal filtering. This is again an advantage of our designed loadcell over the similar works [5], [6], [9].

In programming the Arduino board, the resolution of the ADC at the input is enhanced from 5/1023 V (default) to 1.1/1023 V by using the built-in function ‘analogReference (INTERNAL)’. Finally, the output result is taken in millivolts for display. The system is then used to obtain output voltage for controlled impacts. After calibrating the system, program is made to display impact energy or force caused by any unknown impact event.

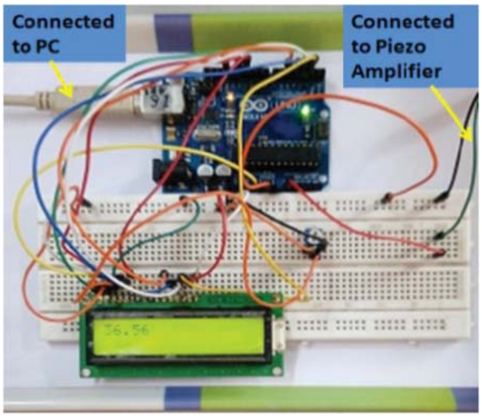


Fig. 3 The setup of the system

III. Result

A. Sensitivity Estimation with Respect to Impact Energy

The impact of the steel ball is measured by our system starting with an empty beaker. The impact energy of the steel ball is varied by varying the falling heights of the ball. The impact event for the ball of falling height as low as 1 cm is detected reliably. The system output responses for different impact energy are shown in Table I. The linearity of impact energy test is shown in Fig. 4. When the falling height is increased to more than 7 cm, the output response becomes non-linear. Therefore, falling heights of 1-7 cm (corresponding to impact energy of 1.8–12.3 µJ produces linear response) is considered and presented.

The sensitivity with respect to impact energy of our system is found to be 20.7 kV/J. It is to be noted here that the sensitivity of our system is much higher than the reported sensitivity of similar measurement systems [4], [5], [7]. The sensitivity comparison is shown in Table II. In addition to higher sensitivity, the lowest impact energy detection capability is better for our system. In fact, we have reliably detected impact energy as low as 1.8 µJ which is three orders of magnitude better than the reported lower range of impact energy [4]-[7].

B. Hysteresis

In order to measure the hysteresis error of our system, the steel ball is dispensed using the electromagnet is considered. The impacts created by the steel ball in the beaker are sensed by our sensor. The range of impact energy of the steel ball is considered to be same as in sensitivity test. The hysteresis curve of the system is shown in the Fig. 5.

The hysteresis error is usually expressed in terms of the maximum hysteresis error as percentage of full-scale-output-range (*FSOR*):

$$\%Hysteresis_{error} = \frac{H_e(\max)}{FSOR} \times 100. \qquad (2)$$

where, H_e(max) = maximum of (upscale reading – downscale reading). For our system hysteresis error is found to be only 1.68%.

TABLE I
Impact Energy versus System Response

Mass of steel ball (m in kg)	Acceleration due to gravity (g in m/sec^2)	Falling height (*h* in cm)	Impact energy (E_{imp} in µJ)	Output voltage (V_{out} in mV)
18×10^{-6}	9.81	1	1.764	38.97
		2	3.528	63.67
		3	5.292	107.93
		4	7.056	128.89
		5	8.82	166.93
		6	10.584	211.11
		7	12.348	262.96

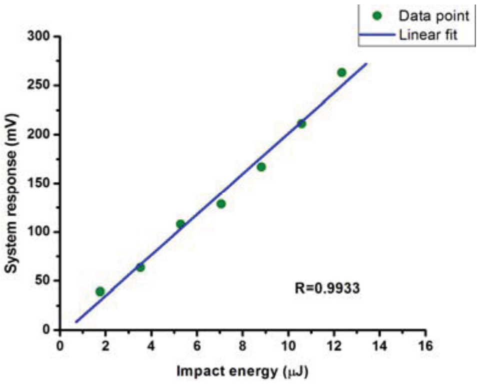


Fig. 4 System responses (in mV) for different impact energies (in µJ)

TABLE II
A Comparison of Sensitivity and Range of Impact Energy between our System and other Similar Works

Sensitivity (kV/J)	Energy Range (J)	Reference	Fixture material	Remarks
2.8	10.09×10^{-6} to 50.46×10^{-6}	4	Aluminum block	Sensitivity, lowest range of detection etc. are better for our system.
0.096	20×10^{-3} to 80×10^{-3}	5	Sponge supported	
0.082	20×10^{-3} to 80×10^{-3}	5	Rubber supported	
5.6	0.01×10^{-3} to 1.2×10^{-3}	7	Plexiglass supported	
20.7	1.8×10^{-6} to 12.3×10^{-6}	This Work	Sandwich between glass epoxy FR4 material (PCB)	

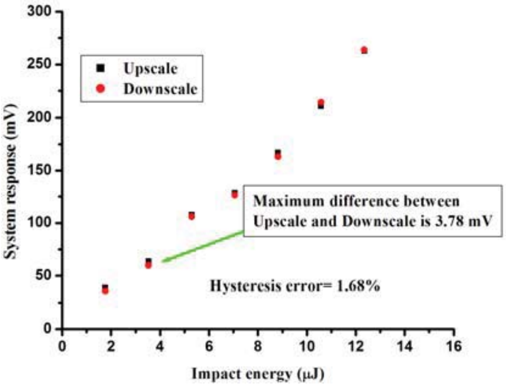


Fig. 5 The upscale and downscale reading from which hysteresis analysis of our system is performed; Rectangular symbol (black) and solid circle symbol (red) show the upscale and downscale reading respectively

C. Repeatability

The repeatability is the degree of closeness with which a measurable quantity may be repeatedly measured. Mathematically, it is defined as the measure of variation in the measured data known as the standard deviation, σ. It is expressed in terms of maximum repeatability error as a percentage of *FSOR*:

$$\%R_e = \frac{2\sigma}{FSOR} \times 100. \tag{3}$$

We have tested repeatability at 8.82 µJ (selected arbitrarily in the *FSOR*) for our system and it is found to be only 3.5% (less than 5%), signifying a good repeatable measurement system. In the estimation of repeatability error, the standard deviation for our system is found to be 0.185.

D. Estimation of Impact Force

In measuring impact energy, we have obtained good system characteristics which in turn motivate us to employ the system for measuring impact force. The impact force is estimated without any loss generosity using the equation [4], [19], [20]:

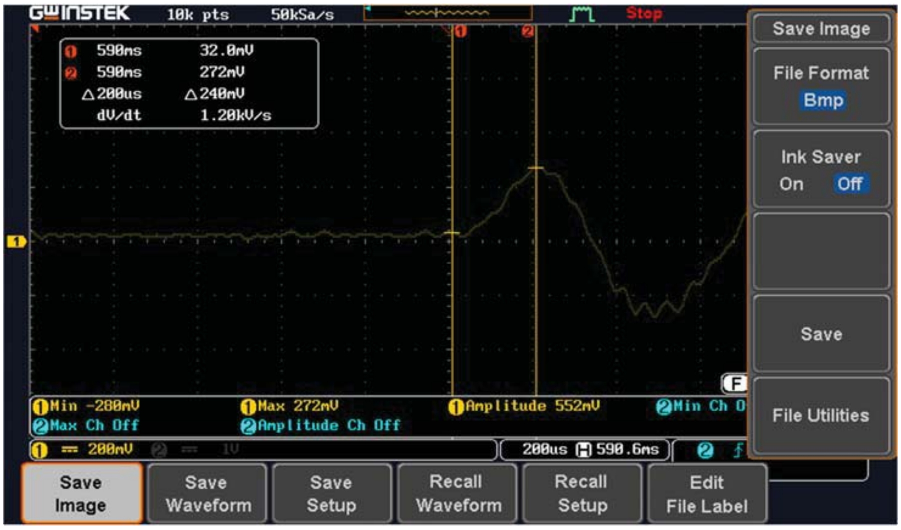
$$F_{imp} = \frac{dp}{dt}. \tag{4}$$

where, F_{imp} is the impact force, *dp* is the change of momentum and *dt* is the impact time. Further, $dp = m(v_1 - v_2)$, where *m* is the mass of the falling object; v_1 and v_2 are the impact velocity and rebound velocity (after impact) of the object. Since, we are working on very low impact energy regime, the ball hardly rebounds. Thus in order to simplify the procedure, we have considered $v_2=0$ together with *dt* = rise-time of the analog output from PVDF film sensor during an impact event [4], [19]-[21]. The rebound phenomenon is not considered in the estimation of impact force due to the facts that (i) the range of impact energy considered to measure is very small (~µJ), (ii) only signal rise-time is considered as impact time and (iii) the mass of loadcell is much higher compared to the steel ball. Hence, the error in our impact force estimation due to the rebound phenomenon can be ignored.

In order to estimate rise-time for an impact event, the output of the sensor is amplified to 40 dB and then the signal is observed through a digital storage oscilloscope. Typical analog output waveform for an impact event is shown in Fig. 6, showing impact rise-time of 200 µs.

Further, we have noticed that for the entire impact energy range of our study, the rise-time remains same. Similar invariance of rise-time with impact energy variation is also observed by Grinspan *et al*. [4]. For an event, the recovery time is found to be about 2 ms which is much lower than the loadcells supported by rubber or sponge [5]. In case of repetitive impacts, the measurement frequency can be increased by lowering the recovery time. For our system, the measurement frequency is estimated to be 500 Hz. This high measurement frequency allows our system to be used in practical applications such as counting of very small objects from a dispenser. Since we have used sandwich type loadcell, we need to consider the mechanical property of the loadcell as a whole instead of the same for bare film sensor. Thus, the equal signal rise-time is expected for the said range of impact energies and is a characteristic of our loadcell due to its own inertia. Thus, the impact force is estimated using the expression:

$$F_{imp} = \frac{mv_1}{dt} = \frac{m\sqrt{2gh}}{dt} = \frac{E_{imp}}{\sqrt{h}}\left(\sqrt{\frac{2}{g}} \times \frac{1}{dt}\right). \tag{5}$$



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① 590ms      32.0mV
② 590ms      272mV
  △200us    △240mV
  dV/dt      1.20kV/s
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①Min -280mV          ①Max 272mV           ①Amplitude 552mV      ②Min Ch O
②Max Ch Off          ②Amplitude Ch Off
① ⎓ 200mV  ② ⎓ 1V                          200us 590.6ms
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Fig. 6 Typical analog waveform for an impact event. Here, the steel ball falling height is 6.5 cm and the signal amplification is 40dB. From this measurement, the signal rise-time is found to be 200 µs

The result of the impact force estimation is shown in Fig. 7. It is to be noted here that though the impact energy is proportional to the falling height (as per (1)); the impact force is proportional to square root of the falling height (since, *dt* is constant in (5)). Hence, a non-linear output response is expected for impact force. However, within in a limited range of falling heights of 1–7 cm (corresponding to impact force range of 39.9–105.5 mN), we have obtained highly linear response.

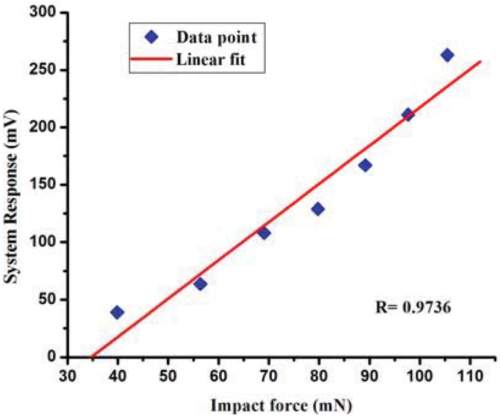

Fig. 7 System responses (in mV) for different impact forces (in mN) are plotted here. A linear fit to the data points shows the sensitivity of the system. The regression coefficient, R=0.9736 shows a good signature of linearity within the specified limit.

E. System Integration

The system is integrated to measure unknown impact energy or force within a specified range independent of a PC. For simplicity in the integration, the range within which both impact energy and force are linear is considered. From the linear relationship between the output voltage (from Arduino) and impact energy obtained earlier (as shown in Fig. 4), we express unknown impact energy as:

$$E_{imp}^{u} = 0.048(V_{out} + 6.63)\mu J \tag{6}$$

in which the output voltage V_{out} is in mV. The corresponding impact force can be expressed as:

$$F_{imp}^{u} = 6.08E_{imp}^{u} + 34.02mN \tag{7}$$

The last two expressions are valid within the range of 1.76–12.35 µJ (or 39.9–105.5 mN). When an unknown impact event causes the V_{out} to be in the range of 39–263 mV, then the LCD displays the value of impact energy in µJ and corresponding impact force in mN. To power up the system, a 5 V battery is used. Thus, a self-contained, compact and miniature impact measurement system is developed. A plastic ball (mass: 37.9 mg, density: 1.41 g/cm^3) is released from a height of 1.5 cm. and the corresponding measurements are found to agree well with our experiment.

IV. DISCUSSION

We have noticed that the degree of tightness of the bolts of the loadcell affect the noise and sensitivity drift. Here, noise means the signal magnitude in the absence of the impact events. When all the four corners of the loadcell are highly tighten, both the noise and sensitivity drift becomes zero. Further, it is noticed that the noise of the output signal becomes zero if the piezo-amplifier is used. There are mainly two factors that limit the measurement range. The first factor arises from the consideration of linear relationship between the output voltage (due to impact event) with the impact energy (or with the impact force) and such relationships are valid for a limited range. The second factor is the tendency to rebound of the falling ball when the failing height is more than 7 cm. This factor complicates the measuring process and thus limits the highest range of impact energy detection.

Change in sensitivity is observed for softer materials e.g. impact created by falling liquid droplets of mass 22 mg from a burette. When free fall of water droplets (of mass 22 mg) from a burette is considered to create impact events, the sensitivity is found lower as compare to that of obtained using steel ball. In case of water droplet, obtaining lower sensitivity is quite obvious since, the droplet changes its shape and imparts lower impact force. On the other hand, the signal rise-time for water droplet is found be 2 ms which is one order of magnitude higher in comparison to that of steel ball (~ 200 µs). Since, the impact force is inversely proportional to the signal rise-time; our system is capable of detecting lower impact force than the range considered in our investigation. In fact, in case of water droplets, we have reliably detected impact force as low as 6.9 mN. Thus, there must be a trade-off between the sensitivity and lowest range of impact energy to be detected. Hence the impact between the materials of interest is to be well studied to calibrate the system before a practical application of the instrument.

The dominant frequency comments of the output signal are measured using spectrum analyzer (Make: GW-Instek, Model: 9300). A typical spectrum is shown in Fig. 8. For impact created by plastic ball, it is the found the bandwidth is about 1.2 KHz, the lower and upper ranges of the spectrum are 8.91 KHz and 10.11 KHz respectively. These findings will help to design filter circuit or signal conditioning circuit for further processing of the signal in practical application.

Note that our system does not require a linear response. A non-linear response can easily be adapted by using higher degree polynomial fitting and programming the Arduino board accordingly. However, in that case the constancy of sensitivity within the range of interest will be lost. Thus, if constant sensitivity is not required, then the range and accuracy of instrument can easily be improved only by programming which is one of the important advantages of our system.

V. CONCLUSIONS

A low-cost Arduino-based impact energy measurement system is developed. Together with impact energy, the system is also able to estimate the impact force for an impact event. In the system, PVDF film sensor is employed as primary sensing element with a simple and efficient loadcell. The linearity, hysteresis and repeatability of the system are presented. The sensitivities and lowest detectable impact energy (or impact force) are found to be better than that of the similar reported works. In short, an efficient, cost effective and high-speed impact energy (as well as impact force) measurement system is developed and presented in detail.

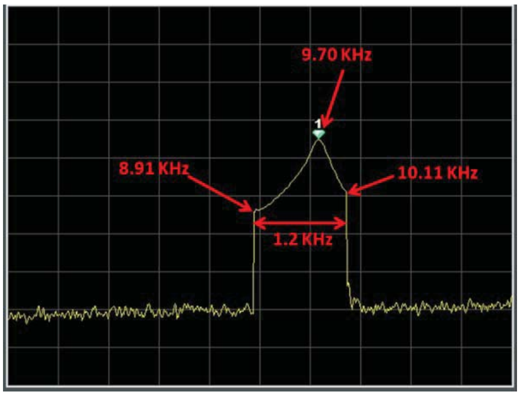

Fig. 8 Typical spectrum for an impact created by the plastic ball.

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REFERENCES

[1] L. Song, Y. Zheng, G. Hu, J. Ma, T. Werner, M. Zhao, and F. Fang, “Highly Sensitive, Precise, and Traceable Measurement of Force,” *Instru. Sci. Technol.*, vol. 44, no. 4, 2016, pp. 386-400.

[2] Y. R. Lee, J. H. Shin, I. I. S. Park, K. Rhee, and S. K. Chung, “Energy Harvesting based on Acoustically Oscillating Liquid Droplets,” *Sensors and Actuators A: Physical*, vol. 231, 2015, pp. 8-14.

[3] Y.R. Wang, J.M. Zheng, G.Y. Ren, P.H. Zhang,C. Xu, “A flexible piezoelectric force sensor based on PVDF fabrics,” *Smart Mater. Struct.*, vol. 20, 2011, pp. 045009-15.

[4] A. Sahaya Grinspan, R. Gnanamoorthy, “Impact force of low velocity liquid droplets measured using piezoelectric PVDF film,” *Colloids and Surfaces A: Physicochem. Eng. Aspects*, vol. 356, 2010, pp. 162-168.

[5] Y. Jia, X. Chen, Q. Ni, L. Li, C. Ju, “Dependence of the impact response of polyvinylidene fluoride sensors on their supporting materials’ elasticity,” *Sensors*, vol. 13, 2013, pp. 8669-8678.

[6] Y. Wang, Y. Gai, L. Kang, J. Qu, “PVDF piezoelectric film based force measuring system,” *Res. J. Appl. Sci. Eng. Technol*., vol. 4, 2012, pp. 2857-2861.

[7] J. M. Basahi, G. Fipps, M. J. McFarland, “Measuring droplet impact energy with piezoelectric film,” *J. Irrig. Drain Eng*, vol. 124, 1998, pp. 213-217.

[8] Y.-Y. Chiu, W.-Y. Lin, H.-Y. Wang, S.-B. Huang, M.-H. Wu, “Development of a piezoelectric polyvinylidene fluoride (PVDF) polymer-based sensor patch for simultaneous heartbeats and respiration monitoring,” *Sensors and Actuators A*, vol. 189, 2013, pp. 328-334.

[9] F. Wang, M. Tanaka, S. Chonan, “Development of a PVDF piezopolymer sensor for uncostrained in-sleep cardiorespiratory monitoring,” *Journal of Intelligent Material Systems and Structures*, vol. 14, 2012, pp. 185-190.

[10] A. Kimoto, N. Sugitani, “A new sensing method based on PVDF film for material detection,” *Meas. Sci. Technol.*, vol. 21, 2010, pp. 075202-8.

[11] Y. Mneng, W. Yi, “Application of a PVDF-based stress gauge in determining dynamic stress-strain curves of concrete under impact testing,” *Smart Mater. Struct.*vol. 20, 2011, pp. 065004-10.

[12] A. Sutor, R. Lerch, H.-P. Hohe, M. Gavesi, “New CMOS-compatible mechanical shear stress sensor,” *IEEE Sensors Journal*, vol. 1, 2001, pp. 345-351.

[13] A.V. Shirinov, W.K. Schomburg, “Pressure sensor from a PVDF film,” *Sensors and Actuators A*, vol. 142, 2008, pp. 48-55.

[14] D. Vatansever, R.L. Hadimani, T. Shah, E. Siores, “An investigation of energy harvesting from renewable sources with PVDF and PZT,” *Smart Materials and Structures*, vol. 20, 2011, pp. 055019-055025.

[15] Z. Chen, Y. Shen, N. Xi, X. Tan, “Integrated sensing for ionic polymer-metal composite actuators using PVDF thin films,” *Smart Mater. Struct.*, vol. 16, 2007, pp. S262-S271.

[16] K.J. Kim, Y.M. Chang, S. Yoon, H.J. Kim, “A novel piezoelectric PVDF film-based physiological sensing belt for a complementary respiration and heartbeat monitoring system,” *Integrated Ferroelectrics*, vol. 107, 2009, pp. 53–68.

[17] Y. Fu, E.C. Harvey, M.K. Ghantasala, G.M. Spinks, “Design, fabrication and testing of piezoelectric polymer PVDF microactuators,” *Smart Mater. Struct.*, vol. 15, 2006, pp. S141–S146.

[18] B.L.F. Daku, E.M.A. Mohamed, A.F. Prugger, “A PVDF transducer for low-frequency acceleration measurements,” *ISA Transactions*, vol. 43, 2004, pp. 319-328.

[19] M.A. Nearing, J.M. Bradford, R.D. Holtz, “Measurement of force vs time relations for water drop impact,” *Soil Sci. Soc. AM. J*, vol. 50, 1986, pp. 1532-1536.

[20] Y. Fujii, “Measurement of steep impulse response of a force transducer,” *Measurement Science and Technology*, vol. 14, 2003, pp. 65-69.

[21] Y. C. Wang, Y. W. Chen, “Application of piezoelectric PVDF film to the measurement of impulsive forces generated by cavitation bubble collapse near a solid boundary,” *Experimental thermal and Fluid science*, vol. 32, 2007, pp. 403-414.

Miss Priyanka Guin received her M.Sc. degree in Electronic Science in 2013 from West Bengal State University (Barasat, India). She stood First-Class-First in M.Sc. Priyanka has also qualified NET (National Eligibility Test, conducted by UGC govt. of India) in 2013. She is the recipient of prestigious DST Inspire Fellowship, Govt. of India. Presently she is pursuing Ph.D. at the Department of Electronics, West Bengal State University (Barasat, India). Her main area of research is Instrumentation and Piezo-sensor.

Mr. Dibyendu Chatterjee completed B.Sc. degree in Electronics (Hons.) and stood first class first (gold medalist) from Bankura Christian College (under Burdwan University, West Bengal, India) in 2006 and M.Sc. degree in Electronic Science from Jadavpur University (West Bengal, Kolkata, India) in 2008. He is also qualified prestigious examinations such as NET (National Eligibility Test, conducted by UGC govt. of India) and GATE (Graduate Aptitude Test in Engineering, conducted by IITs& IISC) in Electronics and Communication Engineering. Presently Mr. Chatterjee is pursuing Ph.D. at the Department of Electronics, West Bengal State University (Barasat, India). His main area of research is Quantum Computation.

Dr. Arijit Roy has attended many prestigious institutes like IITs, NTU, Infineon Technologies in his career. He earned Ph.D. from School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore in 18 Jan 2008. Before pursuing full-time research career, he obtained M.Tech. (Instru.Tech.) and M.Sc. (Physics) from Indian Institute of Technology-Delhi and Indian Institute of Technology-Kharagpur in 2001 and 1999 respectively. He has published many research papers in peer-reviewed international journals of high impact factor, four peer-reviewed research papers in international conference of repute (like IRPS, IPFA etc). Apart from these, Dr. Roy has delivered few invited talks in recognized conferences. His research articles are being cited more than 200 times as of now. Among his various publications, a 75-journal-page-size review article (the longest documented work in the history of the topic) on Electromigration published in Materials Science and Engineering Reports: R is well received by the community. Dr. Roy’s another novel work is published in Microelectronic Engineering 113 (2014) 152-156. His research interest includes: micro/nano-electronics, quantum computation, circuits and systems and science teaching.

He was awarded “International Research Scholarship” from NTU for pursuing PhD. His research work was additionally funded by IME, Singapore during his PhD career. He won the prize for second-best-paper in “Symposium on Microelectronics–2004”. Also, he ranked 31 (all India) in GATE’99 examination.

Presently, Dr. Roy is Assistant Professor in Electronics at West Bengal State University. Before joining to this position, he was employed at Infineon Technologies and NTU respectively. He is the first Head of the Department of Electronics at WBSU, and is involved in shaping the department for academic excellence.