A NOVEL TECHNIQUE BASED ON IoT ACCELEROMETER FOR TRANSMITTING CIRCULAR CHART RECORDERS TO ELECTRICAL DATA

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The omnipresence of the Internet of Things (IoT)-based accelerometer in the industry has been considered as an alternative to paper chart recorder yet it is unprecedentedly tested on pressure recording variation. To this end, this paper contributes to the improvement of data acquisition which is obtained from pressure chart recorders through accelerometer devices. Firstly, the accelerometer device is thoroughly described. Then, the implementation of the accelerometer and IoT based accelerometers in a variety of domains is discussed. Secondly, the used materials to carry out the bench test are presented, namely accelerometer, ADXL345, H3LIS331DL, Barton , DEWEIT pressure chart recorder, Raspberry pi and Arduino. The aforementioned devices are purposefully coupled, explicitly two types of accelerometers are plugged into the raspberry pi for the sake of comparing the accuracy of transmitting mechanical to electronic charts. Finally, it is found that the accelerometers combined with wireless communication can offer a reliable alternative for expensive tasks. In addition, it perfectly facilitates data acquisition from a pressure chart recorder which is considered the first integration of an accelerometer in a pressure chart recorder. Interestingly, the H3LIS331DL accelerometer is way better than ADXL345 when it comes to processing high-pressure variation more than 3900 PSI within few seconds. It is noteworthy to say that the proposed IoT-based accelerometer to assess the pressure variation in industry is considered for the first time as an electrical chart recorder.

Keywords: Internet of Things, IoT, microelectromechanical systems , MEMS, accelerometer, ADXL345, H3LIS331DL, cost-less monitoring, raspberry pi, wireless monitoring, pressure chart recorder.

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1. Introduction

Technological developments in the domain of microelectronics and wireless sensors, as well as reduced device prices, pave the way to coming up with a mechatronic idea since it facilitates the integration of sensors in many fields. Recently, internet of things (IoT) has been emerged as a powerful tool, which describes the integration of sensors in various applications that can be industrial IoT as in this paper or IoT home automation. The application of IoT technology in industry refers to the so-called industrial IoT, in particular when it comes to using sensors to monitor or acquire data. The second most sold sensor in the world is the kinematic sensor also named the accelerometer [1]. The principal function of the accelerometer sensor is to translate mechanical data into electric and numeric. A simple microelectromechanical system (MEMS) sensor is composed primarily of a mechanical structure that receives the physical signal as an external stimulus. Depending on the type of sensor, external stimulation produces a change in dimension, displacement, pressure, stress, plate or film movement, or vibration, which results in an electric signal.

The approach of detection defines the type of accelerometer, and each type of accelerometer has its features [1]. Capacitive accelerometer [2] can detect low-frequency oscillations and can't be affected by ambient conditions. But the piezoelectric accelerometer [3] is ideal for detecting oscillations over 0.5 Hz and requires temperature compensation. There is also another type of accelerometer called resistive accelerometer [4] that has high linearity and good resolution. Optical accelerometers [3] are recognized as GPS-based sensors because of their higher resolution.

Especially, the accelerometer type, considered in this paper is a capacitive accelerometer, which is mainly composed of a poly-silicon surface micromachined structure built on top of a silicon wafer. Furthermore, poly-silicon springs suspend the structure over surface of the wafer and provide resistance against accelerometer forces. Basically, the accelerometer is simply powered by exclusively 3-5 V. Furthermore, the accelerometer operates approximately in high temperature ranges between -40 C to +85 C. For a detailed description of both accelerometers types ADXL345 and H3LIS331DL, we refer the readers to [5], [6].

The accelerometer is widely used in many fields. Recently, researchers have conducted a research about the bridges expectancy life [7] using the inspection sensing vibration method and stress non-destructive test (NDT) to determine the optimal value of the nonlinear vibration index (NVI). By probing bridges expectancy life, engineering can avoid the sudden failure of bridges structure. Additionally, the capacitive accelerometer is used as a seismometer and tilt meter for measuring and logging mechanical and magnetic data that is commonly used in astronomy [8]. Overall, a detailed review of the different uses of the accelerometer is properly given in [9], for instance, accelerometer can be also used to probe the atoms motion in nuclear experiments. Furthermore, the IoT-SHM (structural health monitoring) system is an adjustable system that can be used in "smart constructions", "smart historic masonry", which serves at enhancing safety and lowering the management effort/time/-cost [10]. Motion-Recognition of Rings and a Paper Keyboard developed as virtual Wireless keyboards [11]. Accelerometer sensing fall detection as an IoT in Apple watch 5 [12]. Moreover, microelectromechanical system IoT-Accelerometer can monitor large rotor vibration [13]. Interestingly, accelerometers invade applications that rely on systems that are able to deal with and use new information immediately and therefore influence or direct the actions of the objects supplying that information and which is also called real-time application, for instance, real-time detection of line sags in overhead power grids using an IoT-Based Monitoring system : theoretical foundations, system implementation, and long-term field verification [14].

However, in this paper, a novel pressure chart recorders-based accelerometer is attached to a needle-like pen to transfer the chart recorder 's mechanical movement to electronic chart. Pressure Circular chart recorders are a crucial component of the monitoring process in the industry. We will highlight why we believe that upgrading or keeping a hybrid analog-digital pressure data logger side by side is not very demanding when it comes to cost and time for most short-term testing in this brief comparison.

The crucial first step towards measurement success is accuracy. Within the same context, accelerometer is proved to be a handy tool for obtaining accurate results. Its accuracy [9] has been considerably improved which makes it omnipresent in various fields. For instance, in industry, more clearly companies commonly use conventional materials to acquire data, however with the improved accelerometers accuracy; data can be accurately acquired and that helps to achieve great results.

The workbench tests was carried out using various components, in which we elaborately analysed the accelerometer-based tehnique to transfer mechanical movements to electric. Basically, the accelerometer is programmed using raspberry pi that is python-based language. The developed python code is used to make the accelerometer save the detected motion when it is attached to any object and in our case the mobile circular chart recorder is the considered object. Then, the accelerometer was plugged into a needle-like pen through electric wires and firmly put on a conventionally paper-based chart recorder. In addition, a separate screen was connected to raspberry pi to visualize the resulting graphs obtained from the accelerometer. During the motion of the conventional chart recorder, the needle-like pen attached to accelerometer accurately records data at each caption and visualizes it via the used monitor (screen).

The rest of this paper is organized as follows. In section 2, the required components used in this test bench are presented. In section 3, different experiments are performed and the obtained results are thoroughly discussed. In section 4, advantages of the proposed chart recorder-based accelerometer are provided and compared to the already existing chart recorder system. The drawbacks of the proposed system are given in section 5. Finally, this paper is concluded with the most obtained findings and followed by future potential works.

2. Description of the used system

The proposed chart recorded-based-accelerometer is composed of a raspberry pi 3 B+ and an accelerometer as it is shown in figure 1.

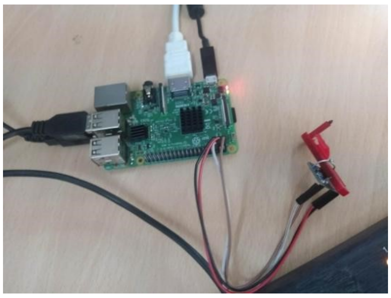

Figure 1. View of the used devices for the considered chart recorder-based accelerometer

2.1. Required components

2.1.1. *Chart recorders.* A chart recorder is a large and hefty piece of equipment that monitors and records system operating parameters such as gas and liquid flow rate, the liquid level in a vessel, and other system variables. Overall, the recording mechanism consists of a needle-like pen that is attached to an accelerometer. The main purpose of this mechanism is to permanently save data during operation, in our case, the operation task is to measure pressure variation. In this paper, we distinguish two types of chart recorders:

- Cameron's BARTON Chart recorders are the industry standard for precise, accurate pressure measurement and recording in a wide range of applications such as controlling pressure variation in pipelines or vessels. As the actuation unit, a BARTON rupture-proof bellows Differential Pressure Unit (DPU) with over-range safety and pulsing dampening is used [15].
- DEWIT Chart recorders have a wide temperature range of -170 to 600 degrees Celsius, a minimum temperature span of 60 degrees Celsius, a

pressure range of up to 60,000 psi (4000 bar), a bottom or back connection, a mechanical spring-wound clock, switchable clockwork, some models support dual or triple pen and a panel mount [16].

2.1.2. *Accelerometer.* the adopted accelerometers' types in this paper are:

- H3LIS331DL tri-axial accelerometer has low noise with a high-g range of 200 g per axis [6] with six degrees of freedom an operating temperature interval of − 50 c to + 85 c flexibility high survivability [17] due to its features. This sensor is used to predict and measure head injury in rugby and boxing [18] and traumatic brain injury [19]. Additionally, Model-based Logger for measuring stone kinematics [20] and in Hexacopter for logging data [21].
- The ADXL 345 is a tiny, thin, low power, 3-axis accelerometer with high resolution (13-bit) measurement at up to 16 g. Digital output data is formatted as 16-bit twos complement and is accessible through either a SPI (3- or 4-wire) or I2C digital interface. The ADXL 345 is well suited for mobile device applications. It measures the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion or shock. Its high resolution (4 mg/LSB) enables measurement of inclination changes less than 1.0 degree [5]. Interestingly, ADXL 345 is used as an IoT-enabled accelerometer-based home security system [22], smart IoT helmet for motorbikers [23].

2.1.3. *Raspberry Pi Board: 3B +.* Raspberry Pi is used as a microcomputer in IoT such as a data collecting system based on IoT sensors with adjustable processing on-board for cow activity recognition [24]. The raspberry pi third-generation single-board computers can be found in detail in the manual [25].

2.1.4. *Arduino UNO R3.* Arduino is an excellent board for learning both electronics and coding, this multifunctional microcontroller is equipped with the well-known ATmega328P and the AT Mega 16U2 Processor. This board provides a great first experience within the world of Arduino [26]. Basically, the monitor is a multi-sensory smart gadget based on the Internet of Things that monitors cow behavior [27].

Figure 2 is a global view of the used components in the carried out experiments.

3. Discussion and results

In this section, the whole procedure for the experimental bench of the proposed system is depicted in Figure 2-3. To emphasize, when the pressure takes high values, the needle (designed by element 1, grey color) of the circular chart recorder (designed by element 2, green dashed color) remarkably displaces along with the pen (designed by element 3, red color), which makes it draw the recording values of pressure on the circular chart paper at each displacement. Accordingly, the recorded data from this chart recorder can be

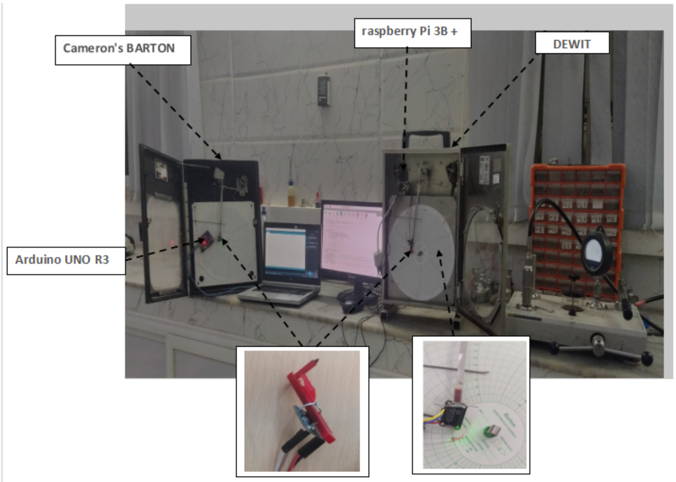

FIGURE 2. Arduino, Raspberry pi, and accelerometer plugged into the pressure chart recorder

easily transferred as electric data by attaching an accelerometer (element 4) to the pen's head. It is noteworthy to say that, the pen's head moves according to the pressure variation, namely when the pressure increases, the pen's head moves up and vice versa. For this exact reason, an accelerometer is attached to the pens head to easily acquire data for each single heads displacement within a large number of hours contrary to the conventional needle which can fail during data acquisition due to the mechanical failure of the analog clock.

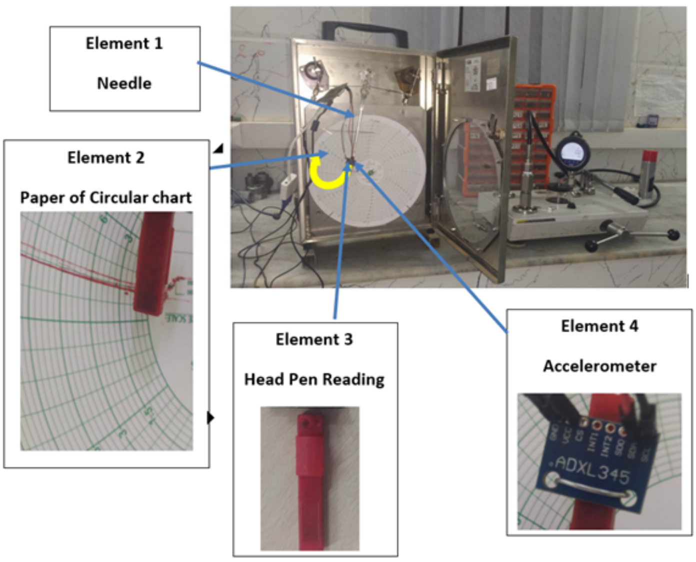

FIGURE 3. Detailed experimental bench

Among the carried out experiments, only a few experiments were picked up decisively. Explicitly, we chose a few experiments to merely point out the crucial utility of using IoT-based accelerometer as an original idea in acquiring data from conventional chart recorders instead of using paper-based analog circular chart recorder. Thus, the idea of electronically recording data can be broadened and applied to a large number of tests if big data is required.

Firstly, the installation of the raspberry pi -accelerometer (H3LIS331DL) system is set up for the sake of visualizing chart pressure variation. The obtained accelerometer-based graph (see figure 5) is compared with the already existing circular paper chart as it is shown on the right side of figure 4. in the former, the pressure is deliberately set up at an upper and lower value as it is shown in figure 6, and that is performed to assess the needles displacement variation according to the accelerometer. However, in the latter; the pressure variation is steadily increased to evaluate the steadiness of the needle (see figure 7).

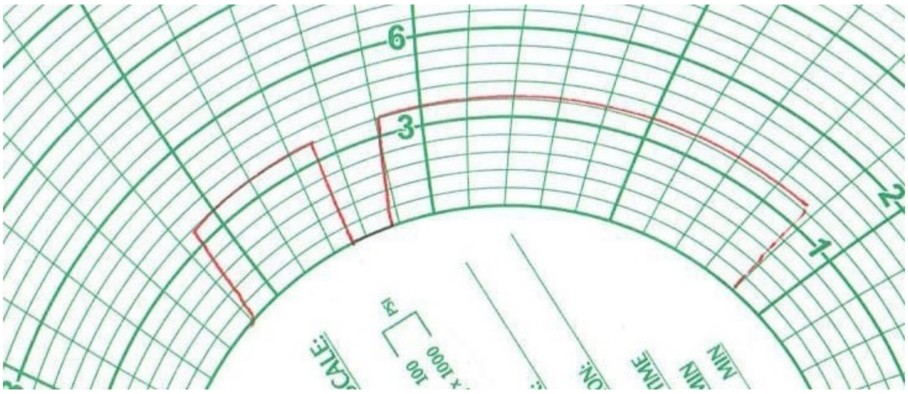

FIGURE 4. Chart 1 pressure variation

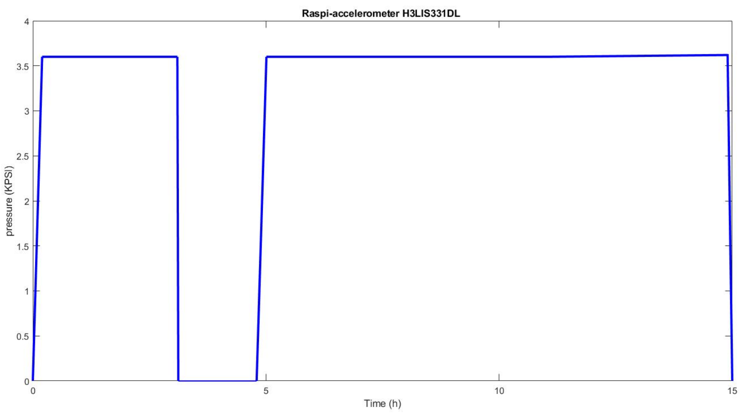

FIGURE 5. Electronic chart related to chart 1

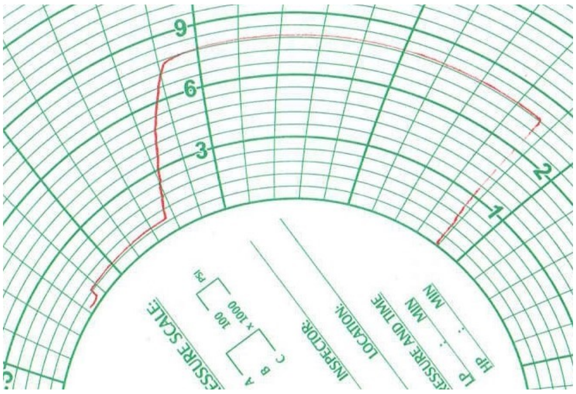

FIGURE 6. Chart 2 pressure variation

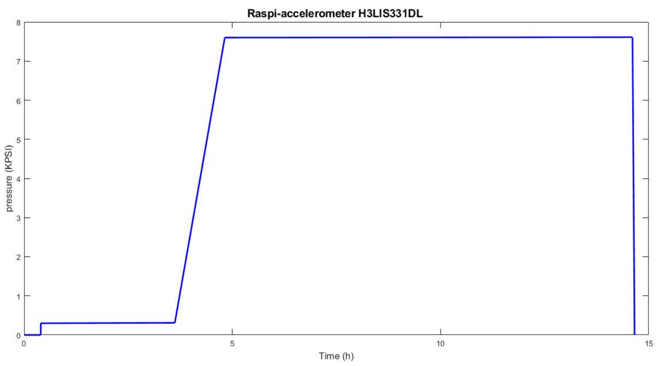

FIGURE 7. Electronic chart related to chart 2

It is obviously clear that the resulting graphs of pressure from the proposed chart record-based accelerometer overlap those obtained from circular paper-based chart recorder.

In the second experiment, the system raspberry pi-accelerometer (ADXL345) is used instead of the previously proposed system.

The accelerometer-based graph (see figure 9) is compared with the circular paper-based chart recorder as it is shown on the right side of figure 8. Noticeably, ADXL345 fails to record data that represents pressure variation (more than 3900 PSI) when the needle displacement exceeds roughly 125 mm. Remarkably, When the needle of the circular chart recorder displaces progressively within a few seconds, that triggers a sudden failure in recording data which originally bounces back to the massive data being recorded at each caption.

The accelerometer recorders data which presents the pressure variation. Remarkably, when the needle of the circular chart recorder displaces progressively within a few seconds, that triggers a sudden failure in recording data

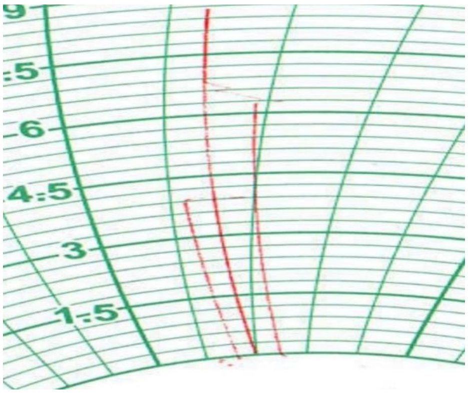

FIGURE 8. Chart 3 pressure variation

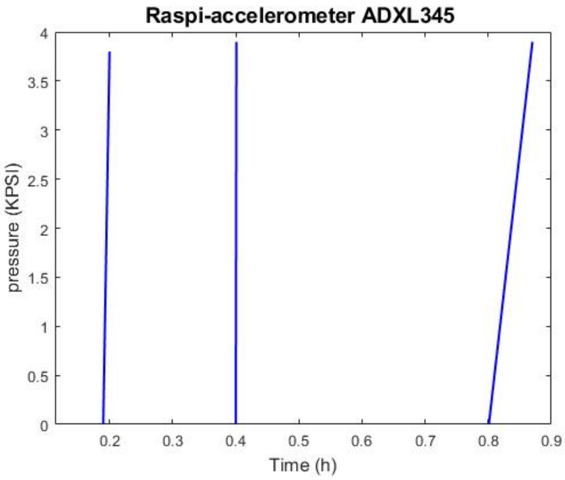

FIGURE 9. Electronic chart related to chart 3

which originally bounces back to the massive data being recorded at each caption.
We conclude that the accelerometer ADXL345 cannot sense massive variations of the needle of more than 3900 PSI in a few seconds.

4. **The main feature of the proposed system**

Interestingly, the established system or mechanism in this paper provides a costless analysis since it does not require expensive components. Furthermore, this system can record instantaneous responses which helps to acquire data, in our case, the recorded data is pressure variation. To emphasize, the developed system in this paper is strongly relied on IoT which is a perfect tool to remotely monitoring pressure and it can also be considered as an alert system in the case of unwanted pressure variations. Last but not least, this system noticeably facilitates the monitoring of oil pipelines which yields in an increasing pace of production. Axiomatically, these features pave the way to implementing this IoT system in the industry.

Besides the aforementioned advantages, we put the accent on the benefits of paperless recording as an interesting idea that can be used to replace the classical methods of recording data. To say the least, the advantages of using paperless recording are [28]:

- Users will be able to decrease and eliminate their paper processing and will no longer be required to manage, save, or maintain huge volumes of paper records.
- Data can be electronically formatted and analyzed.
- Paperless recordings don't require pens, a paper chart, or a clock chart, which makes the whole procedure costless.

5. Drawbacks of the proposed system

Despite the numerous advantages of the developed IoT system in this paper, there are also some disadvantages such as the need for a long-duration energy storage. Furthermore, the proposed IoT system of explosion can trigger a sudden failure in the electrical system.

6. Conclusion

The integration of microelectronics sensors (MEMS-based accelerometer) is considerably changing our lives to make it easier, handy, more efficient and reliable in the concept of translating inertial movement to numerical signal.

Moreover, there is a higher level of monitoring required for self-operated machines compared to conventional machines. For this reason, IoT monitoring is aimed at maximum productivity and efficiency with the least investment.

The developed raspberry pi accelerometer H3LIS331DL system is inexpensive, simple to set up, and offers a variety of data collecting and flexible possibilities. It also provides accurate and high-quality data to the received server. The implementation of IoT-based accelerometer can be improved in terms of accuracy and sensitivity by adjusting its intrinsic electrical structure. Particularly, the accelerometer can be used inside rotating machines to assess their vibration during operation without the need for human interaction.

The future potential work resides in developing a new chart recorder based on the internet of things as well as coming up with software monitoring.

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