Investigation on magnetometer as potential sensors for infusion pump utilisation status

E A R Engku Ariff1,2, A Zakaria1,2, L M Kamarudin2,3, S M M Syed Zakaria2,3, S Zakaria2,4 and R Visvanathan5

1 Faculty of Electrical Engineering Technology, University Malaysia Perlis (UniMAP), Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.  
2 Centre of Excellence for Advanced Sensor Technology (CEASTech), Lot 16-21, Pusat Pengajian Jejawi 2, Jalan Jejawi Permatang, 02600 Jejawi Arau, Perlis Malaysia.  
3 Faculty of Electronic Engineering Technology, University Malaysia Perlis (UniMAP), Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.  
4 Faculty of Mechanical Engineering Technology, Universiti Malaysia Perlis (UniMAP), Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.  
5 IDERIA Sdn Bhd, Lot 30, Tingkat 1, Jalan Medan Niaga, Taman Sri Firdaus, 01000 Kangar, Perlis, Malaysia.

Abstract. The utilisation of medical device e.g. an infusion pump is commonly treated as non-trivial process in service and maintenance section albeit in actuality, it is a crucial process for determining its correct maintenance cycle. Therefore, a discussion on the capability of magnetometer sensor as one of potential sensors to be used to keep track the utilisation status of infusion pump. The variation of magnetic flux density and its frequency produced by the stepper motor inside the infusion pump is measured and analysed through magnetometer sensor, embedded inside a Bluetooth Low Energy (BLE) device. Obtained result shows that magnetometer sensor has the potential to track the utilisation status of the tested infusion pumps.

1. Introduction
The utilisation of medical devices plays an important role in service and maintenance section. However, due to medical device utilisation is not being tracked efficiently, and hence resulting in incorrect maintenance cycle. As a result, this may indirectly give an impact where the medical device always having a breakdown and shortening its lifespan. Therefore, it is essential to keep track the utilisation status in order to improve its service and maintenance cycle as well as optimising the cost for not assigning unnecessary service and maintenance.

The solution that is chosen, utilise the radio frequency wireless technology in medical devices, thus introduces some unique risks that should be addressed. Hence, it must adhere to the specification and recommendations to ensure safe and effective wireless medical devices. U.S. Food and Drug Administration (FDA) recommends that any development of wireless devices must be in range of unlicensed basis in frequency bands such as the Industrial, Scientific, Medical (ISM) bands [1]. Bluetooth Low Energy (BLE) technology is one of these bands.

This paper discusses the investigation of the potential placement for a BLE device onto the given medical devices and the potential type of sensors for detecting the status or its usage. The medical devices are Terumo Terufusion Syringe Pump – TE331 and BJ Braun Perfusor Space. Since the devices use motorised mechanism when operating, the potential method of detecting whether they are in used or not is through the strength of magnetic field radiated from the motor through magnetometer.
sensor [2]. Furthermore, the potential placement of the sensor in order to locate the highest measured signal for the motor’s electromagnetic radiation also needs to be identified. For the given medical device, four potential placements for the sensor are identified based on the location where the motorised system unit is mounted in the device.

2. Investigation methods

In order to determine whether the medical device, in this case an infusion pump is in used or not, the strength of magnetic field produced by its motor can be used as an indicator. Hence, chosen sensors will be placed at several positions on the medical devices such that the measured signal can be properly obtained and analysed. The identified locations for Terumo Terufusion Syringe Pump – TE331 are at the front, top, back and bottom as shown in figure 1. These positions are chosen based on the location where the motor is mounted inside the device as indicate in a blue box in figure 1 [3]. As for B|Braun Perfusor Space, the tested placements are at the top, side, and bottom as shown in figure 2 which is in accordance to the mounted location of the motor for this device [4]. The placement at the back of the device is not being considered since a speaker is mounted at that location where it will interfere with measurement of magnetometer sensor.

The magnetometer sensor that will be investigated to ensure the indication for the usage of the intended device is properly obtained is Bosch BMM150 3-Axis Magnetometer [5]. The sensor is capable on measuring the strength of magnetic field with 0.3 μT resolution. Hence, it is expected that it is capable of measuring even the strength of magnetic field produced by the motor is small. Typically, the speed of the motor i.e. in this case stepper motor is proportional to the power it is supplied with [6]. It is expected that the measured waveform from the magnetometer sensor will has variation of amplitude and frequency based on the infusion rate (in mL/h) set to the medical device i.e. as the infusion rate increases, the operation speed of the motor also increases. The magnetometer sensor is tested when the device is on stand-by mode and for five different infusion rates, from 10 mL/h up to 50 mL/h, with 10 mL/h increment. Obtained signals are analysed for the changes on the magnitude and fundamental frequency.

Figure 1. Potential placement of sensor on Terumo Terufusion Syringe Pump – TE331.
3. Results and discussion
The magnetometer sensor is expected to measure the strength of magnetic field produced by the motor at different infusion rates. The sensor is tested at each placement with five different infusion rates for ten minutes. The magnitude of the measured signal as well as the fundamental frequency are observed and analysed. The analysed measured signals each infusion rate are shown in figure 3 and figure 4. Note that, only the measured signals for the top placement are shown in figure 3 and figure 4. This is because, the signals measured by the magnetometer sensor is the highest at this location. In addition, the placement at the top give the least inconveniency with the routine operation of the user. Thus, the best location to place the BLE device is at the top of the device (refer to figure 1 and figure 2).

Although the two medical devices are tested with the same infusion rates, their waveforms are entirely different (refer to figure 3 and figure 4) since the motor’s magnetic flux density as well as operating speed also varies in accordance to the construction of the stepper motor. In other words, depending on the motor model used and its operating requirements, the strength of the produced magnetic flux will be different. However, the general characteristic of the measured waveforms of those medical devices re-mains the same. As can be seen in figure 3 and figure 4, the strength of motor magnetic field in-creases as well as its frequency as the infusion rate increases for both tested medical devices. This is expected since the more power is supplied to the motor and its speed increases. Nevertheless, the variation of the strength of the magnetic flux is imprecise but may serve as general indicator for medical device utilisation status.

On the other hand, the frequency spectra of each measured signals with respect to the set infusion rate are shown in figure 5 and figure 6. One can see that at each infusion rate, the frequencies of the measured signals are varies. As the infusion rate increases, the frequency of the measured signals also increases with a constant increment. Thus, it can be said that the infusion rate of the tested medical devices are proportional to the frequency of magnetic flux density produced by their respective motors as shown in figure 7. Therefore, in addition to variation of the strength of the produced magnetic flux, its frequency may serve as a firm indicator for the tested medical devices utilisation status.
Figure 3. Measured signals of magnetometer sensor for Terumo Terufusion Syringe Pump – T331.

Figure 4. Measured signals of magnetometer sensor for B|Braun Perfusor Space.

Figure 5. Frequency spectra of measured signals for Terumo Terufusion Syringe Pump – T331.

Figure 6. Frequency spectra of measured signals for B|Braun Perfusor Space.
4. Conclusion
An investigation of magnetometer as one of potential sensors to determine either an infusion pump is in used or not, i.e. its utilisation status, has been discussed in this paper. Obtained result shows that magnetometer sensor can be used for this purpose due to variation of the strength and the frequency of the produced magnetic flux by the motor. However, it is also essential to identify the location of the sensor placement to ensure the obtained signals are as consistent as possible and the sensor itself does not cause a nuisance to the user. Nevertheless, in order to increase the robustness of detecting the utilisation status of infusion pump, the usage of an additional sensor is recommended.

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