MICRO-MINIATURE REED SWITCH SOLUTION FOR LOW POWER CLINICAL APPLICATIONS

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ABSTRACT

Improving the ease of configuring low power embedded microcontroller-based devices used within clinical rehabilitation settings and prosthetic limb systems can be a challenging problem for engineers and clinicians. This problem arises, in part, due to the fact that the desired product designs often tend to be in a small compact sealed form. As a result, gaining access to the system is difficult and time consuming. The work presented in this paper aims at overcoming this problem by developing a solution that uses a series of micro-miniature reed switches in conjunction with small magnets to configure different modules of the embedded devices without the need for disassembly and/or compromising the hermetic seal.

INTRODUCTION

Many clinical rehabilitation cases require small, compact, and reliable solutions to help improve the lives of patients. The challenges faced by engineers and clinicians are often amplified when designing a battery-operated system which require a low power consumption strategy while maintaining a high level of functionality. Some of these functions, such as a wireless communication module used to configure a device, may not always be in use but will often continuously consume power. Ideally, it would be preferable to provide the clinicians with the ability to activate/deactivate some of the system's functionality without the need to disassemble the unit or to incorporate a mechanical switch that may compromise the hermetic seal. Such a feature would reduce the power consumption of a system thereby extending the unit's battery life.

In order to design such a feasible and compact solution, a form of wireless sensor technology needed to be identified with a small footprint in both the physical dimensions and supporting circuitry. With these constraints in mind, reed switches are a potential type of sensor for the described application. These sensors are activated by any nearby magnetic field in order to either close or open its electrical connection.

METHODOLOGY

The reed switch needed to be small enough such that several could be placed in a relatively confined area and subsequently used to produce specific activation 'patterns' to enable/disable features within the embedded system. Additionally, the space and power requirements of the associated electrical circuitry needed to be minimized. An initial investigation identified the low power MMS surface mount reed switches (Meder Electronic, Singen, Germany) as a possible sensor for the design [1].

Given that the manufacturer does not publish the characteristics of this particular reed switch model, a series of experiments were conducted to reliably determine the acceptable activation/deactivation distances of the sensor. This information would be invaluable to designing a practical solution that would incorporate several of these switches positioned in a patterned configuration which activate/deactivate some of the device's functions based on the proximity of specific magnetic keys.

Experimental Protocol

The first experiment consisted of placing the MMS sensor in a fixed location, moving the x, y, and z position of a magnet, and recording whether the switch's electrical connection was open or closed. The x-y plane represented a surface perpendicular to the sensor while the magnet's distance from the sensor was indicated by the z-axis value. The experiment was repeated such that 10 data samples were recorded for each magnet location as well as for several magnets of varying field strength. The results are presented in Figure 1. The second experiment evaluated the potential attenuation effect that would result from the reed switch being placed within a sealed enclosure. These results can be found in Figure 2. The final experiment used several reed switch sensors in combination with an 8-bit comparator IC (SN74HC688N) to produce a specific magnetic 'pattern' that would only be activated if the correct subset of sensor were activated. This type of implementation would be used to avoid inadvertent activation due to a strong magnetic field. Five reed switch sensors were tested concurrently in combination with the 8-bit comparator IC in order to determine if a specific pattern could be used such that a valid result would be produced only if a subset of sensors were activated by magnets. For this test, four of the sensors were arranged in a square with one sensor in the middle of the square. The specific geometry of the arrangement was such that the distance between the sensor at the center and any corner of the square was 1 cm. This distance was chosen based on preliminary experimental data. A magnet was used to activate the sensor at each corner of the square while the middle sensor remained inactivated. The results from this final experiment can be found in Figure 3.

RESULTS

Figure 1 represents the repeatability of switch activation versus X-Y plane location at three different distances along the Z-axis. At each Cartesian coordinate, the magnet used to activate the sensor was iteratively moved into position along the Z-axis 10 times while the activation state of the switch was recorded. This set of data was subsequently averaged to produce a probability of activation for each particular location. The probability of activation versus position of the magnet relative to the sensor can be seen in figure 1, in which a darker shaded dot represents a higher probability of activation.

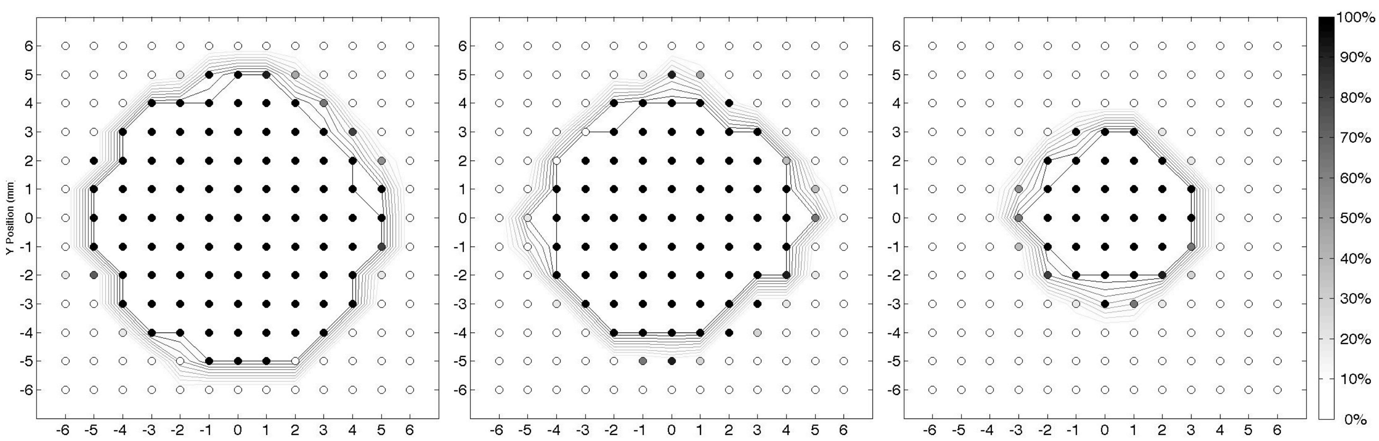

Figure 1: Activation profile of the reed switch sensor with magnetic field distances (z-axis) of 3mm, 5mm, and 7mm respectively. Each point found on the x-y plane represent the activation percentage where a darker shade represents a higher repeatability. Contour curves are plotted to illustrate the general region of high repeatability.

The system was then tested with a piece of plastic used in prosthetics limb sockets with a cosmetic skin covering placed between the magnet and reed sensor. Once again, 10 iterative tests at each location in the X-Y plane for a fixed Z distance were performed to determine the probability of activation versus position. The results are shown in Figure 2, using the same scheme as Figure 1 in which a darker shaded dot represents a higher probability that the switch will be activated by the magnet.

Finally, the response of the pattern configuration setup where switches 1 through 4 represent the switches at each corner of the square and switch 5 is the switch in the center is shown in Figure 3. The bits being compared to the output of the sensors were set such that the 8-bit comparator would only output a valid comparison result when the four switches at the corners of the arrangement were activated while the switch in the middle remained inactivated. It can be seen from Figure 3 that when the four switches at the corners of the square are activated, the output of the 8-bit comparator chip is also activated.

DISCUSSION

Based on the results shown in Figures 1 and 2, it appears that these reed switches produce a highly repeatable output signal. It should be noted that although only the data for the 3/32" inch diameter magnet is shown, these experiments were repeated with a variety of different magnet diameters and the resulting data for the various sized magnets showed the same level of consistency. It is important to remember that when considering the results shown in Figure 3, for the test using multiple sensors and an 8-bit comparator, that switches 1-4 need to be activated while switch 5 must remain inactivated in order to produce the desired comparator output result. These results indicate that the geometric configuration of the sensors will not trigger a false positive due to the multiple magnetic fields surrounding the sensor at the center of the arrangement. It should also be noted that the output of the 8-bit comparator returns back to the original 'off' state as soon as one of the reed switch sensors reverts back to its original undesired state.

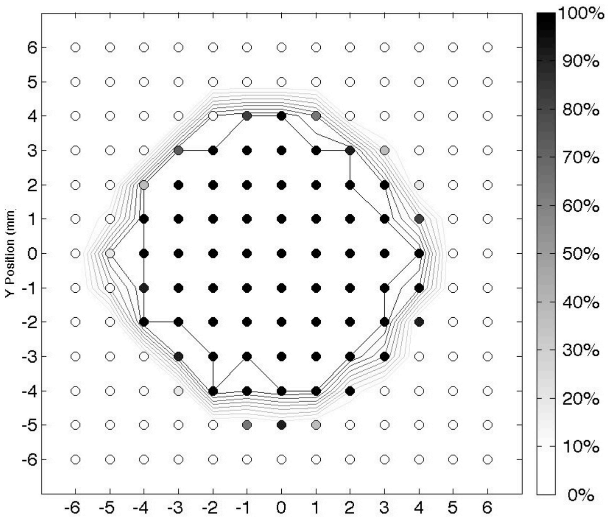

Figure 2: Activation profile of an enclosed reed switch sensor with magnetic field distances (z-axis) of 5mm.

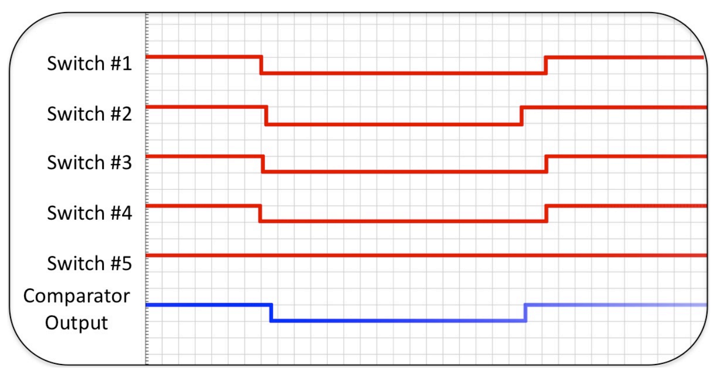

Figure 3: Evaluation of the reed switches' pattern and comparator IC output.

CONCLUSION

This paper presented the ongoing development effort to design a hermetically sealed solution that triggers an embedded microcontroller system according to a particular magnet configuration found within a specifically designed key. The experimental results have shown the micro-miniature reed switches capable of providing robust and highly consistent results. Future work will focus on determining the optimal configuration as to provide the most compact solution for low power embedded microcontroller-based systems used in both rehabilitation and prosthetic limb applications.

ACKNOWLEDGEMENTS

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REFERENCES

[1] http://www.meder.com/mms_smd_reed_switch_uk.html, accessed Tuesday March 20th 2012.