ISSN (Print) 1226-1750
ISSN (Online) 2233-6656
**Journal of Magnetics** 24(1), 57-61 (2019) https://doi.org/10.4283/JMAG.2019.24.1.057

# Suppression of Magnetic Signal Error in Trigger Assembly by Simultaneous Sensing of Bipolar Magnets

**Kisu Lee[1]*, Joon Mo Ahn[1], and Je-Wook Chae[2]**

[1]*The 4th Research and Development Institute, Agency for Defense Development, Daejeon 34186, Republic of Korea*
[2]*The 5th Research and Development Institute, Agency for Defense Development, Daejeon 34186, Republic of Korea*

(Received 24 August 2018, Received in final form 12 February 2019, Accepted 14 February 2019)

**A previous trigger assembly with a single embedded permanent magnet has malfunction problems such as the generation of a virtual trigger signal by an external magnetic field. In this study, we improved a trigger assembly, which can minimize the influence of external magnetic field. In order to improve the trigger assembly, two designs were considered. Through an M&S study for the optimal characteristics of Hall-effect sensor, we confirmed that the magnitude of the driving magnetic field of the Hall-effect sensor should be at least 50 gauss for the application of a trigger assembly. The second design was a magnetic bipolar simultaneous recognition system with a time-interval of 10 ms, which occurs when two embedded permanent magnets with different polarities are recognized simultaneously. As a result, the improved trigger assembly, which reflects the two design results, excluded the malfunction of small arms by the external magnetic field without magnetic shielding.**

**Keywords :** small arms, trigger assembly, hall-effect sensor, magnetic bipolar simultaneous recognition

## 1. Introduction

Recently, with the advancement of weapons systems, various sensors are being mounted on these systems. In extreme environments, such as battle fields, optical and mechanical sensors have limitations in terms of operation due to external impact, dust and so on. The application of magnetic sensors, which are robust to external environments and react to specific magnetic fields for the signal, is being considered. However, these magnetic sensors have a disadvantage of malfunctioning due to other external magnetic fields besides the magnetic field for the signal. In particular, if magnetic sensors can be applied to small arms, the malfunction of magnetic sensors might be a threat to small arms users. In the same vein, multiple rifles, which have a high risk of malfunction, have also stopped being developed in the United States and Germany [1].

Until now, there have been no conventional small arms that require any information from the firing control and do not need to be aware of the trigger. Nevertheless, South Korea has made efforts to apply magnetic sensors to trigger assemblies, which generate a trigger signal in small arms [2]. Unfortunately, the small arms with a previous trigger assembly, to which a magnetic sensor and a single embedded permanent magnet was applied, have had a virtual trigger signal by an external magnetic field, even if the trigger was not pulled. In previous studies, in order to minimize the external magnetic field effects for magnetic sensors in the trigger assembly, it was demonstrated that a magnetic shielding of Fe-Cu-Si-Nd-B had a magnetic-shielding effectiveness of 83 % for an external permanent magnet and 19 % for an alternating magnetic field of 180 dBpT at 60 Hz, respectively. Also, the magnetic shielding had proved experimentally that no virtual trigger signal can be generated by an external magnetic field [3].

However, the shape of the magnetic shielding was restricted by the limited space of small arms and the nature of magnetic sensors that can be operated by a particular magnetic field [4]. Because only partial magnetic shielding can be used for the trigger assembly, it may be impossible to fully shield the magnetic sensor against an external magnetic field in any direction. Therefore, in order to exclude the malfunction of magnetic sensors by an external magnetic field in any direction, an additional safety device is necessary.

In this study, we investigated a trigger assembly with an optimal characteristic magnetic sensor through model and


*Corresponding author: Tel: +82-42-821-0519
Fax: +82-42-823-3400, e-mail: kslee0909@gmail.com

simulation (M&S) and a system of magnetic bipolar simultaneous recognition (MBSR).

## 2. Design of Trigger Assembly

As mentioned above, a trigger assembly is a device that can generate a trigger signal and deliver the signal to the firing control device of small arms. Figure 1 shows a schematic outline of the trigger assembly. When the trigger is pulled, an embedded permanent magnet (EmPM) of the firearms link is mechanically moved to a magnetic sensor position in the x direction, as shown in Fig. 1(b). At this position of EmPM in Fig. 1(b), a magnetic sensor generates an electric signal as a trigger signal.

In this study, a unipolar Hall-effect sensor was considered as a magnetic sensor on the trigger assembly. The unipolar Hall-effect sensor in the trigger assembly has the characteristics of being switched on when a magnetic field exceeds the operating point threshold ($B_{OP}$) and an off state when the magnetic field is reduced below the release point ($B_{RP}$) [5].

In previous cases, when a unipolar Hall-effect sensor with a $B_{OP}$ of 35 gauss and $B_{RP}$ of 25 gauss was applied to the trigger assembly, a virtual trigger signal was displayed by an external permanent magnet (ExPM) or an alternating magnetic field of 180 dBpT at 60 Hz in the state, as shown in Fig. 1(a) [2]. A likely result could be that the Hall-effect sensor is recognized by itself as an ON state by ExPM with a larger magnetic field than $B_{OP}$. When an alternating magnetic field of 180 dBpT at 60 Hz was applied, even if the magnitude of the magnetic field was lower than the $B_{OP}$, the Hall-effect sensor might not be able to be recognized as being in an ON or OFF state by itself [6]. Therefore, it is necessary to design optimal characteristics such as $B_{OP}$ and $B_{RP}$ for the Hall-effect sensor in the OFF state, regardless of the application of magnetic shielding.

The optimal Hall-effect sensor was designed with model

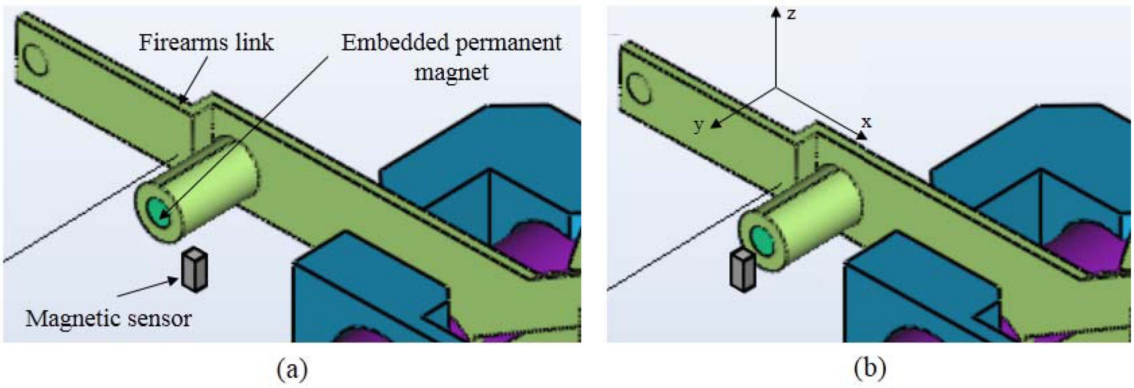


**Fig. 1.** (Color online) Schematic illustration of trigger assembly (a) when the trigger was not pulled and (b) when the trigger was pulled.

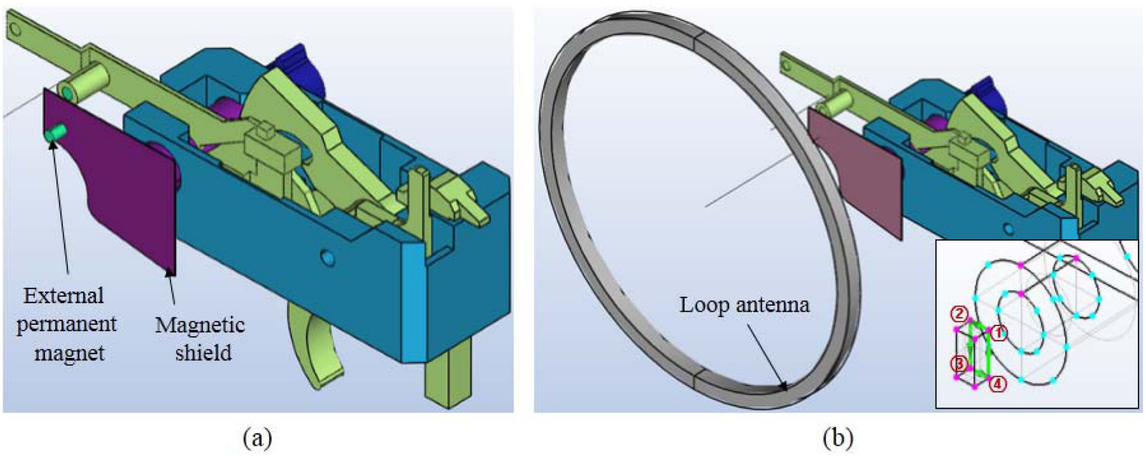


**Fig. 2.** (Color online) Schematic diagram of analytical model with magnetic shielding (a) when an external permanent magnet was applied and (b) when an alternating magnetic field was applied, respectively. The inset of (b) shows the schematic configuration for analysis of surface magnetic flux density of Hall-effect sensor.

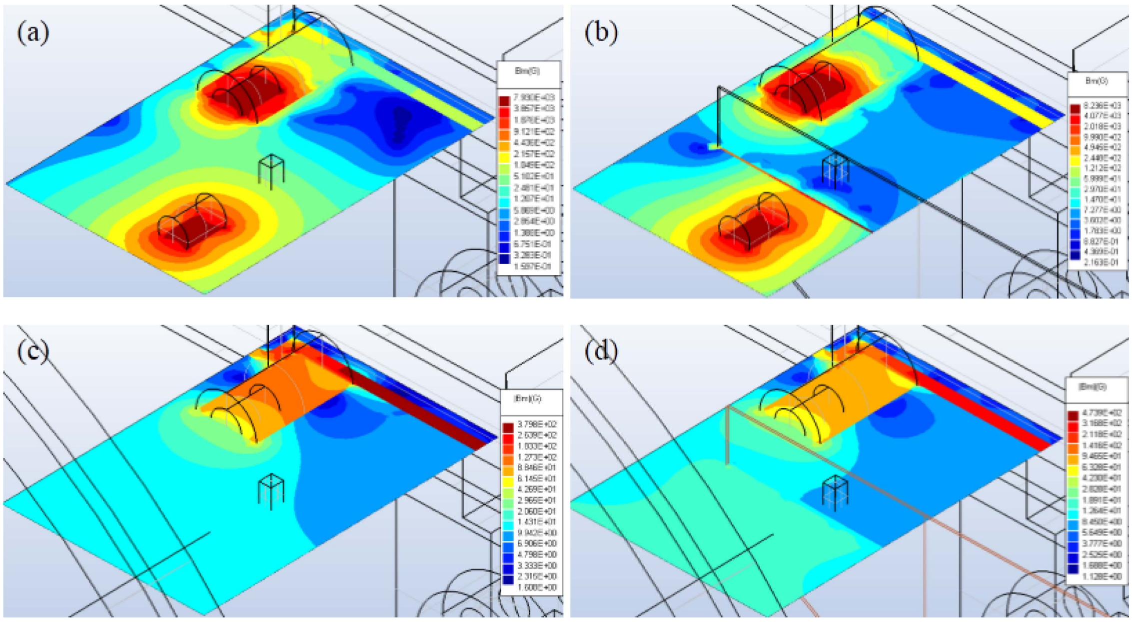


**Fig. 3.** (Color online) Magnetic field distribution diagram of trigger assembly without magnetic shielding (left column) and with magnetic shielding (right column) according to external magnetic field type (In case of (a) and (b), an external magnetic field was permanent magnet with a residual induction of 6,850 gauss. An alternating magnetic field of 180 dBpT at 60 Hz was applied as shown in (c) and (d))

and simulation using the 3D Faraday program. Figure 2 illustrates the schematic diagram of an analytical model for the design of an optimal Hall-effect sensor when an ExPM and an alternating magnetic field were applied to the trigger assembly, respectively. The analytical model was the same as the actual size of a small arm. The body material of the small arm was assumed to be aluminum alloy, and the material of internal components such as firearms link, firing pin, trigger, etc. was interpreted to be alloyed steel. The ExPM and EmPM were equally assumed to be a permanent magnet with a residual induction of 6,850 gauss as having a cylinder shape of 3 mm in diameter and 3 mm in height. The model with an applied ExPM assumed that the ExPM was located 6.5 mm away from the surface of the Hall-effect sensor. At this time, the ExPM and EmPM faced each other with different polarities. An alternating magnetic field of 60 Hz was assumed to be located 10 mm away from the surface of the Hall-effect sensor. The influence of the Hall-effect sensor due to the external magnetic field was analyzed through changes in the surface magnetic flux density of the Hall-effect sensor when the magnetic shielding was applied or not, as shown in the inset of Fig. 2(b) and Fig. 3. In Fig. 3, we assumed that the Hall-effect sensor was in an OFF state, as shown in Fig. 1(a), and the magnetic shield material had a magnetic permeability of 10,000 and

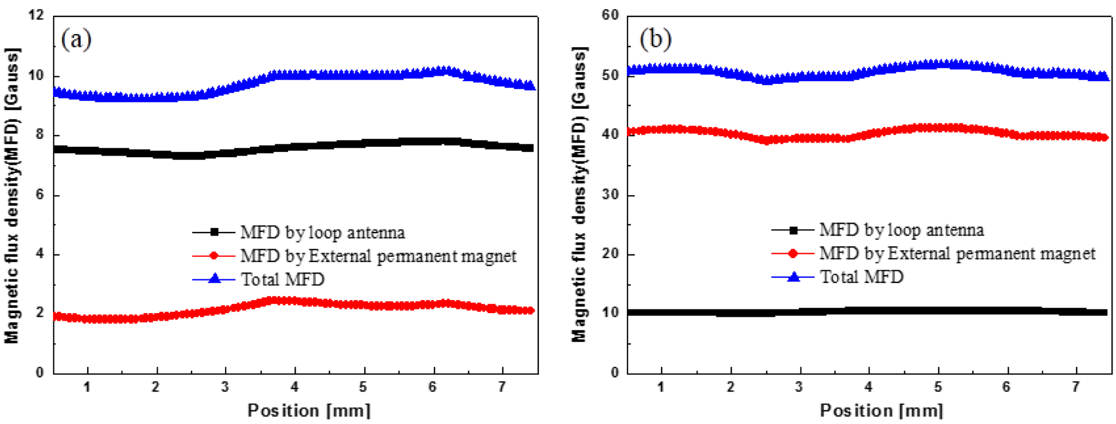


**Fig. 4.** (Color online) Surface magnetic flux density of Hall-effect sensor in terms of position of Hall-effect sensor, as shown in the inset of Fig. 2(b) with (a) or without (b) the magnetic shielding, respectively.

a thickness of 0.2 mm. Figure 4 shows the surface magnetic flux density of the Hall-effect sensor based on the type of external magnetic field and application of magnetic shielding. When the magnetic shielding was applied, we observed that the magnetic fields acting on the Hall-effect sensor significantly reduced. As a result, the $B_{OP}$ of the Hall-effect sensor should be at least 10 gauss and 50 gauss when the magnetic shielding was applied or not, respectively. This result indicates that, in order to minimize the effect of the trigger assembly by an external magnetic field, regardless of the application of magnetic shielding, a Hall-effect sensor with a $B_{OP}$ of at least 50 gauss should be applied.

A design of the magnetic bipolar simultaneous recognition (MBSR) system can be considered as a method for minimizing the external magnetic influence of small arms. The schematic diagram of the MBSR system is shown in Fig. 5. The principle of the trigger signal generation is the same as that shown in Fig. 1(b), but this system consists of two EmPMs with different polarities and two Hall-effect sensors that respond to the polarity of each EmPM. The distance between the two EmPMs is the same as the separation distance between the two Hall-effect sensors. When the MBSR system is applied to the trigger assembly, it may minimize the influence of ExPM on the trigger assembly because the ExPM has a single polarity of the N pole or the S pole. However, there is a minute time-interval when two Hall-effect sensors, which are separated by a certain distance, recognize the magnetic field from the EmPMs. This time-interval of magnetic field recognition can be adjusted by the distance between two EmPMs and two Hall-effect sensors. This indicates that the influence of an external alternating magnetic field of 60 Hz on the trigger assembly can be eliminated by the design of a time-interval to be less than 16.6 milliseconds (ms).

In the case of small arms, an analysis of a timeline with ignition charge should be necessary for the safety of the soldiers. The ignition signal must be charged after the trigger, and the charging of the ignition signal must take place before a gun-lock hits a detonator and a bullet leaves the gun-chamber [2]. Thus, the time needed to charge the ignition signal was analyzed to be approximately 10 ms. As a result, we developed an improved trigger assembly with two Hall-effect sensors that have a minimum $B_{OP}$ of 50 gauss and a MBSR system with a time-interval of 10 ms in order to exclude the malfunction of small arms by the external magnetic field.

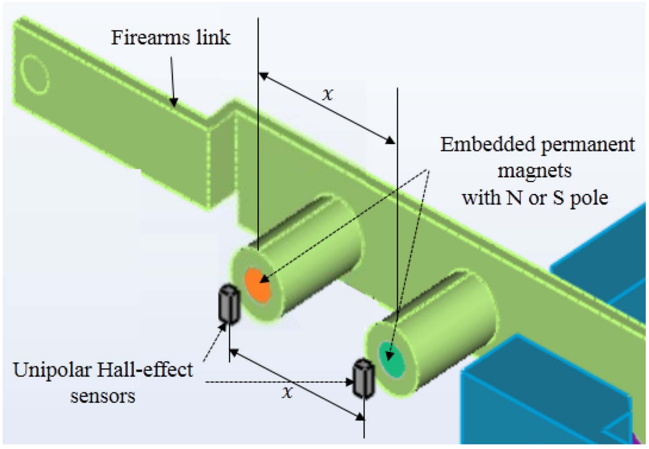


**Fig. 5.** (Color online) Schematics of magnetic bipolar simultaneous recognition system, which consists of two embedded permanent magnets with different polarities and two Hall-effect sensors.

## 3. Proof Testing of Trigger Assembly

A technical proof test was conducted on the small arms by using an improved trigger assembly to check if a virtual trigger signal is generated by an external magnetic field. As a result of M&S analysis, two unipolar Hall-effect sensors used for the improved trigger assembly had a characteristic of a $B_{OP}$ with 60 gauss. The EmPMs were used as commercial Nd-sintered permanent magnets with a residual induction of 300 gauss at a position of 3 mm

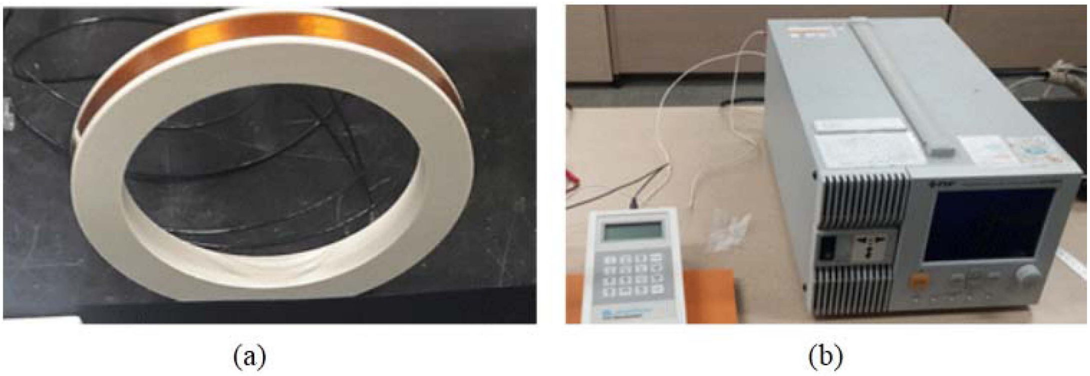


**Fig. 6.** (Color online) Optical image of (a) solenoid coil, (b) AC power supply (right), and gauss-meter (left).

**Table 1.** Technical proof test result of whether the trigger signal for the small arms with each trigger assembly is generated or not.

| External magnetic field | | | Proof test result | | |
|---|---|---|---|---|---|
| Type | Magnitude of magnetic field[1) ] | | Trigger assembly I ($HS^{3)}$ with $B_{OP}$ = 35G) | Trigger assembly II ($HS^{3)}$ with $B_{OP}$ = 60G) | Improved trigger assembly |
| | dBpT | Gauss | | | |
| External permanent magnet[2)] | - | 55.5 | Virtual trigger signal | No trigger signal | No trigger signal |
| External alternating magnetic field at 60 Hz | 160 | 1.0 | Virtual trigger signal | No trigger signal | No trigger signal |
| | 170 | 3.16 | - | - | No trigger signal |
| | 180 | 10.0 | - | - | No trigger signal |
| | 185 | 17.7 | - | - | No trigger signal |

[1)]This magnitude of magnetic field is the magnitude of magnetic field acting on a Hall-effect sensor
[2)]This permanent magnet has a surface magnetic field of 1,000 gauss
[3)]HS stands for Hall-effect sensor.

from the surface of EmPM. In Fig. 5, the distance (x) between two Hall-effect sensors and two EmPMs was properly adjusted so that the time-interval of the MBSR system was 10 ms. In order to confirm the malfunction of the trigger assembly by the ExPM, the ExPM was used as a general permanent magnet with a surface magnetic field of 1,000 gauss. When the ExPM was attached to the surface of the trigger assembly for small arms, it was confirmed whether the trigger signal was received in the firing control device. The effect of an external alternating magnetic field of 60 Hz was also tested in the same way. An alternating magnetic field generator was applied with a solenoid coil with an outer diameter of 144 mm as shown in Fig. 6(a). When an alternating current (AC) power of 8.6 $V_{rms}$ at 60 Hz was applied through an AC power supply (Model EC1000S, California Instrument), as shown in Fig. 6(b), an alternating magnetic field of 180 dBpT at 60 Hz was generated at a position of 10 mm from the solenoid coil surface. Table 1 shows whether the virtual trigger signal for each trigger assembly is generated by an external magnetic field. Trigger assembly I and II were applied to Hall-effect sensor with $B_{OP}$ of 35 gauss and 60 gauss, respectively. This study indicates that the effect of an external magnetic field on a trigger assembly of small arms can be perfectly excluded by applying an improved trigger assembly. This can be done by using the Hall-effect sensor with $B_{OP}$ of 60 gauss and the MBSR system with a time-interval of 10 ms.

## 4. Conclusions

In this study, we successfully demonstrated that the improved trigger assembly can minimize the influence of an external magnetic field on small arms by using the unipolar Hall-effect sensor with a $B_{OP}$ of 60 gauss and a MBSR system with the time interval of 10 ms. This trigger mechanism can be effectively applied to a narrow space of small arms and can be reduced in weight and size without applying a magnetic shield. This result can be applied as a method to minimize the influence of the external magnetic field in various civilian parts where malfunction can occur due to an external magnetic field and when magnetic shielding is difficult to apply.

## References

[1] https://www.millitaryfactory.com/smallarms/detail.asp?smallarms_id=37
[2] J. Chae, et al., Korean Patent No. 10-2017-0156055 (2017).
[3] K. Lee, J. M. Ahn, and J. Chae, J. Korea Institute of Military Science and Technology **21**, 456 (2018).
[4] A. Keshtkar, A. Maghoul, and A. Kalantarnia, Int. J. Computer and Electrical Engineering **3**, 507 (2011).
[5] E. Ramsden, Hall-effect sensor, Elsevier, USA (2006) pp 107-126.
[6] Technical note of the Allegro™ A1101-A1104 Hall-effect switches, Allegro MicoSystems, LLC, USA.