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RFID Anti-Theft Security and Power Regenerative System for Shopping Cart

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Abstract. This system offers a reliable and a low cost design to prevent shopping cart from being missing. Many retail store companies suffer the pain of missing shopping cart because it regularly happen, and yet it cost them. In this case, shoppers seems to push the shopping cart away from the shopping compound and later the cart is will be abandoned outside shopping compound. Currently, a simple security system that use coins or token had been developed to prevent the cart being placed outside shopping compound, but the system is proven not quite effective to prevent the missing cart problem. Therefore, in this project a low cost active Radio Frequency Identification (RFID) along with simple locking mechanism for the shopping cart is proposed. Active RFID unidirectional wireless communication between both shopping cart (receiver) and shopping compound entrance or exit gate (transmitter) will initiate the locking mechanism which leads the carts' wheels get locked. This system also has power regenerative system to charge the main battery by using dynamo. Highly secured, reliable and low cost anti-theft system is expected to be developed.

Keywords: anti-theft, shopping cart, RFID, power regenerative, dynamo.

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1 INTRODUCTION

Shopping cart is a cart supplied by retail store for customer use to carry their goods around the shopping floor until the payment counter. Most of the customers use the shopping cart to carry their purchased goods until the car parking area, and sometimes until outside of the shopping complex. Previously shoppers have to use token or coin to use the cart, and they can retrieve back the token or coin when put back the cart into its parking area. Unfortunately, nowadays those systems no longer being implemented as it is not efficient or proven in order to prevent the cart from being missing. A shopping cart cost ranging from MYR 800 to MYR 1500 depends on size and build quality.

This projects utilizes RFID wireless technology and a locking mechanism for the shopping cart's wheel. RFID is famous for its stability against interference and robust security level which prevents people to hack the communication. RFID comes in many types of packages such as passive RFID, semi-active RFID and active RFID. Passive RFID is the cheapest one whereas the active RFID is the most expensive. Passive RFID normally use a tag (transmitter) which absorbs energy transmitted by a receiver while both tag and receiver in touch, and then transmit its identification code back to the receiver. After that the receiver will analyse and identify the identification code received from the tag, and then proceed to next process. In contrast, the active RFID transmitter uses own power supply unlike tag which depends on receiver's signal power. This means the receiver still can receive the identification code from the transmitter even if the transmitter in distant. The more distance an RFID coverage goes, the more it become expensive. In this project design, RFID transmitter will be placed at every entrance and exit gate of shopping complex compound, while the RFID receiver will be placed inside the shopping cart. To control the whole system PIC16F84A [7] microcontroller will be used because it is cheap and easily available in market. This controller will receive signals from the RFID receiver circuit, then it will initiate the locking mechanism of the shopping cart. Solenoid has been chosen as the locking component since it can be activated easily by combining switching circuit with a microcontroller. Two units of dynamo will be used to convert mechanical motion from the cart's wheel to electric energy for system's battery charging purpose.

2 RELATED WORKS

Previously many security systems for shopping cart were developed but all of them have some lacking in terms of stability, performance, reliability

and cost. However, all these projects are giving some useful recommendations and it is considerable for this project. Here in this segment, previous projects will be discussed particularly about its strength, weakness and recommendations. One of the proposed projects is Shopping Cart Anti-Theft System by N. Othman [1]. The system utilizes 433 MHz RF for communication and simple locking method by using solenoid. This project also involves some techniques in measuring distance of the signal transmitted between transmitter and receiver for triggering the circuit. Transmitter will send a signal to the receiver, and whenever the signal from transmitter did not received by receiver, it will trigger switching circuit which consists of relay, diode and transistor. Thus, solenoid will be pushed down to lock the wheel and prevent the cart from being pushed away from supermarket. Besides, the system's compartment also has been designed to ensure the components in the system not affected by environmental factor. However, the main drawback of the system is RF signals is easy to get interfere with other signal or sometimes the communication between RF transmitter and receiver may break due to environmental factor such as heavy rain. Besides, short distance signal transmission may occur in certain phenomena. Hence, the RFID was proposed by the designer to solve these problems. Figure 1 shows the locking mechanism of this project. Solenoid was used because of its low power consumption and yet it is cheap. The designer did not design the wheel of the cart to fully suitable with the solenoid, in other words the solenoid needs proper mechanical arrangement to lock the wheel firmly.

Figure 1: Simple locking mechanism proposed by N. Othman [1]

Another system is Shopping Cart Theft Prevention System by Anthony M.D. Paolo and John T. Hood [2]. This system designed particularly for security purpose where it prevents the theft to steal the shopping carts from a

parking lot. The parking lot has at least one entrance and exit driveway. The system includes a magnet mounted on the shopping cart and an actuator buried below the surface of the driveway for generating a signal in response to passage of the cart with the magnet over the driveway. The actuator extends transversely with respect to the magnetic pole inside the shopping cart. An alarm issues a warning in response to the signal generated by the actuator. This system also for monitoring the unauthorized entry into restricted area by having a door with magnet and an actuator which is controlled by the magnet to produce signals for opening the door. The sensor is connected to a power source whereby upon passage of a magnet proximate to the sensor at any point along the length of the sensor, one of the reed switches of the sensor is responsive to the passage of the magnet proximate to the reed switch for generating signal. Figure 2 below shows the design system proposed by Anthony M.D. Paolo and John T. Hood. The disadvantage of the design is it depends on magnet to be activated. The magnet will act as a switch; it will turn on or turn off the system. Thus, the magnet needs to be protected from missing. Other than that, the system is a passive system, which requires magnet to activate it.

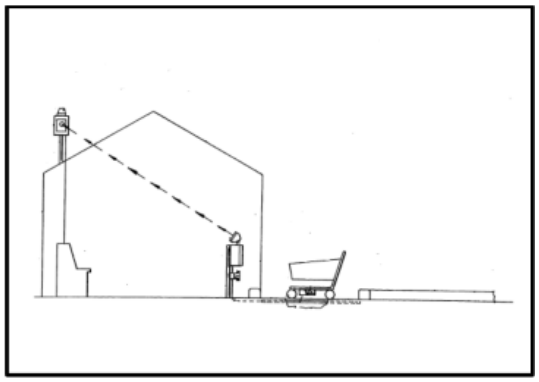

Figure 2: Proposed system by Anthony M.D. Paolo and John T. Hood [2]

Meanwhile, Larry W. Goldstein proposed a system named Shopping Cart Anti-Theft System, SCATS [3]. This project is focusing on anti-theft assembly for shopping carts including a housing adapted to fit adjacent a wheel of a cart, a receiver within the housing for sensing the passage of the cart beyond a preselected range and providing a signal indicative thereof, and an arrangement responsive to the signal for lowering an arm into the direct path of the adjacent wheel.

The clamp-on assembly houses a battery-powered receiver for sensing when cart leaves the area adjacent the business and has means for disabling the wheels of the shopping cart when the shopping cart is outside the area. A

mechanical arrangement is provided within the clamp-on assembly which responds to signals from the receiver to disable the cart by causing at least one of its wheels to turn to an angle such that the cart must be driven in circle. The clamp-on arrangement required little power to operate and thus, it can function for a longer period of time at least for about five years before its batteries need to be replaced. Figure 3 and Figure 4 shows design system by Larry W. Goldstein.

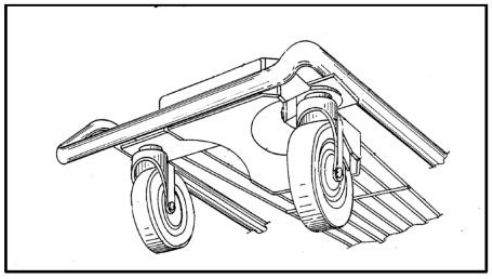

Figure 3: Bottom view of the design by Larry W. Goldstein [3]

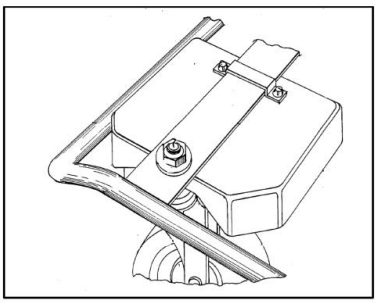

Figure 4: Top view of the design by Larry W. Goldstein [3]

On the other hand, Jeffrey J. Lace proposed a system called Anti-Theft Vehicle System. The system is designed for a vehicle wheel having a rotational axis includes at least one inhibitor disposed within the vehicle wheel to selectively engage the vehicle wheel. This is to prevent the vehicle from rotating about its rotational axis. This system includes an electronic wire that extends around and defines a perimeter of normal operating space which is used by operators of a store's shopping carts. The electronic wire produces an electromagnetic field which could be sensed by a sensor located on one of the wheels of the shopping cart. The sensor sends a signal to a motor which moves a brake pad against the wheel of the shopping cart. Two limit switches are used to stop the motor when the motor has either moved by the brake pad into or out of engagement with the wheel of the shopping cart. Figure 5 shows wheel design of the proposed system. The system used electronic wire as a transmitter. Thus, whenever the cart passes through the

wire, it will be locked. If the electronic wire breaks, then the system will not able to function. This is the main drawback of this system.

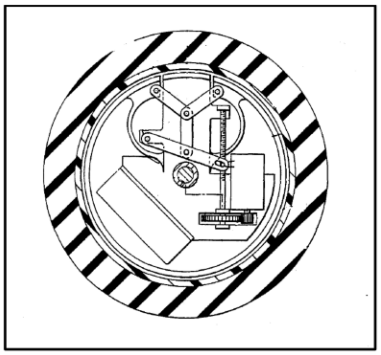

Figure 5: Wheel design by Jeffrey J. Lace [4]

3 PROBLEM STATEMENT

Shopping cart missing phenomena regularly occurs around the world. According to survey done by N. Othman [1] around Melaka, Malaysia, almost 70 units of shopping cart reported missing yearly in Mydin MITC, and Jusco Melaka.

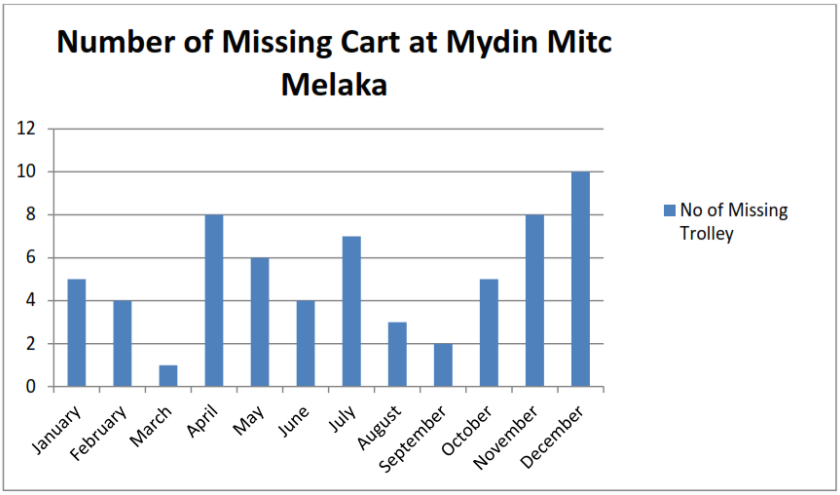

Figure 6: Missing cart statistics in Mydin MITC for year 2012 [1]

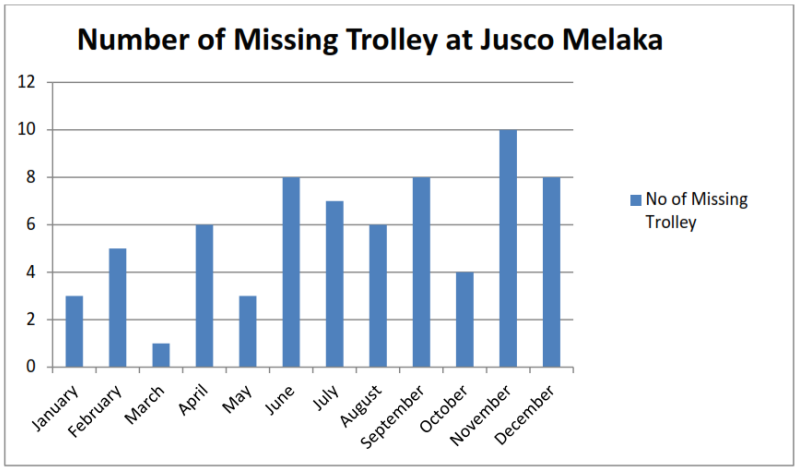

Figure 7: Missing cart statistics in Jusco Melaka for year 2012 [1]

Such phenomena much be avoided as it cost much for the retail store owners. Below Figure 8 shows a worker gathering back the cart which has been pushed away from the shopping complex by customer. This scenario happens nearby Kiara Square, Bahau. From these, we can simply tell that this problem getting serious and there is no proper solution until today.

Figure 8: A worker gather back missing cart at Kiara Square, Bahau

4 PROPOSED PROJECT DESIGN

Basically the proposed system design involves two main working areas which consist shopping complex entrance/exit gate and the shopping cart itself. RFID transmitter will be placed beside entrance/exit gate, while receiver unit of the RFID will be placed at shopping cart. Since it uses an active RFID, both transmitter and receiver able to communicate wirelessly. Input and output for the whole system is controlled by PIC16F84A, which means the controller will activate locking mechanism immediately after the RFID receiver acknowledge the signal from RFID transmitter. In spite this, while customers using the cart, the force applied to move the cart will be converted to electrical energy to charge the 12V lead acid battery. This part is called power regenerative system where this system act likes a backup power for the entire system and at the same time it is able to increase the longevity of the system's main battery. In overall, this project design is mainly rely on RFID communication, power regenerative system, and locking mechanism. Figure 9 briefly shows how the proposed system design works.

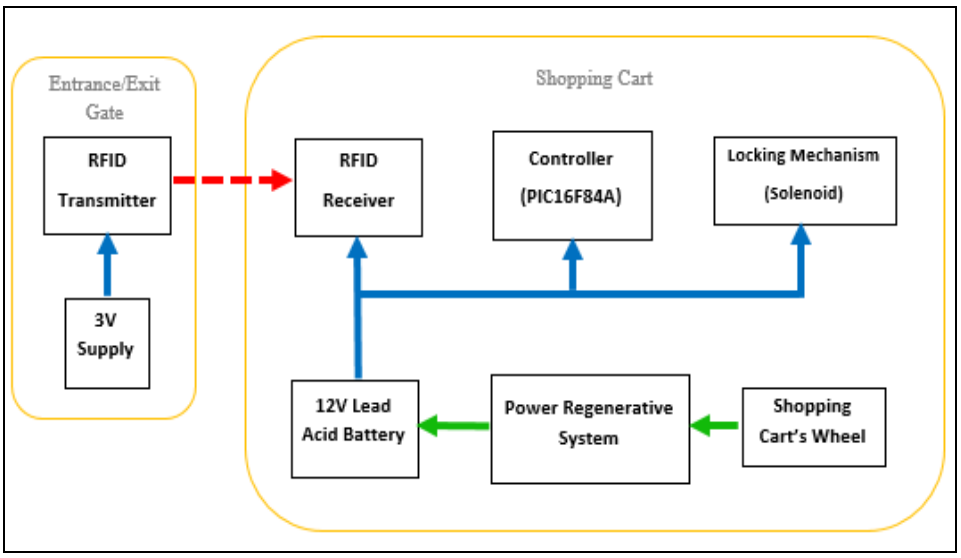

Figure 9: Block diagram of the proposed system design

4.1 RFID Communication

The RFID transmitter is programmed to transmit a unique 4 characters (A-Z, a-z, 0-9) every 2 second in order to save power. The receiver will acknowledge the transmitted ID which covers up to 8 meter radius because

typically an entrance/exit gate size only between that range. Anti-collision algorithm has been employed where the receiver can handle up to 160 units of transmitter at same time. Meanwhile, the transmitter will only turn ON when ID is transmitting (<10ms). As a result it will not cause data jam to other devices that are using the same frequency band. If more than one receiver nearby a transmitter, it will never cause problem as all the receivers are able to capture the ID at same time. Such scenario is when a more than one shopping cart within 8 meter radius from the entrance/exit gate. Figure 10 below shows unique 4 character which has been transmitted. RFID receiver were connected to Hyper Terminal interface via RS232 serial protocol in order to view the transmitted ID.

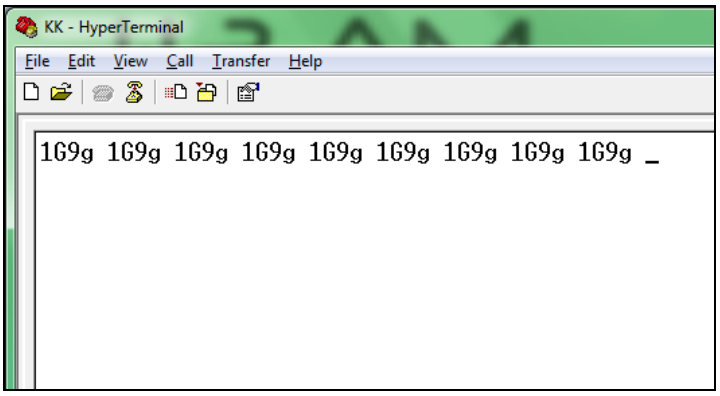

Figure 10: Unique 4 characters from the RFID transmitter

4.2 Power Regenerative System

The system use 2 units of dynamo to convert mechanical motion to electrical energy from the shopping cart's rear wheel. Each dynamo is fixed to one rear wheel. The maximum output of each dynamo is 12 Volt at 600mA [5]. This can only be achieved if the dynamo gets enough revolution per minute (rpm). The main problem here is how fast a user will push the shopping cart around the mall? Normally users will push the shopping carts at very low speed. Hence it is impossible to pull out maximum power from the dynamo.

Since the main system's battery is 12 Volt lead acid type, it should have 12 V source to charge it. How about the current? Lead acid batteries capacity is rated in Ampere/Hour (Ah) unit. The system's battery has 4.5Ah capacity,

thus the battery needs approximately 4.5A current to get fully charged within 1-3 hours. In this scenario, the dynamo can only deliver 600mA when peak, so this means it could take 7-10 hours to charge the battery fully. However, in real condition this dynamo (12V, 600mA rated) only able to produce approximately 8V 400mA if the shopping cart's wheels moving speed is assumed at 3.2 to 4 kilometre per hour [6], which is the speed of average human walking speed. Hence, a DC boost converter will be implemented to step up the generated voltage to 12V. The output from dynamo is known to be alternating, thus it should be rectified to get a DC output before go through the DC boost converter. About 10 to 12 hours needed to fully charge the system's battery from the source which was stepped up to 12V 400mA. Figure 11 shows how the overall power regenerative system works.

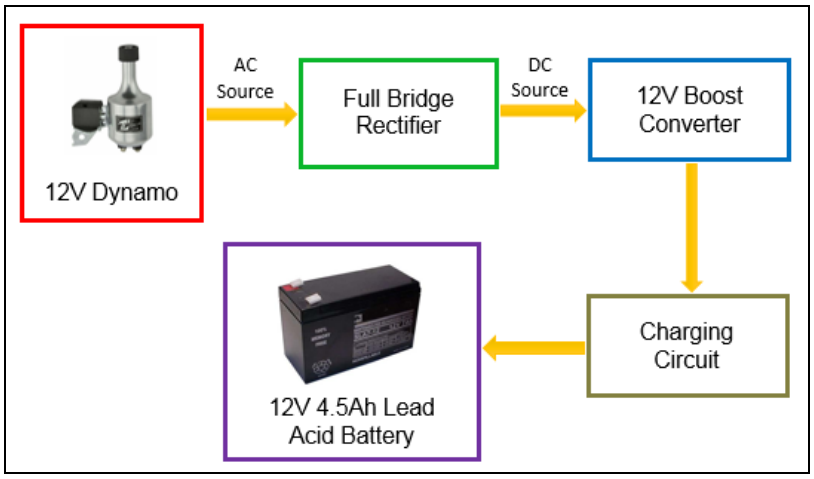

Figure 11: Power regenerative system for the shopping cart

4.3 Locking Mechanism

The main objectives for the locking mechanism design are to ensure users unable to hack the locking mechanism, and to design a steady locking mechanism with minimal mechanical and electrical parts. A pair of 12V DC solenoids were used to lock both rear wheels since it is very low cost and it's only consume minimal power of 200mA. The rod from the solenoid will extend when it is initiated by the controller. The extended rod is used to get into a hole in the wheels, thus the wheels cannot move anymore. Figure 12 shows the DC solenoid which has been used in the system.

Figure 12: 12V DC solenoid

5 CONCLUSION

The whole project design is yet to complete. Currently power regenerative system is being analysed in detail to achieve good efficiency. Active RFID and locking mechanism is ready and waiting for the integration with power regenerative system. In future, the designer can step up current from the dynamo which draws small current, as the small current takes long duration to charge the battery. However, stepping up the current needs a complex electronic circuit.

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