

## ***A Supermarket Anti-Theft RFID Scanner : digiSCAN***

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### ***Abstract***

*Supermarket shopping is an essential part of the livelihood of most people around the world. Consumers can acquire items essential for their daily activities. However, in an ever-evolving world with an increasing population and increasing crime rates, supermarket theft is becoming a prevalent problem with supermarket owners spending large sums of money on hiring security often with little effect. Organized Retail Crime (ORC) costs the retail industry approximately \$30 billion each year, with 71.3% of retailers reporting an increase in ORC year-over-year. With the current global economic conditions, high labor costs are longer feasible. Consumers also face the issue of paying for items they did not select. Advanced camera systems, for some, may be an escape however, this approach is not feasible for all aspects of shopping and in underdeveloped countries that have technical constraints. The advent of digitization has helped improve the livelihood of consumers in Ghana. Currently, many large-scale retailers are oblivious to some of these advancements. The oblivion of the management of such retail services results in the loss of products, customer dissatisfaction and the mismanagement of untracked products by employees. To reduce theft and the mismanagement of products by employees, a smart anti-theft system should be deployed in supermarkets; at the till and before the exit of supermarkets to ensure all products leaving the store are paid for and accounted for. The system consists of a deactivation and theft detection system. The product is deactivated by the store attendant at the till when the customer pays for the product. However, if a customer crosses the initial warning zone without paying, a warning sound is triggered and after the customer crosses the final warning zone, the alarm is triggered indicating an attempted theft by the customer. A log of products is also kept ensuring employees are not stealing products. This paper presents a smart way of detecting theft during supermarket shopping using Radio Frequency Identification (RFID) readers and tags, microcontroller-based control system, a database server and an Integromat.*

**Keywords:** *anti-theft, embedded systems, RFID, supermarket*

### **Introduction**

In industrial warehouses, retail and shopping centers, variety of monitoring, detection and control mechanisms have been implemented to check shrinkage. The use of barcodes, quick response codes among other anti-theft detection methods have provided some success but leaves much to be desired.

The emergence of radio frequency identification (RFID) technology has imperatively redefined several facets of our everyday life. This type of automatic identification and data capture (AIDC) technology involves the assignment of special identifier to product and has contributed immensely to the area of wireless communication, monitoring, tracking and control applications. RFID technology primarily employs electromagnetic fields to detect, identify and track tagged objects. It essentially consists of an RFID reader which collects radio waves from an RFID tag and converts them into data which can be relayed to a host computer through a communication interface with the aid of an antenna. Based on their mode of operation (data collection), an RFID reader can be fixed or mobile. RFID transponder tags on the other hand are made of very small integrated circuits (IC) which incorporates a radio transmitter and receiver. It essentially transmits data to an RFID reader when activated by an electromagnetic interrogation pulse from a reader in proximity. RFID tags are categorized into either passive tags or active tags based on their design. Active tags in their design have an onboard power supply unit to always ensure effective transmission of data. Unlike active tags, passive tags are powered by the RFID reader to enable data transmission. This feature makes them less expensive to design and develop. Thus, passive RFID tags are predominantly used. RFID technology does not need direct line of sight for its operation.

To reduce or eliminate shrinkage and boost revenue in business centers, RFID technology can be optimized with internet of things (IoT). This paper presents a smart anti-theft scanning system (digiSCAN) which applies spreadsheet applications like Microsoft excel and google sheets. The Microsoft excel features

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a calculation, graphing tools and a macro programming language called Visual Basic for Applications (VBA). Google sheets are compatible with Microsoft excel file formats and therefore allows users to create and edit files online while collaborating with other users in real-time. Thus, users can track edits with a revision history.

Most existing anti-theft detection devices like the code scanners are often less effective when solely employed in shopping areas. Thus, may need to be complemented with other supporting systems such CCTV surveillance cameras in order to improve their efficiency. In spite of this peripheral additions, instant detection of theft is a major challenge. Therefore, this paper presents an RFID based anti-theft detection systems that provides instant theft detection alert in shopping areas to reduce or eliminate shrinkage and boost revenue in business centers.

## Related Works

The increase spate of theft cases recorded daily in supermarkets and malls have led to the development of stringent mechanisms aimed at tackling this menace head-on. Besides the enactment of strict laws to curtail this situation, technological advancements have provided a few innovative solutions to this problem with different developed models.

A few models have been proposed to aid theft detection by scanning barcode of products [1][2]. In [1], a model was designed for shoppers to self-scan products using barcode scanners. This model primarily employs a barcode reader, microcontroller, liquid crystal display (LCD) and oscillator. A barcode reader is used to read and decode the unique identity (ID) of the product. The decoded data is delivered to a microcontroller for instant processing and billing. The purchased products and bills are displayed on an LCD for the shopper. Although this system facilitates faster payment of products which reduces congestion at the payment terminals, manual inspection of shoppers by security is required to determine whether an item stolen by a shopper has been accounted for enroute to exit the supermarket. Hence, automatic detection of stolen products is impossible with this system.

[3-5] proposed an anti-theft detection system using quick response (QR) code scanners. Unlike barcode scanning which requires LED or laser lights for operation, QR code scanners are dependent on camera-based scanning technology. Regarding the model in [4], an advanced shopping trolley was designed based on QR code. A QR code scanner is used to capture and decode the product ID. This information is sent to a microcontroller where it is processed, stored, and displayed on an LCD. This data is simultaneously transferred to a payment terminal computer via ZigBee. Even though this system is user friendly and provides shoppers with convenience at payment terminals, manual inspection is needed to assist with theft detection which can be laborious and ineffective. Additionally, QR codes cannot be provided on all products. Thus, are product biased or selective.

A few works have presented variety of designs that uses anti-theft radio frequency identification (RFID) technology [6-11]. Some of these models have incorporated different communication modules to their system [12-15]. In reference to the model proposed in [8], the system incorporates an RFID reader, LCD and ZigBee transceiver mounted on a cart. The RFID reader with the help of a passive RFID tag scans and tracks the purchased product. Information and bill of the purchased product is recorded and displayed on an LCD. The ZigBee transceiver communicates with a centralized server to recommend and provide online transaction. More so, an RFID reader at the exit door detects theft of unpurchased products. This proposed model enhances customers shopping experience, prevents shrinkage and reduces labour cost. However, it is capital intensive and requires routine checks.

Closed circuit television (CCTV) cameras have experienced a fair share regarding theft surveillance in supermarkets [16-19]. The model showcased in [16] offers the monitoring and detection of theft behaviors using high definition (HD) cameras in combination with convolutional neural network (CNN). This system employs an HD camera mounted at vantage points in the supermarket to monitor the customer. Real time data of the customer's behavior is recorded, transmitted, and collected onto a personal computer (PC). Based on recognition models or algorithms trained using CNN, the PC identifies theft actions and subsequently sets off an alarm. This system provides fast response, high recognition accuracy, enables modification and addition of new data sets and reduces labour cost. Despite these benefits, this model requires intensive programming and experts for routine maintenance and upgrades. Hence can be capital intensive.

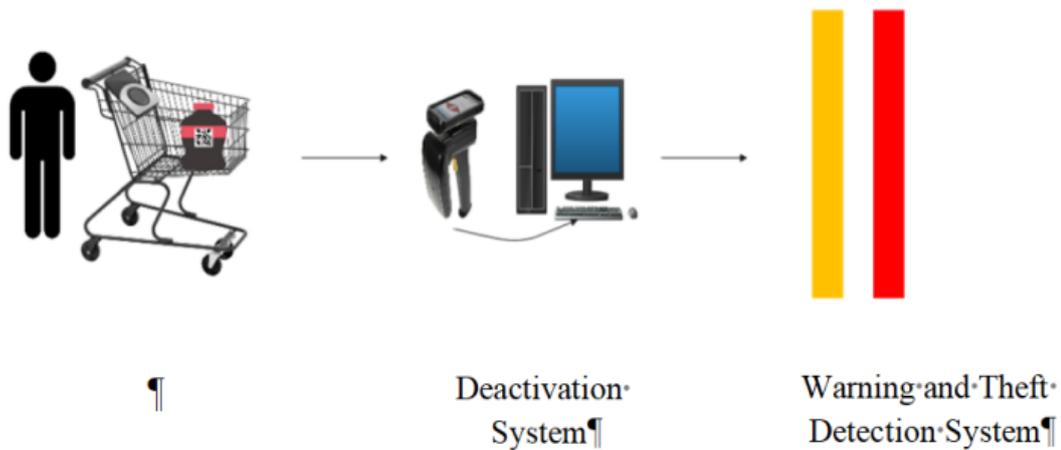
Alternatively, there are theft detection systems based on infrared technology [20-23]. [21] suggested a model that incorporates pyroelectric infrared (PIR) sensor with a microcontroller and a global system for mobile communication (GSM) module. The PIR sensor senses and forwards logic signals to the

microcontroller upon detection of objects in proximity. This information is processed by the microcontroller which subsequently activates a GSM module to trigger an alert via call or short message service (SMS) to a corresponding GSM mobile phone number. Though this system provides a high level of security against theft, it is only applicable to certain products in the supermarket.

[24] proposed a smart IoT surveillance system which utilized a gyroscope to detect angular disturbances of doors in shopping centers. Heavy disturbances such as knocking or cutting of the door is detected by a MEM sensor, processed by a microcontroller and as per the programming algorithm, an alert system is triggered. Even though this system detects grand theft in supermarkets, it cannot detect theft of products under normal shopping conditions. Hence requires additional anti-theft mechanisms.

## Methods and Procedures

### *DigiSCAN System Architecture*



**Figure 1.** DigiSCAN System Architecture

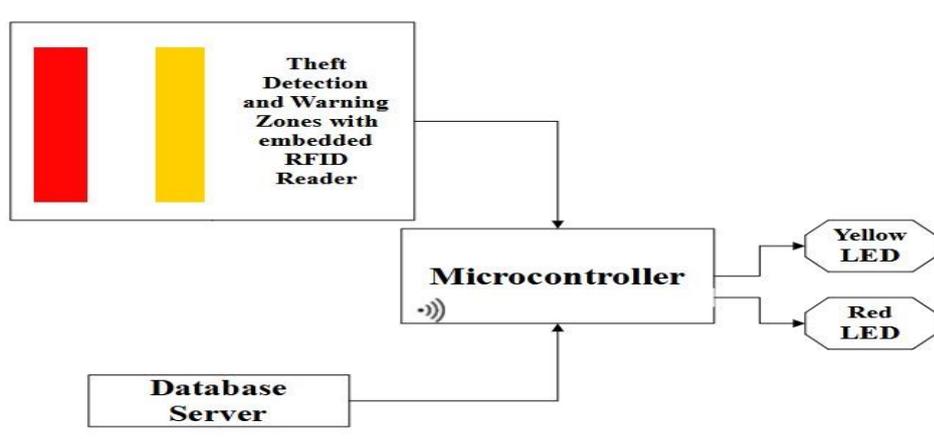
Figure 1 shows the digiSCAN system architecture consisting mainly of three (3) zones i.e., Free zone FZ, Deactivation zone DZ and Warning and Theft Detection zone TDZ. A customer after shopping in the free zone, moves to the deactivation zone and would be attended to by waitress, sales cashiers, or shop attendants. The tag on the item is then deactivated when the customer pays for the item at the till of the store. The store computer has a bespoke software which facilitates the billing process. A warning sound is sounded when the customer crosses the yellow zone in the Warning and Theft Detection zone to alert the customer to pay for an item, he or she may have forgotten to pay for or otherwise. If the customer ignores the warning and continues to cross the red zone, security is alerted, and an alarm is sounded to indicate theft attempted by the customer.

**DigiSCAN System Block Diagrams**



**Figure 2.** DigiSCAN Deactivation Block

Deactivation Block DB: As shown in Figure 2, in the DB, the RFID reader deactivates the active tag on product taken and updates the centralized database through the on-board Wi-fi system.

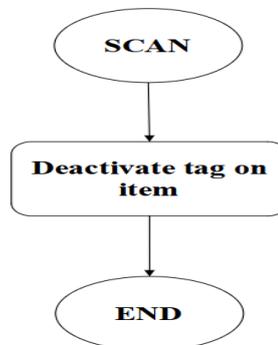


**Figure 3.** DigiSCAN Warning and Theft Detection Block

Warning WB and Theft Detection Block TDB: Figure 3 illustrates the WB and TDB, where initially, the database will compare the status of the product at the warning zone and the information in the database. If the customer is in the yellow zone, a warning is triggered to alert the customer to go back and deactivate any active tags he or she may have. If the customer ignores this and proceeds to move on to the red zone, security is alerted, and an alarm is sounded.

The digiSCAN software application can be installed on any desktop or laptop which will serve as the store computer for product deactivation and for the warning and theft detection alarm system which are the spreadsheet applications (Microsoft Excel and Google Sheets) with Integromat integration for live communication and update of tag status.

**DigiSCAN System Deactivation Flow Chart**



**Figure 4.** DigiSCAN System Deactivation Flow Chart

When the items are scanned, the RFID Reader reads the tag, then the microcontroller updates the database server to indicate a tag has been deactivated.

**DigiSCAN System Warning and Theft Detection Flow Chart**

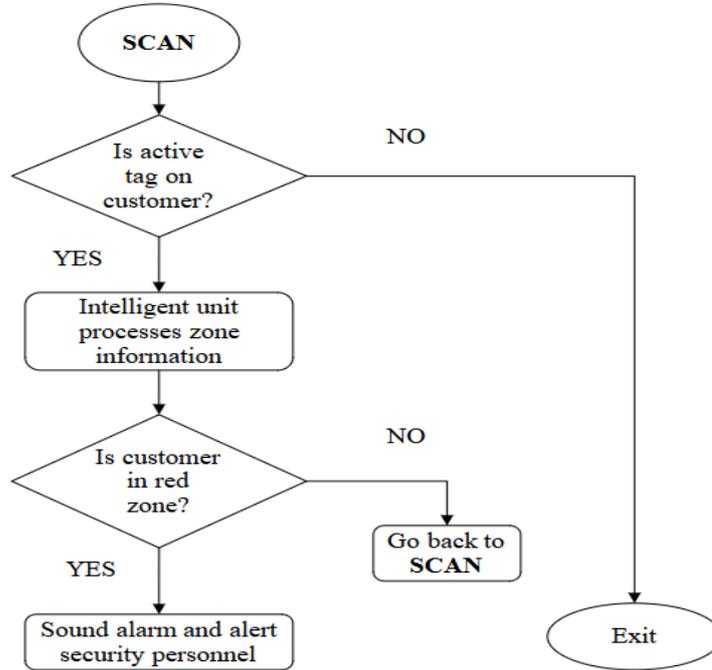


Figure 5. DigiSCAN System Warning and Theft Detection Flow Chart

When the items are placed into the cart, the RFID Reader reads the tag, and the microcontroller updates the database server to indicate an item was picked.

**Results**

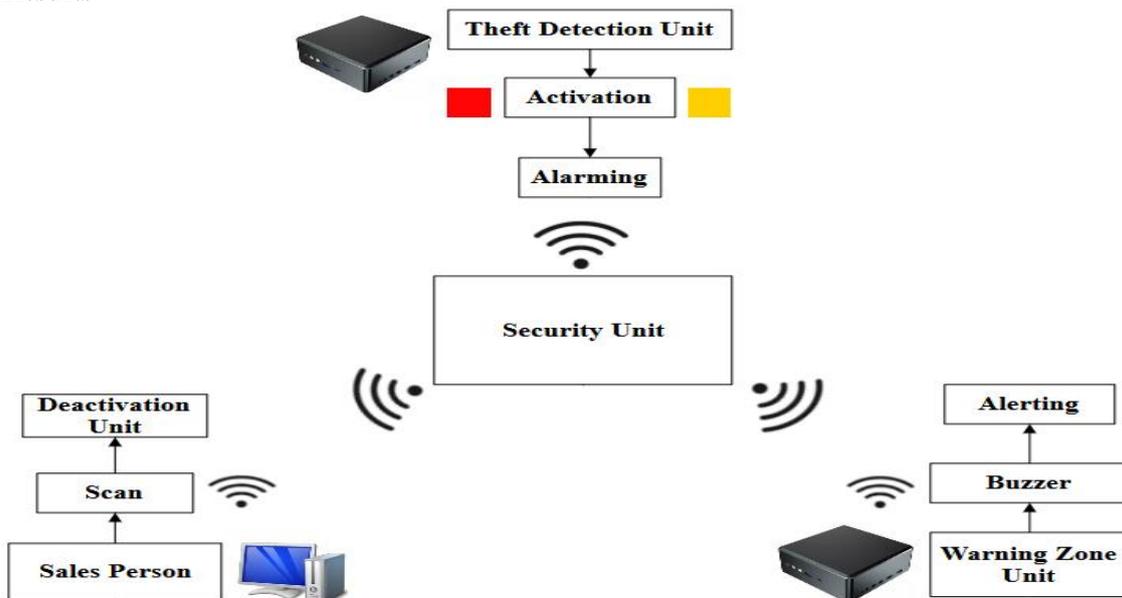


Figure 6. DigiSCAN System Test Overview

As depicted in Figure 6, the digiSCAN system setup used for testing consists of four functional units: the deactivation unit, warning zone unit, the theft detection unit, and the security unit. It was ensured that the

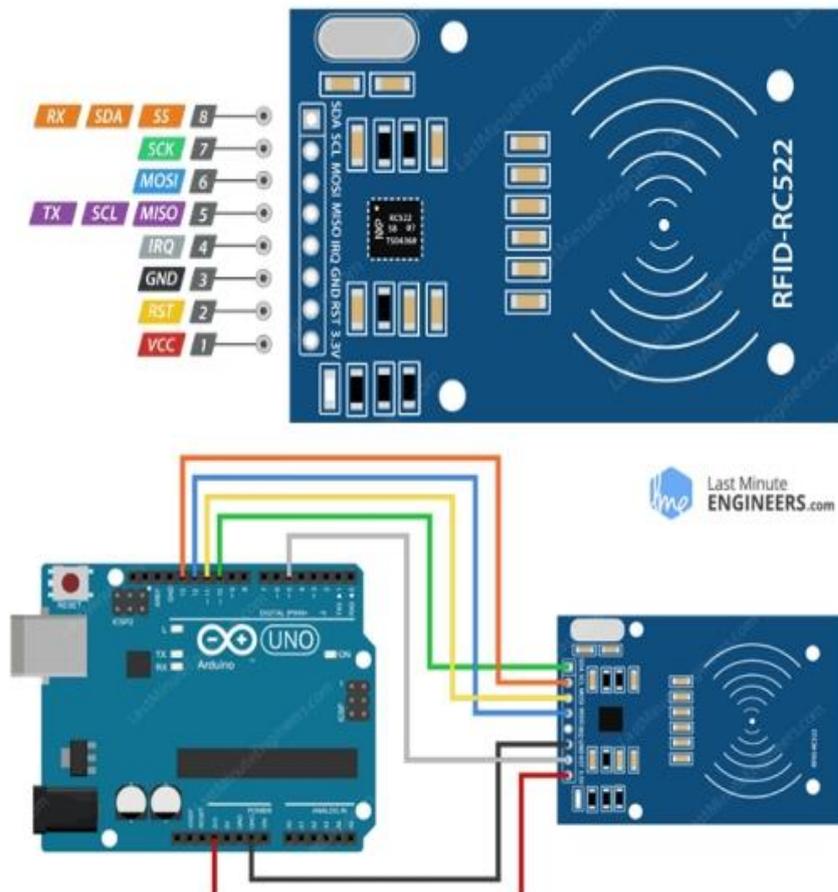
various units and software API, in this case Google Sheets, Warning Zone Excel sheet and Theft Detection Unit used are synchronized using the Integromat API. Active connections are established at the Warning and Theft Detection Units to facilitate this process.

Once the information from the two units is fed into Google Sheets, a VLOOKUP is made to check if the incoming tag has been deactivated or not. The state of this lookup is then written into the Security Unit. Table 1 contains the various unit tests and outcomes.

**Table 1.** DigiSCAN Unit Test Outcomes

Unit	Outcome
Deactivation Unit	All deactivated tags from checkout are sent to a given column on Google Sheets.
Warning Zone Unit	The Data Streamer functionality of Excel is used to communicate serially with an Arduino board connected to this unit. Through Excel and Visual Basic, tags that are read are sent to a third-party API, namely Integromat, to handle syncing between Excel and Sheets. This allows for real-time communication between tags read in the warning zone and Google Sheets.
Theft Detection Unit	Like the Warning Zone Unit, the Data Streamer functionality of Excel is used to communicate serially with an Arduino board connected to this unit. Through Excel and Visual Basic, tags that are read are sent to a third-party API, namely Integromat, to handle syncing between Excel and Sheets. This allows for real-time interaction between tags read in the theft detection zone and Sheets.
Security Unit	Information processed from the Warning Zone Unit and the Theft Detection Units are sent as Boolean values into the Security Unit in the form of a tuple as (ZONE, STATUS). Based on the state of the operation and the zone, the appropriate buzzer is sounded to alert authorities of an ongoing theft or of a successful transaction.

The digiSCAN embedded hardware was tested using the Arduino Uno board for the Theft Detection Zone and Warning Zone units. An Arduino Mega board was used in the implementation of the Security Unit. Other components used in the digiSCAN setup are MFRC522, breadboard, LEDs, and buzzers as well as useful Arduino libraries and headers. Figure 7 shows the hardware components and Table 2 contains some digiSCAN software application sample codes used to read and pass the values of the RFID into the sheets (google and excel) in hexadecimal values.



**Figure 7.** DigiSCAN Test Hardware Components [25]

Table 2. DigiSCAN Software Application Sample Codes

```

#include <SPI.h>
#include <MFRC522.h>

#define SS_PIN 10
#define RST_PIN 9

MFRC522 rfid(SS_PIN, RST_PIN); // Instance of the class

MFRC522::MIFARE_Key key;

// Init array that will store new NUID
byte nuidPICC[4];

void setup() {
  Serial.begin(9600);
  SPI.begin(); // Init SPI bus
  rfid.PCD_Init(); // Init MFRC522

  for (byte i = 0; i < 6; i++) {
    key.keyByte[i] = 0xFF;
  }
  for (byte i = 0; i < 4; i++) {
    nuidPICC[i] = rfid.uid.uidByte[i];
  }

  printHex(rfid.uid.uidByte, rfid.uid.size);
  Serial.println();
  rfid.PICC_HaltA();

  rfid.PCD_StopCryptol();
}

void printHex(byte *buffer, byte bufferSize) {
  for (byte i = 0; i < bufferSize; i++) {
    Serial.print(buffer[i] < 0x10 ? " 0" : " ");
    Serial.print(buffer[i], HEX);
  }
}

void loop() {

  // Look for new cards
  if ( ! rfid.PICC_IsNewCardPresent() )
    return;

  // Verify if the NUID has been readed
  if ( ! rfid.PICC_ReadCardSerial() )
    return;

  for (byte i = 0; i < 4; i++) {
    nuidPICC[i] = rfid.uid.uidByte[i];
  }
}

```

The RC522 module data transfer code snippet is as shown in Figure 8. The sample code also shows how the warning and theft detection zones work with the buzzer and LEDs to warn customers or indicate theft.

```
const int buzzer = 10;
const int LED1 = 9;
const int buzzer1 = 12;
const int LED2 = 11;

void setup() {
  // put your setup code here, to run once:
  pinMode(buzzer, OUTPUT);
  pinMode(LED1, OUTPUT);
  pinMode(buzzer1, OUTPUT);
  pinMode(LED2, OUTPUT);
}

void loop() {
  // put your main code here, to run repeatedly:
  const bool Warn = false;
  const int Theft = false;
  if(Warn==true){
    digitalWrite(LED1, HIGH);
    tone(buzzer, 2000);
    delay(1000);
    digitalWrite(LED1, LOW);
    noTone(buzzer);
    delay(1000);
  };
  if(Theft==true){
    digitalWrite(LED2, HIGH);
    tone(buzzer1, 2000);
    delay(1000);
    digitalWrite(LED2, LOW);
    noTone(buzzer1);
    delay(1000);
  }
}
```

Figure 8. RC522 Data Transfer Code Snippet

Integromat, a third-party API was used for the automation and synchronization between the individual units. Figure 9 shows some scenarios applied for active connection during testing.

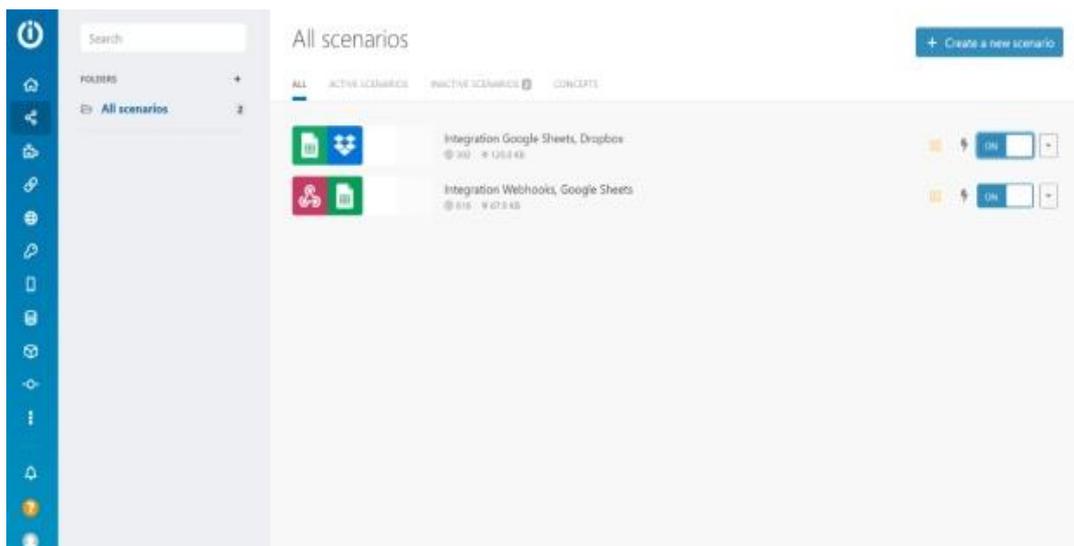


Figure 9. DigiSCAN Test Scenarios

Using Visual Basic, an active GET is created to Integromat as a listening event. Once it detects a change (which represents a card has been read), it sends an instant acknowledgment to Integromat with an update of the card value being made on Google Sheets. Figure 10 depicts the Microsoft VBA macro in action and Table 3 contains a few macro functions applied for this test and the expected results

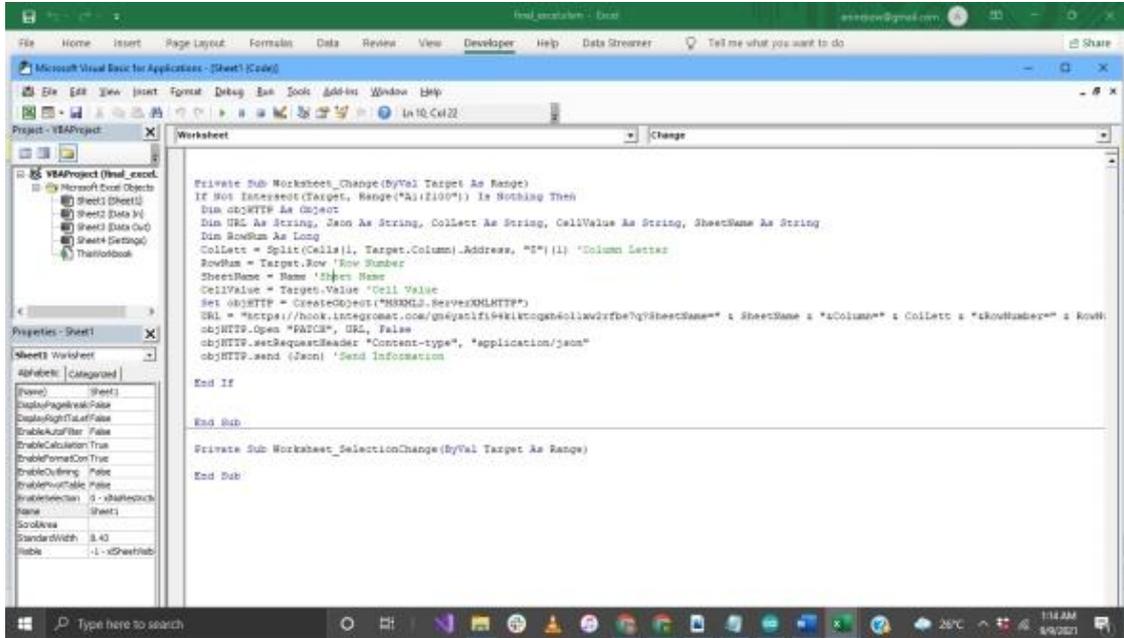


Figure 10. DigiSCAN VBA Macros

Tabel 3. DigiSCAN VBA Macros

Macro	Function
=Data In! B22	Sheet linking between Arduino serial input and synchronized sheet on Excel for Google Sheets
=IF (ISERROR (VLOOKUP (A1, \$B\$1001,1, FALSE)), FALSE, TRUE)	Performing VLOOKUP to check if a given RFID tag has already been accounted for. The output of this lookup is fed together with the current zone into the Arduino Mega for the Security Unit to process.

Other Approaches Considered during testing are:

- Using Radio Frequency to generate metallic resonance.
- Use of OneDrive instead of Integromat for synchronization.

Tabel 4. Test Case Scenarios

Tags	Read range	Alert response	Time of alert
1	<1cm	Theft detected	<5s
2	1cm - 2cm	Theft detected	<5s
3	2cm - 3cm	Theft detected	<5s
4	3cm - 4cm	Theft detected	<5s
5	4cm - 5cm	Theft detected	<5s
6	>5cm	No theft detected	-

Using the theft case scenarios, five (5) out of the six (6) tags were detected and recorded accordingly. This indicates an 83.3% efficiency for the digiSCAN system implementation. The Warning and Theft Detection Zones also work well independently of each other with no false alarms or false positives. The reading range of the MFRC522 however, was very short with a range of < 5cm.

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## Conclusion

Based on the testing and evaluation of the system, the Supermarket Antitheft Scanner System was successful in detecting and eliminating theft. The spreadsheet application integration (Google Sheets and Microsoft Excel) helps keep inventory of store items. The system is also highly scalable. Further improvements to the system could be embedding of product information into tags for product identification, a police alert through an SMS alongside the Warning Zone alarm and the use of a different database system such as Mongo DB instead of Google Sheets for very large-scale applications. UHF RFID readers can also be used with this implementation to increase range of reading.

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