David Owino

# Smart Bag

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This project has been motivated by a desire to solve the problem caused by dishonest luggage handlers who occasionally open travellers' bags while these bags are on transit. Such acts have been filmed through hidden cameras around airports and reported on various internet platforms with one such case having been posted on Facebook in October 2017. Passengers being unable to notice the loss of their items until they arrive at their homes means that very little of such items can be recovered. It is therefore important to build a system that will sound a warning when a theft has occurred to enable quick reaction and possible recovery. This system will help in this regard by alerting supervisors of luggage handlers whenever an incident of theft has occurred.

The project has been carried out through lab tests and simulations, research by use of text books and other online sources.

The tests have confirmed the possibility of the objective, the results from lab test are consistent with the theoretical analysis and principles set out for such circuits. There may be however variation of results depending on the location of the tests and accuracy of instruments used but the results here have confirmed firmly that the idea is implementable.

While this project is merely a foundation in search for a more refined system, it points to the direction of such refined system. With a little more improvement, the system may be improved to send notifications as to when and where the theft took place. Additional systems like cameras can be made available in bags containing highly valuable contents, which could further make the system a complete solution to theft at airports and other transit corridors around the world.

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| Keywords | Sensor, Resistive Sensor, Smart Bag, Anti-theft |

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**Contents**

Appendices

## List Of figures



Metropolia

**List of Tables**



Metropolia

## List of Abbreviations

| | |
|---|---|
| V | Voltage |
| $R_s$ | Sensor Unit Resistance |
| $R_r$ | Reset unit Resistance |
| SP | Sensor Plate |

## 1 Introduction

On October the 16th 2017, a Facebook user uploaded a video in which unidentified luggage handler is seen opening passenger's bags with intention to steal valuables from them. There are numerous other videos on various online platforms alluding to similar incidences at various airports around the world. These actions by dishonest luggage handlers raise the question concerning the security of the luggage contents as they are moved at various airports to their destinations. Is there something we can do to raise alarm when such dishonesty occurs to guarantee quick action from airport luggage supervisors and stop dishonest handlers from robbing passengers?
This project research seeks to improve the security of the luggage content by raising such alarm when necessary.
The main objective of this project was to create a sensor device capable of raising alarm, whenever the contents of a trolley bag in which it is installed, are taken away in acts of robbery, and whenever the trolley bag, in which it is installed, is opened irregularly by dishonest handlers while it is on transit at a transport station or at home.

## 2 Background Information

Trolley bags have been in existence for centuries. Ancient kings and rulers owned heavy metal or wooden built boxes to keep important kingdom documents safe from any destructions. Smith's men used them to carry hummers, tape measures etc.

Over the years, like in every other sector, bags have evolved in sizes, shapes and materials used for their manufacture. With commercial flights becoming more regular around the world, companies have endeavored to produce bags with great focus on weight and security of the contents in them, putting every effort to allow travelers to carry more luggage at lower cost.

With technology evolving and more and more valuable gadgets getting produced, the contents of luggage's today greatly differ from those in the early centuries. A typical traveler's bag today would contain expensive things like laptops, iPads, expensive designer clothes, rings, lotions and much more. With this change in content, a new headache for carryon luggage manufacturers has shifted to the security of the contents in the bags.

Locking devices like Zips, padlocks and manual coded locks have all been used to enhance the security of the luggage while on transit. While these locks have played a great role in securing luggage's for years, incidents of missing items from travelers' bags continue to emerge all the time. Dishonest luggage handlers use master keys to open padlocks and other means only known to them to disable zips and manual locks. These incidents require us to develop a new security measure that would raise alarm when bags are forced open and items taken out of them irregularly.

To develop such a security system, we need a sensor or transducer which can convert the mechanical movement or change in volume of the bag when an item is taken out into electronic signal capable of driving an alarm. There are various types of sensors, and sensors have been used tremendously in improving security situations of properties including homes. Example of places where sensors have been used include supermarkets where sensors are used to detect shoplifters etc.

In this project, fixed value resistors are used to create a unit of variable resistance. The resistance of the unit changes depending on the weight of items placed in the bag. With proper tolerance set, it will be possible to prevent false alarms and monitor the content of the luggage effectively.

## 3 Concept and Method

As already explained in the background information, this project seeks to curb the possibility of dishonest luggage handlers picking items from passenger's bags unnoticed. To achieve this task, a sensor is necessary to detect any change in the content of the bag.

The sensor is designed to act as a transducer that converts the weight of the items placed inside the bag into a voltage level by varying the resistance level of a circuit, mechanically attached to a moving arm inside the bag.

Normally, bags are constructed with a fixed volume so that items are packed from bottom to top. The construction with regard to the volume remains the same with only a little modification with regard to the bottom of the bag in this particular project. Instead of a fixed bottom, this project proposes a movable bottom that would be high up when the bag is empty and down at the bottom when the bag is fully occupied with items. This modification is possible by simply integrating a dynamic spring into the bag. The dynamic spring will carry the platform on which the items are placed. As more items are placed, the dynamic spring moves downwards. Below the movable platform (sensor plate) is a contact head which touches respective resistor terminals at each level and consequently connecting it to the circuit (voltage division circuit). Figure 1 below shows a construction of a trolley bag with a movable platform.

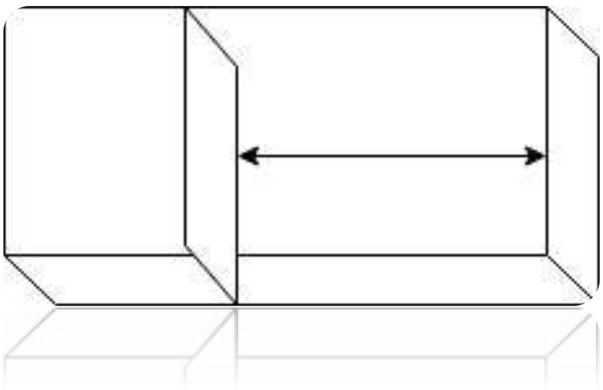

Figure 1. A bag with movable platform on which items are placed

The operation of this sensor relies on the principle of voltage division, the ability to vary voltage drop across two resistors connected in series. The two resistors are constructed into two separate units. One unit (sensor unit) consist of stacks of fixed value resistors. The resistors in this unit are selected by a moving arm of the sensor itself. The other unit (reset unit) is a variable resistor adjustable by the user to achieve specified predetermined resistance values at specified corresponding values of the sensor unit. Together, the two units control the voltage level across the sensor unit.

Across the sensor unit, at its output, a low voltage alarm is connected. This alarm remains on for as long as the voltage at its input is above predetermined voltage level. When the voltage drops below the specified alarm voltage level, the alarm goes off. Figure 2 in the next page explains the functioning of the sensor in block diagram.

The double arrow between the sensor plate and the sensor unit represents the dynamic spring which enables the weight of the items placed on the sensor plate to vary the resistance of the sensor unit. The sensor plate is the platform on which items are placed.

It moves downwards depending on the weight of the items placed on it or upwards depending on the weight of items removed from it. The alarm is the condition indicator of the system. Its purpose is to go off when an item has been taken from the bag irregularly therefore achieving the main purpose for this project which is to give sound alerts whenever theft occurs affecting the content of the bag by an act of one or more items being taken away.

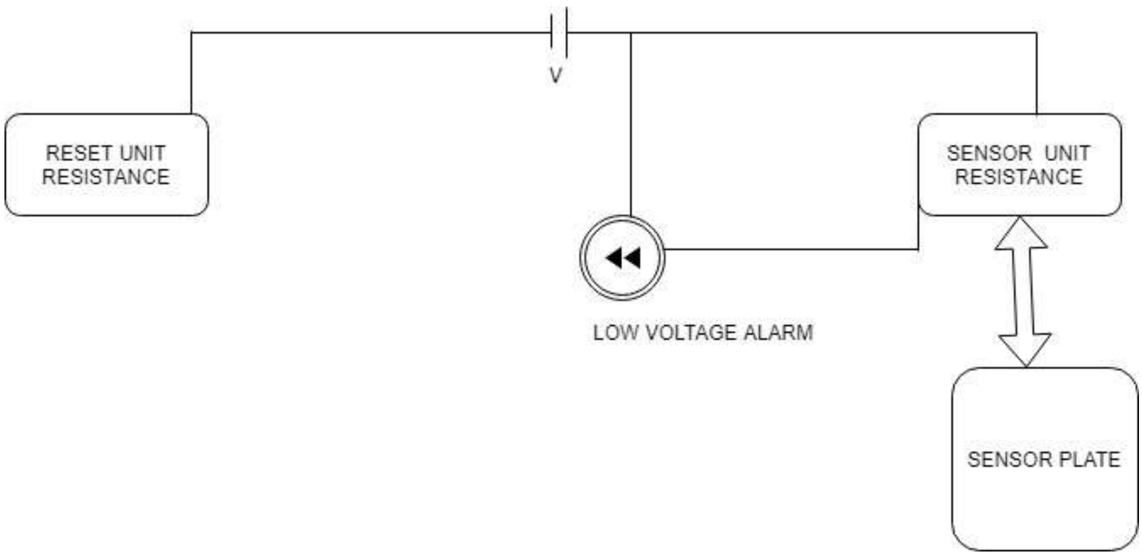


Figure 2. Block diagram showing various parts of the smart bag sensor

While the resistance selection in the sensor unit depends on the weight of the items on the sensor plate which forces the dynamic spring to move down or upwards accordingly, the selection of resistance in the reset unit is done manually by the device user. The user chooses the resistance value to select in the reset unit according to a user guide that will be introduced in the later chapters. The resistance selected in the reset unit should be sufficient enough to ensure a voltage value across the sensor unit that will keep the alarm on, prevent false alarm in case of any movements or turbulences and also prevent false silence of the alarm.

Any change in the contents of the bag will occasion a corresponding movement of the dynamic spring resulting in a new resistor being connected to the circuit. The movement of interest in this project to prevent stealing, is an upward movement which basically means that an item is out and the weight on the dynamic spring is reduced. Since the resistors are arranged such that the smallest value resistor is at the top and the largest at the bottom, an upward movement will occasion a lower voltage level across the new resistor connected because of the movement. The values of the resistors are carefully chosen to ensure that such movement will guarantee a voltage drop to a value of less than 3.3 voltage to ensure that the alarm is triggered off. The alarm can then only be reset by resetting the resistance value of the variable resistor at the reset unit which is a hidden button in the construction of the bag only known to the user. It will therefore be impossible for anyone else to silence the alarm after triggering it off by taking an item from the bag.

# 4 Main Components

The device is made up of five main components which include: The sensor unit, the reset unit, low voltage alarm, a voltage supply and a voltage indicator. The sizes and number of components required in the construction depend on the target bag. A smaller bag would require very smaller sensor unit as compared to a larger sized bag. For purposes of demonstrating the application of this device in this project, an ordinary carton box is used in place of a trolley bag. Other parts shall be as described in subsequent chapters.

## 4.1 Sensor Unit

This unit is made of several resistors getting connected to the circuit one at a time, making the unit to operate as a variable resistor. The resistors are jointly connected together on one side and to the other side each gets selected by the contact head as shown below. The entire unit forms one block of resistance connected to the voltage division formula. Figure 3 below shows the construction of the unit, the resistors arrangement and other connection leads.

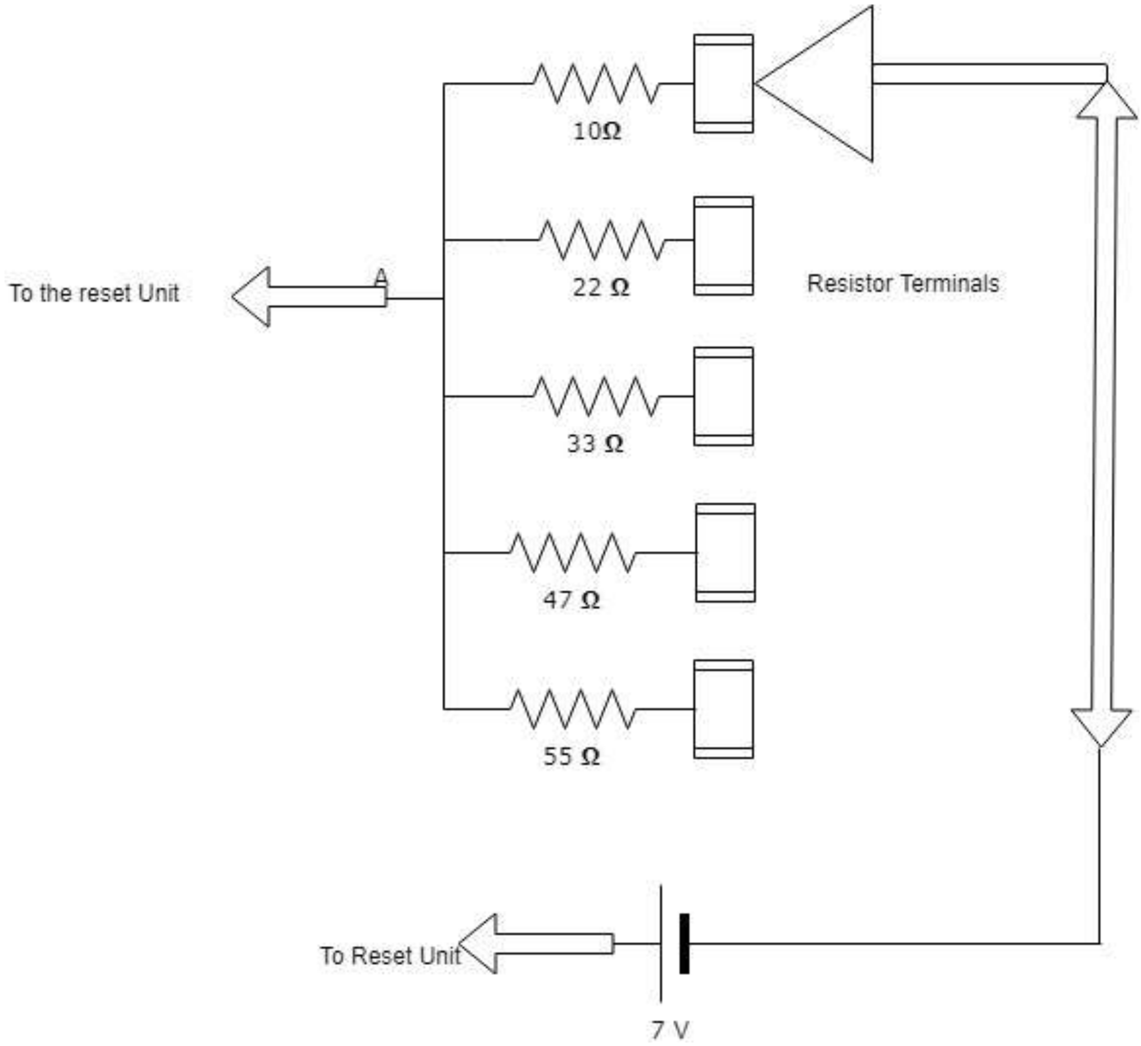


Figure 3. The sensor Unit

The selection of the resistors as already mentioned is done through a contact head as shown in the figure above. When the contact head touches a specific resistor terminal, the resistor immediately becomes part of the voltage division circuit.

In some instances, it is predictable that two adjacent resistors in the sensor unit may both be connected to the circuit. In such instance, the two connected resistors will be in parallel to each other but a combination of the two will be in series to the reset unit. This prediction of simultaneous connection of two resistors in the sensor unit will require the reset unit to be designed in such a way that it includes values of combined resistors of two adjacent resistors in the sensor unit for appropriate operation should such a situation arise. A resistor basically restricts the flow of electrons in a circuit. The unit of resistance is Ohms (Ω). There are two types of resistors, namely: fixed resistors and variable resistors. Fixed resistors have their values set during manufacturing and cannot therefore be changed. The figure 3 below shows samples of fixed resistors in circulation.


Figure 4. Typical Fixed Resistors [2, 41]

Figure 4 shows that resistors can be found in various forms. As standalone components such as in 1a, in some instances, several resistors can be grouped into a chip as in 1e. Resistors come in different values depending on intended use. Fixed value resistors also have different color codes depending on their values. Appendix 1 lists color codes and reading procedures

### 4.1.1 Variables Resistors

The sensor unit is made of fixed value resistors but the selection method of each of the resistors makes the unit to function as a variable resistor. Variable resistors are resistors whose values can easily be changed by the user. They can either be a potentiometer when used to divide voltage, or rheostat when used to control current. [2, 46]. In this project, the two units will control voltage to the low voltage alarm, hence operating as a potentiometer.

Variable resistors are made with a movable arm used to vary the resistance between the two fixed terminals. Figure 5 below shows the various symbols of variable resistors.

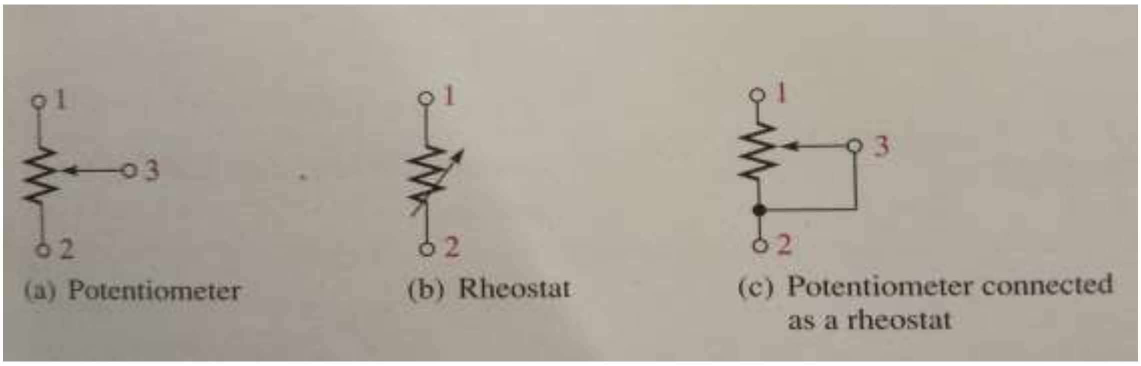


Figure 5. Potentiometer and rheostat symbols [2, 46]

The resistance is set by sliding the moveable arm to the desired position to attain the required resistance. In other variable types of resistors certain physical conditions can be used to change the resistance of the resistor. Such resistors include the LDR light dependent resistor, thermistors which depend on heat to vary the resistance etc. In this project, several resistors of predetermined values, shall be arranged at intervals, as shown in Figure 6 below. As in other sensors where physical quantities are used to change resistor values, in this project, the weight of items will determine the resistor value which gets connected to the voltage divider circuit.

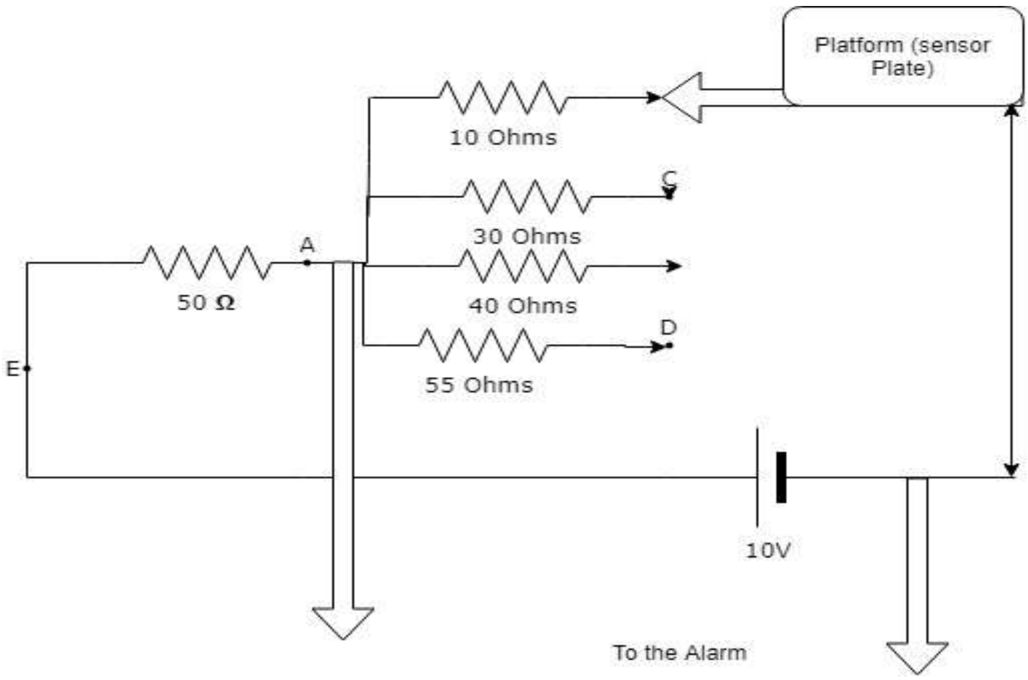

Figure 6. Resistor arrangement in the smart-bag

### 4.1.2 Construction of the Sensor Unit

The main objective in the construction of this unit is to ensure that depending on the weight of items packed in the bag, the resistance of the sensor can change appropriately. The construction also predicts a situation where the bag is turned upside down a situation which can alter the already established resistance due to the movement of items inside the bag resulting in false alarm.

The sensor unit forms the main part on which items are placed in a trolley bag. As opposed to the usual fixed volume in all trolley bags, the sensor makes the volume of the bag to change depending on the number of items available in it. The sensor consists of a movable plate on which the items are placed. The plate is held into position by dynamic springs on both ends. Under the plate is an arm attached to the contact head. The contact head touches the respective resistor terminals, as shown in figure 5 and 6 above to connect the respective resistor to the voltage divider circuit.

### 4.1.3 Voltage Rating of the Sensor

The voltage level at which the circuit operates is determined by the voltage rating of the alarm connected to the circuit. The sensor should trigger the alarm to go off whenever the voltage level falls below the preset value of the alarm. Alarms may be preset to go off for voltages below 5 Volts, 3.3 Volts, 10 Volts etc. For this project, we designed the sensor unit to trigger the alarm if the voltage supply to the alarm falls below 3.3 V. Since the alarm is connected across the sensor unit and not the reset unit, the sensor circuit is therefore designed to ensure that if the voltage drop across the sensor circuit falls to below the alarm operating voltage, the alarm goes off immediately. The voltage across the sensor circuit and across the reset circuit maybe set to equal each other depending on the number of items available. For example, when the bag is fully packed and the sensor unit resistance value is at its maximum value, the reset unit will also be at its maximum value. On other instances when the bag is not fully loaded with items, the reset unit resistance will be higher than the sensor unit resistance but at a level which ensures that the voltage across the sensor unit is slightly above the alarm operating voltage be equal for the sensor to work properly. It therefore means that if the alarm connected to the circuit should detect voltage level below 5V, the circuit must be constructed to maintain a voltage of 5V or slightly above 5 V on the sensor circuit for normal operation. Any change in the bag content will result in voltage imbalance and consequently trigger the alarm. Figure 6 above shows the construction of the sensor unit. The major parts which include the dynamic spring, the sensor plate, the contact head, the resistor arrangement and the resistor terminals.

In the figure 6 above, the sensor plate forms the platform on which items are packed inside the bag. As more items are placed on it, it moves downwards by the action of the dynamic springs (Represented by the double arrow). This movement causes the Sensor contact head to move and make contact with the next resistor terminal effectively connecting it to the voltage divider circuit. The 50 Ohms resistor represent the reset unit adjustable by the user.

#### 4.1.4 Voltage Indicator

This device is connected across the sensor unit. Its purpose is to indicate the voltage level across the sensor circuit. This device was used at the testing mode in the laboratory. For the final product, resistance meter will replace the voltage indicator.

#### 4.1.5 Resistor Meter

The purpose of this device is to indicate the resistance value of the sensor circuit for the user to select an appropriate resistor value on the reset unit for purposes of securing the packed items.

#### 4.1.6 The Reset Unit

The purpose of this unit is to adjust the voltage level across the sensor unit. Once items are placed in the bag and an appropriate resistance value has been connected to the voltage divider circuit. This unit ensures that the voltage on the sensor unit is just slightly above the alarm operating voltage. The slight tolerance above the operating voltage is to take care of vibrations that may cause slight movements of items after packing. It should always be preset to the highest value of resistance before items are placed into the bag. The construction of this unit takes into account a situation where two adjacent resistors in the sensor unit both get connected to the circuit simultaneously. For example, when two adjacent resistors of value x and y are both connected at the sensor unit, they will form a parallel circuit between themselves. As such, to equate their value at the reset unit for effective balanced voltage, a resistor z whose value is calculated as in equation (4) is necessary in the reset unit of the device. Determination of resistor values of this unit are based on the values assigned for the sensor unit to ensure that at all times appropriate voltage across the sensor unit, will be achieved to drive the alarm. The values will be shown in subsequent chapters when we analyze the component values for the device construction.

$$Z = \frac{X\,Y}{X\ +Y} \tag{4}$$

In the equation (4) above x and y are the two adjacent resistors on the sensor unit and Z is their corresponding value on the rest unit should they get connected both at the same time by the action of the sensor contact head touching their terminals. The unit is a basic variable resistor adjustable from 0 Ohms to 100 Ohms.

### 4.1.7 Dynamic Springs

These springs are compressible depending on the weight placed on them. The springs are available with various specifications depending on the expected stress to which they will be exposed. Figure 7 below shows a dynamic spring.


Figure 7. Dynamic spring

Dynamic springs are used also in cars and other automobiles as shock absorbers, depending on the expected stress to which they will be exposed. A careful selection can be made to ensure their durability and reduced costs of occasional replacements.

### 4.1.8 Sensor Plate

This is the platform on which items are placed inside the smart bag. It is attached to the dynamic springs which hold it in position as shown in figure 6 above and ensure its movement depending on the weight of items on it. The plate must be made of a nonconducting material. The more the weight placed on it, the greater distance it will move downwards to create more space for more items until the capacity of the bag is fully occupied beyond which the dynamic spring cannot be compressed further. The plate has a protruding arm (Contact Head) which contacts the resistor terminals and connect resistor to the main circuit.

### 4.1.9 Voltage Alarm

This is the device that is triggered to ring whenever there has been a change in the bag contents leading to reduced voltage below the preset levels.

### 4.1.10 Voltage Supply

The purpose of voltage supply in this project is to supply a constant direct current. The capacity of the source should be able to last the longest duration of a single journey of about twenty to twenty-four hours.

### 4.1.11 Straps

Straps are used to fasten the items once the packing is complete. This ensures that the dynamic spring does not adjust the resistance of the sensor in case the bag turns upside down or in case of turbulent movements the items are not affected by the vibrations likely to change the resistance of the device. Figure 8 shows a strap that can be used to secure bag contents ant ensure minimum disturbance in case of vibration or impulse force applied to the bag.

Figure 8. Straps

The straps are fixed in such a way that they originate from the fixed base of the bag. This way, they will hold the dynamic springs when locked and prevent any movements should the bag be turned upside down.

## 5 Device Operation

The purpose of the sensor is to raise alarm each time a significant change of voltage supply to the alarm device occurs. The alarm device is triggered each time the voltage drop across the sensor unit goes below its predetermined voltage limit. The voltage drop across the sensor unit and the reset unit should always be equal and just slightly above the minimum voltage below which the alarm goes off. Before packing items into the smart bag, the reset unit resistance must be adjusted to maximum resistance value. The maximum resistance value of the reset unit is always equal to the maximum achievable resistance value across the sensor unit when the bag is fully loaded with items.

#### 5.1.1 The Packing and Testing

Once the reset unit is tuned to its maximum resistance value and no item has been placed on the sensor plate, the voltage across the senor unit will be lower than the voltage drop across the reset unit. At this point, if the sensor switch is turned on, the alarm will go off since the voltage across the sensor unit is below its minimum operating voltage. Assume the minimum resistance of the sensor unit is 10 Ohms (Resistance when the bag is empty and sensor plate fully raised), the maximum resistance across the reset unit is 100 Ohms, minimum alarm voltage is 3.3V and a voltage of 10V is connected to the circuit. The following voltages will be dropped across the two units.

$$V_s = \frac{Rs}{Rs+Rr} x\, V \qquad = \frac{10}{10+100} x\, 10 = 0.91V \tag{5}$$

$$V_r = \frac{Rr}{Rr+Rs} x\, V \qquad = \frac{100}{10+100} x\, 10 = 9.09V \tag{6}$$

Where $V_s$ is the voltage across the sensor unit, $V_r$ is the voltage drop across the reset unit, $R_r$ is the resistance across the reset unit, $R_s$ is the resistance across the sensor unit and V is the voltage supplied to the circuit.

From the calculations above, in the initial state when the reset unit is at maximum resistance and the sensor unit is at minimum resistance, the alarm will go off. This stage is also called the testing stage, at which the user can tell the serviceability of the sensor device before packing.

Once the placing of items on the sensor plate begins, the weight of the items begins to compress the dynamic spring forcing it to compress downwards, this downward movement of the spring and the sensor plate changes the value of $R_s$ . As more items are packed, the sensor plate moves further downwards and the resistance of the senor unit increases. The increase in the sensor unit resistance also increases the voltage value dropped across it. Let us assume, that the maximum resistance of the sensor unit is 100 Ohms same as that of the reset unit, but after packing all the items available, the plate only moves a few inches downwards to a resistance value of 60 Ohms. Note that the reset unit resistance is still set at 100 Ohms. Let us calculate the new voltage values across the sensor unit and the rest unit.

Given $R_s$ = 60 Ohms, $R_r$ = 100 Ohms, V = 10V

$$V_s = \frac{60}{60+100} x\, 10 = 3.75V \quad and\ Vr = \frac{100}{100+60} x\, 10 = 6.25\text{ V} \tag{7}$$

Since the alarm installed is triggered to go off when the voltage across the sensor unit is less than 3.3V, at this instance when the packing is complete and the voltage across the sensor circuit is 3.75V, the alarm will not be triggered off because the voltage across it is above the 3.3 Voltage limit. Since the items are held into position by a strap, it is expected that there will be no movement that can lower the voltage below the minimum

3.3 Voltage. However, to ensure that adverse vibrations do not cause sudden fall of the voltage, resistance across the reset unit is lowered accordingly to raise the voltage drop across the sensor unit. This creates a tolerance voltage within which some unpredictable movements due to vibration or impulsive force on the bag will not cause the alarm to go off. The adjustment also considers voltage drop resulting from current drawn from the battery. After a certain number of hours, the voltage supply is no longer 10 Volts but we still need the alarm to function properly without giving false alarm.

### 5.1.2 Power Consumption and Recharge Duration.

The main purpose of smart bag technology is to provide security to the bag contents while on transit. It is necessary that the battery installed can provide the required voltage for the entire duration of the transit. On average, long distance travel durations last about eight to ten hours except in very extra ordinary long trips with lots of waiting time which can last up to 20 hours. Battery capacity is a function of current supplied to the circuit. To ensure that false alarms are not triggered, a careful selection of the resistors must be done to ensure that the least possible amount of current is drawn from the battery at any combination of the sensor resistor values and the reset unit resistor values.

## 6 Initial Calculations

To be able to proceed to the next level of setting up the circuits for laboratory testing, resistor values must be predetermined depending on the low voltage alarm we intend to use. Arbitrary values for the sensor unit resistors are chosen, albeit with caution to minimize overheating and reduce the load on power supply. Calculations are then necessary to establish the corresponding reset unit resistor values taking into account the possibility of each of the resistors on the sensor unit getting connected to the circuit one at a time and secondly taking into account a situation where two adjacent resistors are connected as already explained earlier.

Sensor unit resistors are arbitrarily chosen to range between 10 Ohms to 100 Ohms. 10 Ohms is the list resistance that the sensor unit would have when no item is on the sensor plate. The given the supply voltage is 10 volts, alarm threshold voltage is 3.3 volts and vibration tolerance voltage set to 1 Volt. Table 1 on page 17 shows the sensor unit resistors and the corresponding reset unit resistor values.

To calculate the reset unit resistance, we must know the expected voltage across the sensor unit resistance. The expected voltage for normal performance without the alarm being triggered off must be above 3.3 Volts. To 3.3 V we add a tolerance voltage of 1V therefore the expected voltage across the sensor unit is 4.3V for a supply of 10 Volts.

When sensor unit resistance is 10 ohms, reset unit resistance to keep the alarm on is given by:

$$Vs = \frac{Rs}{Rs+Rr} x\ V \quad = \frac{10\Omega}{10\Omega+Rr}\ x\ 10V \qquad Vs = 3.3V + 1V \tag{8}$$

$$4.3\text{V} = \frac{10\Omega\ x\ 10V}{10\Omega+Re} \qquad 4.3Re = 100 - 43 \tag{9}$$

$$Re = \frac{100-43}{4.3} = 13.25\ \Omega \tag{10}$$

Where Vs is the expected voltage across the sensor unit, Rs is the sensor resistance, Rr is the reset unit resistance and V is the supply voltage

From the above calculation, it is imperative to deduce that, for the alarm to remain on and operate at the predetermined voltage of 4.3V across the sensor unit, the reset resistance is given by a general formula below.

$$Re = \frac{(Rs\ x\ V)-(4.3\ x\ Rs)}{Vs} \qquad V\ = 10\text{Volts} \tag{11}$$

$$Re = \frac{5.7Rs}{4.3} \qquad Re = 1.33Rs \tag{12}$$

This general equation gives the value to which the resistance of the reset unit resistor must be set after packing to ensure that the alarm does not give false alarms but still ensures that if an item is irregularly taken out of the bag, the voltage across the sensor unit will fall considerably to trigger the alarm warning. A user will only need to check the resistance indicator to ensure that after packing and strapping the items in the bag to set a corresponding resistance value on the reset unit.

Table 1. Resistor Values for Reset and Sensor Units when only one resistor in the sensor unit is connected to the circuit.

| SENSOR UNITRESISTANCE Rs | RESEST UNIT RESISTANCE Rr |
|---|---|
| 10 ohms | 13.3 ohms |
| 20 ohms | 26.6 ohms |
| 30 ohms | 39.9 ohms |
| 40 ohms | 53.2 ohms |
| 50 ohms | 66.5 ohms |
| 60 ohms | 79.8 ohms |
| 70 ohms | 93.1 ohms |
| 80 ohms | 106.4 ohms |
| 90 ohms | 119.7 ohms |
| 100 ohms | 133 ohms |

When two adjacent resistors in the sensor unit are connected simultaneously to the circuit, the two resistors will be in parallel to each other but in series to the reset unit resistor. As such the combined resistance of the two resistors will be calculated as per the formula below.

$$Re = \frac{R1\ x\ R2}{R1+R2} \tag{13}$$

Given the sensor unit resistor values as listed above, the table 2 below shows the combined resistance for any two adjacent resistors and the corresponding reset unit resistance necessary to keep the device performing normally.

Table 2. Table showing combined values for adjacent resistors on the sensor unit and their corresponding reset value resistor values

| Sensor resistance | Combined resistance | Reset unit resistance |
|---|---|---|
| 10 ohms | 10 and 20 ohms = 6.67ohms | 8.87 ohms |
| 20 ohms | 20 and 30 ohms = 12 ohms | 15.96 ohms |
| 30 ohms | 30 and 40 ohms = 17.15 ohms | 22.8 ohms |
| 40 ohms | 40 and 50 ohms = 22.22 ohms | 29. 55 ohms |
| 50 ohms | 50 and 60 ohms = 27.27 ohms | 36.27 ohms |
| 60 ohms | 60 and 70 ohms = 32.30 ohms | 42.96 ohms |
| 70 ohms | 70 and 80 ohms = 37.33 ohms | 49.65 ohms |
| 80 ohms | 80 and 90 ohms = 42.35 ohms | 56.32 ohms |
| 90 ohms | 90 and 100 ohms = 47.37 ohms | 63 ohms |

# 7 Test Results and Analysis

The above figures in table 1 and table 2 are based on theoretical calculations with the expectation that it will be possible to tune the sensor unit to always have an output voltage of 4.3 Voltage. The first step in carrying out tests is establishing the availability of the listed resistors. The first test will aim at the accuracy of the voltage drop across the sensor unit as we change the reset unit resistor and the sensor unit resistor values. We shall also establish the ability of the circuit to trigger the voltage alarm at preset values.

## 7.1 Circuit Set Up

Initial tests were built on a laboratory bred board. Two sets of resistors were connected as shown in the figure 10 below. On the right are resistors representing the sensor unit and to the left are resistors representing the reset unit.

From the multisim design environment, the circuit looks as shown in the figure 9 below

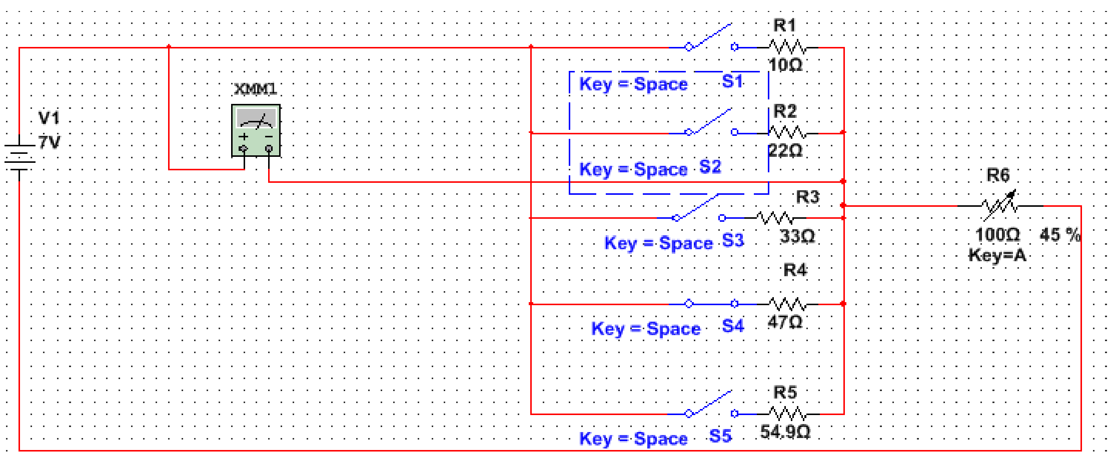


Figure 9. Test circuit

R6 is variable resistor representing the reset unit of the smart bag. Resistors R1 to R5 are fixed value resistors representing the sensor unit resistor assembly. For purposes of carrying out the test in the laboratory, switches S1 to S5 were used to connect one resistor to the voltage divider circuit one at a time or two as appropriate. In the construction of the bag, the switches were not necessary as the closing and opening of the circuit will be done by the moving contact head attached to the sensor plate as already explained earlier. The multimeter shows the voltage across the resistor connected to the circuit, otherwise it shows the voltage value of the voltage source when no resistor within the sensor unit is connected to the circuit. The voltage indicator as already explained earlier is helpful to the user in determining the resistance value to select on the reset unit to ensure proper security for the items enclosed in the bag.

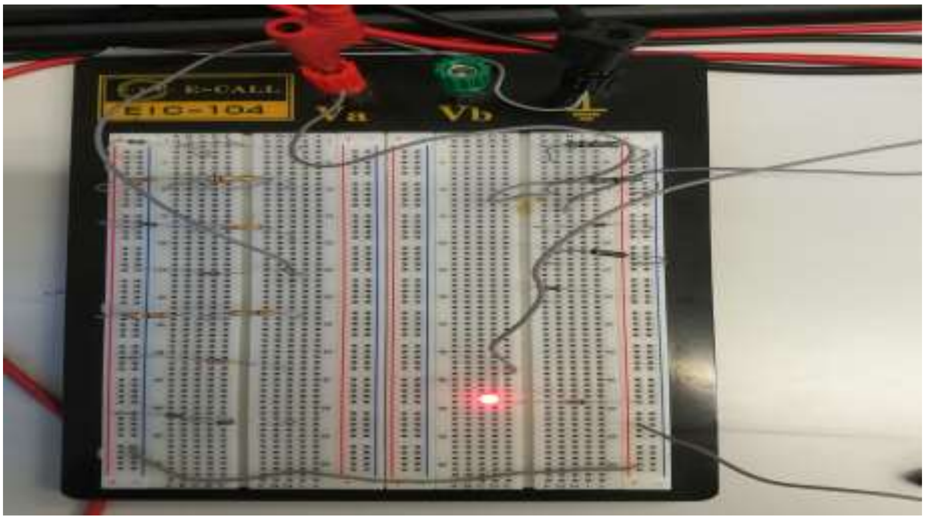


Figure 10.Sensor circuit and Reset circuit set up

In the figure 10 above, a voltage source of 7 DC voltage is used. In the initial calculations, it was estimated that a 10 volts source would be used but at the laboratory, initial tests proved that 10 volts would require higher resistor values than the intended values for this project. Connecting a 10-voltage source to certain resistor combination in the set up would lead to as high as 2 Amperes of current which is too high to cause resistor break-down. As such a lower voltage of 7 volts was discovered to be the perfect solution for this project. Other calculations as already explained in the initial calculations remain the same.

In the set up shown in figure 10, resistor values of the sensor unit are varied by connecting each of them to the voltage divider circuit one at a time for a specific value of resistance in the reset unit. The voltage drop across the sensor unit is then recorded. As shown in the table 3 below.

Table 3. Table showing the various voltage drops across the sensor unit at different resistor values

| **Reset Resistors** | | | | | | |
|---|---|---|---|---|---|---|
| | **Sensor Resistors** | **10 R** | **22 R** | **32 R** | **47 R** | **55 R** |
| 9.075 R | | 3.53 V | 4.72 V | 5.34 V | 5.74 V | 5.91 V |
| 15R | | 2.67 V | 4.02 V | 4.69 V | 5.19 V | 5.43 V |
| 17.424R | | 2.45 V | 3.78 V | 4.46 V | 4.99 V | 5.23 V |
| 25.53R | | 1.88 V | 3.09 V | 3.77 V | 4.33 V | 4.59 V |
| 29.04R | | 1.69 V | 2.88 V | 3.59 V | 4.17 V | 4.47 V |
| 43.56R | | 1.29 V | 2.92 V | 3.01 V | 3.61 V | 3.9 V |
| 62.04R | | 0.96 V | 1.8 V | 2.38 V | 2.96 V | 3.24 V |
| | | | | | | |

From table 3 above, the 10 ohms resistor represent the resistance of the sensor circuit when the bag is empty (no item is placed on the sensor unit). The 55 ohms resistor represent the resistance of the sensor unit when the bag is fully loaded with items, the dynamic springs holding the sensor plates are fully compressed and the sensor plate pushed down to create maximum volume inside the bag. The alarm is expected to go off whenever voltage across the sensor resistor is less than 3.3 voltage. To cater for vibrations and other forces that may vary the resistance level across the sensor unit, the resistance of the reset unit must be set to a level that creates a tolerance voltage above the 3.3 minimum voltage across the sensor unit. For example, when the bag is empty, the alarm will go off if the resistor values of the reset unit is set to any other value other than 9.075 ohms as this is the only resistor value which would allow a voltage drop of more than 3.3 volts across the sensor unit.

When the bag is fully loaded with items and the resistance value across the sensor is at 55 ohms, we can see from the table that setting the reset unit resistance to 62.2 would cause the alarm to go off since it will create a voltage of less than 3.3 volts across the sensor unit, the alarms would however remain on for the other resistor values in the reset unit. But since the alarm is installed to indicate if an item has been removed from the bag, setting a resistor value which produces a voltage drop of 5 volts across the sensor unit would create opportunity for an item to be taken out but without the alarm going off as the voltage change would still be well about the minimum voltage necessary to cause the alarm to go off. This means that only a slight tolerance should be allowed. A tolerance of +0.6 above the minimum voltage of 3.3 volts proves to be the best value to maintain proper security for the bag items. Therefore, once an individual has put his or her items inside the bag, he or she must check the resistance indicator across the sensor unit and adjust the reset unit resistance to a level that will create a voltage drop of just 3.3 + 0.6 volts across the sensor unit resistor.

In determining the resistance value to be set on the reset unit to ensure security of the bag, to prevent false alarms, we have to pay attention to two adjacent resistors and the voltage value across them for similar resistance value on the rest unit. Say for example, in table 3 above when the sensor unit resistance is 47 ohms after packing and closing the bag, and the reset unit resistance is set to 25.3 ohms, a voltage of 4.33 will be across the sensor unit resistance which is high enough to keep the alarm on given that it will only go off if the voltage across this unit falls below 3.3 volts. However, something to note is that, if an item is taken out of the bag and the sensor plate moves slightly upwards to make contact with the next resistor in the sensor unit which has a value of 33 Ohms, the voltage across the unit will be 3.77 volts without changing the reset unit resistance. This voltage is still high enough to keep the alarm on even though an item has been removed. This is false silence, we don’t want it to occur as it will not be able to indicate that an item is missing even though an item has been taken out of the bag. To correct this situation, we must check all options available for every resistor value in the sensor unit. The idea is to ensure that we pair each resistor value in the sensor unit with a resistance value in the reset unit which will ensure that any significant change in the value of resistance triggers the alarm to go off. We do this by selecting a reset unit resistance at which two sensor unit resistors adjacent to each other have a significant voltage difference for the same reset resistance!

To accomplish this task, we now look at all possible resistor values and voltage drop across them for each resistor value in the reset unit. We now consider the instances where two resistors in the sensor unit are both connected to the circuit. The table below now shows voltages expected across the sensor unit both when only a single resistor is connected to the circuit and in a case where two adjacent resistors are connected to the circuit.

Table 4. Voltage values across the sensor unit for various resistor value combinations

| RT | RS | VT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10R | 6.875R | 22R | 13.2R | 32R | 19.34R | 47R | 25.34R | 55R |
| 9.075R | 3.53 V | 1.9V | 4.72V | 3.71V | 5.34V | 4.7V | 5.74V | 5.07V | 5.91V |
| 13.2R | 2.67 V | 1.9 V | 4.02V | 3.18V | 4.69V | 3.87V | 5.19V | 4.3V | 5.43V |
| 17.424R | 2.45 V | 1.9 V | 3.78V | 2.97V | 4.46V | 3.64V | 4.99V | 4.1V | 5.23V |
| 25.53R | 1.88 V | 1.4V | 3.09V | 2.32V | 3.77V | 2.96V | 4.33V | 3.42V | 4.59V |
| 29.04R | 1.69 V | 1.3V | 2.88V | 2.11V | 3.59V | 2.72V | 4.17V | 3.17V | 4.47V |
| 43.56R | 1.29 V | 0.9V | 2.32V | 1.64V | 3.01V | 2.17V | 3.61V | 2.59V | 3.9V |
| 62.04R | 0.96 V | 0.7V | 1.8V | 1.23V | 2.38V | 1.66V | 2.96V | 2.02V | 3.24V |
| | | | | | | | | | |

From the set of value generated above, the values in green represent voltage values when the sensor plate contact head connects two adjacent resistors to the circuit. For example, when the contact head touches both a resistor of value 10 Ohms and 22 Ohms, the resulting sensor resistance will be 6.875 according to the parallel resistors formula and the resulting voltages will be as indicated there under for each resistor values in the reset unit. The resistance value to be set on the reset unit for every resistance value on the sensor unit must therefore meet the following conditions:

a. It must ensure that the voltage across the sensor unit is just slightly above 3.3V for that resistance value on the sensor unit.
b. It must be such that should the sensor plate move upwards one step to the adjacent resistor value, the voltage across the sensor unit will fall below 3.3 volts and trigger the alarm off.

With these two conditions in mind, we can now create a user guide that will inform the user what resistance value to set on the reset unit for every number of items packed in the bag. A close look at the table 4 above reveals that for the middle figures, that is, when the contact head connects two resistors in the sensor unit, the second condition in our list of conditions is not achieved in anyone instance. As such, it will be dangerous to allow the sensor to operate it in a way that it can make contact with two resistors in the sensor unit. An improvement to ensure that only one resistor can always be connected is therefore achieved by ensuring a much narrower contact head that can only connect to one resistor at a time.

For the user, he/she will only need to look at the meter reading indicating the resistance value achieved by the items in the bag after packing and strapping the items firmly into position, then select a corresponding resistance value on his or her reset unit to secure the items in a way that will ensure that if any theft does occur, the alarm will go off immediately.

The table 5 below shows the resistor values that will ensure appropriate functioning of the sensor, that is, ensure that false alarms are avoided and ensure that false silence is also avoided.

Table 5. Resistor combinations for proper functioning of the bag

| Sensor Unit Resistance | Reset Unit Resistance Values |
|---|---|
| 10 ohms | 10 ohm s |
| | |
| 22 Ohms | 17.4 Ohms |
| | |
| 32 Ohms | 25.56 Ohms |
| | |
| 47 Ohms | 43.56 Ohms |
| | |
| 55 Ohms | 43.56 Ohms |

The resistor value combinations in the table 5 above will always ensure that the two conditions set earlier are met at all the time. The user only needs to check the value of the value of the sensor unit resistance after packing and strapping the items then set the appropriate value of the sensor unit and the bag is ready to go on transit or safe storage.

## 8 Conclusion

The tests have proved that we can divide voltage on two arms, on the sensor unit and the reset unit and use the voltage variation as a basis to control an alarm whose on or off status will help determine the condition of the bag in which it is installed.

Form the test findings, it is discovered that it is impossible to allow the contact head to connect two adjacent resistors as that will compromise the accuracy of the sensor, it is therefore important to note that, in the construction of this device, a contact head must be shaped in such a way that it can only connect one resistor at time to the voltage division circuit.

## 8.1 Recommendations

This research in itself, is a foundation on which a more refined technology can be focused to produce a more efficient system. The system will serve a much better purpose if further improvement can be made to enable it send text messages or email notification to the bag owner when predetermined voltage changes occur. This will improve its efficiency and improve its demand among users.

## References

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3. Kransly J. Evolution of the carry-on Bag [online]. USA: TheStreet, Inc; April 2018. https://www.thestreet.com/story/12789219/1/evolution-carry-bag.html. Accesed on 13th March 2018.
4. Sze S, Kwonk NG. Semiconductor Devices. Hsinchu, Taiwan: Wiley-Interscience 2007.

**Resistor Color Code Reading Procedure**

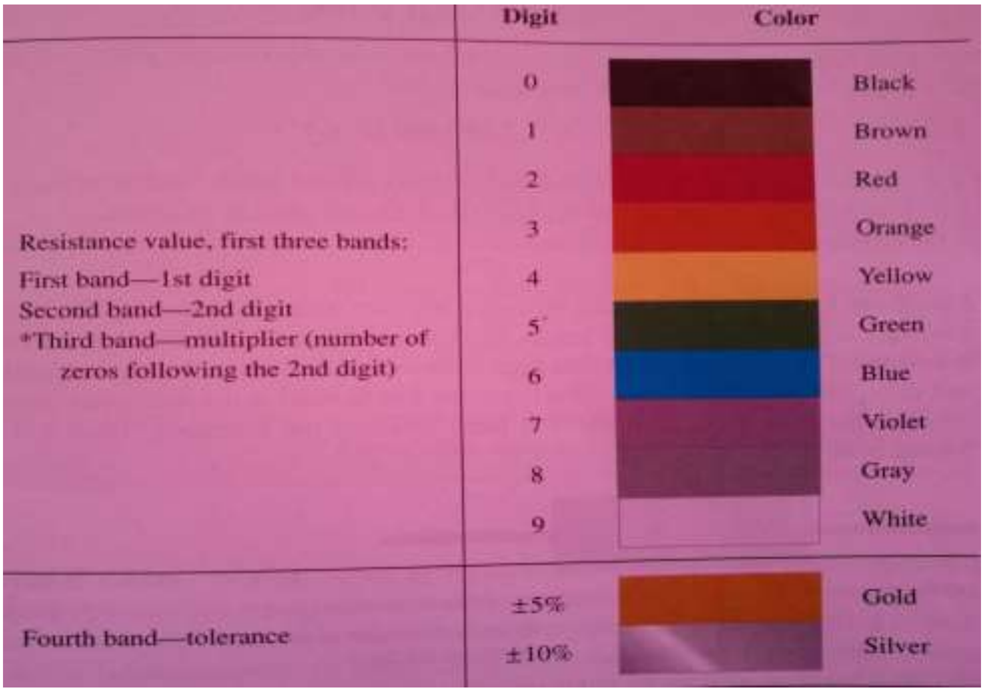
1. Start with the band closest to one end of the resistor. The first band digit is the first digit of the resistance value. Ensure the starting band is not silver or gold in color.

2. The second band is the second resistance value

3. The third band is the number opf zeros following the second digit also called multiplier

4. The fourth band indicates the percentage tolerance and is always golr or silver in color

Below are the color codes and associated values.



| | Digit | Color |
|---|---|---|
| Resistance value, first three bands: First band—1st digit Second band—2nd digit *Third band—multiplier (number of zeros following the 2nd digit) | 0 | Black |
| | 1 | Brown |
| | 2 | Red |
| | 3 | Orange |
| | 4 | Yellow |
| | 5 | Green |
| | 6 | Blue |
| | 7 | Violet |
| | 8 | Gray |
| | 9 | White |
| Fourth band—tolerance | ±5% | Gold |
| | ±10% | Silver |

Figure 11. Color codes and associated value

## Datasheet for the fixed value resistors

# Standard Metal Film Leaded Resistors

A homogeneous film of metal alloy is deposited on a high grade ceramic body. After a helical groove has been cut in the resistive layer, tinned connecting leads of electrolytic copper are welded to the end-caps.

The resistors are coated with a colored lacquer (light-blue for type SFR16S; light-green for type SFR25 and red-brown for type SFR25H) which provides electrical, mechanical, and climatic protection. The encapsulation is resistant to all cleaning solvents in accordance with IEC 60068-2-45.

## FEATURES

- Small size (SFR16S: 0204, SFR25 / SFR25H: 0207)
- Low noise (max. 1.5 µV/V for $R$ > 1 MΩ)
- Compatible to both lead (Pb)-free and lead containing soldering processes
- Material categorization:

  for definitions of compliance please see www.vishay.com/doc?99912

## APPLICATIONS

- General purpose resistors

| TECHNICAL SPECIFICATIONS | | | |
|---|---|---|---|
| DESCRIPTION | SFR16S | SFR25 | SFR25H |
| DIN size | 0204 | 0207 | 0207 |
| Resistance range | 1 Ω to 3 MΩ; jumper (0 Ω) | 0.22 Ω to 10 MΩ; jumper (0 Ω) | 0.22 Ω to 10 MΩ |
| Resistance tolerance | ± 5 %; ± 1 % | | |
| Temperature coefficient | ± 250 ppm/K; ± 100 ppm/K | | |
| Rated dissipation, $P_{70}$ | 0.5 W | 0.4 W | 0.5 W |
| Thermal resistance | 170 K/W | 200 K/W | 150 K/W |
| Operating voltage, $U_{max.}$ AC/DC | 200 V | 250 V | 350 V |
| Operating temperature range | -55 °C to 155 °C | | |
| Permissible film temperature | 155 °C | | |
| Max. resistance change at rated dissipation $\|\Delta R/R$ max.$\|$, after 1000 h | ± (2 % $R$ + 0.05 Ω) | | |

Note

- $R$ value is measured with probe distance of 24 mm ± 1 mm using 4-terminal method.

## TEMPERATURE COEFFICIENT AND RESISTANCE RANGE

| TYPE | TOLERANCE | TCR | RESISTANCE | E-SERIES |
|---|---|---|---|---|
| SFR16S | ± 5 % | ± 250 ppm/K | 1 Ω to ≤ 4.7 Ω | E24 |
| | | ± 100 ppm/K | 4.7 Ω to 100 kΩ | |
| | | ± 250 ppm/K | > 100 kΩ to 3 MΩ | |
| | ± 1 % | ± 100 ppm/K | 5.6 Ω to 100 kΩ | E24; E96 |
| | | ± 250 ppm/K | > 100 kΩ to 976 kΩ | |
| | Jumper (0 Ω) | - | ≤ 30 mΩ; *I*max. = 3 A | - |
| SFR25, SFR25H | ± 5 % | ± 250 ppm/K | 0.22 Ω to 4.7 Ω | E24 |
| | | ± 100 ppm/K | > 4.7 Ω to 1 MΩ | |
| | | ± 250 ppm/K | > 1 MΩ to 10 MΩ | |
| | ± 1 % | ± 250 ppm/K | 1 Ω to 4.7 Ω | E24; E96 |
| | | ± 100 ppm/K | > 4.7 Ω to 1 MΩ | |
| | | ± 250 ppm/K | > 1 MΩ to 10 MΩ | |
| | Jumper (0 Ω) (1) | - | ≤ 30 mΩ; *I*max. = 5 A | - |

Note
(1) Jumper is only available for SFR25.

## PART NUMBER AND PRODUCT DESCRIPTION

PART NUMBER: SFR2500001001FA500

| S | F | R | 2 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | F | A | 5 | 0 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| TYPE | VARIANT | TCR/MATERIAL | RESISTANCE | TOLERANCE | PACKAGING | SPECIAL |
|---|---|---|---|---|---|---|
| SFR16S0<br>SFR2500<br>SFR25H0 | 0 = neutral<br>Z = value overflow (special) | 0 = standard<br>Z = jumper | 3 digit value<br>1 digit multiplier<br>MULTIPLIER<br>7 = $*10^{-3}$<br>8 = $*10^{-2}$<br>9 = $*10^{-1}$<br>0 = $*10^{0}$<br>1 = $*10^{1}$<br>2 = $*10^{2}$<br>3 = $*10^{3}$<br>4 = $*10^{4}$<br>5 = $*10^{5}$<br>Z = 0000 | F = ± 1 %<br>J = ± 5 %<br>Z = jumper | N4<br>A5<br>A1<br>R5 | The 2 digits are used for all special parts.<br>00 = standard |

PRODUCT DESCRIPTION: SFR25 1 % A5 1K0

| SFR25 | 1 % | A5 | 1K0 |
|---|---|---|---|
| TYPE | TOLERANCE | PACKAGING (1) | RESISTANCE VALUE |
| SFR16S<br>SFR25<br>SFR25H | ± 1 %<br>± 5 % | N4<br>A5<br>A1<br>R5 | 47K = 47 kΩ<br>51R1 = 51.1 Ω |

Notes
- The products can be ordered using either the PRODUCT DESCRIPTION or the PART NUMBER.

(1) N4 packaging indicates SFR25 and SFR25H radial version.

## PACKAGING

| TYPE | CODE | QUANTITY | PACKAGING STYLE | WIDTH | PITCH | DIMENSIONS |
|---|---|---|---|---|---|---|
| SFR16S | A5 | 5000 | Taped acc. to IEC 60286-1 fan-folded in a box | 52 mm | 5 mm | 75 mm x 73 mm x 270 mm |
| | R5 | 5000 | Taped acc. to IEC 60286-1 on a reel | | | 92 mm x 278 mm x 278 mm |
| | A1 (1) | 1000 | Taped acc. to IEC 60286-1 fan-folded in a box | | | 75 mm x 28 mm x 262 mm |
| SFR25, SFR25H | A5 | 5000 | Taped acc. to IEC 60286-1 fan-folded in a box | 52 mm | 5 mm | 75 mm x 98 mm x 270 mm |
| | R5 | 5000 | Taped acc. to IEC 60286-1 on a reel | | | 93 mm x 300 mm x 298 mm |
| | A1 (1) | 1000 | Taped acc. to IEC 60286-1 fan-folded in a box | | | 75 mm x 28 mm x 262 mm |
| | N4 (2) | 4000 | Taped acc. to IEC 60286-2 fan-folded in a box | - | 12.7 mm | 45 mm x 262 mm x 330 mm |

Notes
(1) A1 packaging only available for resistors with ± 5 % tolerance.
(2) N4 packaging only available for SFR25 and SFR25H radial version.

## MARKING

The nominal resistance and tolerance are marked on the resistor using four or five colored bands in accordance with IEC 60062, marking codes for resistors and capacitors.