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# Design And Implementation Of Microcontroller And Internet Of Things-Based Device Circuit And Programs For Revenue Collection From Commercial Tricycle Operators

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***Abstract—*** **In this paper, the design and implementation of microcontroller and internet of things-based device circuit and programs for revenue collection from commercial tricycle operators are presented. The proposed microcontroller and internet of things-based revenue collection system for tricycle operators is meant to minimize revenue leakages that is inherent in the present manual approach that is used in the various State across Nigeria. The methodology of the research includes, overall system block diagram, subsystem circuit diagrams, circuit analysis and the overall system development and implementation. In addition, a mobile application is developed to facilitate the collection of the tricycle operators bio-data and payment information via mobile phone. The main device in the system is called the levy box. Among other things, two microcontroller-based sub-circuits are designed and implemented which are packaged in the levy box. One of the sub-circuits interfaces the android cell phone and the thermal printer, while the other sub-circuit interfaces the android cell phone, the GPS/GPRS and the cloud internet of things (IOTs). Wi-Fi is used to provide internet connectivity for the set up. The system also has the tracker mechanism which is used for monitoring the movement of the tricycles and to identify levy evaders. In any case, this paper focused more on the levy box; its operation, circuit design, circuit analysis and its interface with other system subunits.**

***Keywords— Revenue Collection System, Internet Of Things, Microcontroller, Wi-Fi, GPS, GSM, Tracker System, Levy Box***

## 1. Introduction

Commercial tricycle, popularly known as Keke NAPEP is an intra-city commuter transportation system in Nigeria. The purpose of its birth is to assist the government to realise its poverty alleviation goal, particularly among Nigerian youths. Right from the time commercial tricycle was introduced in Nigeria, there has been consistent growth in the number of the tricycles plying Nigerian roads, research findings deduced that passengers choose tricycle to motorcycle because of its relative availability, affordability and safety [1]. In addition, most State governments have banned the operation of motorcycles in many parts of the State as a result of incessant road accidents attributed to it. Due to this fact, commercial tricycles have been generally accepted as intra-city commuter transportation system in many States across Nigeria.

Given the tremendous increase in the adoption of commercial tricycle, it has become a major subsector in land transportation across Nigeria. In[2], the author disclosed that the number of registered tricycle increased from 6,786 in 2001 to 30,036 in 2003. Similarly, it has been revealed that the number of registered tricycle increased drastically from 218,802 in 2006 to 288,474 in 2007. The major cause of the increase is the lingering poor economic conditions in Nigeria.

Tricycle operators have contributed a lot to the growth of the economy of the various States where they operate. The operators contribute to Internally Generated Revenue (IGR) through the levies they are made to pay. Revenue is the fuel of every government as it is the crucial instrument by which government funding is assured. As such, high revenue collection performance is vital to promote efficiency in the service delivery and economic development at the State and any level of Government. However, studies and other published researches have indicated that most government face serious setback in their revenue collection performance. In [3], the authors presented a study where governments were unable to realize sufficient funds to cover their budget expectations.

Currently, the methods employed by State governments to collect revenues generated from the operation of the commercial tricycle operators are inefficient. Majority of the operators dodge payment of their daily levies which results to government not being able to realize the exact amount of money they are supposed to make per day from the tricycle operators. Therefore, in this study an Internet of Things (IoT)–based system for collecting revenues from the commercial tricycle operators is designed and implemented. Basically, IoT is about harnessing the capabilities of the internet beyond the computers and smart phones, in this case, a whole range of other things, such as sensors, devices processes and environments are interconnected and communicate seamlessly. Each of those "connected" things has embedded sensors that are employed to collect information, send information back, or both [4]. Particularly, this study is centred on the development of

Internet of Things-based commercial tricycle operator's revenue collection system that runs on a smart phone. The smart system is capable of capturing and storing bio-data of all registered operators, and keeps record of all revenues realised every day from the commercial tricycle operators. Also, a tracker is involved to monitor the daily activities of the tricycles and also save records of all operated tricycles per day, indicating those that have paid their daily levies of operation and as well as those that did not, including those that did not operate on that day. The system is designed to assist the Government tax force on transportation to apprehend levy evaders who may tamper with the installed tracker circuit. In all, the system has additional functions that are designed for efficient and effective revenue collection from the tricycle operators. The case study for the study is Uyo metropolis in Akwa Ibom State.

## 2. Methodology

The focus of this paper entails the development of a microcontroller and internet of things-based tricycle revenue collection system. The method adopted includes design and analysis of the system circuit, the implementation of the system circuitry and the development of an android application is developed which is used as input interface for bio-data information collection.

### 2.1 Circuit Design

Basically, the system has Android app running on smart phones which enables the capture of the tricycle operator's data as well as payment information. There is also a remote thermal printer that enables the printout of the information from the smart phones. Then there is a levy box unit which consists of an interface circuitry that enables communication between the smart phone and the remote thermal printer.

Notably, system consists of two major sub circuits, namely, the levy box and the tracker circuits. The tricycle tracker is a microcontroller-based circuit that uses GPRS/GSM to track the location of the tricycle in real-time. The circuit components of the tracker circuit and their ratings/specifications and quantities are as contained in Table 1.

Apart from the tracker circuit, the system has another major sub-circuit which interfaces with the wireless network and the android smart phone to facilitate the printout of the tricycle operator's profile and payment details. This paper focuses on the operations of the levy box, the detailed design and analysis of the levy box circuits and then the operations of the android app that runs on the smart phone.

Table 1: The Circuit Components of the tracker Circuit and their Ratings/Specifications and Quantities

| **Components** | **Model/Rating** | **Quantity** |
|---|---|---|
| Microcontroller (M1 &M2) | ATMEGA8 | 2 |
| Transistor (Q1 – Q5) | 2N2222 | 5 |
| Resistor (R1 – R14) | | 14 |
| Relay (RL1) | 12V | 1 |
| Diode (D1 – D7) | 1N4001 | 7 |
| Thermal Printer (P1) | 27200KJ | 1 |
| Android phone | Samsung | 1 |
| Logic gate module (A1 & A2) | 74L803 | 2 |
| WiFi Module (W1) | A7 | 1 |
| GSM/GPRS & GSM/GPS Module (G1 & G2) | SIM 800L | 2 |
| | | |

### 2.1 The Tricycle Levy Box Circuit Diagram and Operation

The circuit diagram in Figure 1 is the levy box circuit which is basically a control circuitry attached to the thermal printer. The levy box circuit acts as an interface subsystem between thermal printer, the Wi-Fi device and the android smart cell phone.

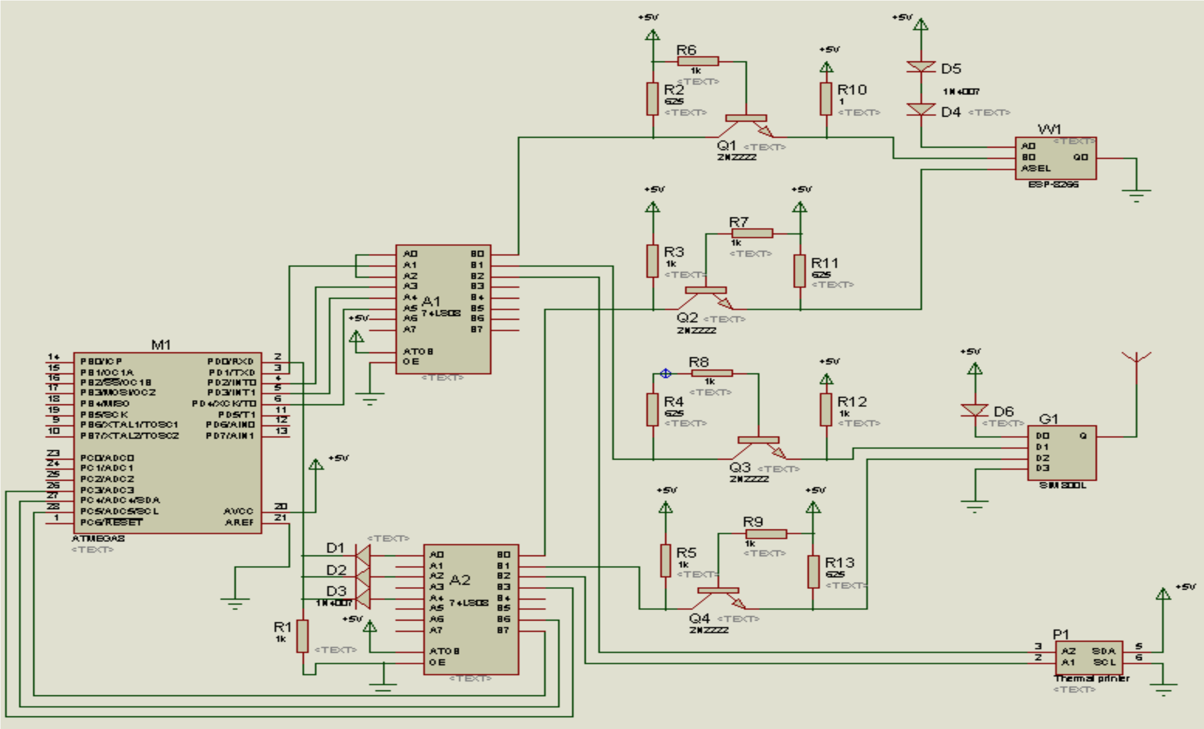


Figure 1: Tricycle levy box circuit diagram

The circuit comprises of two quad AND logic gate (IC) Integrated Circuit (74LSO8), Wi-Fi module (ESP-8266), microcontroller (Atmega8), GSM/GPRS module (sim-800L), thermal printer and four NPN bipolar transistors (2N2222). Basically, the circuit diagram of the levy box is achieved when the microcontroller which is connected to the two AND gates (A1, A2), shares a single input source and multiplexes it into three output signals. The three output signals are used to feed the three output components via voltage control units, which are the Wi-Fi module (W1), the GPS/GPRS (G1) and the thermal printer (P1).The current limiting units are configured with four NPN transistors (Q1, Q2, Q3, and Q4). The current limiting units are introduced because the three modules (Wi-Fi, GPS/GPRS and thermal printer) operate with low currents as data signal pulse set. However, the voltage applied to the modules are also regulated before it is used to power the three modules such that it matches their operational voltages.

For instant, the Wi-Fi module operates with an extreme low voltage of 3V; the GPS/GPRS module operates with 4.2V, while the thermal printer operates with 5V. This is achieved through the use of the voltage regulator to power the three modules. The signal flow in the current control unit is such that the signal flows out through pin B0 in the 74LS08 (A2) IC to the Wifi module and return back to the microcontroller (M1) through the AND gate (A1). In other words, transistor Q2 and Q5 are used to send data, information or command to the modules from the microcontroller, M1 via the AND gate A2, while transistor Q3 and Q4 serve as feedback switches to the microcontroller via the AND gate (A1).

The circuit operation starts when all the Vcc terminals are engaged with voltage source of +5V, and the Wi-Fi module (W1) initiates and establishes a network (internet of things) connection of appropriate frequency range for GSM/GPRS module (G1) to engage. The GSM/GPRS module (G1) then provides a link for all information captured (registered bio-data) via smart android phone to be stored in the cloud server. In this case, the microcontroller (M1) is programmed to perform a task of coordinating all information and disseminate to different section appropriately. The thermal printer is used to print any information sent from the android smart phone.

## 2.2 Circuit Analysis for the Tricycle Levy Box

Circuit analysis is conducted to determine appropriate circuit component values. Calculations were done on the switching components (transistors) output to determine the switch signal (current) and few other components values. Considering the circuit in Figure 2, where the NPN transistor $Q_1$ is biased as a current limiter the voltage drop across the resistor $R_6$ is given as;

$$V_{in} = I_2 R_6 \quad (1)$$

$$R_6 = \frac{V_{in}}{I_2} \quad (2)$$

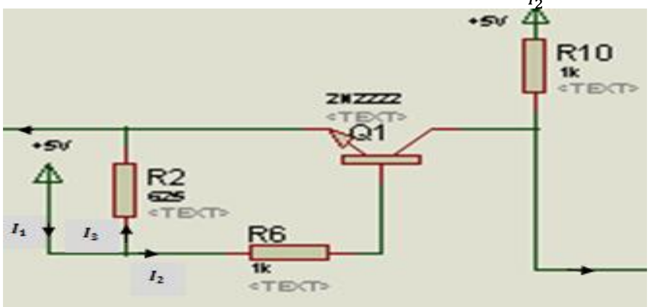


Figure 2: Sub-circuit of current limiting unit

Given that $V_{in}$ = 5V and according to transistor data book [5], the base current ($I_B$) is given as $I_B = I_2$ = 5mA, then;

$$R_6 = \frac{5}{0.005} = 1000\Omega = 1k\Omega$$

Hence, the required value of resistor needed to maintain a 5mA current at the base of transistor Q1 is 1kΩ.

Consequently, according to 74LS08 quad AND gate, the maximum operational current is 8mA. Then, according to Kirchhof current law (KCL) the total current flowing into junction Q is given as;

$$I_I = I_2 + I_3 \qquad (3)$$

Then, $I_I$ = 5mA + 8mA= 13mA. However, since the $I_3$ is designed to flow into 74LS08 IC, the required value of the resistor is given as;

$$V_{in} = I_3 R_2 \qquad (4)$$

$$R_2 = \frac{V_{in}}{I_3} \qquad (5)$$

Then, $R_2 = \frac{5}{0.008} = 625\Omega$

From the calculation, it shows that 625Ω resistor is needed to limit the current to 8mA 74LS08 IC. Therefore, it is important to note that, the same values of resistors are also used to configure transistor Q2, Q3 and Q4 irrespective of the changes in position of the resistors and transistor.

The pull up resistor (R10) is determined by simple ohms' law as;

$$V_p = IR_{10} \qquad (6)$$

Where the normal current for transferring or receiving data is chosen as 5mA, and pull up voltage ($V_p$) = +5V, hence,;

$$R_{10} = \frac{V_p}{I} \qquad (7)$$

Then, $R_{10} = \frac{5}{0.005} = 1000\Omega = 1\text{k}\Omega$

The microcontroller (Atimega8) integrated circuit is programmed using embedded C-language. An application to run on the android smart phone is also developed using Java language.

### 2.3 Implementation of the Circuit and the Enabling Android App and Microcontroller Program

The circuits are constructed in sub-units. All the circuit components pertaining to each sub-circuit are assembled on vero board, as shown in Figure 4 and Figure 5. The constructed circuit for the GSM and GPRS control sub-circuit unit is shown in Figure 4.

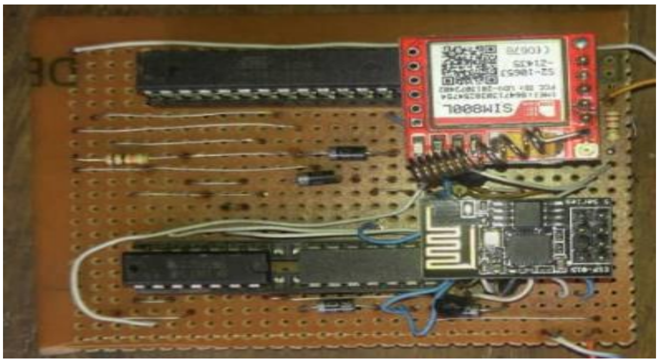

Figure 4: Printer GSM and GPRS Control Unit

The construction is carried out using Vero board. First, all the components in each of the sub-circuit unit are carefully tested and mounted, before soldering them to the Vero board. As shown in Figure 4, the red and black components placed side by side are the GPRS and GSM respectively. The Atmega8 IC is mounted directly opposite to the two AND gate ICs, while the other components like resistors, diode and transistors and also mounted accordingly as shown Figure 4.

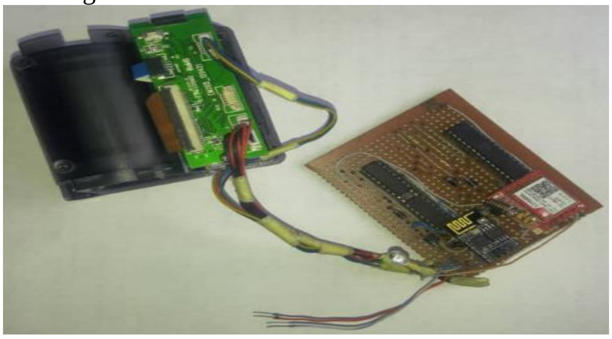

Figure 5: Thermal printer coupled with control circuit

The construction picture of the thermal printer coupled with the GSM and GPRS Control circuit is shown in Figure 5. It shows how the thermal printer is interfaced with the control circuit. The thermal printer data cables are used to communicate with the control circuit. This is carried out using low resistance data cables (red and black). These cables enable the printer to implement all the command or instruction sent from the control circuit and finally print out the receipt of the transactions.

Notably, the GSM and GPRS control unit is part of the circuits in the levy box (in Figure 6) and it enables the levy box to facilitate communication between the smart phone and the thermal printer, as shown in Figure 5.

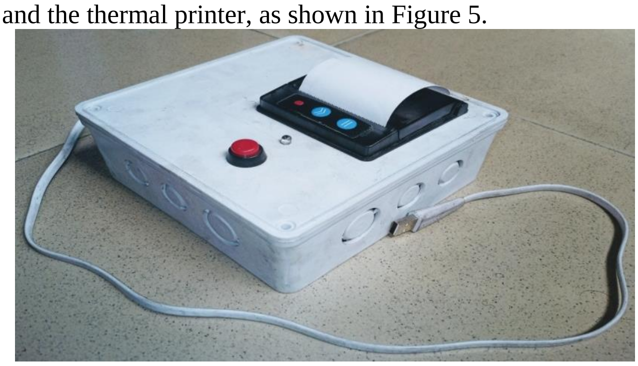

Figure 6: Tricycle Levy box

The tricycle levy box which is a conglomerate of the thermal printer, Wi-Fi module, GPRS/GSM module and controller systems is shown in Figure 6. The system is designed to perform smart tasks, as it can track the tricycle in real-time, record and store relevant information about the tricycle and payment details, as well as print the information. The universal standard box (USB) cord is used to power the system with +5V dc power supply. The picture shows how it prints the receipt of payment of already registered tricycle operator. When the system is powered, the red LED start blinking, indicating that it has been energized, and it is scanning and initializing the modules, after which the blinking stop, which signify that it is ready for use. At this point, the tricycle application on the android cell phone is launched and connected via the cell phone Wi-Fi connectivity, after which it can start functioning.

The tricycle operators are required to register their details through the android app that runs on mobile phones. The registration detail includes page, payment platform, tracking platform and driver's (operator) platform, as shown in Figure 7 and Figure 8.

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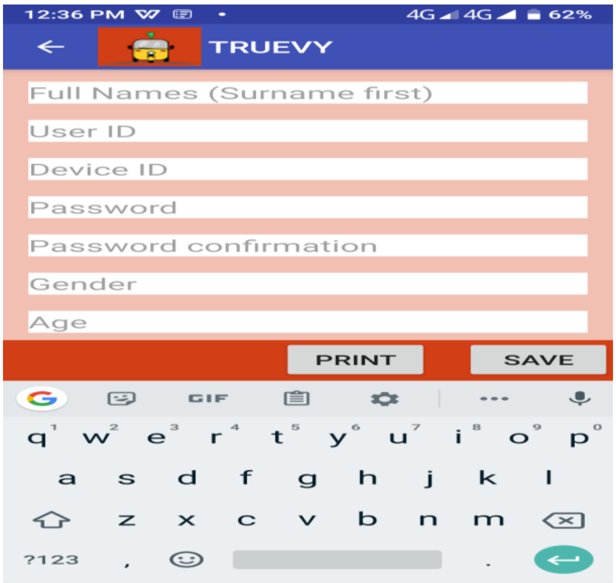


Figure 7: Screen shot of registration page


Figure 8: Screenshot page of a registered Tricycle operator

Once the levy box android application is tapped on the mobile phone, it takes about two seconds to launch. At this point, the bio-data information concerning the tricycle operator (driver) can be obtained, captured and printed, while the system also store these information automatically in the server (cloud). The information captured through the registration platform is shown in Figure 8 below.

In order obtain the tricycle position/location, the longitude and latitude generated by the GPS/GSM module embedded in the tracker mechanism that is mounted on the tricycle is copied to the Google search, where the current position/location will be displayed. This information contains the tricycle's operator's position (Longitude/Latitude), speed of the tricycle, tricycle distance and condition (i.e either it is in a push state or powered by engine). With the distance covered by the tricycle, the application can decide if the tricycle has operated or not for the day, based on the pre-determined distance a tricycle must cover per day before it is count that it has operated.If operated, the levy due is accrued to the tricycle operator's account.

## 3 Conclusion

The design and implementation of the circuit and programs for the key subunits of an Internet of Things-based tricycle revenue collection system, which is used to minimize revenue leakages in the process of revenue collection from commercial tricycle operators is presented. The IoT-based revenue collection system utilizes a tracker mechanism that is mounted on the tricycle for monitoring the location of the tricycles in real-time. Also, the system has android app that runs on mobile phone and enables data capture from the tricycle operator. Furthermore, the system has the levy box which includes some other sub-circuits and devices such as the thermal printer, the GSM/GPRS module, the Wi-Fi interface module and other circuitries that facilitates the communication between the android phone and the thermal printer. Notably, the detailed description of the operation and analysis of the circuits associated with the levy box is presented in this paper.

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