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Automatic Maintenance Alert System for Heavy Duty Haulage Machines

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A B S T R A C T

The timely maintenance of haulage machines is important to prevent machine breakdown and reduce productivity down time. An unintended breakdown or machine stop due to inadequate maintenance causes huge financial loss to the company due to delivery delays. Excessive maintenance also increases production cost due to down time and workshop maintenance. Most haulage companies like Mantrac Ghana Limited have a maintenance schedule for their customers. However, most of these customers do not maintain these machines on time, largely due to forgetfulness or sheer disregard for the maintenance schedule. It is thus important to implement an automatic alert system to notify operators of this machinery when it is time for maintenance. This paper seeks to design an automatic alert system using ATmega328 microcontroller, SIM900 GSM module and alarm unit. A sensor connected to the engine of the haulage machine is used to monitor the condition and operational hours of the machine. The microcontroller is programmed using proteus software to receive instructions from the sensor and issue commands to activate both the GSM module and the buzzer simultaneously. The type and time of maintenance to be done is displayed on the LED display. A corresponding message is sent via the GSM module to both Mantrac Ghana Limited and the customer to undertake the type of maintenance. It can be concluded that an automatic alert system would improve strict adherence to maintenance schedule and help reduce machine.

INTRODUCTION

Haulage machines are commonly used in the industries for the transportation of materials and equipment. Maintenance of these machines are important to ensure that they operate at their optimal efficiency and give maximum satisfaction [1]. The inability to carry out maintenance on schedule will result in a gradual deterioration and eventual breakdown of these machines. Companies like Mantrac Ghana Limited deals with the sales and servicing of haulage machines. The company currently has a protection system policy that requires the maintenance of their equipment within a specific time duration depending on the type of maintenance to be done.

However, the challenge of keeping track of these equipment and following maintenance schedule due to numerous trucks at various working sites remains a headache for the company. The maintenance schedule is usually documented and made readily available and accessible to all service technicians. Customers who purchase or rent these machines tend to ignore the maintenance schedule put in place to protect the machine against a major breakdown. These customers employ a reactive maintenance strategy thus reducing the lifespan and efficiency of the machine.

This paper seeks to design a maintenance alert system that will monitor the operation of the vehicle and alert both Mantrac Ghana Limited and a customer when maintenance is due. The alert system will be via GSM technology to make it easy for vehicles in rural areas to be monitored.

Review of Relevant Literature

Over the years, several literatures have proposed solutions to vehicle monitoring and alert systems.

In [2], a vehicle remote monitoring system was proposed using machine learning algorithm. This proposed approach focused on predicting failures that were likely to occur in the system. The machine learning algorithm was implemented using data from the vehicle operating in both normal and fault conditions. The data is transmitted to an online server which analysis the data and draws a pattern which helps it to predict future failures. The objective of this research was to reduce vehicle maintenance time because of breakdown fault and was demonstrated on Toyota corolla vehicles.

A vehicle maintenance assistant system was proposed in [3] to monitor vehicle health and propose solutions to vehicle occupants. An expert system was modelled using an artificial

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learning programming to detect faults on the vehicles and to provide solutions to the proposed faults. This proposed system has a computer user interface which has documented fault profile and solutions to these faults. On the occurrence of a fault, the system detects the type of faults using sensors and provides the best probable solutions to the problem.

A vehicle alert system was presented in [4] to detect vehicle situation and send an alert to emergency services on the occurrence of an accident. This approach uses Internet of Things (IoT) to detect the geographical location when an accident occurs and sends an SMS using GSM technology to health facilities or emergency institutions. The IoT monitors the health system of the vehicle and is triggered when the vehicle malfunctions because of an accident.

In [5], an Arduino based monitoring system was used to measure the temperature of vehicles and an SMS message sent to vehicle owner when temperatures in the vehicle is abnormal. A buzzer is attached to the system in the car which sounds when movement is detected in the vehicle. The focus of this project was to prevent the death of children left unattended in vehicles.

A carbon monoxide monitoring system in vehicles was proposed in [6] to alert vehicle occupant of high carbon monoxide content in vehicles. This system monitors the content of carbon monoxide periodically and triggers an alarm when the system exceeds abnormal levels. A text message is sent to vehicle owner to lower power windows automatically thereby allowing the carbon monoxide to be eliminated from the vehicle.

To the best of the authors' knowledge, no vehicle alert maintenance system using ATmega328 microcontroller and GSM technology is available in literature.

Maintenance System

Maintenance is a combination of actions carried out to retain an equipment or item or restore it to an acceptable operating condition. Like any other equipment, haulage machines need periodic maintenance to keep them in good shape and ready to operate at any given time. Economically, effective maintenance of haulage machines is to ensure high quality and reliability of equipment supplied to customers [7]. The function of maintenance is to ensure that plant and equipment are available in a satisfactory condition for operation when required. To prevent unforeseen circumstances and achieve a reliable and continuous operation of machines, there should be a maintenance plan which will be accepted by the staff of any company that uses this type of equipment [8]. There are various ways in which maintenance can be done and each of them depends on the activities performed during the process

Planned Maintenance

It is a maintenance activity that is pre-programmed and consists of two main activities preventive and corrective. Planned maintenance involves inspection based on "look, feel and listen", testing, measuring and minor adjustments at predetermined intervals and replacement of deteriorating minor components discovered because of such inspection [9]. It also involves minor repairs, usually of short-term planning, that may crop up between inspections and planned overhauls.

Preventive maintenance (PM) is a calendar-based program in which very comprehensive test routines are applied to off-line equipment [10]. In a PM program, data are collected during both on-line and off-line periods. Offline periods are intentionally scheduled for the implementation of preventive maintenance procedures. Equipment which is discovered to need repair will be scheduled for outages to implement those repairs.

Corrective maintenance is a form of system maintenance which is performed after a fault or problem emerges in the equipment, with the goal of restoring operability to the system [11]. In some cases, it can be impossible to predict or prevent a failure, making corrective maintenance the only option. The process of corrective maintenance begins with the failure and diagnosis of the failure to determine why the failure occurred. The diagnostic process can include a physical inspection of the machine, the use of diagnostic computer to evaluate the machine, interviews with system users and several other steps.

Breakdown Maintenance

Breakdown maintenance is the emergency repair of inoperable equipment performed by operators or maintenance crews [12]. The plant and maintenance supervisors are responsible for emergency repairs. The utility and maintenance shops usually develop a coordinated plan to efficiently handle emergency breakdowns.

Emergency Maintenance

Maintenance activity that is necessary to be undertaken urgently to restore plant integrity and/or prevent or minimize a healthy plant [11]. Emergency maintenance is usually carried out depending on the priority rating of the equipment. An example of such a breakdown repair rating is shown in Table 1.

Table 1. Breakdown Repair Rating [13]

Rating	Meaning
A	Must be repaired immediately
B	Must be repaired within one day
C	Must be repaired within two days
D	Must be repaired within one week
E	Can be carried out at the first available opportunity.

METHOD

The proper functioning of any automatic maintenance alert system relies on proper selection of components and correct application of design. The components used for the design are an alarm system, sensors, GSM module and a microcontroller.

Alarm System

The alarm system is a warning device that cautions against an eminent danger. This usually involves design incorporating the

connection of a series of electrical and electronic components working together to serve the sole purpose of warning against an eminent danger. The alarm system used for this project is the piezoelectric buzzer due to the numerous benefits it has to offer. The piezoelectric buzzer is based on the inverse principle of piezoelectricity [14]. Piezo materials generate electricity when mechanical pressure is applied to them. When exposed to an alternating electric field, their rate of extension or compression is equal to the signal frequency thereby producing sound. The piezoelectric buzzer selected has a high resonant frequency of 2-6kHz, a high sound level of 85-120 dB and a low current consumption of 5 -20 mA.

Sensors

The sensor receives and responds to signals by acquiring a physical quantity and converting it into a signal suitable for processing. The magnetic pick-up sensor (MPU) used in this paper has coil wound around its permanently magnetized probe [15]. The MPU is placed closer to the gear tooth and the gap between the gear tooth and the magnetic pick-up is set at 0.25 – 1.02 mm at the closest point. The sensor will be damaged if it touches the moving gear. Voltage induced at the end of the magnetic pick-up is directly proportional to the distance between the sensor and the gear tooth. This MPU sensor is selected because it produces good electrical frequency, easily installed on the engine, requires no energizing circuit from control and widely used with all electronic controls

GSM Modem

A GSM modem is a device which can be either a mobile phone or a modem device which can be used to make a computer, or any other processor communicate over a network. A GSM modem requires a Subscriber Identity Module (SIM) card to be operated and operates over a network range subscribed by the network operator. It can be connected to a computer through serial, Universal Serial Bus (USB) or Bluetooth connection. A GSM modem can also be a standard GSM mobile phone with the appropriate cable and software driver to connect to a serial port or USB port in a computer. Figure 1 is a diagram representation of components of a GSM modem [16].

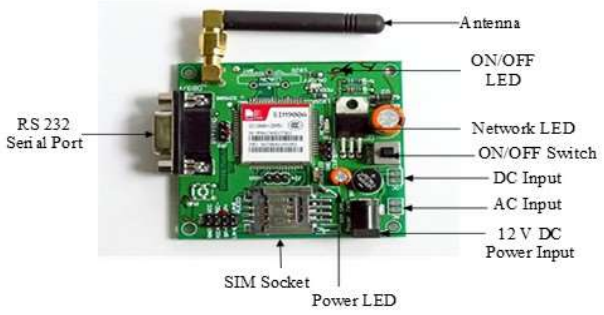

Figure 1. Components of a GSM Modem

Microcontrollers

A microcontroller is a small low-cost and self-contained computer on a chip that can be used to control the functions of embedded systems in office machines, robots, home appliances, motor vehicles, and several other gadgets. Microcontrollers usually must have low-power requirements since many devices they control are battery-operated. A microcontroller comprises of components like memory, peripherals and most importantly a processor. Microcontrollers are basically employed in devices that need a degree of control to be applied by the user of the device [17]. Figure 2 shows the architecture of a typical microcontroller.

Table 2. Parts of Microcontroller and their Function

Part of a Microcontroller	Function
CPU	Serves as the brain of the microcontroller and is employed to fetch data, decode it and at the end complete the assigned task successfully
Memory	The memory chip inside the microcontroller stores all programs and data.
Input/ Output ports	The I/O ports are basically employed to interface or drive different appliances such as printers, LCDs, LEDs etc.
Serial Ports	These ports give serial interfaces of the microcontroller with various other peripherals such as parallel ports.
Timers	The timers and counters control all counting and timing operations within a microcontroller. Timers are employed to count external pulses.
Analogue Digital Converter (ADC)	ADC is employed to convert analogue signals to digital ones. The input signals need to be analogue for ADC. The digital signal production can be employed for different digital applications such as measuring gadgets.
Digital Analog Converter (DAC)	This converter executes opposite functions to that of ADC. This device is generally employed to supervise analog appliances like DC motors etc.
Interpret Control	This controller is employed for giving delayed control for a working program. The interpret control can be internal or external.
Special Functioning Block	Some special microcontrollers manufactured for special appliances like robots comprise of this special functional block.

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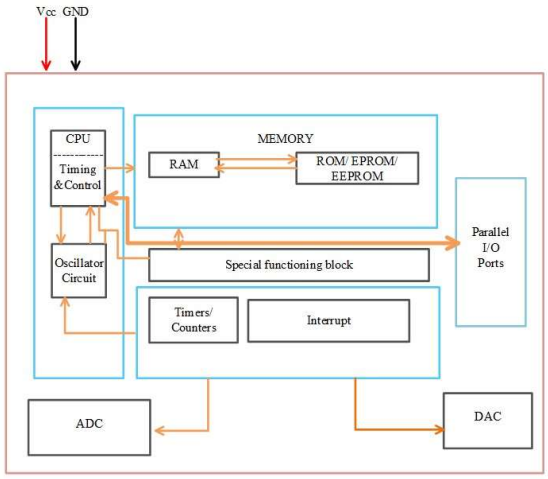

Figure 2. Elements of Microcontroller

The Arduino UNO microcontroller was used because of the numerous benefits it has to offer. The advantages are relatively faster speed of execution, flexibility of usage, simple and easy to troubleshoot and maintain, ability to act as a microcontroller without any digital part, availability of more programmable pins for user and easily interfaced with additional RAM, ROM and I/O ports.

Design Concept and Consideration

Analogue to digital convertor (ADC) module of the microcontroller will read the time. The ADC data will be processed and converted into the actual time the engine is running. The microcontroller is provided with instructions and will automatically decide the time to which the machine should alert depending on the time recorded by the sensor which is represented with remote terminal clock (RTC) for simulation purposes. The microcontroller also displays the time on a liquid crystal display (LCD).

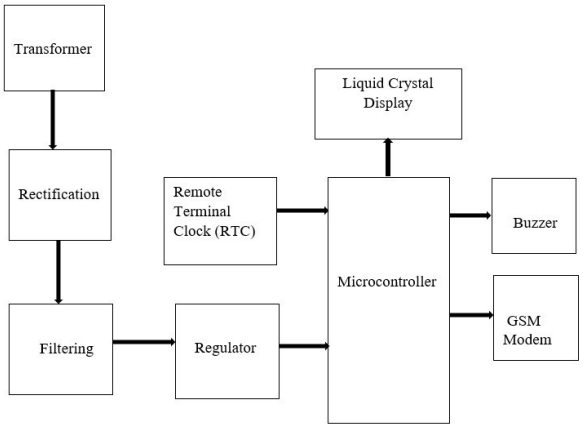

Figure 3. Block Diagram of the Proposed Design

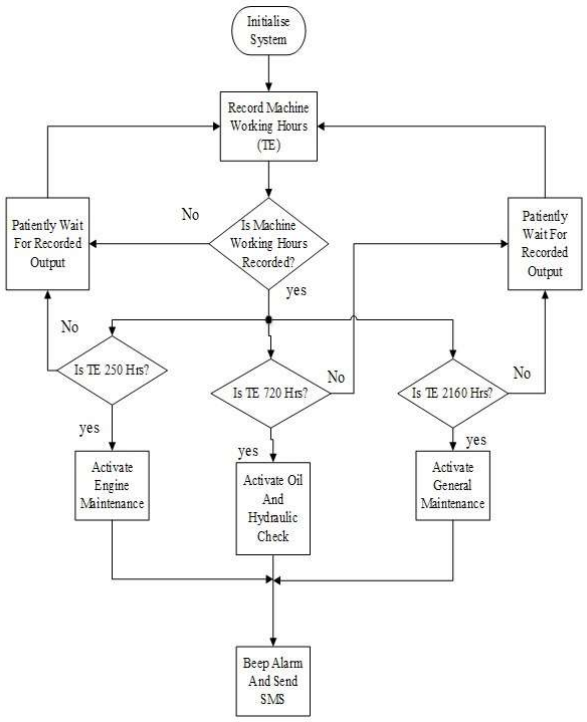

Figure 4. Flow Chart of the System

Materials Used

The materials employed in this system are generally hardware and software. The hardware materials are Arduino UNO microcontroller, SIM900 GSM module, the display unit and alarming unit while the software materials are the programming and simulation software.

Arduino UNO Microcontroller

The Arduino UNO microcontroller is designed using the ATmega328 ideologies. It consists of 14 input/output digital pins and 6 analog inputs. The user can interface with the computer through a USB connection, a power jack and a reset button. Figure 5 shows a diagram of the Arduino UNO board used [18].

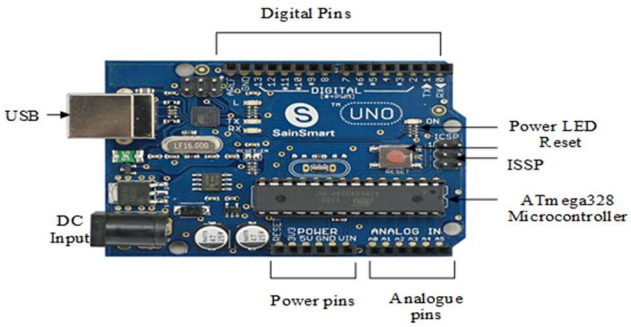

Figure 5. Arduino UNO Board

Arduino GSM Shield

SIM900 module from SIMCOM is well-matched with Arduino and its duplicates. The GSM shield is based on SIM900 principles. The GPRS shield provides a way to communicate via the GSM cell phone network. This shield makes it possible to achieve SMS, MMS, GPRS and Audio through UART by sending AT commands. It also has 2 PWMs and ADC of the SIM900

module present on board. Data from a remote location is provided by the GSM shield. It is compatible with all boards and the standard Arduino board and aligned using AT commands based on the SIM900 module. Figure 6 shows the Arduino GSM modem.

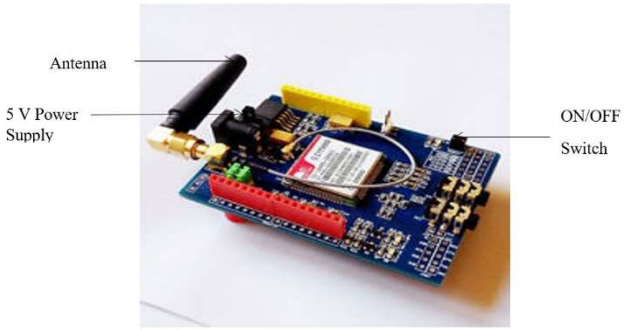

Figure 6. The Arduino GSM Modem

Display Unit

The display unit is an output unit used to give the user the needed information. The display unit is 20 × 4 LCD module. This means it has twenty columns and four rows. Each column can represent only a single character. It can display ASCII alphanumeric characters and some symbols. The LCD screen has a backlight to enable the user to see the character that may be displayed on the screen where external light may be insufficient. Figure 7 shows the 20 × 4 LCD Display Unit.

Figure 7. 20 × 4 LCD Display Unit

Programming Software

The Arduino IDE software consists of text editor for writing codes, a message area, a text console, a toolbar with buttons and a series of menus. IDE is an open-source prototyping platform which is simple to use. It can run on Macintosh OSX, Windows and Linus operating systems. Its programming environment is simple and clear which makes it easy for beginners. Sketches is the name given to programs written with IDE.

Simulation Software

Proteus software version 8.6 is used for the simulations of the designed system. Proteus is a flexible simulation software of various designs with microcontrollers. Proteus software helps the user to interrelate with the designs through on-screen indicators such as LCD. After compiling the codes, proteus software allows the user to load the hex files from their Programming software into the microcontroller to be simulated in proteus. This enables the microcontroller to function according to the codes written by the user. Schematic capture which is a tool for entering designs is also present in the proteus software.

Power Supply circuit of the Design

The power supply circuit consists of a step-down transformer TR1 which step-down the AC voltage from 240 to 12 volts, a capacitor C1 of capacitance 1000 µF, 4 of 1N4007 diodes and LM337L voltage regulator.

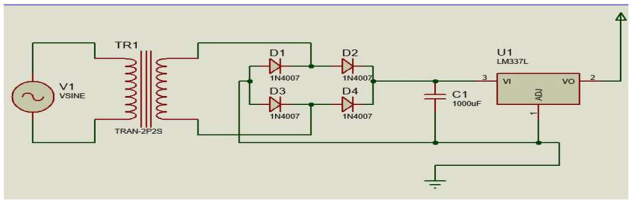

Figure 8. Power Supply Circuit of the Design

The diodes convert the AC voltage from the secondary of the transformer into 7 volts DC. C1 is used in filtering and smoothing the power circuit and the voltage regulator controls and regulate the 7 volts DC to 5 volts DC which is the actual voltage required by the system. The power supply circuit is shown in Figure 8.

Modelling and Simulation of the Designed System

The mobile phone was represented with virtual terminal in proteus simulation of the design. The hours received from the Remote Terminal Clock (RTC) by the microcontroller are sent to the GSM modem represented in this circuit by the "Compin" from the virtual terminal. The virtual terminal is interfaced with the GSM modem through RXD and TXD which serve as the serial input and output pins. The TXD pin sends the data from the virtual terminal whereas the RXD pin of the GSM modem receives the data. AT commands is used to configure the GSM modem.

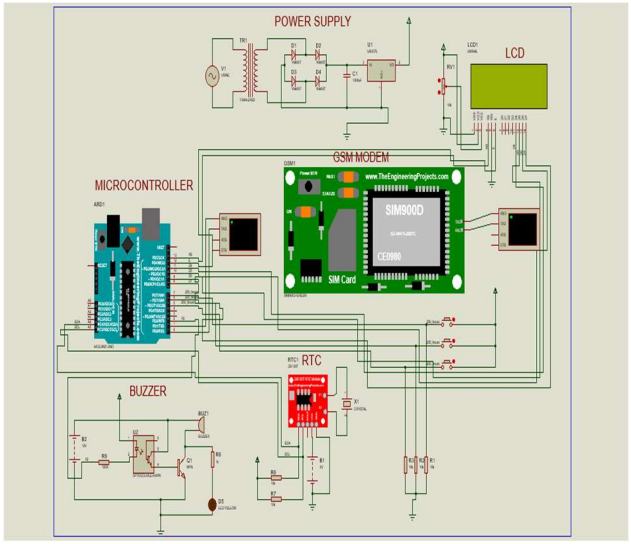

Figure 9. Circuit Implementation in Proteus

The message received by the GSM modem is sent to Mantrac and Maintenance Manager of the company by the SMS taken by the ATmega328 microcontroller through the RXD pins. The message is decoded by the microcontroller which serves as the brain of the system and then sent to the LCD via the digital pins. The contest of the LCD is regulated by a potentiometer.

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RESULTS AND DISCUSSION

The proposed system was successfully simulated using proteus software. The simulation was carried out to verify the functionality of the design before the actual implementation can be carried out. Figure. 10 and Figure. 11 show the snapshot of the simulations of the complete automatic maintenance alert system. Power is fed by the 240 volts AC voltage source and fed through the step-down transformer and 12 volts DC is obtained after stepping down by the transformer from the secondary which is tapped and supplied through pin 1 to microcontroller.

When the time for a particular maintenance activity is up, it is sensed by the magnetic pick-up sensor which sends a signal to the microcontroller and when the comparison made by the microcontroller matches the programmed credentials, the microcontroller will issue a command causing the buzzer to beep depending on the type of maintenance and at the same time an SMS message will be sent to the respective phone numbers.

The yellow LED indicates that the buzzer beeped during the simulation and the intensity of the beeping sound depends on the type of maintenance period which is due. Highest, higher and high sound level of the buzzer represent general maintenance, oil level and engine compartment maintenance periods respectively. The virtual terminal has been used to represent the receiver's mobile phone. During the simulation process, a message was received by the receivers phone (Mantrac Ghana Limited) represented by the virtual terminal.

The message received comprises the machine ID number, the type of machine, the location of the equipment and the type of maintenance to be performed. The LCD displays the results of the process by indicating the type of maintenance, machine ID and the serial number of the machine.

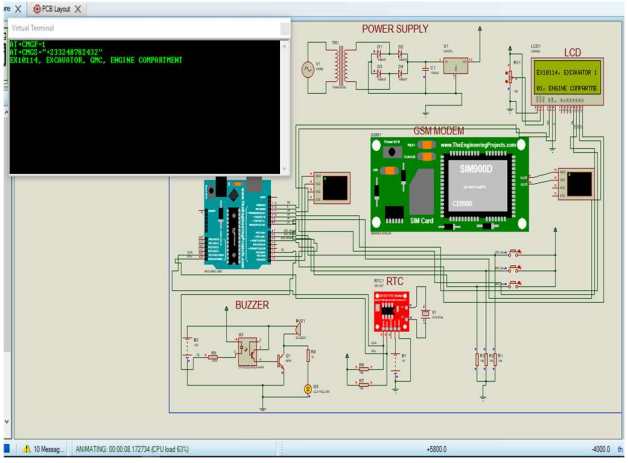

Figure 10. Simulated System when Engine Maintenance is Due

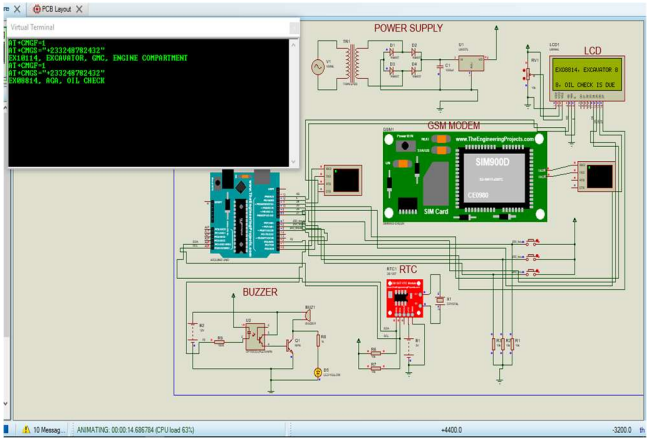

Figure 11. Simulated System when Oil Check Time is Due

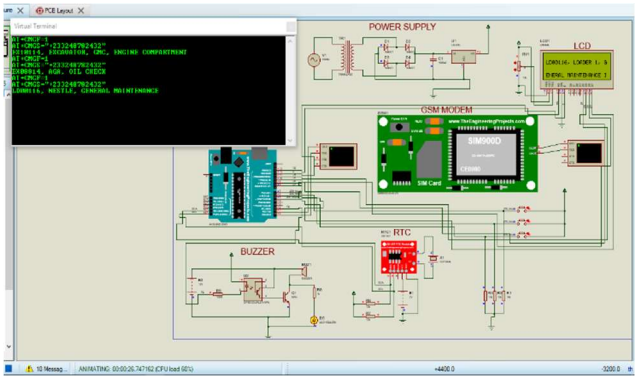

Figure 12. Simulated System when General Maintenance is Due

CONCLUSIONS

Simulation of the system shows the efficiency of the system to alert both Mantrac Ghana Limited and customer when an upcoming fault is due. It can be concluded that installing the automatic maintenance alert system for heavy duty trucks will drastically reduce equipment breakdown and downtime during maintenance. This will also help operators know when maintenance time is due and will pack the machine for maintenance after a session. This will also help the maintenance of Mantrac easily keep track of all trucks that needs to be maintained in the coming days

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NOMENCLATURE

AC	Alternative Current
ADC	Analog - to - Digital Converter
ADRS	Accident Detection and Reporting System
ASCII	America Standard Code For Information Interchange
ATS	Accelerometer based Transportation System
CMMS	Computerized Maintenance Management System
CPU	Central Processing Unit
DAC	Digital - to - Analog Converter
dB	Decibel
DC	Direct Current
DTMF	Dual-Tone Multi Frequency
EDGE	Enhanced Data GSM Environment
FDN	Fixed Dialing Number
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
IDE	Integrated Development Environment
I/O	Input and Output
ISDN	Integrated Services Digital Network
IVHMS	Integrated Vehicle Health Maintenance System
kHz	Kilo-Hertz
LCD	Liquid Crystal Display
LED	Light Emitting Diode
mA	Milli-Ampere
MCDM	Multiple Criteria Decision Making
MMS	Multimedia Message Service
MPU	Magnetic Pick-Up
PC	Personal Computer
PIC	Peripheral Interface Controller
PM	Preventive Maintenance
PWM	Pulse Width Modulation
RAM	Random Access Memory
RF	Radio Frequency
RISC	Reduced Instruction Set Computing
ROM	Read Only Memory
RTC	Remote Terminal Clock
RX	Receive
SIM	Subscriber Identity Module
SMS	Short Messaging Service
SRAM	Static Random Access Memory
TDMA	Time - Division Multiple - Access
TX	Transmit

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UART	Universal Asynchronous Radio Transmitter
USB	Universal Serial Bus
VAAL	Vehicle Accident and Alert Locator
VDC	Direct Current Voltage
VOIP	Voice over Internet Protocol

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Prince Asiamah Addo is a graduate of the University of Mines and Technology and has research interest in electrical control systems. He has hands-on experience in the automation and control of haulage trucks and machinery.

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Lambert Dwomoh is a graduate of the University of Mines and Technology and has research interest in instrumentation and control systems. He has extensive working experience in the use of Arduino and programming tools.

Charles Ofori

Charles Ofori is a Master of Engineering student at the Auckland University of Technology.