DESIGN OF 1.5KVA ROBUST, EFFICIENT, AND COST-EFFECTIVE INVERTER SYSTEM

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ABSTRACT

This work focuses on the design of a 1.5KVA inverter system with an alarm and controls. In our modern world, the use of power is inevitable in industries, banks, hospitals, homes, offices, etc for driving machines, powering appliances, and generating light sources. Due to the epileptic electricity supply by a utility company, there is a need for stabilization of power source. Different technologies have been used to produce alternative sources of power like generators, thermal power generators, solar, biomass, etc. An inverter system emerged as a means of sustaining electric power whenever there is downtime in the electricity supply. In the design of this inverter, special features were in-cooperated to improve the functionality of other exiting inverter systems. These special features include an auto solar/mains charge selector, low battery detector, alarm/delay System, a feedback circuit, shutdown subsystem, user monitoring devices, and overload/ over-current control. Other control features include an auto low battery detector, an alarm/delay System, a feedback circuit, a shutdown subsystem, and overload/over-current control. The system also incorporates an alarm system and monitoring devices which communicate the state of the system to the user. In the design, the circuit is made up of several sub-circuits which consist of the oscillator stage (PWM circuit) driver stage, power amplification stage (MOSFET stage, transformer stage, filter stage, and output stage. The system delivers 220V, 50Hz with modified sine wave output.

Keywords: *Charge controller, PWM, MOSFET, Optimum performance.*

1.0 Introduction

One of the challenges confronting most developing and underdeveloped countries of the world is to maintain an uninterrupted power supply over a long period[1]. Many options came up such as hydroelectric power supply, gas firing generating station, wired tubing of generating power supply to avail man of such problem. Using Nigeria as a case study, her electricity supply is erratic, and fuelling our standby generator is very expensive as the price of petrol is becoming alarming daily[2]. Today, we have the fast-growing availability of renewable energy harvesters such as solar cells; their energy conversion process produces little or no pollution[2][3]. The power that is generated is often intermittent and unreliable[4]. As development advances, there is always a demand for power increases. The demand is not 50% met, so, people resort to using a standby generator which is always noisy and causing environmental pollution. These options seem not to have solved the problem. Inverter came in to fill the gap

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between energy demand and energy supply[3]. An inverter is a noiseless non-petrol power generator that provides uninterrupted power supply to homes, offices, and other power-hungry appliances.

An inverter is an electrical/electronic device that converts DC voltage to an AC voltage [5]. The inverter receives an input of direct current from a battery and delivers it to an output of an alternating current in a range suitable to power low-wattage appliances and devices[6]. There are different types of inverters depending on the voltage output waveform viz sine wave, modified sine wave, and square waveform[7]. These waveforms determine the kind of loads the inverter can power without distortion. The overall methods used in the design of the system comprise the interconnection of many subsystems for optimum performance. These include an oscillator circuit that inverts DC to AC, a driver stage that amplifies the low current output from the oscillator, the transformer stage which transforms the voltage to a sufficient level; an output circuit for power changeover, different control circuitry like automatic low battery detector system, battery charge controller, delay and shutdown system, an alarm system and indicators for the system optimization and maximum utility. At the end of this project, the system is expected to deliver a 50Hz approximate sine wave, 220-240VAC 1.5kVA output with different control and alarm.

2.0 Methodology

Different methods were employed in the design of the inverter system and the different stages or sections are discussed here. We adopted a modular top-down approach. This approach involved breaking down the system into smaller or modular units. Generally, pulse-width modulating IC (SG3524) was used to generate the required frequency of operation and the needed duty cycle for the feedback circuit. This oscillator IC will also receive a shutdown signal which powers off the entire system when needed. MOSFETs arranged in parallel, form a push-pull circuit configuration that receives an alternating signal from SG then providing the main inversion and power amplification. The amplified power is coupled through a 24V center tap transformer which transforms the power with voltage amplification and current reduction generating an output of 220V at 50Hz[7]. The transformer is also designed to provide a feedback signal and charging medium. This output is filtered to provide an approximate sine wave. This final output is then sent to the control circuit which changes the system between inverting and charging mode. It is also pertinent to note that analog electronic components like ICs, relays, operational amplifiers, transistors, resistors, capacitors, diodes, etc. were used in the design of all control sections and alarm systems. There are several inverter design methods normally employed in the design of the inverter system and its different stages or sections which include; oscillated transformed inverter, oscillated transformer-less inverter, and non-oscillated transformed inverter [6]. Also, Inverter types in practice include square wave inverter, modified square wave inverter, and pure sine wave inverter. This work dwells mostly on the design of an oscillated transformer inverter with a modified sine wave output as clearly shown in Fig.1. below. Fig.1, below has the complete integrated circuit with the whole sectional component coupled together which functions as a unit.

3.0 Sub-System or Modular Inverter Design

The entire modules necessary for the realization of this inverter were elaborately handled in terms of design and calculations in this section. Various modules used in the complete design are listed hereunder as the oscillator stage, the driver stage, the power amplification stage, the transformer stage, the filter stage, output stage.

Others like the control sections for the system optimization which include: charge controller, auto/mains charge selector, auto low battery detector, alarm/delay system, a

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feedback circuit, shutdown subsystem, and overload/over-current control.

3.1 Inverter Oscillator

The oscillator circuit in an inverter system is an electronic circuit that converts DC to AC in a very low ampere as shown in Fig.2, below. Different design techniques exist in the design of such a circuit which also determines the inverter frequency of operation or the clocking frequency. The following lists the possible kinds of oscillators; microcontroller-based oscillator, use of transistors configured as Astable multivibrator (free-running oscillator), decade counter-based oscillator, regulated PWM oscillator IC SG3524 etcetera. In this work, regulated PWM oscillator ICSG3524 is used for frequency generation giving the comparative advantages of containing all the control circuitry for a regulatory power supply inverter or switching regulator. The IC operation in Fig.2, starts by receiving power from the V_{cc}, clock pulse enters the chip via RV_1 and C_1, the IC will automatically generate frequency signal through the two output pots which in turn enters into the amplification stage. Some of the ICs came in a 16-pin dual-in-line package with voltage reference, error amplifier, oscillator, pulse width modulation, dual alternating output switches, current- limiter, and shutdown circuitry all integrated into a chip [7][8]. This device can be used for switching regulators of either polarity and designed for commercial applications. Other excellent features of the ICs.

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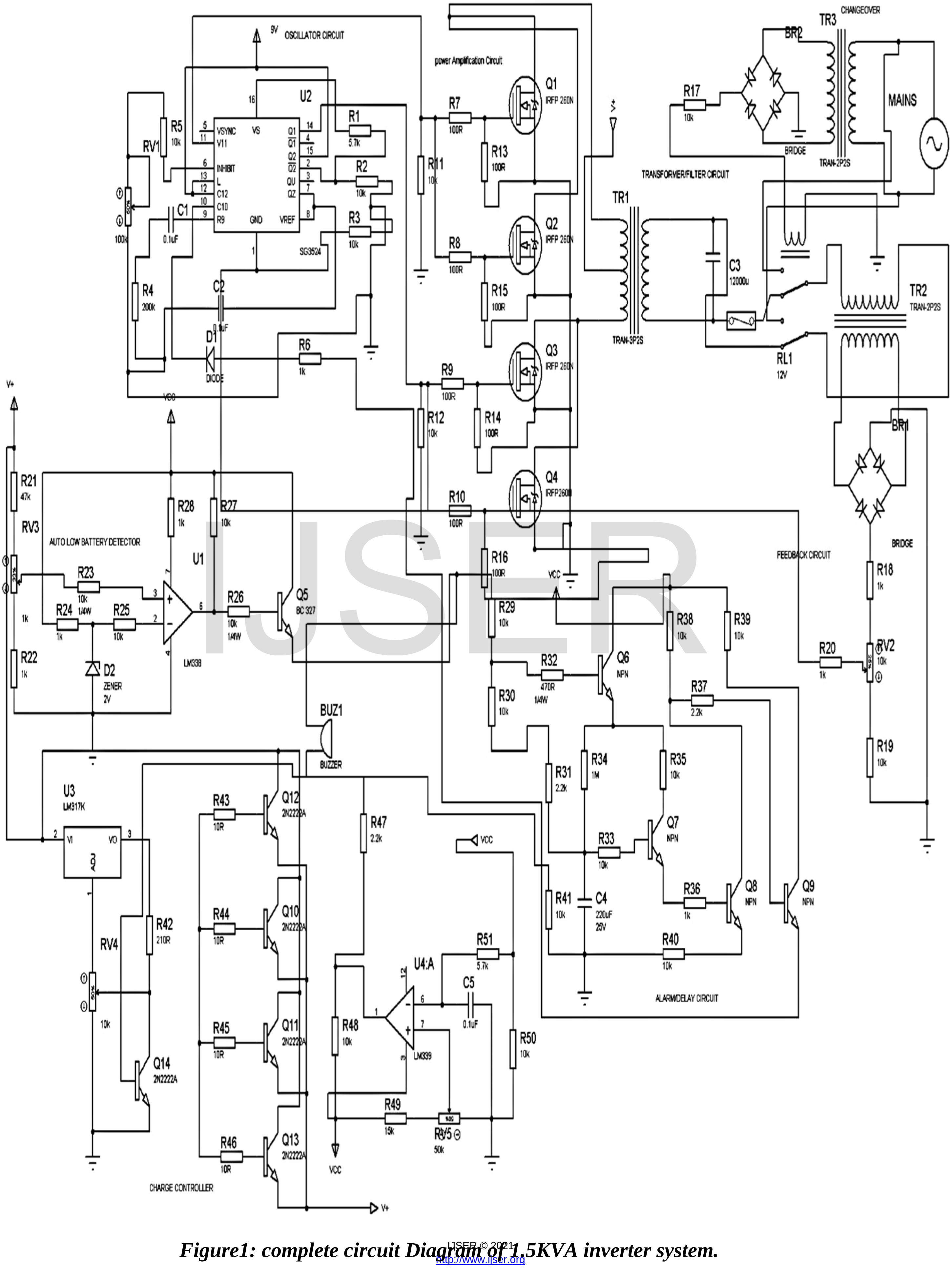

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Figure1: complete circuit Diagram of 1.5KVA inverter system.

include; complete PWM power control circuitry, push-pull output, line and load regulation of 0.2%, 10% maximum temperature variation, and total supply current is less than 10mA [9].

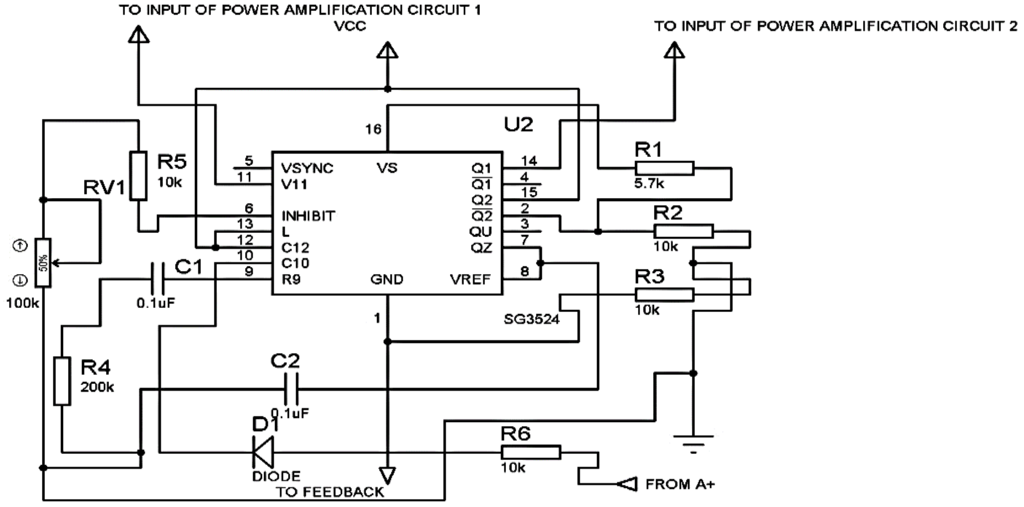

Figure 2: Circuit diagram of an inverter Oscillator.

3.2MOSFET Drivers

This inverter subsystem receives a signal from the low output current and voltage of SG3524 and provides a nearly constant stable voltage for driving the MOSFET through the gate. MOSFET drivers used here are IR2110 IC which is normally used when driving a MOSFET at a high speed. Since the output of SG3524 ranges from 4.6(min) to 5.4(max) is within the range of desired gate voltage 5V. It is, therefore, necessary that a buffer amplifier is incorporated into the aforementioned MOSFET driver IC so that a stabilized voltage is achieved which also gives a sufficient current gain.

3.3 Power Amplification Stage

Fig.3, below consists of a subsystem that receives a certain voltage from the output of the oscillator, via the buffer amplifier and amplifies its current to a sufficient level determined by the inverter capacity when a MOSFET with up to 62.5A drain current is used. Practically, a MOSFET of about 100A drain current which is regulated at 63A is preferable to allow tolerance. As clearly shown in Fig.3, the circuit has two bridges and well arranged in parallel such that the overall output of the amplifier is at least twice the required or rated current.

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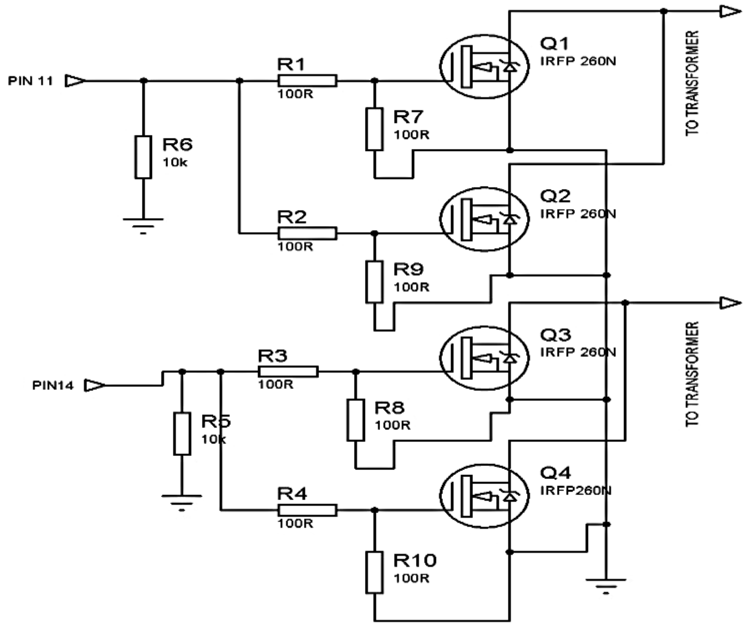

Figure3: Power Amplification Circuit

3.4 Transformer/Filter Stage with Changeover

At this stage, the transformer boosts the input voltage of 24V from the amplifier stage by suppressing current as shown clearly in Fig.4, below. The circuit uses the smoothing circuitry for ripples removal to obtain a perfect output voltage. From Fig.4, the output of the transformer is open coupled to AC source voltage which in turn charges the inverter.

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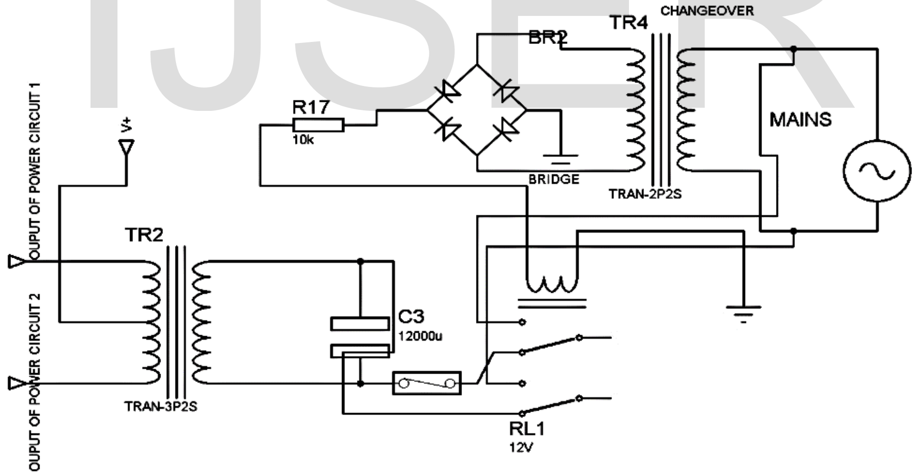

Figure4: Transformer/Filter Stage

3.5 Charge Controller

Fig.5 below shows the controller circuit of the inverter system it is made up of an automatic low battery charger and automatic full battery cut-off. This implies that it triggers charging current when the battery is below a certain threshold and disconnects when fully charged. The idea used in the design is based on an adjustable voltage regulator that regulates the charging current. In the design, a 24V battery was used as the inverter battery which means that the charge controller should be so designed that the system could make an effective charging up to 28V for optimum battery performance. If there is a mains supply, and the battery voltage is below 22V, the charge controller senses the battery voltage using the LM 399 operational amplifier circuit as shown in Fig.5 and triggers a charging signal. The charging of the battery continues until it reaches a voltage of 26V, then the charge controller detects that the battery is fully charged and disconnects it from charging using switching transistors.

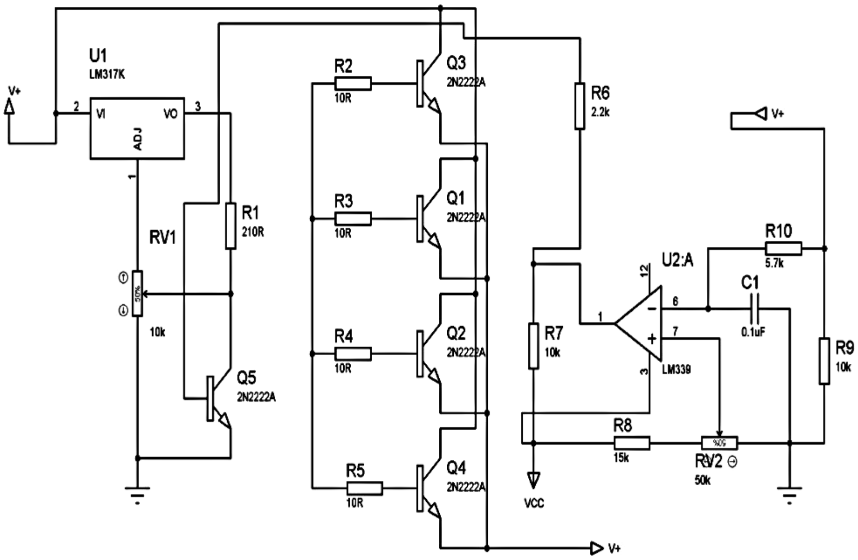

Figure5: Charge Controller

3.6 Alarm/Delay System

From Fig.6, below, the subsystem works as a monitoring device when the battery in the inverter drops below 21V, and the mains is unavailable, the charge controller detects this low voltage, and sends a signal to the alarm circuit alerting the user via buzzer to power off the inverter. If the user continues to run the inverter, the alarm circuit sends a signal to the delay subsystem which will delay the inverter system for a lead time of 2.5 minutes before powering the inverter off automatically by sending a signal back to the oscillator circuit.

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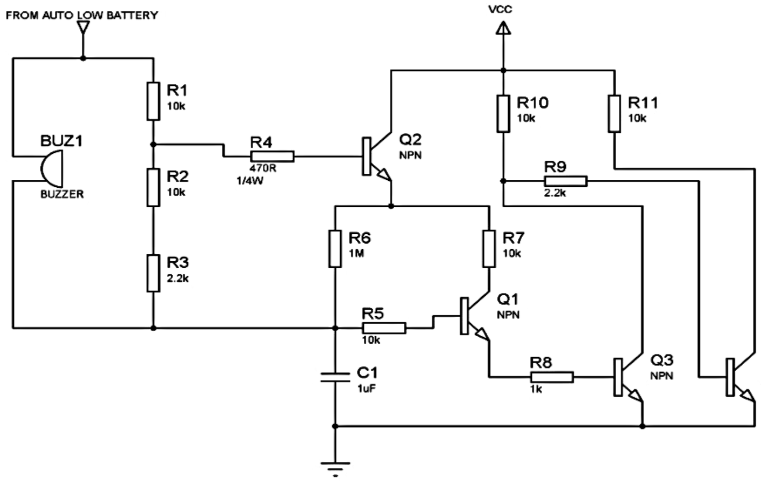

Figure6: Alarm/ Delay Controller

3.7 Feedback Circuit

Feedback is the part of the system that processes signals. The processing parts of a feedback system may be electrical or electronic ranging from a very simple to a highly complex circuit. From Fig.7 below analog feedback control circuit was constructed using discrete resistors, this circuit processes information using variable resistors R_3 for signal comparison and other data processing.

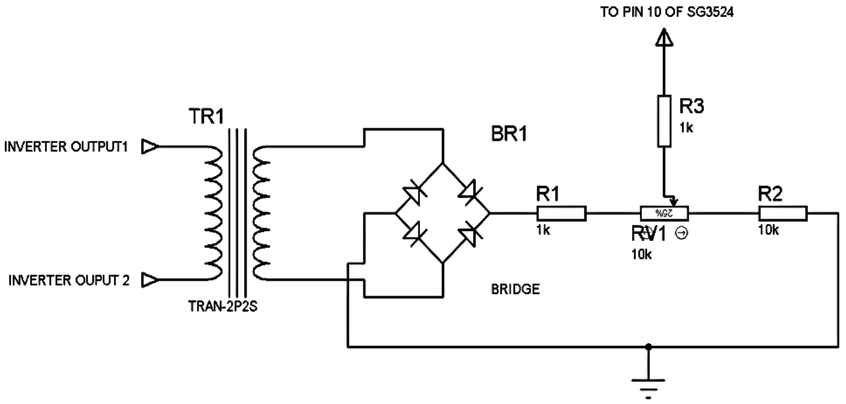

Figure7: Feedback Circuit.

4.0 RESULTS.

The complete circuit of the 1.5KVA inverter was fully designed in Fig.1, and simulation work was done using a proteus software system. The output of the simulation tallied with the range design specifications. The efficiency was also tested for the output performance and suitability in operation. The operations and output of the different subsystems were elaborately studied differently before integrating into the entire circuit to ascertain the individual circuit performance. From Table 1 and 2, at maximum load, the load capacity is 1250W with a maximum charging current of 38A and that of voltage is 28V which is still the of the inverter capacity of 1.5KVA. The result of Table 2 shows the efficiency of the system the inverter efficiency tends to stabilize as the load increases from 800 to 1200W. This proved that an increment in the applied load will not cause variation in the system efficiency. Furthermore, it was also observed that the efficiency of the different subsystems corresponds to the overall performance efficiency of the system.

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Table 1: System specification

Operating frequency	50Hz
Minimum AC input	180Hz
Maximum AC input	260V
Maximum load capacity	1250W
Low battery voltage	22V
Inverter Output	230V
Charging Voltage	28V
Maximum Charging Current	38A

Table 2: showing the result of system efficiency under load conditions.

DC voltage (volts)	**Output voltage (volts)**	**Output Current (Amp)**	**Load (watt)**	**Efficiency (%)**
24	230	0.00	0.00	95.8
24	226	0.88	200	94.2
24	224	1.79	400	93.3
24	222	2.70	600	92.5
24	220	3.63	800	91.7
24	220	4.50	1000	91.7
24	220	5.40	1200	91.7

5.0 CONCLUSION.

This work has shown very clearly evident that a 1.5KVA inverter could be designed and implemented using low-cost and locally available component materials. The modular concept in the design before the integration into the entire system presents easy troubleshooting in the inverter during system maintenance or upgrade. The system has proven to be efficient and reliable during testing by the ICs' responsiveness and the system control. Another interesting part of this inverter is that both the control system and the operation are so simplified that an unprofessional user could operate the system.

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