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SEISMIC WAVE-CONTROLLED SECURITY LIGHT SYSTEM IN POWER MANAGEMENT SCHEME

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Abstract

Knowledge garnered over the years by researchers in the area of shallow seismic refraction surveys, coupled with the global demand for the conservation of scarce energy resources, have motivated the successful design and construction of a simple power-saving security light system. The system was designed based on very simple and well known technologies. The materials used are also readily available. During seismic inactivity time out, the light goes off to conserve energy. The security light system power management scheme not only provides early warning indications of possible trespassers, but exposes and frightens them away. The scheme is ideal for large security zones, resorts, endangered forests and state houses. It can also be modified to a "gorilla warfare" early warning system.

Keywords: *Seismic, power conservation, security light*

Introduction

The conventional security light system can be described as a parallel combination of bulbs and switches Usually all the bulbs are put ON with one switch. In the night the bulbs are put ON and they continuously convert scarce electrical energy to light, even when there is no threat whatsoever to the security zone. Enormous amount of power can be conserved if electric light is supplied only during actual or impending trespass to the security zone. In this paper, we present a security light system that is automatically managed by simple electronic circuits (power managers), which respond to only seismic signals (or sound).

The power managers of the seismic wave-controlled security light system are designed to:

(1) put ON a minimum of a single light bulb when there is a low energy seismic disturbance, such as that caused by a man who is tip-toeing within the vicinity of the bulb,

(2) light up all or most of the bulbs in the security zone (depending on the area of the zone and its geologic setting), if there is a high energy seismic disturbance, such as the movement of a tractor within the vicinity of the security zone,

(3) ensure that the light persists for, about 5 seconds after the cessation of seismic disturbance,

(4) be independent of external power supply for its circuitry, and

(5) be devoid of human control.

Materials and Methods

The materials used for the power management scheme are devices and electronic components that are readily available in electronic shops. They include standard resistors, variable resistors, capacitors, diodes, integrated circuit regulators, step-down transformers, triacs, diacs, operational amplifiers, relays and geophones. These components are used to design the local power supply, amplifier, rectifier, and electronic switch. These units are brought together according to laid down design to form the "power manager" (Fig. 1). The "power managers" are attached to the bases of the poles suspending the light bulbs in a security zone and they are independent of each other.

Design of the "Power Manager"

The "power manager" (Fig. 1) is described in terms of: (1) the local power supply, (2) the amplifier, (3) the signal rectifier, and (4) the electronic switch.

Local Power Supply

The local power supply unit is itself supplied power by the 220V public power line. The 220V supply is stepped down by a 15V centre tap transformer TR-15 shown in Fig. 1. The outputs of the transformer are made inputs to two ICs, LM7912 and LM7812 which combine to give 12V dual power supply. The capacitors C_1 and C_2 are used to reduce ripples in the 12V DC output of the dual power supply unit.

Amplifier

The amplifier is designed from A741 operational amplifier (Op. Amp.). The operational amplifier is connected in the inverting configuration as shown in Fig. 1. The gain G of the amplifier is given by:

$$G = \frac{-1}{X}\left(\frac{R_2}{R_1}\right) \qquad (1)$$

where X is the fraction of output voltage V_2 to which R_3 is connected (Obianwu et al., 1995; Ahmed et al., 1984). The potentiometer R_3 is connected as shown in Fig. 1 so that the effects of spurious signals from the amplifier would be reduced while the gain is varied. The provision for variable gain is made so that the system can be adjusted to suit the cultural noise level associated with the area where it is mounted. R_4 is connected to reduce drift on the amplifier gain due to temperature changes. The value of R_4 is equivalent to the resultant value of R_1 and R_2 in parallel. R_4 does not affect the result of the gain (Ahmed et al., 1984). The ratio of R_2 to R_1 is 100,000 which gives the maximum value of gain G, for the amplifier. The side pins of the potentiometer R_5 are connected to pins 1 and 5 of the amplifier, while the centre pin is connected to the negative terminal and pin 4. R_5 is varied at typical operating temperature to eliminate offset voltage from the system.

Signal Rectifier

The signal rectifier (Fig. 1) is merely made up of four IN4001 diodes, which was found by Obianwu et al. (1995) to be the best suited for this kind of purpose. The input of the rectifier is the output of the amplifier, while the rectifier output is fed to the base of the transistor TRI (2N3773), which controls the electronic switch unit. The capacitor C_3 (470μF) is placed at the output of the rectifier to smoothen the rectified signal and maintain an effective trigger voltage for the transistor TR1.

Electronic Switch

The electronic switch is basically controlled by the transistor TR1 and the electro-mechanical relay R_6. The relay R_6 (Fig. 2) was designed and constructed by the authors because the relay that would meet the specification for this project was not readily available in the market at the time of the construction of the seismic wave-controlled security light system. The coil of the electromagnets which was removed from a 6 V transformer has a d.c resistance R_6 of 750Ω. The power supply cables are connected to the fixed aluminium bars as shown in Fig. 2. The movable aluminium bar opens the circuit with the help of a spring. Fixed to the movable aluminium bar is an iron bolt which pulls down the movable bar to close the circuit when the electromagnet is energized. The capacitor C_4 is used to prolong the relaxation time of the relay. Usually, a high capacitance capacitor is used to increase the relaxation to a few seconds depending on the need of a particular site.

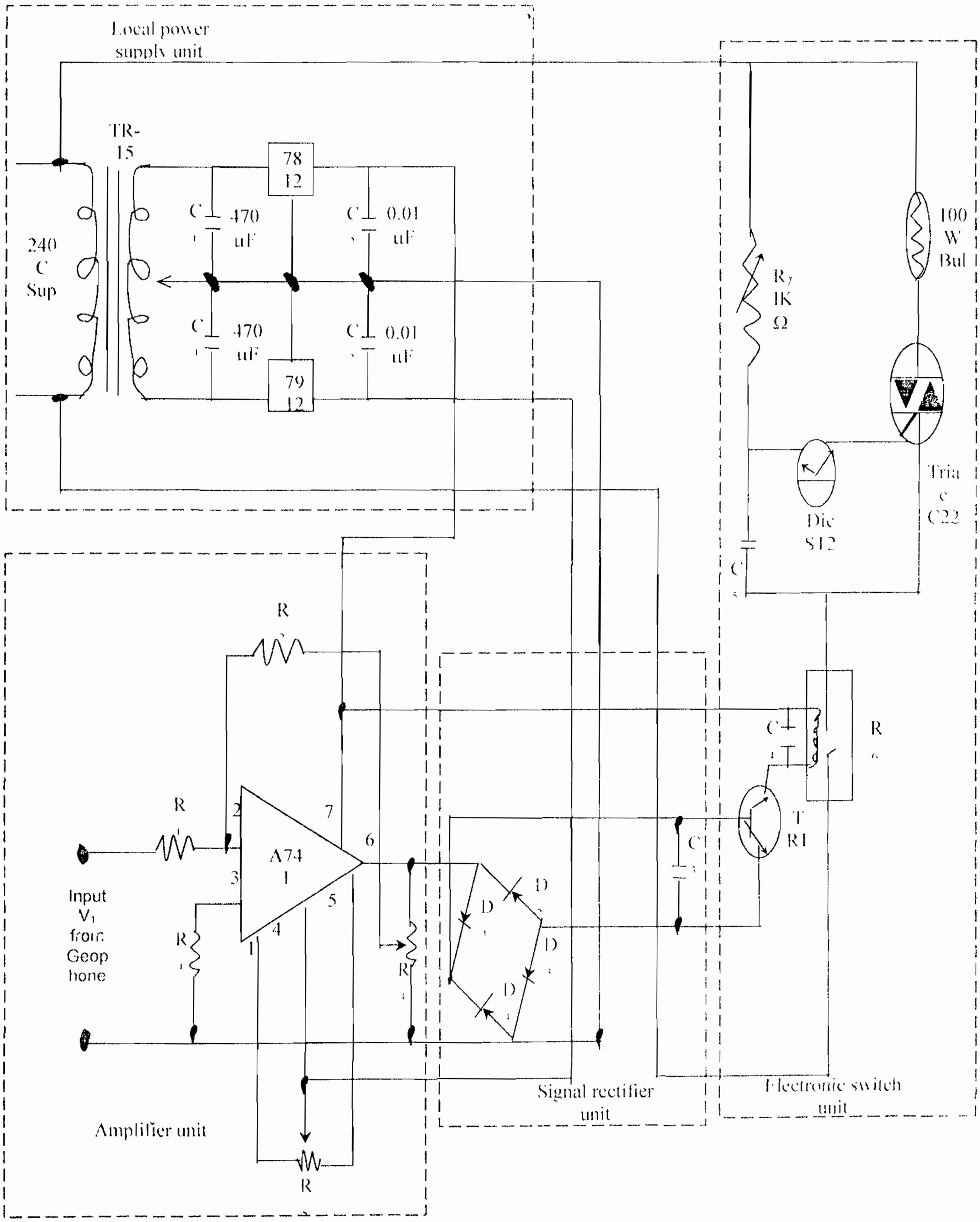

Fig. 1: Circuit diagram of the "Power Manager"

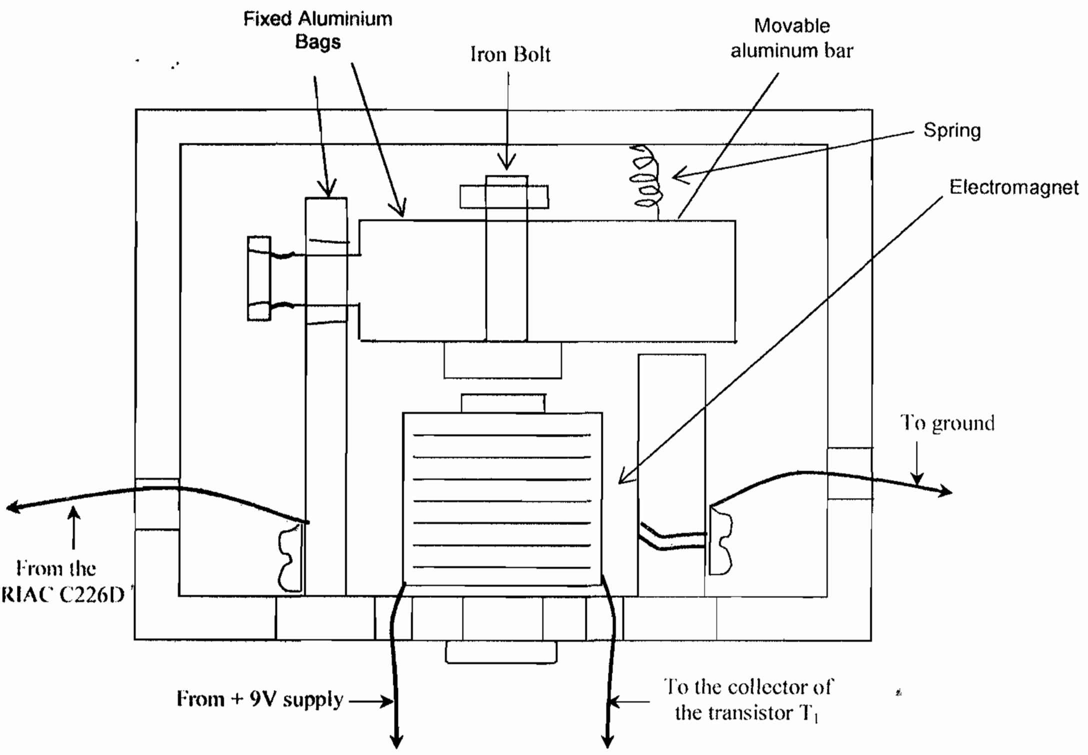

Figure 2: Cross-section of the relay

The minimum voltage V_{RL} required to activate the electromagnet so that it can pull down the movable bar to close the circuit is 6.4V. The minimum ill-defined current gain h_{fe} of the transistor TR1 is 40. The current I_R through the coil of the electromagnet that will give a potential difference of 6.4V at its ends is:

$$I_R = \frac{V_{RL}}{R_6} \qquad (2)$$

$$I_R = \frac{6.4V}{750\Omega} = 8.53mA$$

This requires a minimum base current of:

$$I_B = \frac{I_R}{h_{fe}} \qquad (3)$$

$$I_B = \frac{8.53mA}{40} = 0.21mA$$

Let V_i be the input voltage to the transistor TR1 and V_I be the input voltage to the amplifier A741. V_i is the amplifier output through the rectifier while V_1 is the geophone output. The forward resistance R_B of the IN4001s configured as full-wave rectifier is ~2.2Ω. So, the minimum input voltage V_i that can short circuit the relay R_6 is:

$$V_i = V_{BE} + R_B I_B \qquad (4)$$

For the transistor to be biased in its linear or active operating region, the base emitter junction must be forward-biased to a voltage V_{BE} of about 0.6 to 0.7V (Boylestad and Nashelsky, 1997). Taking a conservative value of 0.7V for V_{BE}, the value of V_i becomes:

$$V_i = 0.7V + 0.00046V$$

$$\therefore \quad V_i = 0.70046V$$

Hence, the minimum output voltage of the amplifier that will trigger the relay is practically 0.7V. Since, the maximum gain of the amplifier is 100,000, it means that the minimum output voltage of the geophone which can cause the bulb to light up is 7μV. However, the cultural noise in a particular security zone may generate a geophone voltage that is far more than 7μV. In this regard, the variable resistor R_3 is used to set the gain at a level at which cultural noise will not affect the system.

Still on the switching circuit, the variable resistor R_6 is used to control the conduction angle of the current through the Triac. Thus, the amount of power consumed by the bulb is controlled. The triac controls the ac power to the load (electric bulb) by switching ON and OFF during the positive and negative regions of input sinusoidal signal. In this design (Figure 1), the diac is used to fire the triac in both forward and reverse directions. When the system is energized, the voltage across the capacitor C_5 will begin to change towards the supply voltage until it is sufficiently high to first turn on the diac and then the triac.

Construction

The circuits for the "power manager" are mounted on two circuit boards. One for the amplifier, the other for the rest. This is to avoid unusual drift in the amplifier gain. The circuit boards are separated from the 6cm x 6cm x 10 cm metal boxes where they are mounted by insulating ceramic materials.

Discussion

The prototype seismic wave-controlled security light system was mounted in a private residence and observed for a week. The prototype worked according to design specifications. The reaction time of the system is well below one second which is quite good for the purpose for which it was built. During seismic inactivity time out (i.e., period of no significant seismic disturbance) the light goes OFF to conserve energy. The variable resistor R_7 is used to control the conduction angle of the triac to save more energy. This power management scheme is ideal for large security zones, resorts, endangered forests, and state houses, where enormous amount of energy is wasted keeping the light ON all night. It is suggested that if the power supply is changed to a portable battery and the load is changed to a vibrator, then soldiers in tight combat situations (gorilla warfare) can use the system to get early warning signal of a tiptoeing enemy soldier.

References

Ahmed, H. and Spreadbury, P. J. (1984): Analogue and Digital Electronics for Engineers: An Introduction, 2nd Edition,Cambridge University Press, London.

Boylestad, R.L. and Nashelsky, L. (2002): Electronic Devices and Circuits Theory, 8th Edition, Prentice Hall, New Delhi.

Obinawu, V.I., Etim, O.N., and Okwueze, E. E. (1995): Design and Construction of a Simple Single Channel Seismic Wave Timer System, Nigerian Journal of Physics, 7: 47-52.