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Operational principles of a Pressure Mat Auto-Light (PMAL) security control system for agricultural farmsteads

Uzoigwe, I.O and Maduakolam.S.C

Faculty of Engineering, Department of Agricultural Engineering, Imo State University Owerri, Nigeria.

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ABSTRACT

In this world of technology and scientific development, there has been great need to intensify researches on the development of security alarming systems in our agricultural farms and farmsteads. The pressure mat auto-light (PMAL) security control system is a sensory device consisting of two separate sensory units (Pressure Mat (PM) unit and Auto-Light (AL) unit) integrated into an efficient single sensory security system. It is designed and constructed with mat transmitter (MT) under a foot mat signaler receiver (FMSR) 12V, 223A buzzer, light emitting diode (LED), integrated circuit (IC), transistor (L8050), LM358N op-amp, a 2-1.5V battery, and resistors of 0.5Ω and 4.5Ω served as signaler receiver (SR), Light Dependent Resistor (LDR), a relay of 1000mA, 1000W/12V power transformation and power source of 220V to 240V. Efficiency of 70%, 95.8% and 90% for the frequency of loop gain $[(\eta)_l)$, transmitter (η_t) and receiver (η_r) circuits respectively showed reliability of the PMAL designed and constructed. From evaluation and testing of the device, the receiver can sense any pressure or weight upon the triggering spring at a distance 150m away from its area of installation, within which the buzzer beeps (sounds out), signaling wave presence in the receiver unit, thereby alerting the presence of intruder(s) in farmstead(s) and thus automatically shut-close the farmstead with the aid of a LDR, so that wild animals such as fox, jackals, wolfs etc will be kept away from fields of forest nursery and confined animals.

Introduction

Although research and development on sensors have been in earliest time, however, recent advancement has given way for the development of more sensitive sensors. A sensor is a device that can react to light, heat, pressure or force, causing it to make a sound, automatically shutting a door close, automatically lighting a dark room etc, whenever such reaction is felt. In our present technological age, so many devices are designed for so many purposes depending on the problems intended to be solved. In the banking, industrial and even agricultural sectors, there is need for security alarming systems which will help in sensitizing the various users on any impending burglary or entrance into a secured room or enclosure, (UNIDO 1980). The PMAL is one of such security alarming systems. It is a sensor that reacts to weight or pressure as well as change in light intensity. The application of pressure or weight on the mat triggers an alarm system through the buzzer at the same time, flashing out light through the light emitting diode (LED), which automatically shut the farmstead close and at the same time, making the user know when an intruder has encroached his/her doorway (inlet).

The PMAL circuit is an innovation/modification of doorway sensor circuit made in our 21st century. The main advantage of the PMAL device over all other doorway sensor is that it is only the user that is aware of the mat and encapsulated pressure switches positioned, so that if anybody should unknowingly step on the mat and encapsulated pressure switch that is well positioned, the flexible mat relays pressure to the switches and activates an alarm from the signaler receiver unit.

Also, the control unit of the PMAL system makes comparison as to the light intensity reaching the LDR. As the light intensity falls slowly, the voltage between the LDR and variable resistor rises continuously until it is efficiently enough for the IC to compare the input voltage with the output voltage, which is triggered by the transistor to make the relay to energized thus shutting the door automatically. Unlike some doorway sensor which may be visible, noticed and thus avoided by strangers/intruders, the PMAL device cannot be noticed by any burglar or illegal intruder into one's privacy, because the position of the pressure mat is such that it is not visible and it is seen as an ordinary foot mat that is of no importance. Another feature of this sensor is the IC which was designed with the LDR, variable resistor, buzzer and the LED to work together. All these make it more useful and advantageous to some other door way sensory device. Components from various works (Jackson, 1959; Jung, 1974; Lancaster, 1975; Carter, 1980; Berlin, 1983; U.S. Pat., 1974, 1985 & 1990; and Armies et al., 2006) used in this work are described below:

Description of Components:

i. Variable resistor: Variable resistors consist of a resistance track with connections at both ends and a wiper which moves along the track as the spindle is turned. Variable resistors may be used as a rheostat or as a potentiometer.

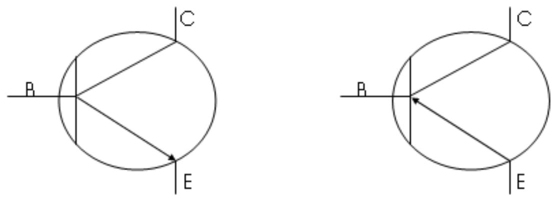
ii. Relay: A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. Because a relay is able to control an output circuit of higher power than the input circuit, it

Tele:
E-mail addresses: luzoigwe@yahoo.com

can be considered to be in a broad sense of an electrical amplifier. The particular relay used in this project is called single pole double throw (SPDT) relay.

iii. Transistors: Transistors amplify current, for example they can be used to amplify the small output current from a logic IC so that it can operate a lamp, relay or other high current device. In many circuits like the PMS project, a resistor is used to convert the changing current to a changing voltage and also to amplify voltage. Transistor types are shown in Figure 1.

iv. The leads are labeled base (B), collector (C) and emitter (E).

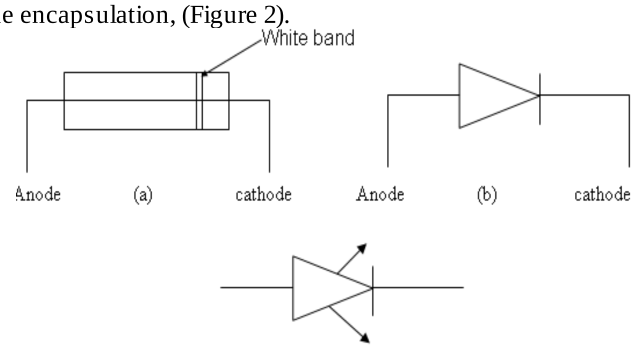


(a) (b)

Figure 1: (a) nPn and (b) PnP Transistors

v. Integrated circuit: Integrated circuit is a small microchip that contains a large number of electrical connections and performs the same functions as a larger circuit made from separate parts.

vi. Diode: The diode is a device that allows current to flow in one direction only. It has two leads, called the anode and the cathode. The cathode is often identified with a white band round the encapsulation, (Figure 2).



c) Light Emitting Diode

Figure 2a & b: anode-cathode white band diode and anode-cathode leads respectively

vii. Light Emitting Diodes: (LED) is a special kind of diode which emits light when in operation. They are mainly used as indicators in equipment which emit light when current flows in the correct direction (V ≥ 2V), Figure 2 (c).

viii. Operational amplifier (op-amp): Operational amplifier is a solid-state integrated circuit that uses external feedback to control its functions. It is one of the most versatile devices in all of electronics. The term ‘op-amp’ was originally used to describe a chain of high performance dc amplifiers that was used as a basis for the analog type computers of long ago (Berlin, 1987). These days, variety of op-amps that will provide the user essentially with functions, such as high common-mode rejection, low-input current frequency compensation, and short-circuit protection etc are now readily available. Op-amps are continually being improved, especially in the low-noise areas.

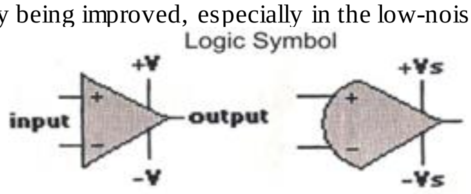
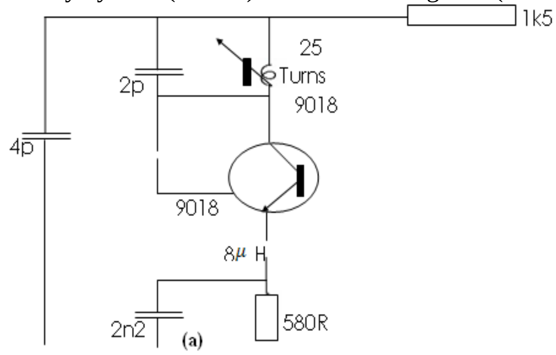


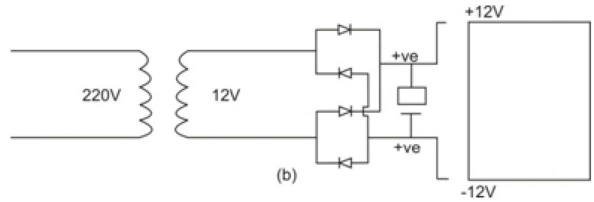
Figure 3: Symbols of op-amp

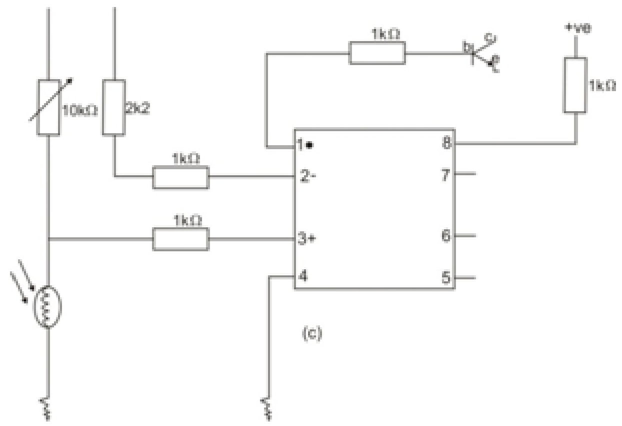
ix. Capacitors: The function of a capacitor in a circuit is to store electric current. It is in effect an electrical bucket that is filled and emptied by the rest of the circuit. The common types include the ceramic, the mica, the electrolytic capacitors, etc. The components required in the design of a pressure mat auto-light security system (PMAL) are shown in Figure 4(a – d).

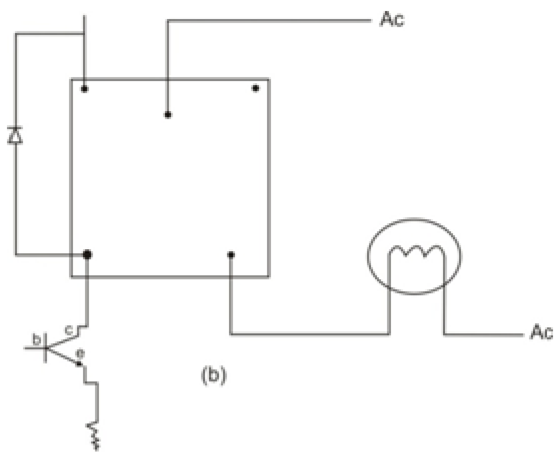


(a)

Source: Doorbell U.S. Pat (www.geeksinn.blogspot.com)







(d)

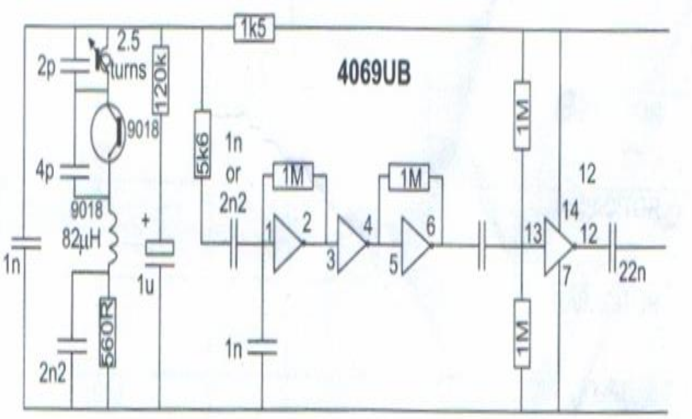
Figure 4(a – d): Component parts of a PMAL

Operational Principles/Materials

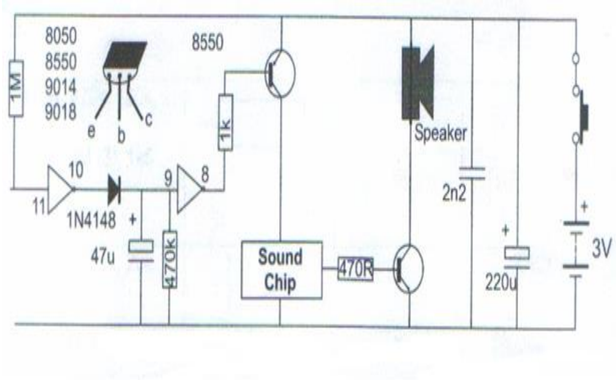
The pressure mat auto-light (PMAL) system can be used in farm houses/farmsteads doorways or in departmental offices to alert the presence of any object(s) within the instrumented area(s). The mat transmitter and the auto-light device are placed in front of the floor of the door, such that when the weight of an object is upon the pressure mat, RF wave is transmitted to the receiver unit causing a LED and light bulb to glow, signaling impulse action, which the user comprehends. At this point, the door automatically shut itself as the auto-light device senses a fall in light intensity due to the presence of an object on the mat. The fall in light intensity raises the voltage between a LDR and a variable resistor until it is efficiently enough for the integrated circuit to compare the input voltage with the output voltage and thus, triggers a transistor which energizes a relay which causes the switch controls revert to their normally closed position which switches on the light bulb, thereby shutting the doors automatically from invaders/intruders or wild animals. The PMAL device comprises the auto-light device, transmitter and the receiver units. The auto-light unit, mat transmitter and the signaler receiver must be at a proximity ranging from (0-150m). Any distance above this will not be sensed by the signal receiver. The transmitter unit uses one 12V, 23A battery, while the signaler receiver unit makes use of a 2-1.5V battery to power the buzzer, LED and other component. In the signaler receiver, the buzzer was connected to the LED such that when the light of the LED glows, the buzzer sounds. The auto-light unit was constructed with a 1000mA relay; LM358N Op-amp, L8050 transistor, 1000W/12V power transformation, 100W bulb and a power source of 220V to 240V. The bottom-top approach method was used for the construction. The materials were connected and laid out on the Vero board large enough to hold all the components of the circuit. Each unit of the PMAL was constructed and tested first before assembling all the units together.

Design and Construction

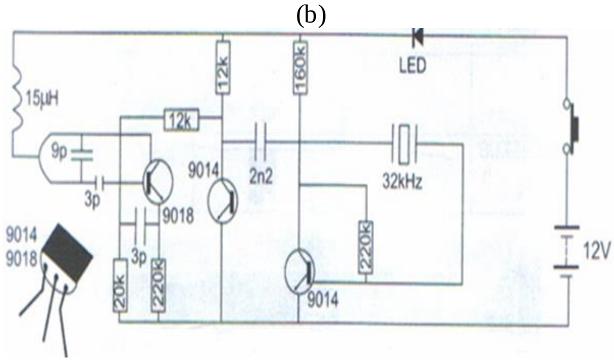
The mat of the PMAL security control system was made of soft wood and mat (rug), cut to required dimensions (370 × 255 mm). The Vero board connections of the transmitter and signaler receiver are 75 × 43mm and 75 × 105mm in dimension respectively. A cavity equal in dimension to the transmitter's Vero board was made and centralized on the wood with two springs placed on top of the wood and fastened with nail at opposite edges inclined at an angle of about 15°. The signaler receiver was screwed into a cuboid-shaped plastic of 110 × 80 × 70mm with openings on one side of so as to allow reverberation of the buzzer, thereby helping to send out its sound outwardly. The auto-light unit was enclosed with softwood of dimensions 350mm × 250mm × 20mm. The circuit diagram of the PMAL security control system is given in Figure 5(a-c).



(a)



(b)



(c)

Figure 5(a-c): Circuits for PMAL security control system

Table 1: Component Symbol and Use

Component	Symbol	Number Use	Name
1n		3	Capacitor
2n2, 22n		3,2	Capacitor
2p		1	Capacitor
4p		1	Capacitor
9p		1	Capacitor
3p		1	Capacitor
100p		1	Capacitor
470R, 470k, 120k, 560R, IM (3), 1k5		16	Resistor
2(12k), 150k, 20k		6	Diode
8050, 9014, 8550, 9018		7	Transistor
		1	LED
		1	Buzzer/Speaker

(a)

(b)

Figure 6: Equipment set-up of the PMAL with its operating components:
(a) Foot mat signaler receiver(FRSR)
(b) Mat transmitter (MT) operational circuit
(c) Auto-light (AL) operational circuit

Testing and Result

From well known equation,

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \qquad (1)$$

The spring in the pressure mat was placed to ease the pressure on the small switch connected inside the transmitter panel/Vero board; therefore, the stress which the transmitter would take is reduced by the two springs. Thus,

$$\text{Pressure on the transmitters panel} = \frac{\text{Load Weight}}{\text{Area of the board}} \qquad (2)$$

As pressure is exerted on the mat, it presses the switch and the transmitter sends RF (radio) wave to the signaler receiver. The sonic sound is heard with emission of light through the light emitting diode (LED). From Ohm's law:

$$V = IR \qquad (3)$$

Where the voltage (V) of the transmitter circuit = 12V and current (I) = 23A

$$\text{Resistance} = \frac{V}{I} \qquad (4)$$

$$= 12/23 = 0.52($$

From the design and construction, emf = 12V, receiver voltage = 3V, power = 2W and frequency = 50Hz.

$$\text{Power}(P) = IV \qquad (5)$$

Putting in equation (5) the values above,

$$2W = I\ 3V$$

$$I = \frac{2W}{3V} = 0.67A$$

$$\text{Resistance }(R) = \frac{V}{I} \qquad (6)$$

$$= 3V/0.67A = 4.5($$

As the current of the transmitter and receiver were closed, current continues to flow through and if the mat was pressed, the voltages of the transmitter and receiver, may reduce say 11.5V and 2.7V respectively. The efficiency (η) of the circuits could be calculated using equation (7) as

$$(= (\text{Power Output})/(\text{Power Input}) \times 100 \qquad (7)$$

For the efficiency of the transmitter circuit ($(_t$):

$$(_t = IV/IE \times 100 \qquad (8)$$

$$= \frac{23 \times 11.5}{23 \times 12} \times 100 = 95.83\% \cong 95.8\%$$

Using equation (9) for calculating the receiver circuit ($(_r$) yields:

$$(_r = IV/IE \times 100 \qquad (9)$$

$$= \frac{2.7}{3.0} \times 100 = 90\%$$

This shows that efficiency of the system depends on the voltages. As the voltage decreases, the efficiency of the circuit also decreases alongside the percentage rating.

Similarly, from Figure 7, the LM358N op-amp of the auto-light unit is a function of frequency at open-loop gain.

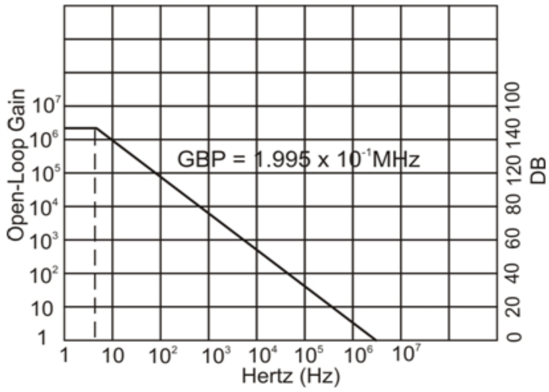


Figure 7: Bandwidth for the LM358N Op-amp and Gain Operation

Source: Roon (http: //www.uoguelph.cal"antoon)

At very low frequencies, the open loop gain is constant, but starts to taper off at about 7Hz or at a rate of – 7dB/Octave or 20dB/decade (Octave according to Roon, (http: //www.uoguelph.cal"antoon) is a doubling in frequency while decade is a tenfold increase in frequency). This decrease continues until the gain is unity or 0dB (unity gain frequency or FT). The Gain - Band-width Product (GBP) at this point is given as $GBP = 1.995 \times 10^{-1}MHz$. From Figure 7, the product of the open-loop gain and frequency is a constant at any point on the curve so that:

$$GBP = AoIBW = 1.995 \times 10^{-1}mHz \qquad (10)$$

From the figure, the closed-loop gain at $10kHz$ is about 7 to 10 and the open-loop gain is 10 (20dB). The transient response or rise time which is the time that it takes for output signal to go from 10-90% of its final value when a step-function pulse is used as an input signal specified under close-loop condition is calculated from:

$$A_{OI}BW = \frac{0.35}{rise\ time\ (sec)} \qquad (11)$$

$$\therefore rise\ time = A_{OI}BW \times 0.35 \qquad (13)$$

$$rise\ time = 0.1995 \times 0.35 = 1.7s$$

The efficiency of the auto-light unit is calculated as the ratio of the open loop gain and the close-loop frequency

$$\eta_l = \frac{7}{10} \times 100 = 0.7 = 70\%$$

The values of the rise time and efficiency of the auto-light unit showed that the op-amp is within an equivalent of the ideal Op-amp.

Conclusion

The design base has improved the use of farmstead electrified fences for confining cows and heifers in a loafing barn, as it triggers alarm to the farmer to either shoot or switch on the electric fence thereby keeping stray or wild animals mostly jackals, fox, hyenas and wolves etc or electrocute them as the case may be. PMAL can also be used in confining animals to a definite area or keeping them out of a particular area, especially on farm producing grain and vegetable crops, whereas on diary far ms PMS can notify the farmer when animals confined within the fence, struggle to escape.

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