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Development of a Handheld Scanner for Completion of Surgery in a Hospital Theater

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ABSTRACT

This research developed a novel handheld surgery completion scanner, an electronic device constructed to be used in a Hospital Theater for detecting forgotten surgical instruments in humans and animals during and after a surgery. This device uses the beat frequency oscillator technology in carrying out the scanning activity, and has a speaker for delivering its output. It beeps immediately a metal surgical instrument is detected. This innovative device functions with the principles of a metal detector, which uses the pulse electromagnetic induction to detect metals. The electromagnetic field is generated with the aid of a coil wrapped on a cylindrical ferrite rod and does not pose any health hazards to the patient. The radiation is generally safe to the body organs. This device is focused on eliminating the rising life risks associated with several reported cases of patients being stitched with surgical instruments forgotten inside their body. The inclusion of this device as part of completion exercise for every surgery will eliminate the possibility of forgetting any instrument in the body. The designed and constructed handheld surgery scanner is portable, cheap, easy to operate, and safe for both the patient and health workers. It is a welcome development in all hospitals worldwide.

1. INTRODUCTION

It is a normal practice for surgeons to count the instruments used before and after surgery to ensure that used surgical instruments are not forgotten inside the body of a patient. This is sometimes very challenging as doctors and nurses participating in a surgery are always under severe pressure and tensed state of mind. There have been several reported cases of patients being stitched with surgical instruments forgotten inside their body (Nemitz, 2013).

Metal detecting devices have been in existence since the 18th century with its application mostly for security activities (Bronkala, 1970). But today the technology is used in many sectors like the health sector, in banks for security, and in military to detect landmines. Furthermore, there are sophisticated technologies like computer tomography scanners and magnetic resonance imaging scanners for detecting and imaging of metallic object stuck in human body or fractured bones (Gavin, 1999). These latest technologies have their specific applications mainly for imaging and all have their associated side effects (Rohan *et al.*, 2016). The idea behind the mini metal detector was first developed by Alexander Graham Bel in 1885, whose design of a metal detector contains two set of coils with one acting as the transmitter and the other as a receiver (Charles, 1991). The operation of the handheld surgery completion scanner is based on the principles of Maxwell's equation and statement (Hageman, 1998). The device contains a copper coil wrapped around a cylindrical ferrite material positioned inside a cylindrical ball head which acts as the transmitter and receiver coil. There are other applications of this technology in the field of medicine. An example is the metal contraband scanner (Posik and Surrow, 2016). This device is used to detect surgical instruments made from metals mistakenly forgotten in clothing or laundry and therefore prevent expensive surgical instruments and tools from being inadvertently discarded in surgical suite waste (Jurgen *et al.*, 2008). This helps to reduce hospital operating cost by rapidly scanning trash bags, laundry and parcels for lost items. Furthermore, the device is used in isolating wastes containing metals such as needles, blades, etc. from other wastes that can be incinerated, so that metal wastes can be isolated and recycled rather than being thrown away where it will constitute health hazards (Bobae *et al.*, 2014). This application is very important in hospital waste management.

Metal detectors works with three different technologies namely, beat frequency oscillation, pulse induction (PI) technology and very low frequency pulse (VLF) shifting (Flind, 1979). The beat frequency oscillator consists of a single coil wrapped around a cylindrical ferrite rod which acts as both the transmitter and receiver. This technology although cannot distinguish between types of metals detected has the advantage of small circuitry (Blazek, 2010). Pulse induction measures the length of reflected pulse by comparing it with the expected length of pulse (Sakthivel *et al*, 2013). If the decay of the reflected pulse takes longer than a few microseconds compared to the normal expected time, then there is probably a metal object interfering with it (Corbyn, 1980). So, the device can sense and detect a metal due to self-induction of the metal. The very low frequency phase shifting detector senses metal by using phase shifting and notching. Phase shift is the difference in timing between the transmitter coil's frequency and the frequency of the target object while notching is a discrimination filter for a particular segment of phase shift, enabling the detector to alert for objects above and below the segment threshold. The pulse induction technology was applied in the development of the handheld scanner because of its small circuitry and the fact that the generated magnetic field is safe. The inclusion of this device as part of completion exercise for every surgery will eliminate the possibility of forgetting any used instrument in the body.

In this research, the technology of scanning for metals has been applied innovatively in the development of a handheld surgery completion scanner towards the elimination of the risk of forgetting surgical instruments in the body. The novelty of this work is in the application of metal detection technique in surgery procedure using pulse induction technology. Although metal detection technique exists, this is the first time it is being applied in surgery procedure specifically for detection of forgotten surgical instruments in the body.

2. MATERIALS AND METHODS

2.1. Materials

The operational amplifier (TDA 2822) was used for low power output of 250 mW. Resistors (330 kΩ) were used in the biasing of the three NPN transistors (BF 494) in the circuit. The inductor and the ceramic capacitor (60 pF) form a tank circuit that generated the oscillations in the circuit. A switch was used to control the 9 V battery that powers the device. The audio output was generated via a loudspeaker (buzzer) (8 Ω/W). All the electronic components used in the development of this device were procured from Electronic shop at the Arena Oshodi market, Lagos, Nigeria.

2.2. Operating Principles

The constructed handheld scanner functions with pulse induction technology and consists of a miniaturized searching coil, which gives it the ability to detect metals no matter their size or depth of penetration in the body. The electronic circuit in the device generates and sends streams of some tiny, weak signals to the device integrator unit. The integrator reads the pulse signals, amplifies and converts them into direct currents. The received direct current is coupled to an audio circuit, which converts same to an audible sound. The system beeps from the connected speakers in response to the presence of a metal which indicates that a target object has been found. The developed handheld scanner cannot distinguish between different types of metals because the reflected pulse lengths of various metals are not easily separated (Carter, 1976). So, the surgical scanner can only detect a metal instrument but cannot determine the exact surgical instrument sensed by the device. The choice of pulse induction technology for this device is because the induced magnetism is brief and safe in the human body (Robert, 1989). The block diagram for the development of this device is presented in Figure 1.

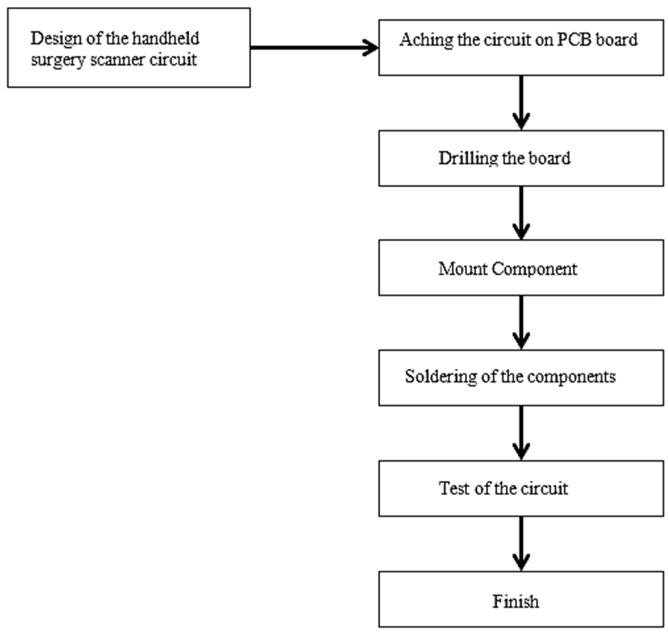

Figure 1: Block diagram for the development of the handheld surgery completion scanner

2.3. The Design

The circuitry of this device and its analysis is illustrated in Figure 2. The operation of the circuit is based on super-heterodyning principle which is commonly used in super-heterodyne receivers (Leutz, 1922). The circuit utilizes two radio frequency (RF) oscillators. The frequencies of both oscillators were fixed at 5.5 MHz. The first RF oscillator comprises of a transistor (Q_1) (BF 494) and a 5.5 MHz ceramic filter commonly used in TV sound-IF section. The second oscillator is a Colpitt's oscillator controlled with the help of a transistor (Q_3) (BF494) and an inductor (L_1), shunted by a trimmer capacitor (VC_1).

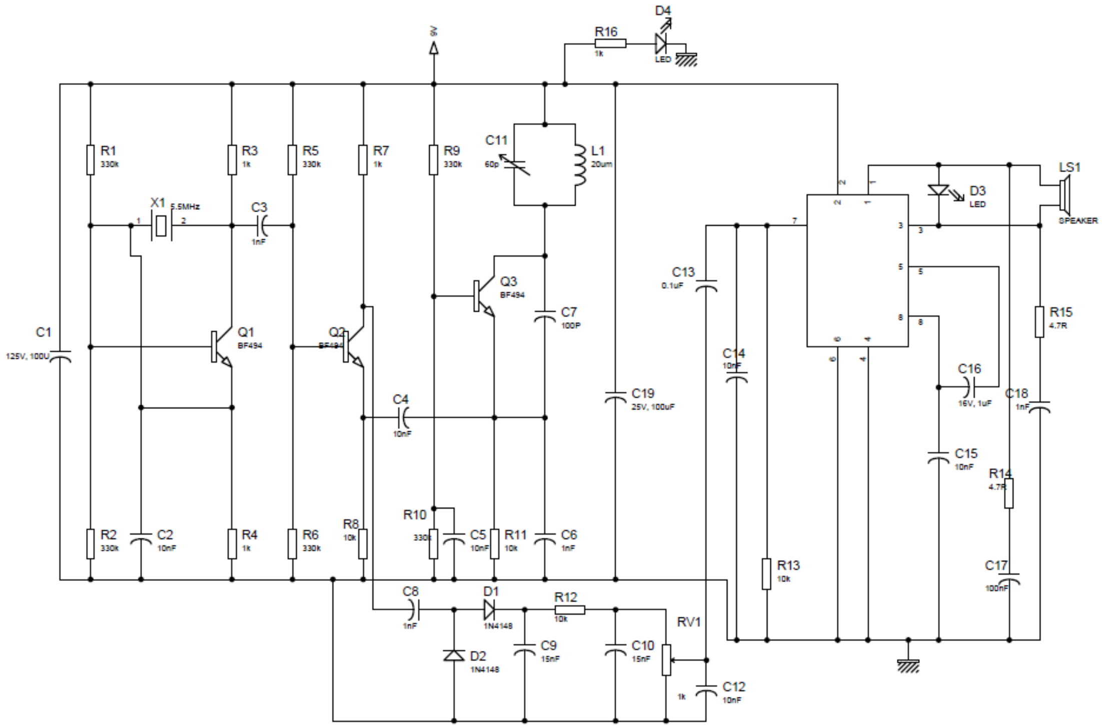

Figure 2: Circuit diagram of the handheld surgery completion scanner

These two oscillator frequencies (termed Fx and Fy) are mixed in the mixer transistor (Q_2) (another BF 494) and the difference or the beat frequency (Fx-Fy) output from collector of transistor (Q_2) is connected to a detector stage comprising of diodes (D_1 and D_2) (both OA 79). The output is a pulsating direct current (DC) which is passed through a low-pass filter coupled with the help of a 10 kΩ resistor (R_{12}) and two 15nF capacitors (C_6 and C_{10}). It is then passed to audio frequency (AF) amplifier (IC_1) (2822M) via a volume control (VR_{16}) and the output is fed to an 8-ohm/W speaker. The inductor (L_1) was constructed using 15 turns of 25SWG wire on a 10cm (4-inch) diameter air-core former and then cemented with insulating varnish. For proper operation of the circuit, the frequencies of both oscillators were made the same so as to obtain zero beat in the absence of any metal in the near vicinity of the circuit (Waddington, 1977). The alignment of oscillator 2 (to match oscillator 1 frequency) was achieved with the help of a trimmer capacitor (C_{11}= 60 pF). When the two frequencies are equal, the beat frequency is zero, i.e. beat frequency=Fx – Fy=0, and thus there is no sound from the loudspeaker. However, when search coil (L_1) is moved close to a metal, the metal changes its inductance, thereby changing the second oscillator's frequency. So, Fx-Fy is not zero causing a sound to beep from the loudspeaker. Thus, the device is able to detect the presence of a metal. The block diagrams for the flow of the signals and the filter of the signals are described in Figures 3 and 4 respectively.

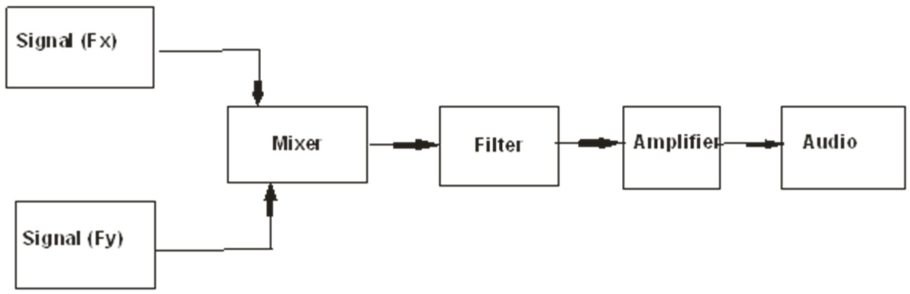

Figure 3: Block diagram for the processing of pulse for the detection of metal

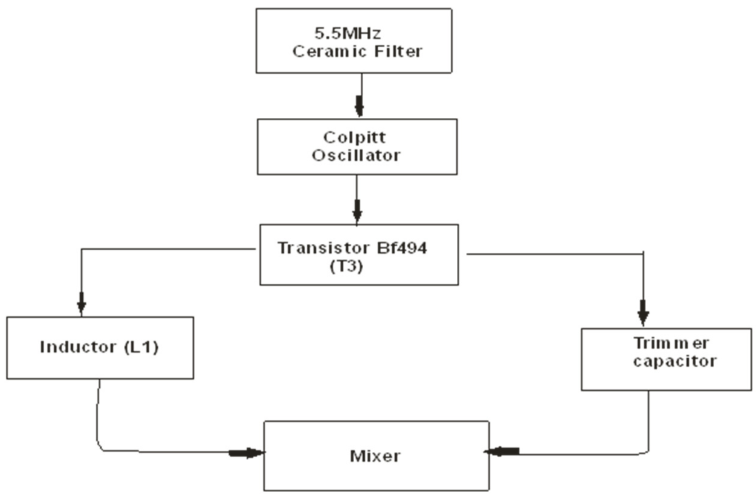

Figure 4: Signal filter block diagram

3. RESULTS AND DISCUSSION

The developed handheld surgery completion scanner was not tested on an operated human body because of inability to obtain ethical approval. However, it was tested by concealing a surgical knife in the palm of the hand. The scanner was used at various distances away from the hand ranging from 5 cm, 10 cm, 15 cm, 20 cm, 25 cm, 30 cm away from the hand. It was observed that for distance up to 25 cm from the hand, the device was able to detect the metal surgical knife. But for distances above 25 cm from the hand, the metal surgical knife was not detected. Also, when the surgical knife was removed from the hand, the device did not beep showing the absence of a metal. The packaging of the developed handheld surgery completion scanner is presented in Figure 5. A foil is used to shield the circuit board from external noise to reduce electromagnetic interference.

The total cost of the handheld surgery completion scanner was ₦4,060.00 (Four thousand and sixty Naira) as presented in Table 1. After the testing of the device some adjustments were made on the variacap (variable diode) in other to improve the sensitivity of the device in detecting metals. A speaker with smaller resistance was used. The sensitivity of the device was confirmed satisfactory after several successful tests. The device made a continuous audible sound on sensing metal concealed on the hand. Also, an LED was added to indicate a metal in range.

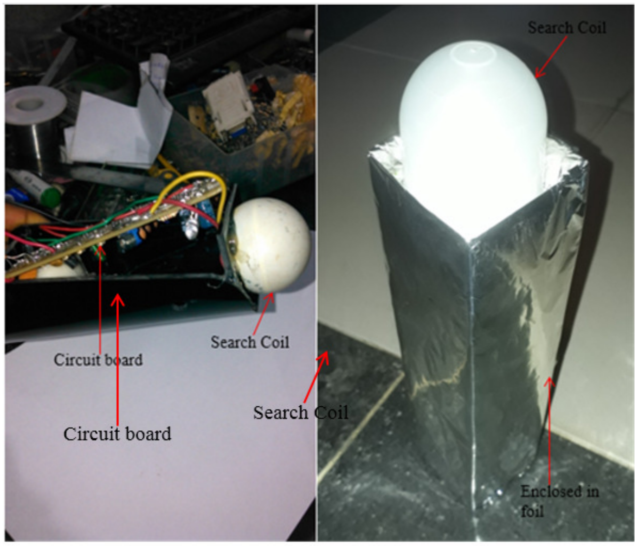

Figure 5: The packaging of the handheld surgery completion scanner

Table 1: Costing of the handheld surgery completion scanner

S/N	Components	Quantity	Unit price (₦)	Total Cost (₦)
1	Switch	1	100	100
2	9 V Battery	1	450	450
3	TDA 2822	1	200	200
4	Resistors	11	50	550
5	Transistors	3	200	600
6	Capacitors	12	30	360
7	Speaker	1	500	500
8	Coil wire	1	500	500
9	Diodes	2	50	100
10	Packaging			700
	Total			4,060

4. CONCLUSION

A surgery completion scanner has been designed and constructed in this work. The electronic device senses any metal within 25 cm penetration range in the body. It is targeted at eliminating the risk of forgetting surgical instruments in the body after surgery. The developed device is used to scan a patient that just passed through surgical incision before the section is stitched. The scanner senses any metal surgical instrument forgotten in the body and beeps with an audible sound. This research seeks the mandatory inclusion of this developed handheld surgery completion scanner device as part of completion exercise for every surgery in order to totally eliminate the possibility of the recurring cases of surgical instruments being forgotten in the body. Although the technology used in the developed scanner has been in existence for a long time now, this is the first time it will be applied in the medical field for the detection of surgical instruments in the body.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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