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Design and Analysis of a Cellphone Detector

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Abstract: *The cell phone detector is particularly designed on the basic principle of radio frequency detector. It is specifically designed to operate with the GSM frequency from 900MHz to 3GHz. It is a special receiver used to detect the presence of an active cell phone within 1 to 2 meters radius. The circuit uses a 0.22µF disk capacitor to capture the Radio frequency signals from the mobile phone. The lead length of the capacitor is constructed as 18 mm with a spacing of 8 mm between the leads to trap the desired frequency. The disk capacitor along with the leads acts as a small gigahertz loop antenna which collects the Radio frequency signals from the mobile phone. The capacitor in conjunction with the lead inductance acts as a transmission line that intercepts the signals from the mobile phone. This capacitor creates a field, stores energy and transfers the stored energy in the form of current to the inputs of an IC which is an Operational Amplifier. This will upset the balanced input of the IC and convert the current into the corresponding output voltage. By using some components such as an aerial, the filter circuit, an Operational Amplifier, the detector circuit, a timer IC and a buzzer, the cell phone detector is thus designed and analysed. An LED is also integrated to alert the reception of a GSM signal.*

Keywords: *cellular, detector, frequency, phone, radio*

1. INTRODUCTION

Information and communication technologies (ICTs) are a diverse set of technological tools and resources, used to communicate, and to create, disseminate, store and manage information (Blurton, 2002). The advancement and wide-usage of mobile-phones have promoted them to become the learning- media, increasing integration of mobile-phones into instruction in the Universities (Masri, 2015). The rapid-explosion of cell-phones at the beginning of the 21st Century eventually raised problems such as their potential-use to invade privacy or contribute to rampant academic-cheating. Curran *et al*. (2011), Built-in sensors, GPS, USB, and operating systems. Mobile phones that offer these and more-general computing capabilities are referred to as smart-phones. Furthermore, the communication-technology a cellular-phone uses such as CDMA, GSM, 3G and 4G is rapidly modernizing (Okebukola, 2014).

Cell phone Detector is a handy mobile phone bug, pocket size mobile transmission detector or sniffer that can sense the presence of an active mobile cell phone from a distance of one and a half metres. So it can be used to prevent the use of mobile phones in examination halls, confidential rooms and so on. The dimensions of cell phones have shrunk dramatically in the intervening years, while their capabilities have grown exponentially, as has cell phone ownership. Their sophistication and ubiquity pose many security challenges, and have given rise to a demand for equally sophisticated cellular phone detection and detecting the use of mobile phones for spying and unauthorized video transmission.

1.1 *Cell phone detector applications*

In addition to being able to make old-fashioned phone calls, today's phones allow text messaging, photography, and recording and real-time transmission of audio and video. In short, they provide a wide variety of ways of recording and communicating information. In addition, the tiny size of modern phones makes them fiendishly difficult to detect if you are trying to prevent their introduction and use in a particular location. In many cases, it is simply not acceptable to pat down visitors and guests to make sure they are not secreting a phone on their person. And there are plenty of times and places you might not want a cell phone to be used. They are a perfect tool for espionage, whether in military or government installations, or for industrial espionage. Security personnel at all such locations frequently deploy cell phone detection measures to assure the security of their information. In other circumstances, they can make possible various kinds of illegal activities, such as in prisons and other correctional institutions: a cell phone detector for prisons is a common application, for example. A mobile phone detector, or a network of them, can also be used to monitor for inappropriate transmissions in a casino, or to ensure that workers in a hazardous area are not using a cell phone that may distract them and cause an accident. These are just a few of the situations in which it is invaluable to deploy a mobile cell phone detector. Furthermore, better techniques for detecting unauthorized-usage of mobile-phones during examination-time is needed (Lawal et al, 2013).

1.2 Mobile phone detection system

Mobile-phone system is referred to as "Cellular-Telephone-system" because the coverage-area is divided into "cells", each of which has a base-station. The transmitter-power of the modern 2G antenna in the base-station is 20-100 Watts (Sujith, 2014). For larger or more sophisticated applications, a single cell phone detector may not be enough. Instead, one should consider a full cell phone detection system, consisting of a network of multiple cell phone detector devices located around the area to be protected. Cell busters' Zone Protector works with Zone Manager to provide just such a solution. The individual Zone Protectors can be distributed across the area to be monitored. Zone manager continuously monitors and collects the details of all activity from one or more Zone Protectors and displays them. One example of such an application is for intrusion detection in any large business facility, where Zone Manager can display the location of unauthorized activity on an interactive map of the building or campus. The GSM is therefore a wireless communication device that can transmit messages in different forms in a network using the free ISM (**industrial, scientific and medical)** radio **frequency** band. Messages can be transferred within the network un-noticed because of the nature of the medium concerned.

This led to the invention of the GSM Detectors to checkmate the un-wanted transfer of information or spying using the GSM network. The GSM detector can detect the presence of an active GSM handset within a network to prevent un-wanted information transfer or espionage.

2. MATERIALS AND METHODS

2.1 Introduction

The study addresses the problems associated with a low signal at a very high frequency for electronic circuits. Therefore, a means of trapping the RF signal is integrated in the design. The trapped RF signal is then amplified using a high gain and high frequency amplifier to provide appreciable high signal level to a detector circuit. The detected signal serves as a trigger to a timing circuit which oscillates in the presence of an input pulse which energises the buzzer at the output.

2.2 The Cell Phone Detector Operation

Cell phone detector is a special type of radio receiver that is used for capturing signals from a GSM hand set whenever the handset is in active mode or in the process transmitting or receiving message from another device. The circuit partitioned into four building blocks of a basic radio receiver, consisting of the RF Circuit, which includes the antenna, the amplifier, the Switching and the timer. The block diagram of the circuit is shown in Figure 2.1 below for ease of reference.

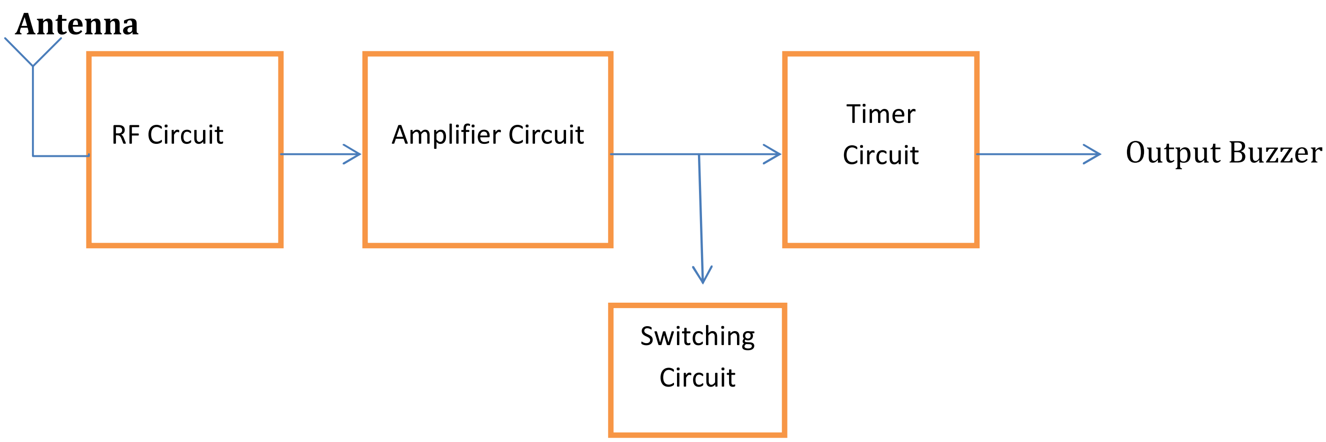

Figure 2.1: block diagram of the cell phone detector

2.2.1 The RF Circuit

An ordinary RF detector uses tuned LC circuits for detecting signals by tuning the circuit to a resonance with the signal frequency. In this case, where the frequency is in GHz range, it is not suitable to use an LC tuned circuit for detecting signals in the GHz frequency band used in mobile phones. The transmission frequency of mobile phones ranges from 0.9 to 3 GHz with a wavelength of 3.3 to 10 cm. Therefore, instead of constructing a tuned circuit for selecting the signal, gigahertz loop antenna is conceived to obtain a band pass filter that can capture the GSM signals operating at GSM frequencies.

The antenna in the RF circuit picks up the RF signal of all frequencies. Capacitors are employed to select or filter the desired frequency into the main circuit for processing; the frequency selection will depend on the values of the capacitors. A disk capacitor can be constructed to form a loop antenna that can capture the RF signals from the mobile phones. This is done by making the lead length and separation of the capacitor that can match multiple of one quarter wavelength of the GSM frequencies, while presenting zero resistance to the induced signal that goes to the amplifier.

2.2.2 The Amplifier Circuit

A high gain Operational Amplifier will be required for the Amplification of signals selected by the arrangements of the capacitors and fed to the inverting and non-inverting input of the Op Amp which is thus amplified to an appreciable level. The feedback loop is connected through a high resistance to the inverting input of the Op Amp to make the inverting input high when the output is high. A CMOS version using gate-protected p-channel MOSFET transistors in the input is required to provide very high input impedance, very low input current and very high speed of performance. The output CMOS transistor is capable of swinging the output voltage to within 10 mV of either supply voltage terminal.

2.2.3 The Switching Circuit

A general purpose transistor is used in the switching circuit. A MOSFET transistor can provide very high input Impedance, very low input current and very high speed of performance. These characteristics are what are required in this kind of arrangement from the output of the op amp circuit.

2.2.4 The Timer

This device should be a precision timing circuit capable of producing accurate time delays or oscillation. In the time-delay or monostable mode of operation, a single external resistor and capacitor network controls the timed interval. In the astable mode of operation, the frequency and duty cycle can be controlled independently with two external resistors and a single external capacitor.

2.2.5 The power supply

Circuit is powered by Miniature 9 - 12V battery of a remote control and a small buzzer to make the gadget pocket-size. The unit will give the warning indication if someone uses mobile phone within a radius of 1.5 meters.

3.0 RESULTS AND DISCUSSION

3.1 Introduction

The design of cell phone detector is conceived as an important tool in today's world of information technology in order to curtail some level of espionage activities in our society so that our environment can be saved and free from unwanted intruder and spying agents who uses cell phone for their activities. To do this design, the GSM operating frequency is paramount and is considered as the first parameter of concern, because there are a lot of signals being propagated freely in space everywhere. The design is made in such a way that only the circuit detects the desired frequency by employing a kind of selection mechanism that allows only the desired frequency to pass through it. A suitable amplifier is also considered in order to operate conveniently at that frequency (GSM frequency).The detected signal can be used at various levels of the circuit, so that, at end of it all, the presence of a dialling mobile phone can be interpreted by the presence of an audible alarm and a blinking LED.

3.2 Design Objective

The design objectives areas highlighted in the introduction, towards understanding the concept of the following namely:

1. The GSM operating frequency
2. The detector design
3. Amplification of the detected signal
4. The Switching device
5. The Alarms: LED and a buzzer
6. Power supply- DC

With this, a conception block diagram of the design is depicted as in fig 2.1 above.

3.3 The Frequency

The GSM frequency that is being used in this country is within the 900-1800GHz as allowed by Nigerian Communication Commission, NCC. The circuit is therefore targeted to be in tune with that frequency so that it is easily captured to the main circuit by the detector circuit. The detected signal is amplified and switched to the alarm unit to produce an audible alarm as an output.

3.4 Detector Unit

The detector unit is as an Antenna Turned with a series capacitance of two capacitors. The arrangement of the capacitors is such that, it present a low resistance path to a 900-1800GHz frequency of the waves that cut the antenna as shown in Fig 3.1 below.

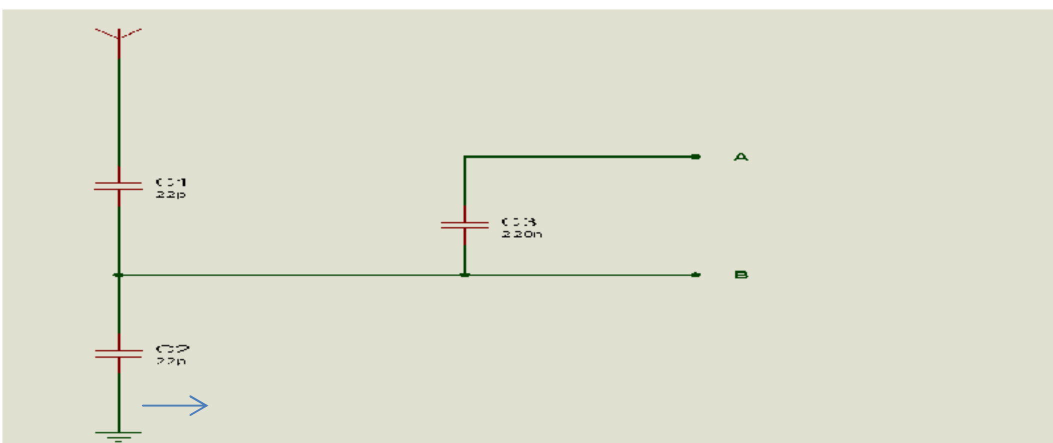

Fig 3.1: The detector unit

At a given frequency f, the value of the capacitors are computed as

$$C_1 = \frac{1}{2\pi f Xc1} = C2 \qquad (3.1)$$

And since the two capacitors are to present almost zero resistance to the ground, the required ohmic resistance to the circuit amplifier should be like a short circuit if a 220pf capacitor is chosen.

The characteristic impedance is then:

$$Xc1 = \frac{1}{2\pi f C1} = Xc2 \qquad (3.2)$$

If the value of f is taken to be 900MHz, it implies that the value of Xc can be determined for that frequency by substituting f and $C1$ in the equation 3.2 above.

Thus:

$$Xc1 = \frac{1X1000000000000}{2X3.14X900000000X22} = 0.008\Omega$$

$Xc1 = Xc2 = 0.008\Omega$

But the signal coupler should present a much lower ohmic resistance to the amplifier circuit, therefore, for the same frequency, let us consider C3 as a 0.22µF and compute the impedance;

$$Xc3 = \frac{1X1000000}{2X3.14X900000000X0.22} = 0.000008\Omega$$

$Xc3=0.000008\Omega$

The value of this capacitor is suitable for this design because, most of the signals at that frequency will pass to the input of the amplifier instead of shorting to the ground. This capacitor is chosen specifically because of its low resistance to high frequency signal as in GSM.

The capacitor C3, in conjunction with the lead inductance, acts like a transmission line that intercepts the signals from the GSM phone.

The capacitor creates a field, stores energy and transfers the stored energy in the form of currents to the input of an op-amps which upsets the balanced input and converts the currents into corresponding output voltages.

3.5 The Amplifier Unit

An Operational Amplifier with a good sensitivity was used at this stage as shown in figure 3.2. By going through the data sheet for electronic devices, the op amp with a good characteristic that fits this design is CA3130 and facilitate better performance at that frequency. The signal is amplified more than 100,000 times using this arrangement.

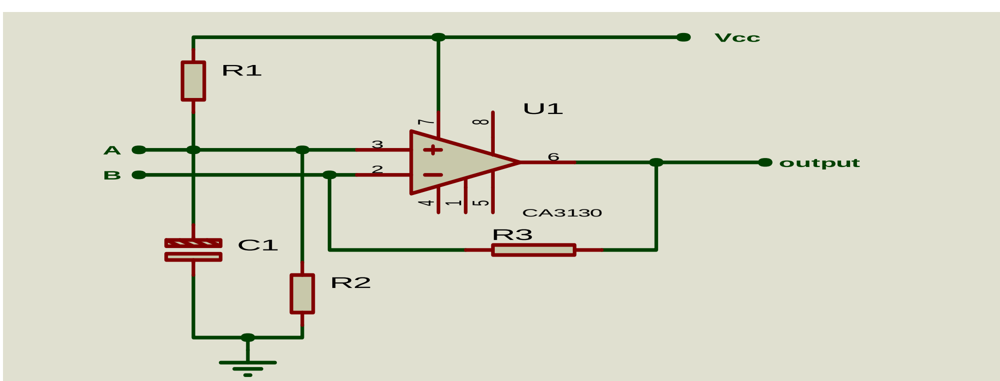

Fig 3.2: the amplifier circuit

The output voltage Vo = AVin

$A = \frac{Rf}{Rin}$ where Rin is the impedance of the capacitor C3 to connected to point A & B in fig 3.3.

Which implies that:

$A = \frac{Rf}{Xc}$.

If an infinite gain is desired, then as in this case, Rf is considered in the Mega Ohms range. Thus, Rf is chosen as 2.2MΩ. The amplification is therefore written as:

$A = \frac{2.2X10-6}{0.000008} = 2.75X10^{13}$

With this high gain setting, the amplifier is capable of amplifying the weakest of GSM signal at close range. From the result above, a simple circuit can be assembled to take some measurements using oscilloscope. As an active GSM is brought close to the circuit, a voltage of about 1 volt is produced at pin 6 of the op amp. With a varying ceramic capacitor connected between pin 1 and pin 8, the voltage is increased or decreased between 1.2 and 0.8 volts. By experimenting with manufacturing specified values, the best result was obtained with a 47PF ceramic capacitor.

3.6 The Switching Unit

The switching is a transistor wired as a switch. When the output of the op amp is high, base current (Ib) flows, consequently drives the transistor to saturation indicated by high collector current (Ic). When the output is low, the transistor is cut off, because the Ib = 0

The output voltage of the op amp IC was 1 Volt and capable of producing a current of 0.8mA which serves as the input Ib. When a small signal transistor BC548 is used, an LED can safely be driven by this current when connected between the emitter and the ground as shown in the fig 3.3 below.

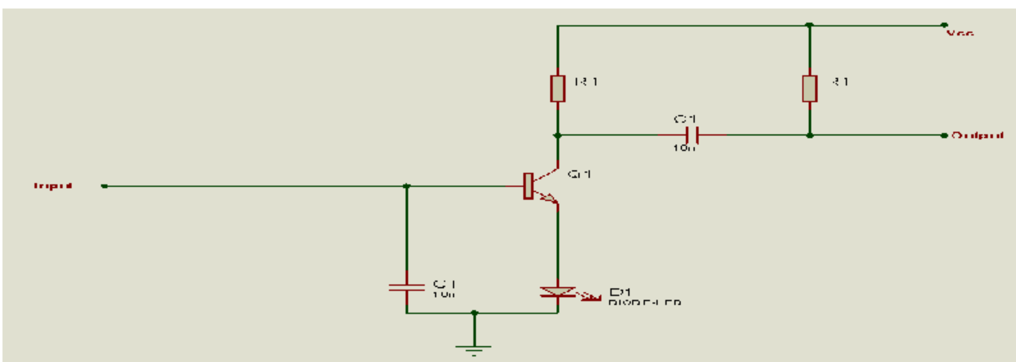

Fig 3.3: transistor as a switch

The R1 with 1K resistor load helps to limit the LED current. Therefore, we know that Ic =hfe x Ib, if hfe = 100 and Ib = 0.8mA, then

$Ic = 100x0.8x10^{-3} = 0.08A$

Ic = 80mA

This collector current used to drive or trigger an alarm i.e. putting on the LED.

3.7 The Alarm Unit

The Alarm unit is the unit that is activated by the presence of a detected signal as shown in figure 3.4. This function can be performed by a triggerable monostable multivibrator. The monostable multivibrator triggered into action by a specified time constant and then goes off. It stays on for certain duration depending on the time constant of the circuit and switches off and the IC commonly used for such behaviour is the 555 timer. This oscillatory behaviour of the signal detected can drive a buzzer at the output of the IC.

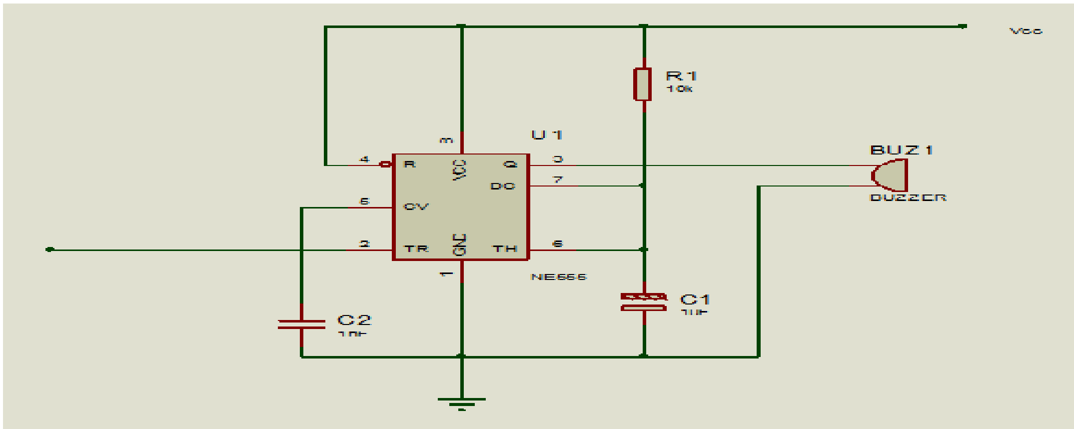

Fig 3.4: Basic Monostable Multivibrator Circuit

The design of the monostable timer is dependent on the timing component R1 and C2

From the formula $f = \frac{1.1}{RaC}$ which implies that

T = RaCx1.1 (3)

as the period of oscillation.

For a time of 1.1RaC to drive the buzzer, if R1 is taken as 150KΩ, the Capacitor C2 is then compute from the equation 3.3 above.

Thus, for a drive time of 1.5 seconds,

$$C2 = \frac{1.5}{150000\ X\ 1.1} = 9\mu F.$$

Therefore, the 150K resistor and 10µF electrolytic capacitor will be adequately used in the timer circuit for better timing response. Using the parameter of the different stages of the Cell Phone detector, the complete circuit was constructed by cascading all the stages together to get the required schematic diagram as depicted in figure 3.5 bellow:

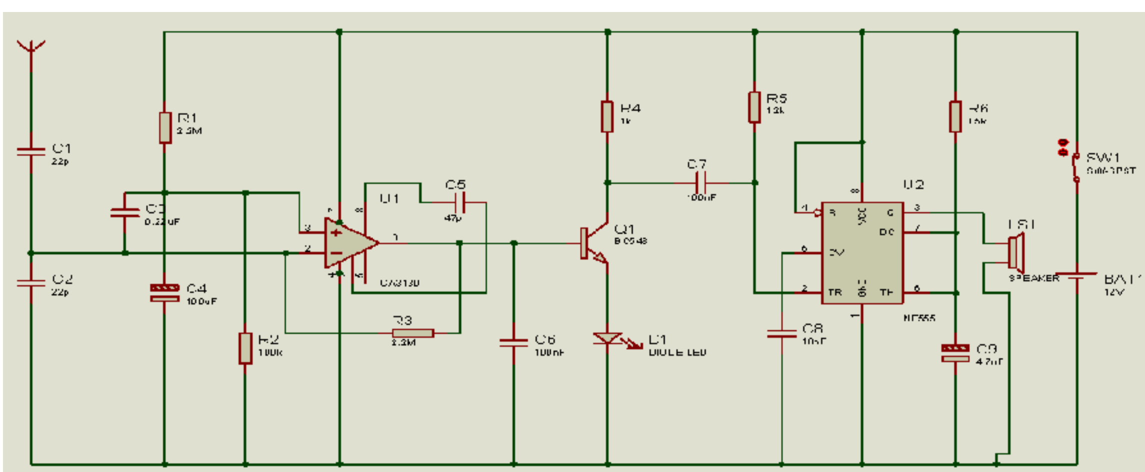

Fig 3.5: cell phone detector schematic circuit diagram

The schematic diagram now contained the value of all the components as described during the design process. These values were used for the construction of practical circuit required for performing tests and measurement.

4. CONCLUSION

The design and analysis of the cell phone detector has been carried out and presented. The design approach was based on the principle of radio frequency receiver specified for GSM frequencies. Within the given specification, the performance objective which is basically to detect an active cell phone at a distance range of about 1 to 2m has been successfully achieved. Intercepted signal GSM cell phone caused the buzzer to sound and at the same time makes the LED blinks. This happens only if the cell phone is on active mode, thus the design objective has been achieved. Therefore, the pocket-sized mobile transmission detector or sniffer can sense the presence of an activated mobile phone from a distance of one and-a-half meters. So it can be used to prevent use of mobile phones in examination halls, confidential rooms. It is also useful for detecting the use of mobile phone for spying and unauthorized video transmission.

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