DESIGN AND IMPLEMENTATION OF CELL PHONE OPERATED METAL DETECTOR

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ABSTRACT:

The design and implementation of a cell phone operated metal detector is presented in this paper. Now days, metal detecting system are becoming very important role in securing live and properties of civilian and military. This metal detector is attached on cell phone operated vehicle. For this paper, the metal detector built in a way that the metal sensor (Colpitts oscillator) senses any electrically or metallic object brought close to it. The metal detector circuit generates a sound which can hear to the end user through the cell phone. The vehicle consists of arduino board, an L293D interface circuit, and a motor driving system. The controlling devices are connected to the arduino board. The arduino board sends signals to the interfacing board L293D that controls the motor driving system. In the course of a call, if any button is pressed, a tone corresponding to the button pressed is heard at the other end of the call. This tone is called ‘dual-tone multiple-frequency’ (DTMF) tone. The vehicle perceives this DTMF tone with the help of the phone stacked in the vehicle.

Keywords: DTMF; Arduino Board; L293D, DC Motors; Metal Detector.

[1] INTRODUCTION

The mobile that makes a call to the mobile phone stacked in the vehicle acts as a remote. Therefore, this simple robotic project does not require the construction of receiver and transmitter units. The vehicle shall be able to detect 90% of Metal and mark the locations of the mines within a tolerance of 5cm. For the safety of the operator, the designed vehicle must be able to operate remotely. The vehicle shall not detonate the mines while scanning the area and marking the locations of the mines. The Control of vehicle involves three distinct phases: perception, processing and action. Generally, the preceptors are sensors mounted on the vehicle, processing is done by the on-board microcontroller or processor, and the task is performed using motors. In this project the vehicle, is controlled by a mobile phone that makes call to the mobile phone attached to the vehicle in the course of the call, if any
[2] DTMF and Working of the System

DTMF signaling is used for telephone signaling over the line in the voice-frequency band to the call switching center. The version of DTMF used for telephone tone dialing is known as Touch-Tone. DTMF assigns a specific frequency (consisting of two separate tones) to each key so that the electronic circuit can easily identify it. The signal generated by the DTMF encoder is a direct algebraic summation, in real time, of the amplitudes of two sine (cosine) waves of different frequencies, i.e., pressing the "1" key: For example, in order to generate the DTMF tone for "1", mix a pure 697 Hz signal with a pure 1209 Hz signal, like so: 697 Hz Sine Wave + 1209 Hz Sine Wave = DTMF Tone "1" DTMF generated signal is very distinct and clear. The horizontal axis is in samples. The frequency of the tone is about 1900 Hz - close to the 1906 Hz predicted by Table 1 (697+1209).

The tones and assignments in a DTMF system are shown in Table 1.
<table>
<thead>
<tr>
<th>Key</th>
<th>Low DTMF Frequency (Hz)</th>
<th>Low DTMF Frequency (Hz)</th>
<th>Binary Coded Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>697</td>
<td>1209</td>
<td>0 0 0 1</td>
</tr>
<tr>
<td>2</td>
<td>697</td>
<td>1336</td>
<td>0 0 1 0</td>
</tr>
<tr>
<td>3</td>
<td>697</td>
<td>1477</td>
<td>0 1 0 0</td>
</tr>
<tr>
<td>4</td>
<td>770</td>
<td>1209</td>
<td>0 1 1 0</td>
</tr>
<tr>
<td>5</td>
<td>770</td>
<td>1336</td>
<td>0 1 1 0</td>
</tr>
<tr>
<td>6</td>
<td>770</td>
<td>1477</td>
<td>0 1 1 0</td>
</tr>
<tr>
<td>7</td>
<td>882</td>
<td>1209</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>8</td>
<td>882</td>
<td>1336</td>
<td>1 0 0 0</td>
</tr>
<tr>
<td>9</td>
<td>882</td>
<td>1477</td>
<td>1 0 0 1</td>
</tr>
<tr>
<td>0</td>
<td>941</td>
<td>1209</td>
<td>1 0 1 0</td>
</tr>
<tr>
<td>#</td>
<td>941</td>
<td>1336</td>
<td>1 0 1 1</td>
</tr>
<tr>
<td>*</td>
<td>941</td>
<td>1477</td>
<td>1 1 0 0</td>
</tr>
</tbody>
</table>

Table 1: Tone assignment of DTMF

[3] DTMF Decoder IC-CM8870

It is 18 pin IC. The operating voltage is 2.5V-5.5V. One wire of the headphone is connected to the wire of the IC and another to ground. The cell phone (receiver) to a 3.5mm jack is connected at the other end. The cell phone must be kept at auto answer mode. Now call on that phone from another phone (transmitter). Press the keys on the remote phone and the robot moves forward (press 2), backward (press 8), left (press 4) and right (press 6). The four output pins (D0,D1,D2,D3) of the IC is connected to any part of the microcontroller.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>1209 Hz</th>
<th>1336 Hz</th>
<th>1477 Hz</th>
<th>1633 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>697 Hz</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>A</td>
</tr>
<tr>
<td>770 Hz</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>B</td>
</tr>
<tr>
<td>852 Hz</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>C</td>
</tr>
<tr>
<td>941 Hz</td>
<td>*</td>
<td>0</td>
<td>#</td>
<td>D</td>
</tr>
</tbody>
</table>

Table 2: MT8870 Output Truth Table


This is the brain of this vehicle in which the program is loaded to do the required functioning and is interfaced with decoder IC and the motor driver to make the system work as required. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software running on a computer (e.g. Flash, Processing, and MaxMSP) and three in another group. The LEDs labelled TX and RX light up when data is being transmitted or received between the Arduino and
attached devices via the serial port and USB. The little black square part to the left of the LEDs is a tiny microcontroller that controls the USB interface that allows your Arduino to send data to and receive it from computer.

[5] Motor Drive IC (L293D)

The L293D IC Motor Driver ICs are primarily used in autonomous robotics only. Also most microcontrollers operate at low voltages and require a small amount of current to operate while the motors require a relatively higher voltages and current. Thus current cannot be supplied to the motors from the microcontroller. This is the primary need for the motor driver IC.

The L293D IC receives signals from the microcontroller and transmits the relative signal to the motors. It has two voltage pins, one of which is used to draw current for the working of the L293D and the other is used to apply voltage to the motors. The L293D switches it output signal according to the input received from the microprocessor. For Example: If the microprocessor sends a 1(digital high) to the Input Pin of L293D, then the L293D transmits a 1(digital high) to the motor from its Output Pin. An important thing to note is that the L293D simply transmits the signal it receives. It does not change the signal in any case.

The L293D is a 16 pin IC, with eight pins, on each side, dedicated to the controlling of a motor. There are 2 INPUT pins, 2 OUTPUT pins and 1 ENABLE pin for each motor. L293D consist of two H-bridge.

Working: The received tone is processed by the atmega8 microcontroller with the help of DTMF decoder (MT8870). The decoder decodes the DTMF tone in to its equivalent binary digit and this binary number is send to the microcontroller. The microcontroller is pre-programmed to take a decision for any given input and outputs its decision to motor drivers in order to drive the motors for forward or backward motion or a turn.

![Connection Diagram of Microcontroller](image)

Figure 3: Connection Diagram of Microcontroller

[6] Metal Detector
A metal detector is a simple electronic device used to detect & locate metallic objects above and below the surfaces. The operation of a metal detector is based on the principle of electromagnetic induction. Metal detectors contain one or more inductor coils. When metal is placed in a close proximity to a varying magnetic field (generated by the coil or coils), currents are induced in the metallic part. These currents are called eddy currents. The eddy currents, in turn, induce their own magnetic field (called eddy fields). These fields act in such a direction as to oppose that generated by the coils. The resultant field (H applied – H eddy) and using a specially designed electronic circuit can indicate the type of material being magnetized. While designing a metal detector, range is the important factor. Range of the metal detector depends upon oscillating frequency. Here we have decided to go for variable frequency oscillator have been design. The Colpitts Oscillator is the best suited for them. In Colpitts oscillator the tank circuit consists of two capacitors in series and an inductor connected in parallel to the serial combination. Colpitts oscillator is generally used in RF applications and the typical operating range is 10 KHz to 300MHz. In Colpitts oscillator, the capacitive voltage divider setup in the tank circuit works as the feedback source and this arrangement gives better frequency stability.

[7] The design of the hardware

The hardware consists of the following units namely: the Power supply unit, sensing unit, the triggering unit and the alarming unit. Sensory/Oscillator design. The inductance to be used is calculated using

\[ L = \frac{2.8\pi^2 N}{R^2 + 4.45} \]  

Where \( L \) is inductance in \( \mu H \), \( S \) is the depth of turn, \( R \) represents the radius of coil, while \( N \) is the number of turns. For the purpose of this project, the sensor (coil) is desired to be reasonably small. So, radius \( R \) and length \( S \) is chosen to be 0.04 and 0.004 respectively. Therefore using the above equation to derive the value of \( L \) when \( S=0.004m; R=0.02m; N=26 \) is

\[ L = \frac{2.8 \times 0.025^2 \times 26}{0.025^2 + 4.45 	imes 0.004} = 1.545 \mu H \]  

The frequency of the oscillating discharge current depends on two factors;

- Capacitance of the capacitor to be used
- Self inductance of the coil to be used

To realize the oscillation of 9.34MHz, the oscillatory tank in Figure 4 was considered. The choice of 10nF and 2.2nF was considered in such away that their equivalent capacitance when combine with the inductor using equation 1 gives the frequency of oscillation to be 9.34MHz as calculated below.
\[ ceq = \frac{C_1 \times C_2}{(C_1 + C_2)C_2} \]  
\[ C_1 = 1 \; \text{and} \; C_2 = 220 \text{pF} \]
\[ ceq = 1.8 \text{nF} \]

Since the oscillator to be used is a Colpitt oscillator,

\[ F = \frac{1}{2\pi \sqrt{L \cdot C}} \]  
\[ F = \frac{1}{2\pi \sqrt{1.645 \times 10^{-6} \times 1.8 \times 10^{-9}}} \]
\[ F = 3.31 \text{MHz} \]

To stabilize the oscillation generated by the oscillatory tank, a BC547 transistor was considered. The slope of a transistor amplifier as we all know is given by:

\[ -\frac{1}{R_e} = \text{change in} I_c \text{axis} / (\text{change in} V_{ce} \text{axis}) \]
\[ -\frac{1}{R_e} = \frac{I_c}{V_{ce}} \]
\[ I_c = \frac{I_c}{V_{ce}} \]  
\[ I_c = \frac{I_{bc}}{125} \]  
\[ I_{bc} = 0.15/125 \]
\[ I_b = 1.20 \text{mA} \]

For the voltage across the base of the transistor \( Q_1 \): Resistors that will act as voltage divider will be connected to the base of \( Q_1 \), i.e., two resistors such that the voltage drop at \( R_2 \) is half \( V_{cc} \)

\[ R_3/R_1 + R_2 = \frac{1}{2} \]
\[ R_3 = \frac{R_2}{R_1 + R_2} \]  
\[ R_1/2R_1 = 0.5, \text{lets choose} \; R_1 = 10k, \text{then} \; R_2 = 10k \]

Capacitor \( C_3 \) was chosen to serve as ac by pass to \( R_3 \) while \( C_4 \) is meant to filter or block dc signals, \( C_3 = 4.7 \text{nF}, C_4 = 10 \text{nF} \).

Calculation of \( R_e = V_o/I_E \)
\[ V_{cc} = 10\% \text{ of } 5v \]
Since I_C>>I_B
R_E=V_E/I_E=0.12V/1.2mA=1K
Calculation of R4= Vcc / I_c
Vcc = 10% of 12v
Rc = 1.2/1.2mA = 10KΩ

![Sensory unit (colpitt oscillator)](image)

**Figure 5:** Sensory unit (colpitt oscillator)

Triggering unit A shaping circuit that is capable of converting sinusoidal wave to rectangular wave is desired, and to adequately give a low or high output, CD4093 was the choice. CD4093 is a quad 2 input Nand gate Schmitt trigger, but only two Nand gate were required; first for converting the sinusoidal waveform to square and the second for converting the square waveform to either a low or high output.

![Triggering Unit](image)

**Figure 6:** Triggering Unit

[8] Alarming unit

Since the output of the triggering unit is either high or low, a transistor switch arrangement is required to properly power the buzzer. The high of the CD4093 is equivalent to the Vcc. The buzzer is off at high which means that transistor Q2 is saturated and transistor Q3 is cut off. At low, Q2 is cut off and Q3 is at saturation with Vout = Vce(sat) = 0.2v. A buzzer that will produce an alarm is needed when the voltage drop across it is Vcc − Vce(sat). The operation of a transistor in saturation is determined by the value of Ib.

\[ Vin - IbRb - Vbe = 0 \]
To determine the minimum value of $R_b$ to be used from equation 6,

$$R_b = R_5 = \frac{(Vin - V_{be})}{I_B}\max$$

$I_b = 1.15$, for $V_{cc} = 12v$, $V_{be} = 0.7v$ and $Vin = V_{cc}$, then $R_b = 9826.1\Omega$

A resistor of 10k is a good choice for $R_b$ since $10k > 9826.1$

Therefore, $R_5 = 10k$

$R_6$ is used to limit the current entering the collector of $Q_2$.

$R_6 = 6.8k$

![Figure 7: Alarming Unit](image)

**[9] Conclusions**

In this program the two frequencies which are going to produce the dual tone when we press any button that is why it is called Dual Tone Multiple Frequency (DTMF). The only constraint is if the number we pressed is not there in the list then it will generate the output as invalid number. But here the frequencies are fixed. If we want to generate different tone we have to change the frequencies every time. Dual Tone multiple frequency (DTMF) signaling is also used in systems such as voice mail, electronic mail and telephone banking. The duration for which each tone lasts can be decided by manipulating the value of N. Greater the value of N, longer the duration of the tone and vice versa. Generally, if the DTMF keypad is on the phone, the telephone company’s ‘central office’ equipment knows what numbers are being dialed. On the other hand if DTMF keypad is connected to a remote control equipment, the tones can identify what functions to be controlled. Hence the multi faceted nature of DTMF signals is brought forward.

**References:**


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