NYU TANDON SCHOOL OF ENGINEERING

Mechatronics Project Report

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Motivation

This project involves the use of DTMF decoder to allow the user to send commands to the Basic Stamp microcontroller wirelessly using a mobile phone. This allows for the design of a simple remote controlled robot. Sensory feedback can also be implemented to gather information from the robot's surroundings to confirm the safety of the area before lives are put at risk. A Boe-Bot was constructed with DS1620 (Temperature sensor), Parallax Ping))) (Ultrasonic sensor), MQ-5 (Gas sensor), automated by two servos, and is controlled by DTMF MT8870DS decoder module through an available mobile phone.

DTMF Theory

DTMF stands for dual tone – multi frequency. In a standard phone keypad, each row and column of buttons are represented by a row and column frequency. Each individual key can therefore be represented by a combination of one row and one column frequency. Each time a button is pressed, two tones of the corresponding row and column frequencies are generated. A diagram of these frequencies is provided below:

1	2	3	697 Hz
4	5	6	770 Hz
7	8	9	852 Hz
*	0	#	941 Hz
1209 Hz	1336 Hz	1477 Hz	

Figure 1: Simultaneously generated frequencies for each corresponding key

When using a phone keypad to dial a phone number, the generated frequencies from each button press instruct the system to connect your call to the correct destination. By using a DTMF decoder, the dual tone signals generated by button presses can be changed into a four bit binary representation. These binary signals can then be used to control any device. [2]

Sensor and IC Technical Data

<u>DTMF Decoder</u>

For this project, an MT8870DS DTMF Decoder was used to receive and decode input from the cellular phones. As stated above, the decoder work by detecting the dual frequencies emitted by the phone's keypad and decoding these signals into a series of binary bits. The DTMF board has pins which can be plugged directly into a common breadboard. Two of the pins correspond to power and ground. A signal pin activates and emits a logic high value when the decoder detects a button being pressed. Four other pins emit logic high values corresponding to the value of the button which was pushed. The signal pin turns off when the button is released. The four value pins, however, remain in the same state until a new input is received or the device is turned off. [1] Functional block diagrams and pin descriptions for the board are shown below:

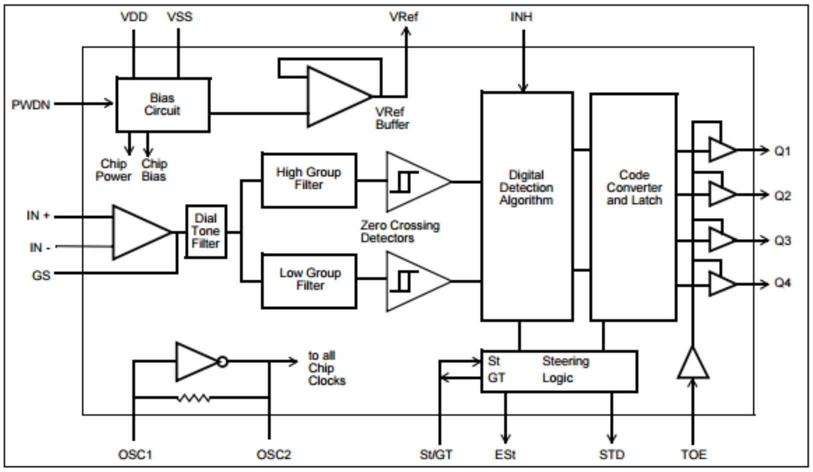


Figure 2: MT8870DS Block Diagram

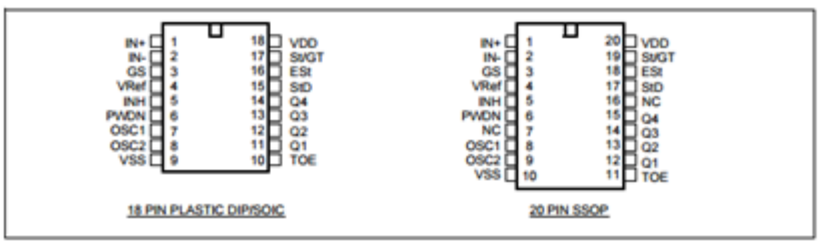


Figure 3: MT8870DS Pin Connections

Pin Description

Pin #		Name	Description
18	20		
1	1	IN+	**Non-Inverting Op-Amp (Input).**
2	2	IN-	**Inverting Op-Amp (Input).**
3	3	GS	**Gain Select.** Gives access to output of front end differential amplifier for connection of feedback resistor.
4	4	V_{Ref}	**Reference Voltage (Output).** Nominally $V_{DD}/2$ is used to bias inputs at mid-rail (see Fig. 6 and Fig. 10).
5	5	INH	**Inhibit (Input).** Logic high inhibits the detection of tones representing characters A, B, C and D. This pin input is internally pulled down.
6	6	PWDN	**Power Down (Input).** Active high. Powers down the device and inhibits the oscillator. This pin input is internally pulled down.
7	8	OSC1	**Clock (Input).**
8	9	OSC2	**Clock (Output).** A 3.579545 MHz crystal connected between pins OSC1 and OSC2 completes the internal oscillator circuit.
9	10	V_{SS}	**Ground (Input).** 0 V typical.
10	11	TOE	**Three State Output Enable (Input).** Logic high enables the outputs Q1-Q4. This pin is pulled up internally.
11-14	12-15	Q1-Q4	**Three State Data (Output).** When enabled by TOE, provide the code corresponding to the last valid tone-pair received (see Table 1). When TOE is logic low, the data outputs are high impedance.
15	17	StD	**Delayed Steering (Output).** Presents a logic high when a received tone-pair has been registered and the output latch updated; returns to logic low when the voltage on St/GT falls below V_{TSt}.
16	18	ESt	**Early Steering (Output).** Presents a logic high once the digital algorithm has detected a valid tone pair (signal condition). Any momentary loss of signal condition will cause ESt to return to a logic low.

Table 1: MT8870DS Pin Description

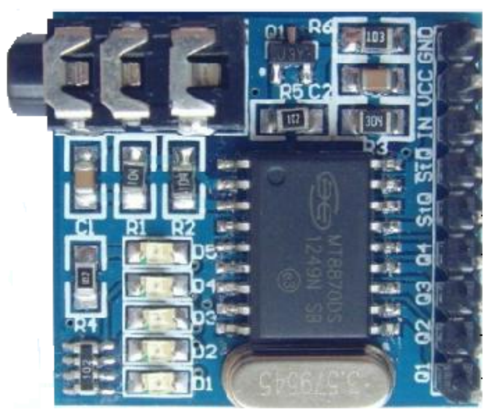
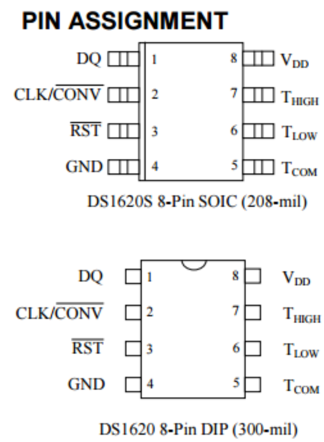


Figure 4: DTMF MT8870DS Decoder module

<u>Temperature Sensor</u>

A DS1620 Digital Thermometer was used to measure the temperature of the surroundings. This sensor is capable of measuring temperatures of -55°C to 125°C in increments of 0.5°C. The sensor comes as an 8 pin DIP IC (Dual In-line Package Integrated Circuit). This is very beneficial to the design in this project because it easily attaches to the Boe-Bot's breadboard and takes up very little space. [3] Pin assignment and description for the temperature sensor are shown below:



PIN DESCRIPTION

DQ	- 3-Wire Input/Output
CLK/$\overline{\text{CONV}}$	- 3-Wire Clock Input and Stand-alone Convert Input
$\overline{\text{RST}}$	- 3-Wire Reset Input
GND	- Ground
T_{HIGH}	- High Temperature Trigger
T_{LOW}	- Low Temperature Trigger
T_{COM}	- High/Low Combination Trigger
V_{DD}	- Power Supply Voltage (3V - 5V)

Figure 5: DS1620 Pin assignment and description

The sensor is capable of providing 9-bit temperature readings. The most significant bit (MSB) is used to represent positive or negative. The remaining 8 bits are used to represent the value. Each increment of 1 bit represents half of 1 degree Celsius. Example binary outputs for various temperature readings are shown below:

TEMP	DIGITAL OUTPUT (Binary)	DIGITAL OUTPUT (Hex)
+125°C	0 11111010	00FA
+25°C	0 00110010	0032h
+½°C	0 00000001	0001h
+0°C	0 00000000	0000h
-½°C	1 11111111	01FFh
-25°C	1 11001110	01CEh
-55°C	1 10010010	0192h

Table 2: Temperature/Data Relationships

<u>Ultrasonic Sensor</u>

The Parallax Ping))) sensor was used as a safety feature in the robot's design. The Ping))) sensor uses ultrasonic pulses to determine the distance between the robot and obstacles in its path. In the design of this system, it prevents the robot from accidentally crashing into a wall, which may damage the circuitry and necessitate costly repair.

The Ping))) sensor has 3 pins which can be directly connected to a breadboard. Two of the pins correspond to power and ground while the third is connected to a BASIC Stamp pin. [4]

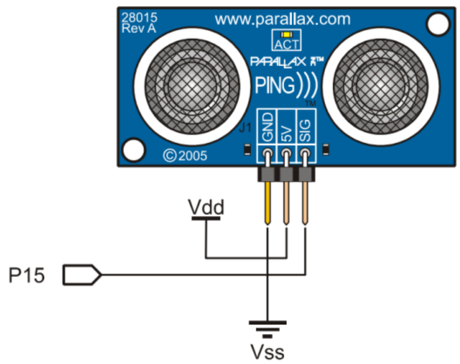


Figure 6: Parallax Ping))) and Pin connections

The ultrasonic sensor works by sending out a series of ultrasonic chirps and measuring the time taken to hear the echo from that chirp bouncing off an object. If the speed of sound is known and the time of flight for the sound pulse is known, the distance of flight can be found. Chirps are initialized by a starting pulse from the BASIC Stamp. An echo time pulse is then sent back to the BASIC Stamp from the sensor when the echo is received. The duration of the pulse tells the BASIC Stamp the time of flight.

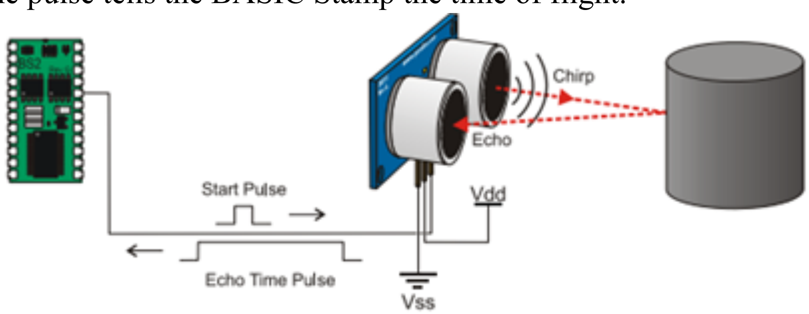


Figure 7: Parallax Ping)) Working concept

<u>Gas Sensor</u>

In order to detect the presence of particular gases, MQ-5 Gas Sensor was used. This sensor is sensitive to a variety of gases, one of which is Liquefied Petroleum Gas (LGP), or butane. Heating current is supplied to the sensor for operation, but measurements are accurate only during short periods of use. When gas is detected, the output voltage measured will vary as the sensor's resistance changes. For a fixed load resistance, the MQ-5 proves to be most sensitive to LPG. [5]

Figure 8: MQ-5

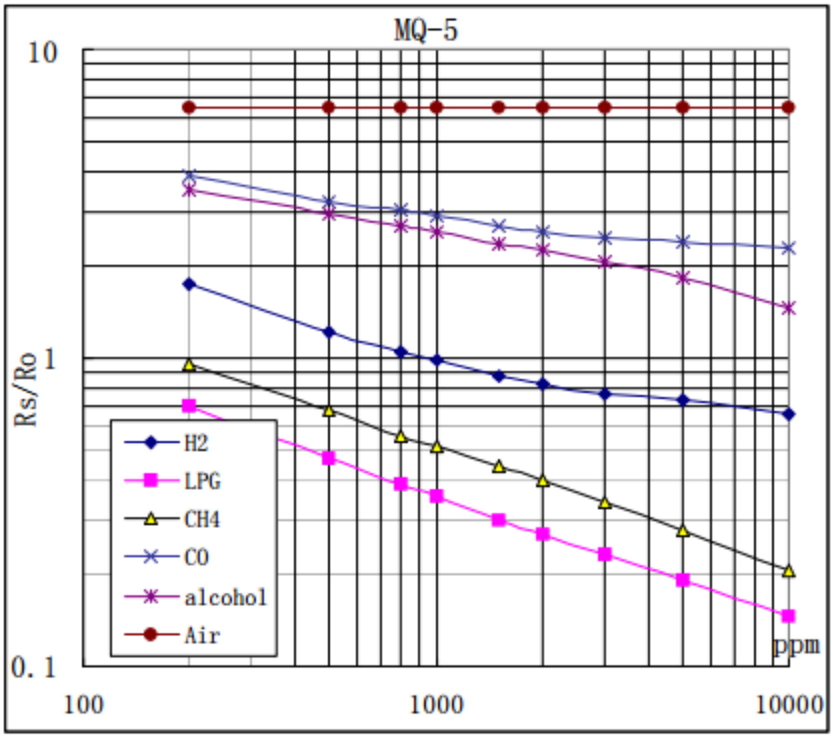


Figure 9: MQ-5 sensitivity to variety of gases

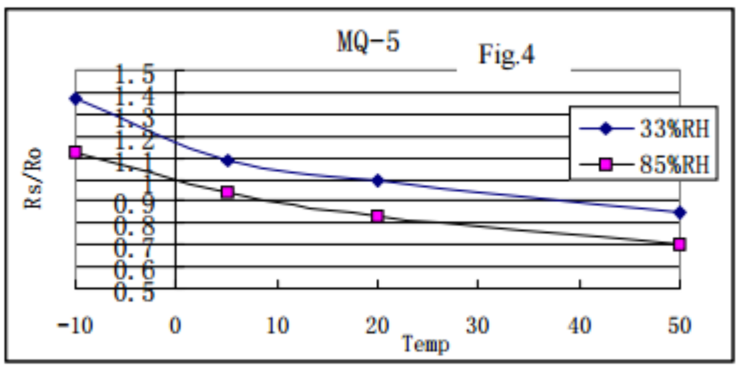


Figure 10: Sensor Resistance variation with time

Justification of Materials

For this project, the Boe-Bot was selected as the main system which the project was built around. This was done for multiple reasons. Financially, the Boe-Bot was an ideal choice. It is a comprehensive, low cost package. All requisite controllers, actuators, and basic electrical equipment (such as wires, resistors, and LEDs) were included were included in the purchase. It is also ideal for this group's level of experience with robotics. The use of BASIC Stamp, PBASIC programming, and easy to use breadboard integration allowed rapid prototyping to quickly modify and enhance the design.

The use of the Boe-Bot kit dictated the choice of sensors and actuators used in the design. The ultrasonic sensor, temperature sensor, servo motors, microcontroller, and basic electrical equipment all came with the package and integrated with each other seamlessly. Only the DTMF decoder and gas sensor were not part of the Boe-Bot kit.

The MT8870DS DTMF decoder was used, as it is cost effective and functioned exactly as was required by the design. The design required the button presses from a keypad to be translated into binary representations. This functionality is accomplished by the MT8870DS. Additionally, built-in LEDs on the board allowed for quick conformation that the board was working as intended during the prototyping stage of development. Similarly, the selected gas sensor was easy to use and integrate with other components of the design.

Circuit Schematic

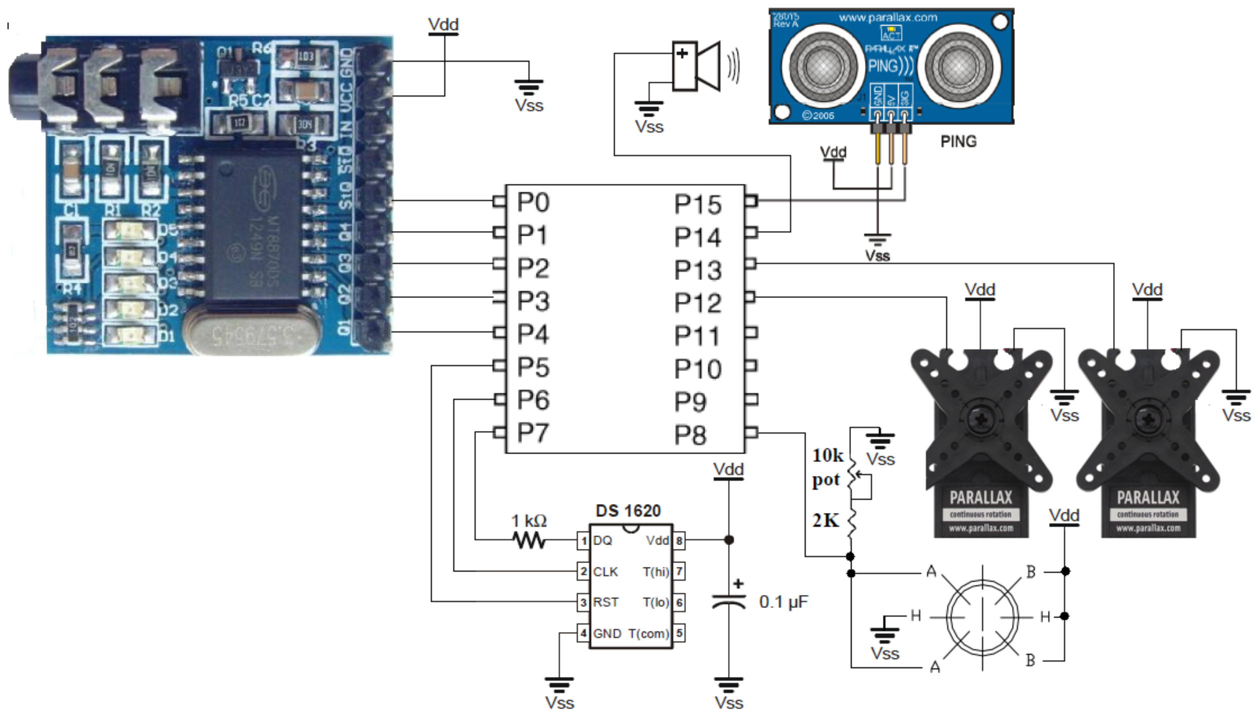


Figure 11: Circuit connection with BS2

Potentiometer used for the MQ-5 Gas sensor was tuned so that the voltage measured from the gas sensor is just below basic stamp's high-low voltage threshold. Input is provided through the DTMF to control the servos. All sensors, except gas sensor, constantly gather data as the program progresses. Piezo transducer is used to signal to the user if the area is unsafe.

Code Rundown

- Read Temperature sensor
    - Waits for stable temperature
    - If too high, output piezo transducer
- Reads output from gas sensor
    - If reading is HIGH, output piezo transducer
- Read distance from object
    - If too close, disable servos forward motion
- Waits for input to DTFM

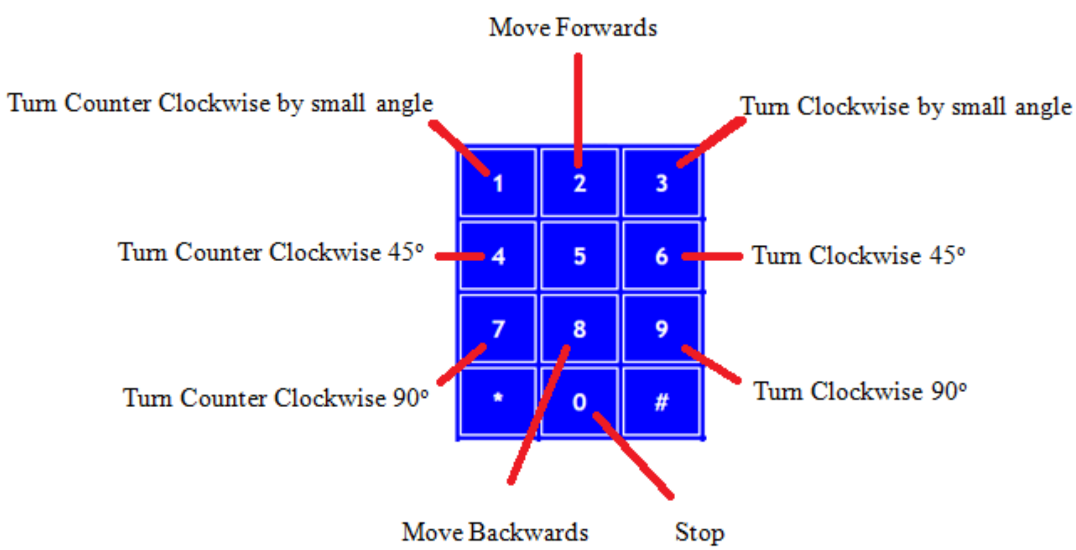


Figure 12: Keypad Controls

Code:

```
' {$STAMP BS2}
' {$PBASIC 2.5}

'Variables for DTMF
DTMFread VAR Byte 'read 4-bit signal from DTMF
counter VAR Word 'General purpose variable for increments
STQ PIN 0 'Pin indicates whether DTMF detects a signal from input device
Q1  PIN 4 '2^0 position in binary
Q2  PIN 3 '2^1 position in binary
Q3  PIN 2 '2^2 position in binary
Q4  PIN 1 '2^3 position in binary

'Variables for Ultrasonic Sensor
ultsonic PIN 15 'Pin used to interface Ultrasonic sensor
time VAR Word 'Time of flight measurement [2 microsecond units]
cmDist VAR Word 'Stores distance [cm] between Ultrasonic and object
'D[cm] = (1/2)*(100*344.8)*(T*2*10^-6)
'D[cm] = T*0.03448, multiply high *65536
'D[cm] = T[s]**2260
cmConst CON 2260

'Variables for Gas sensor MQ-5
Gasread PIN 8 'Used to read gas sensor voltage
'Variables for DS1620
RST PIN 5 'Activate DS1620 conversion
CLK PIN 6 'Clock
DQ PIN 7  'Receive data bytes
ds VAR Byte 'stores temperature measurement
degC VAR Byte 'temperature measurement in degrees celsius
waiting VAR Nib 'variable used to avoid chatter
waiting = 0
OUTS=%0000000000000000 'initialize all pin as low
HIGH RST 'start conversion sequence
SHIFTOUT DQ, CLK, LSBFIRST, [238] 'Command to convert temperature into digital code
LOW RST  'end conversion sequence
DO
'Temperature measurement using DS1620
HIGH RST 'start conversion sequence
SHIFTOUT DQ, CLK, LSBFIRST, [170] 'Command to send temperature reading to bs2
SHIFTIN DQ, CLK, LSBPRE, [ds] 'Stores measurement in variable ds
LOW RST  'end conversion sequence
degC = ds / 2 'Convert DS1620 reading to degrees celsius
IF ds>=55 THEN
  IF waiting<15 THEN
    waiting = waiting + 1 'waits for temperature reading to stablize above threshold
  ENDIF
ELSE
  IF waiting>0 THEN
    waiting = waiting - 1 'waits for temperature reading to stablize below threshold
  ENDIF
ENDIF
IF waiting>=10 THEN
  FREQOUT 14, 50, 1900 'Buzzes piezo transducer when temperature reading above threshold
ENDIF
PAUSE 5
```

```
IF Gasread = 1 THEN
  'if gas is sensed, Gasread goes high
  FREQOUT 14, 50, 1900
ENDIF


'Distance measurement using Ultrasonic
PULSOUT ultsonic, 5 'send out pulse for 10 microseconds
PULSIN ultsonic, 1, time 'record time taken for signal to return [2 microseconds]
cmDist=time**cmConst 'calculates distance [cm] using time and conversion factor
PAUSE 5
'Read signal from DTMF
IF STQ=1 THEN 'if keytone is pressed
  DTMFread = 0
  'converts binary returned by DTMF to decimal
  IF Q1=1 THEN
    DTMFread = DTMFread + 1
  ENDIF
  IF Q2=1 THEN
    DTMFread = DTMFread + 2
  ENDIF
  IF Q3=1 THEN
    DTMFread = DTMFread + 4
  ENDIF
  IF Q4=1 THEN
    DTMFread = DTMFread + 8
  ENDIF

  IF (DTMFread = 1) THEN
    'Rotates counterclockwise for as long as 1 is pressed
    PULSOUT 12, 650
    PULSOUT 13, 650
    PAUSE 20
  ENDIF
```

```
IF (DTMFread = 4) THEN
  PAUSE 20
  'Rotates counterclockwise 45  degrees
  FOR counter = 1 TO 8
    PULSOUT 12, 650
    PULSOUT 13, 650
    PAUSE 20
  NEXT
ENDIF

IF (DTMFread = 7) THEN
  PAUSE 20
  'Rotates counterclockwise  90  degrees
  FOR counter = 1 TO 19
    PULSOUT 12, 650
    PULSOUT 13, 650
    PAUSE 20
  NEXT
ENDIF

IF (DTMFread = 3) THEN
  'Rotates clockwise for as long as 3 is pressed
  PULSOUT 12, 850
  PULSOUT 13, 850
  PAUSE 20
ENDIF
 IF (DTMFread = 6) THEN
   PAUSE 20
   'Rotates clockwise 45 degrees
   FOR counter = 1 TO 8
     PULSOUT 12, 850
     PULSOUT 13, 850
     PAUSE 20
   NEXT
 ENDIF

 IF (DTMFread = 9) THEN
   PAUSE 20
   'Rotates clockwise 90  degrees
   FOR counter = 1 TO 19
     PULSOUT 12, 850
     PULSOUT 13, 850
     PAUSE 20
   NEXT
 ENDIF

ENDIF
```

```
IF cmDist>20 THEN
  'as long as robot is greater than 20cm away from object
  IF (DTMFread = 2) THEN
    'moves forward
    PULSOUT 12, 850
    PULSOUT 13, 650
    PAUSE 20
  ENDIF
ENDIF
IF (DTMFread = 8) THEN
  'moves backwards
  PULSOUT 12, 650
  PULSOUT 13, 850
  PAUSE 20
ENDIF
LOOP
```

Advantages and Disadvantages

The main advantages of using a DTMF based design is

1. Cost
2. Ease of use
3. The long range use capability (it can be used wherever there is mobile range)
4. Adaptability
5. Availability

The main disadvantages are

1. The Boe-Bot needs to be in line of sight
2. Needs to be in mobile tower range
3. Limited control capabilities (only able to use 4 bits or 0 through 15 to control the robot and or any Additional functionality)
4. Security (anyone can make a call to the robot and control it)
5. Gas sensor is not accurate after long duration of use.
6. Cannot climb
7. Cannot detect wall approaching from an angle

Cost Analysis

The major part of the cost of the whole project was the Boe-Bot kit itself. The DTMF decoder itself is of very less cost and the other sensors are also of negligible cost. Mass production of the kit can cause the cost to go down even more.

Further possible developments

We could make this a line following robot that checks for gas leaks at regular time intervals or if initialized. If a gas leak is found during the regular checks then we could make a specific call using the DTMFOUT functionality in the BS2 Board.

References

[1] MT8870D. Microsemi Corporation, n.d. Web. <http://www.microsemi.com/products/telephony/dtmf-receivers/mt8870d#docs-amp-specs>

[2] "DTMF Format." *Genave*. Genave Electronics, n.d. Web. <http://www.genave.com/dtmf.htm>

[3] E. "DS1620 Digital Thermometer and Thermostat." *DS1620* (n.d.): n. pag. *Data Sheets*. Maximintegrated. Web. <http://datasheets.maximintegrated.com/en/ds/DS1620.pdf>

[4] Tajan, V., Paul Gonnard, and M. Troccaz. "Elaboration of PZT Thick Films by Screen Printing." *3rd International Conference on Intelligent Materials and 3rd European Conference on Smart Structures and Materials* (1996): n. pag. Web. <https://www.parallax.com/sites/default/files/downloads/28029-Smart-Sensors-Text-v1.0.pdf>

[5] "Technical Manuals." *MQ-5 GAS SENSOR* (n.d.): n. pag. *Parallax*. HANWEI ELECTRONICS CO.,LTD. Web. <https://www.parallax.com/sites/default/files/downloads/605-00009-MQ-5-Datasheet.pdf>