MARMARA UNIVERSITY
FACULTY OF ENGINEERING

GRADUATION PROJECT

Sound Source Direction Estimation Using by Microphone Array

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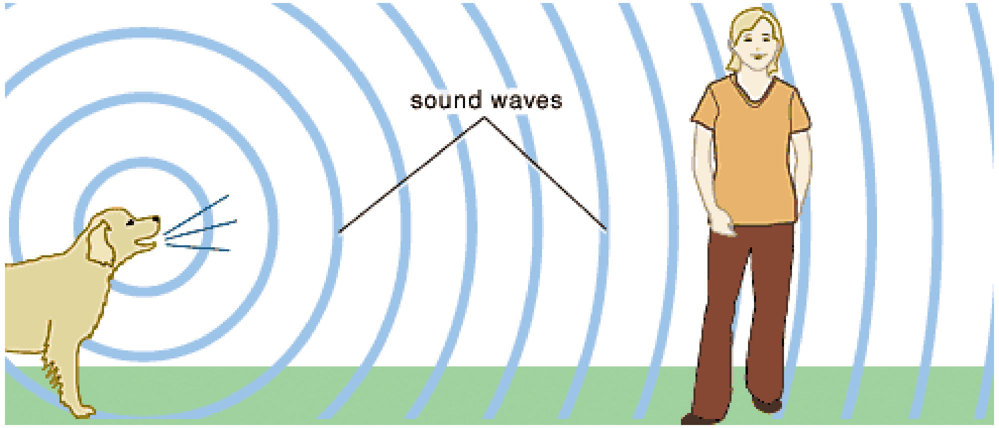
ABSTRACT



Application of sound energy → Sonar systems, security devices, ultrasound imaging and many more

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Our two ears analyze coming voices and locate where they come from. With taking inspiration of it, we aimed to locate the sound source and work like a radar. As we found the location, we aim for pointing the source of voice using a pointer motor.

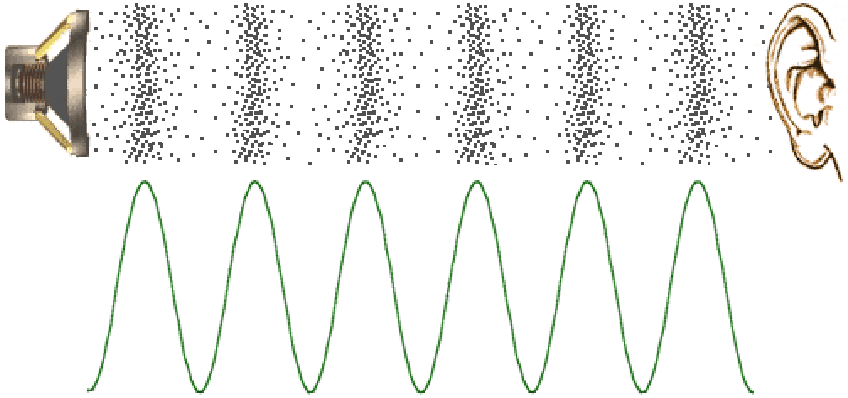
Physics of Sound

- It is a mechanical energy.
- In dry air at 20 °C, the speed of sound is 343 meters per second.
- The sound wave vibrates the air and travels to microphones

$$v_{sound\ in\ air} \approx 331.4 + 0.6T_C \ \ m/s$$

for temperatures reasonably close to room temperaature, where T_C is the celsius

Variations in Air Pressure and Corresponding Waveform



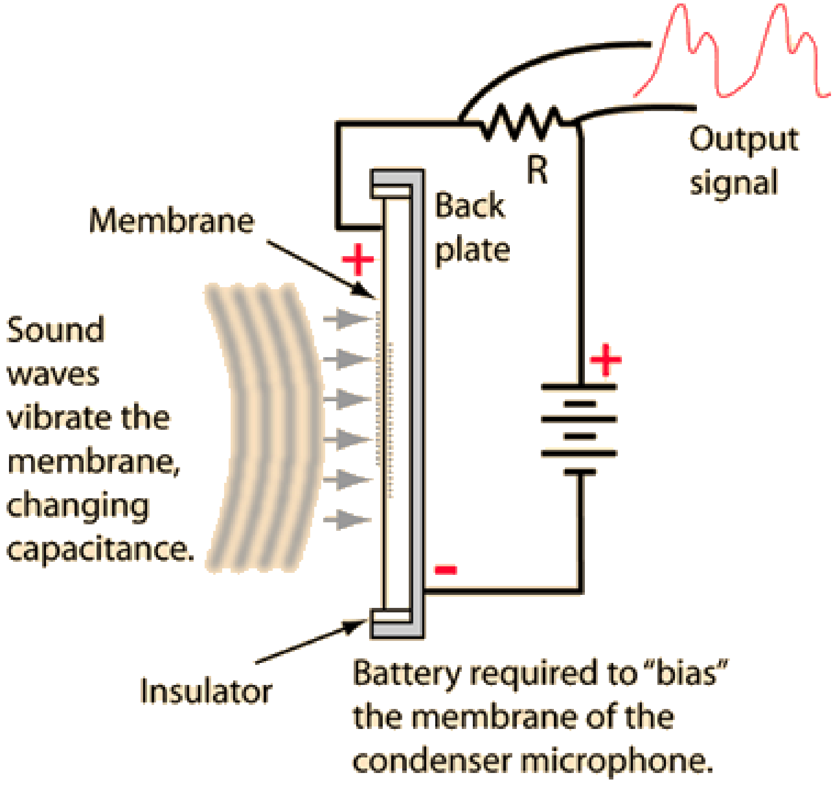
Air molecules do not actually travel from the loudspeaker to the ear (that would be wind).
Each individual molecule only moves a small distance as it vibrates, but it causes the adjacent molecules to vibrate in a rippling effect all the way to ears or microphones.

METHODS

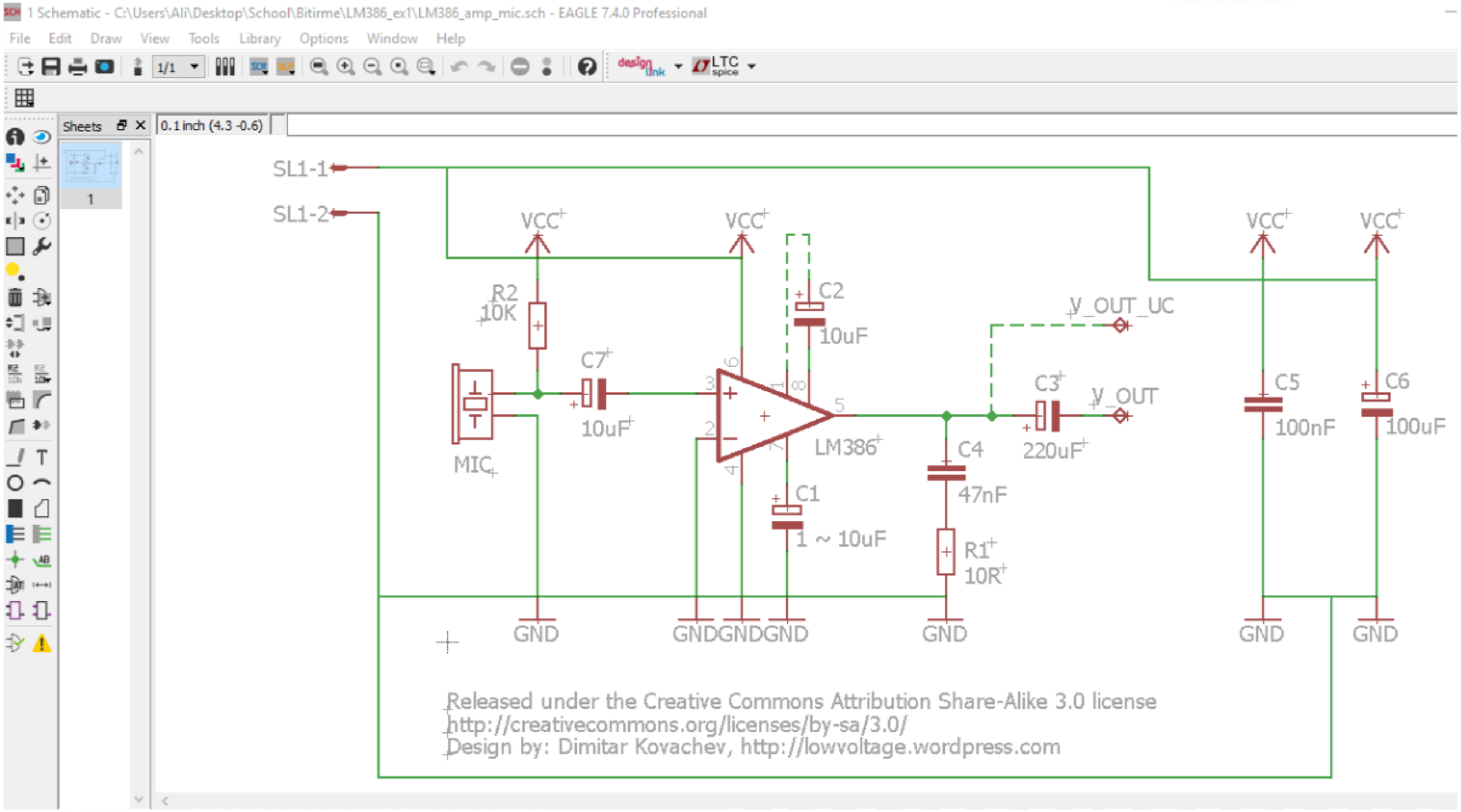
From Sound-Waves to Electrical Energy

Capacitive microphones

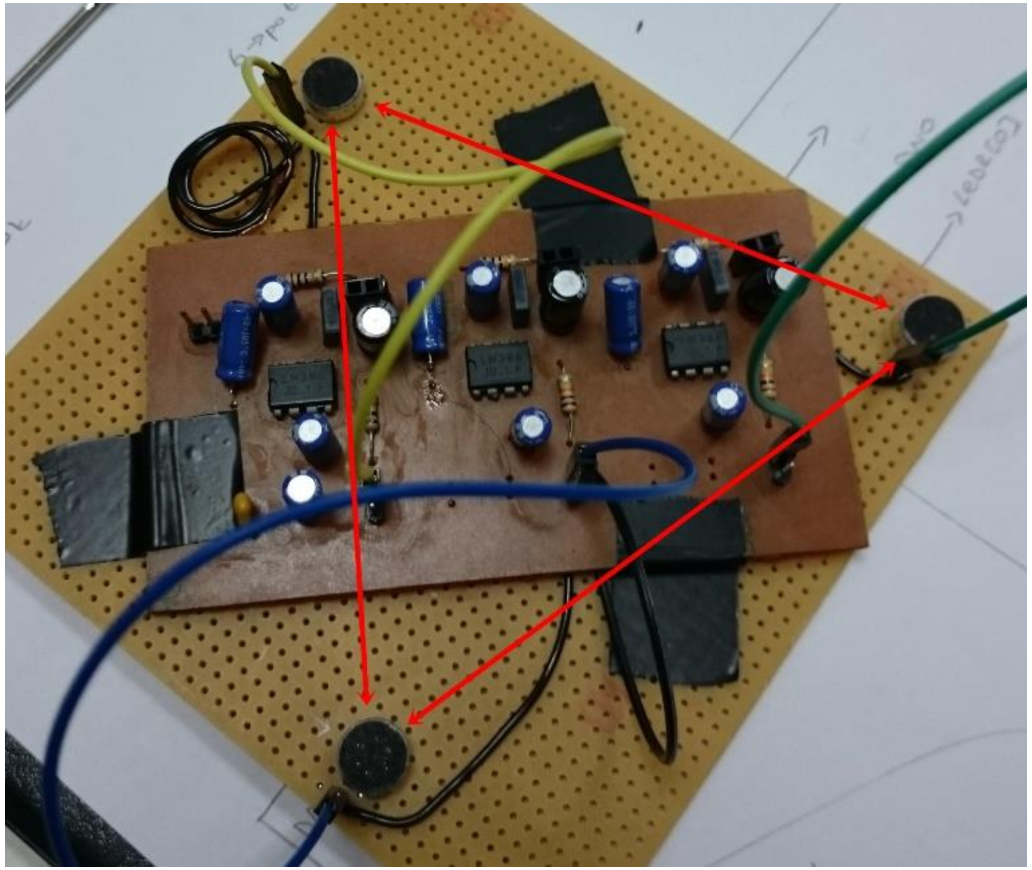
Audio amplifiers (LM386 ic op-amp) to amplify signal from microphone



Printed Circuit Board by using EAGLE



First Prototype



Triangle shape

Three microphone

Three amplifier circuit

Microphone Spacing & Quantities

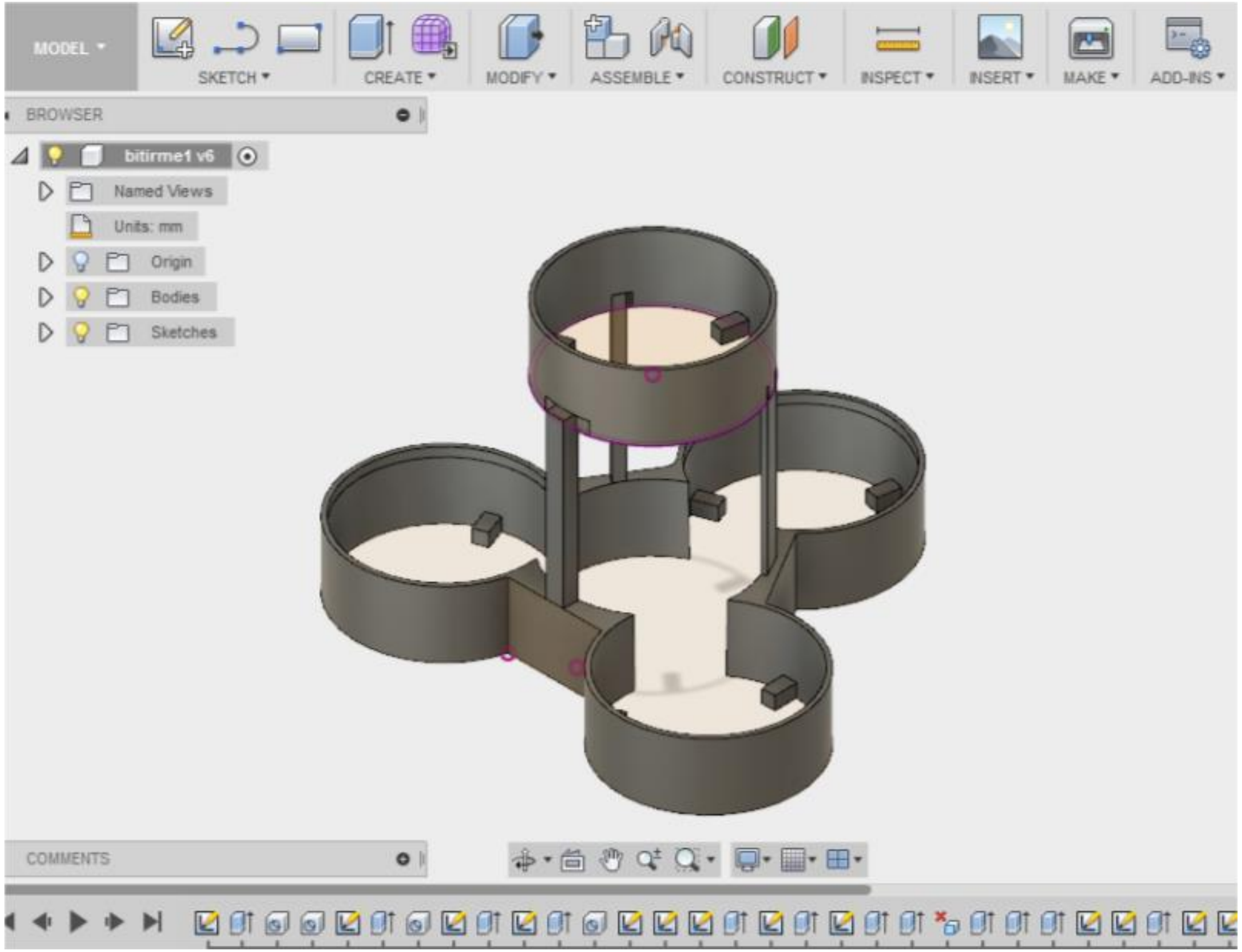
One-microphone: just hearing something, no info about direction

Two-microphone: gives points which are at same distance to microphones respectively. It means a circle.

Three-microphone: gives the particular point of source (above surface)

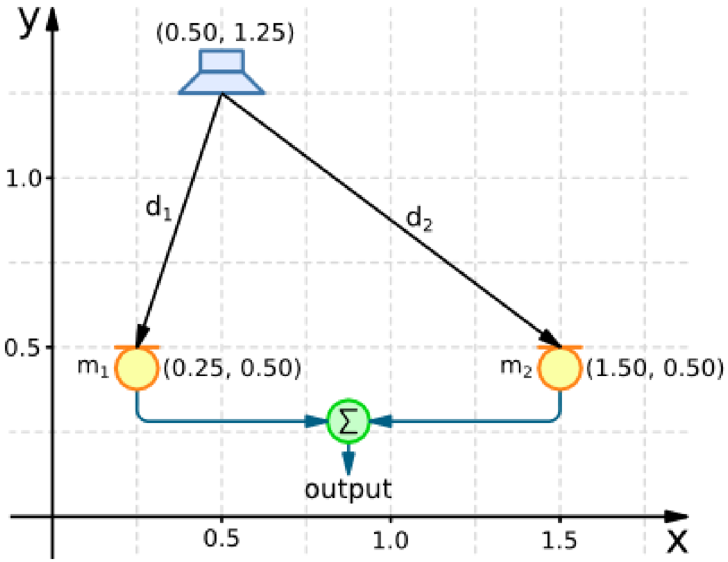
Four-microphone: gives points under surface also.

3D printing by using Fusion 360



Placing microphones into sockets as an triangular pyramid

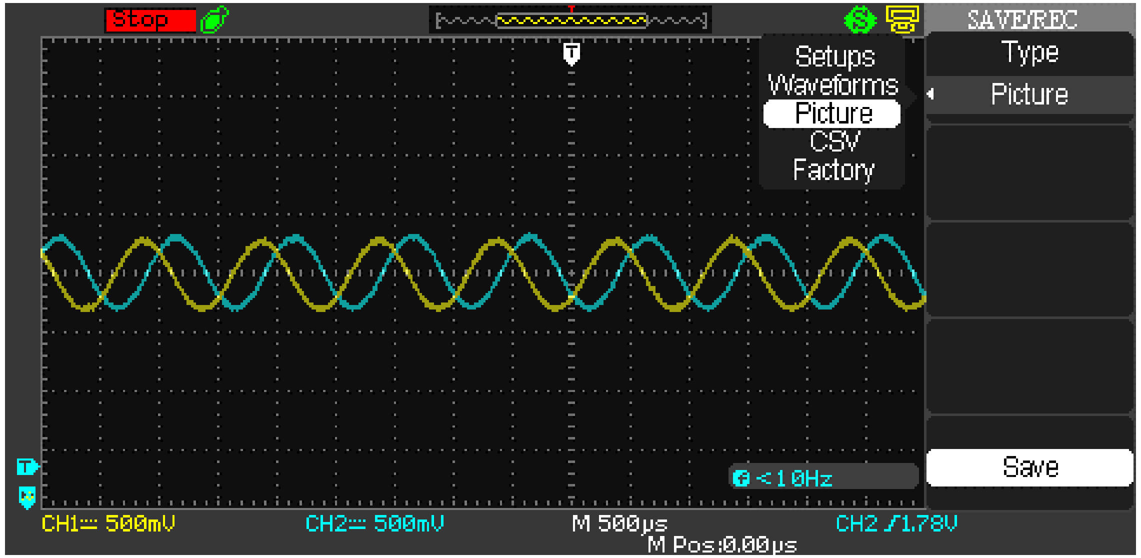
Delay Calculation



$$d_1 = \sqrt{0.25^2 + 0.75^2} = 0.7906\text{m}$$
$$d_2 = \sqrt{1.00^2 + 0.75^2} = 1.2500\text{m}$$

if $c = 343$ m/s

$$t_1 = \frac{0.7906}{343} = 2.3049\text{ms}$$
$$t_2 = \frac{1.2500}{343} = 3.6443\text{ms}$$



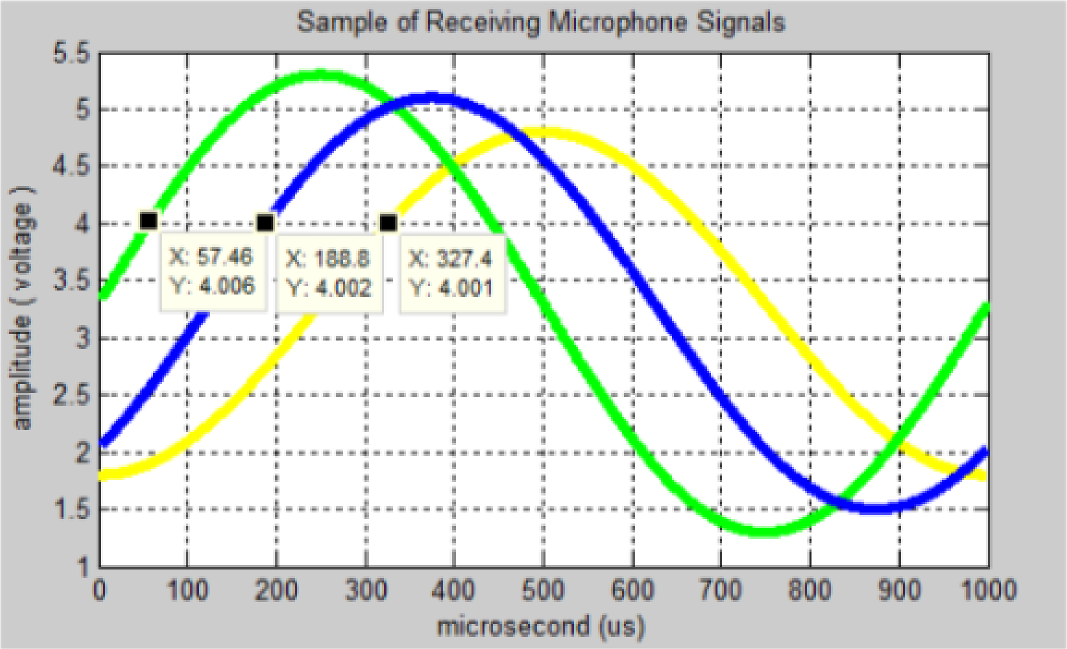
A sample of delay calculation for two microphones

Mic1 is triggered. Let’s say t1=0

Delay to mic2 after mic1 is received: t2-t1=delay2

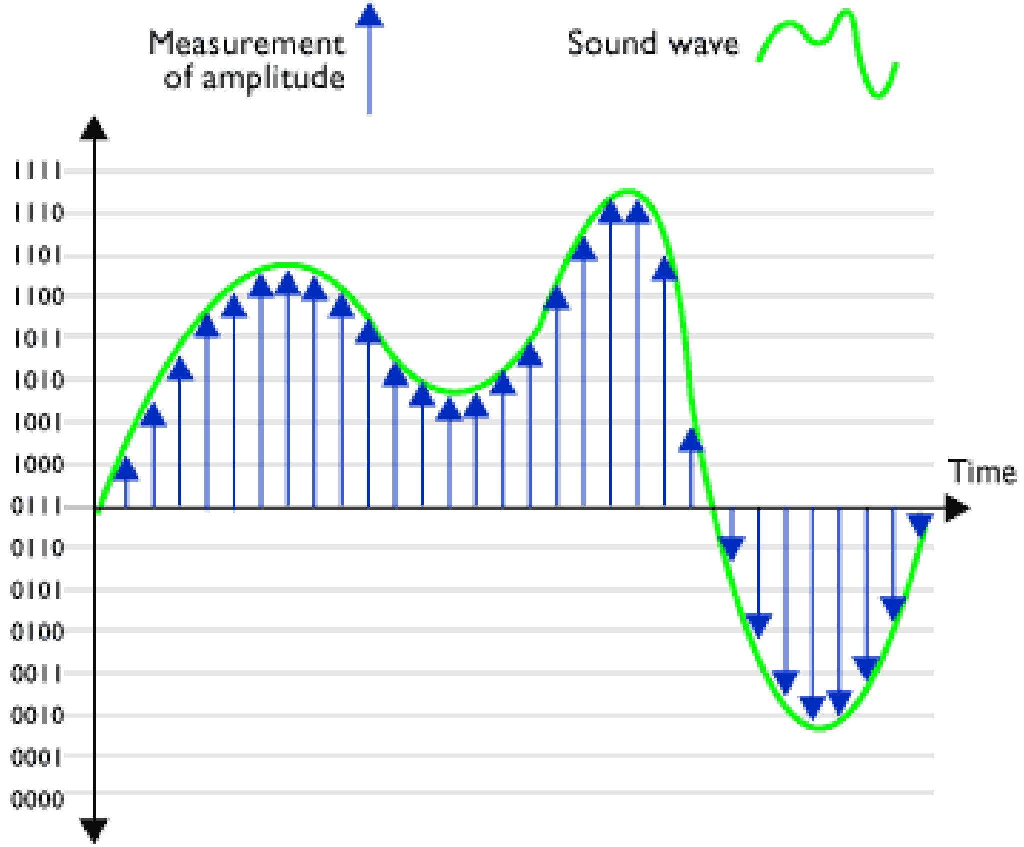
Delay Times for 3-microphone case

Delay times of three signals are shown in the graph below. Phase differences between every receiving sound signal can find out by selecting threshold voltage value (it’s 4 V at this example).

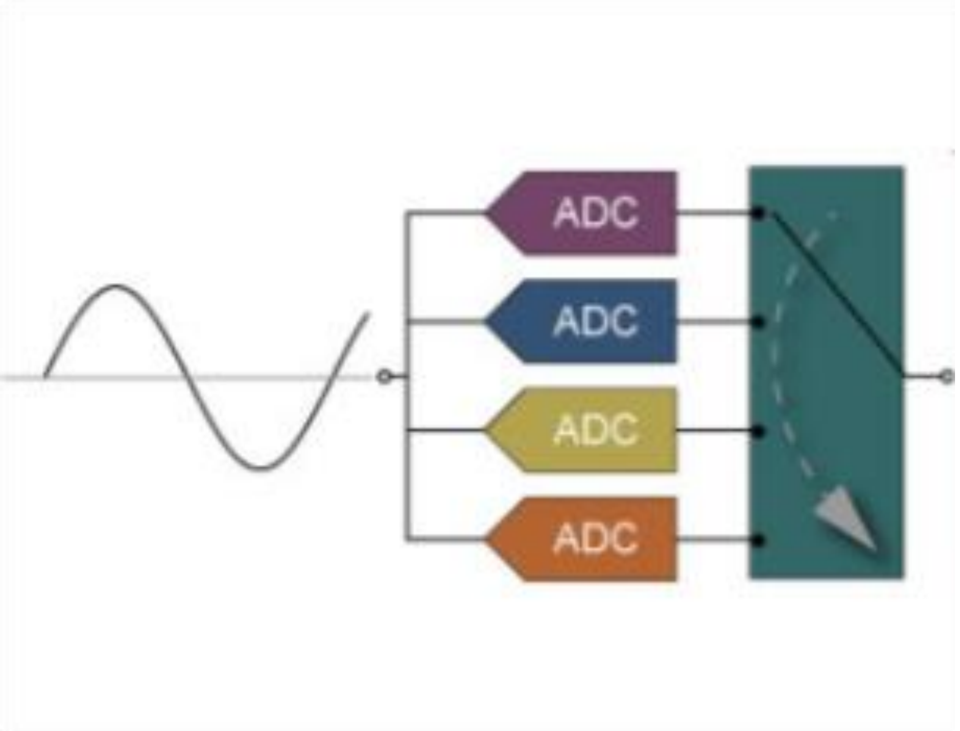


By looking delay times points at graph, we can estimate position for the sample above.

Analog-To-Digital

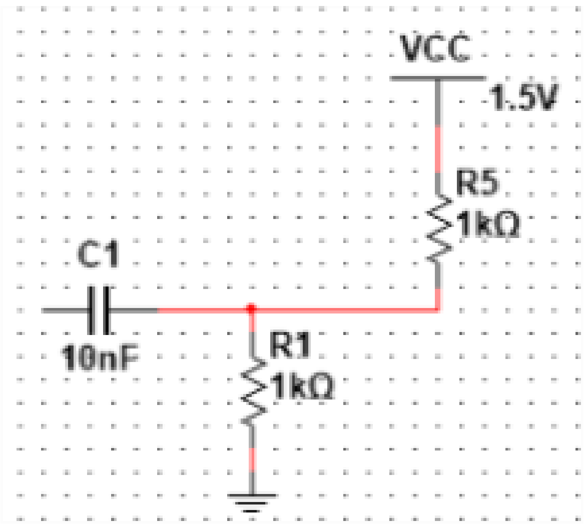


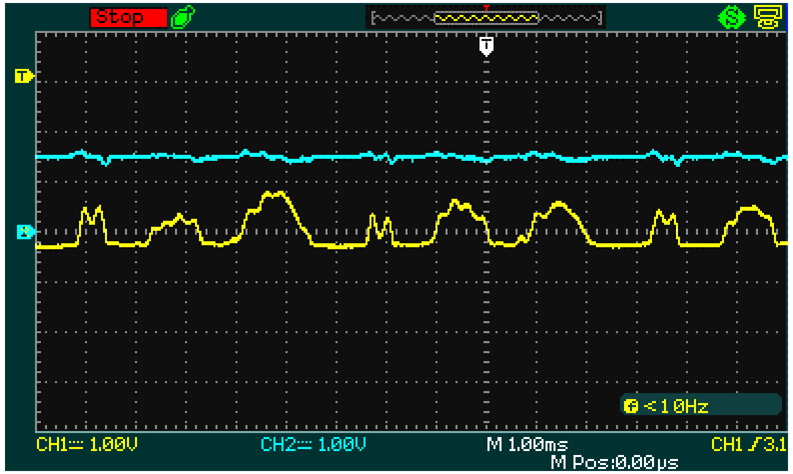
Each measurement is assigned a number (byte) according to its amplitude. The end result is a file comprising a string of bytes, eg ...
1001 1110 0001 1010 0111 0100 1111 1101 etc

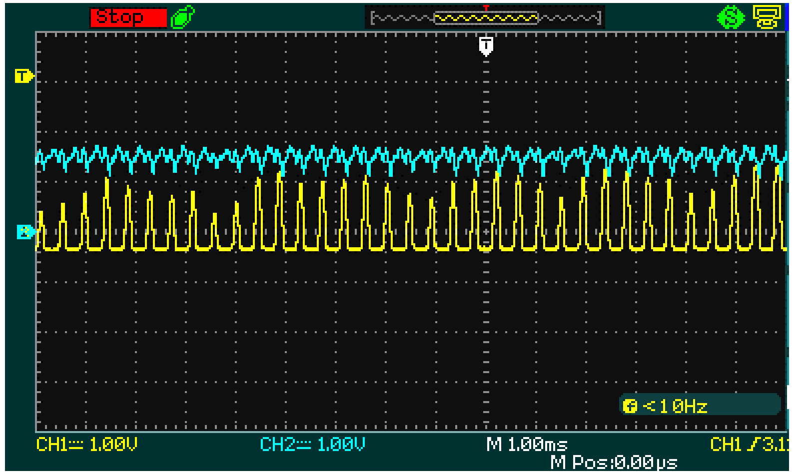


Filtering The Sound

- RC high pass circuit
- 1.5 V pull-up







CH1 Low frequency signal
CH2 Filtered signal

CH1 High frequency signal
CH2 Filtered signal

Taking Delays to uC

- Afer the sound trigger the closest microphone:

Delay2: delay time to second received microphone

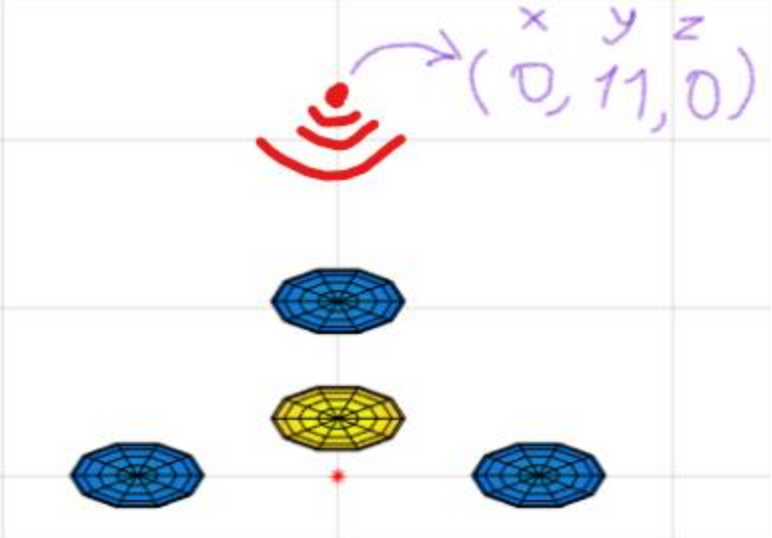
Delay3: delay time to third received microphone

Delay4: delay time to fourth received microphone

- Distance between each microphone = 6 cm

  Max delay time = 176 us

- Stm32 uC is calibrated 1M Hz clock work. In otherwords ADC sampling frequency = 1 MHz



For example;

First mic is mic1.

Delay2=130us

Delay3=130us

Delay4=155us

Calculations

```
  // 343m/s speed sound takes 6cm distance in 174.9us
  speedOfsound=343; // meter/second
  speedInCmUs=speedOfsound*0.0001;  // cm/us
  //Cx=174*speedInCmUs;

  // Convert times values into cm
  delay2 = times[1] * speedInCmUs;
  delay3 = times[2] * speedInCmUs;
  delay4 = times[3] * speedInCmUs;

//  delay2=0.5927;
//  delay3=3.5332;
//  delay4=3.9540;

  SystemCoreClockUpdate();
  if (SysTick_Config(SystemCoreClock/SystemCoreClock)) {
    while (1);
  }


  sel_error=1000;

  for(x=-spaceSize; x<spaceSize; x+=stepSize){
    for(y=-spaceSize; y<spaceSize; y+=stepSize){
      for(z=0; z<spaceSize; z+=stepSize){

          loc_sound[0]=x;loc_sound[1]=y;loc_sound[2]=z;
          dist_mic1=distance(loc_mic1[0],loc_mic1[1],loc_mic1
          dist_mic2=distance(loc_mic2[0],loc_mic2[1],loc_mic2
          dist_mic3=distance(loc_mic3[0],loc_mic3[1],loc_mic3
```

In a test point (-10, 11,3);

Trigger mic is mic1.

Delay2=70

Delay3=95

Delay4=130

There is very big error between measured and calculated values.

In another test point (-2,11,0);

Delay2=120

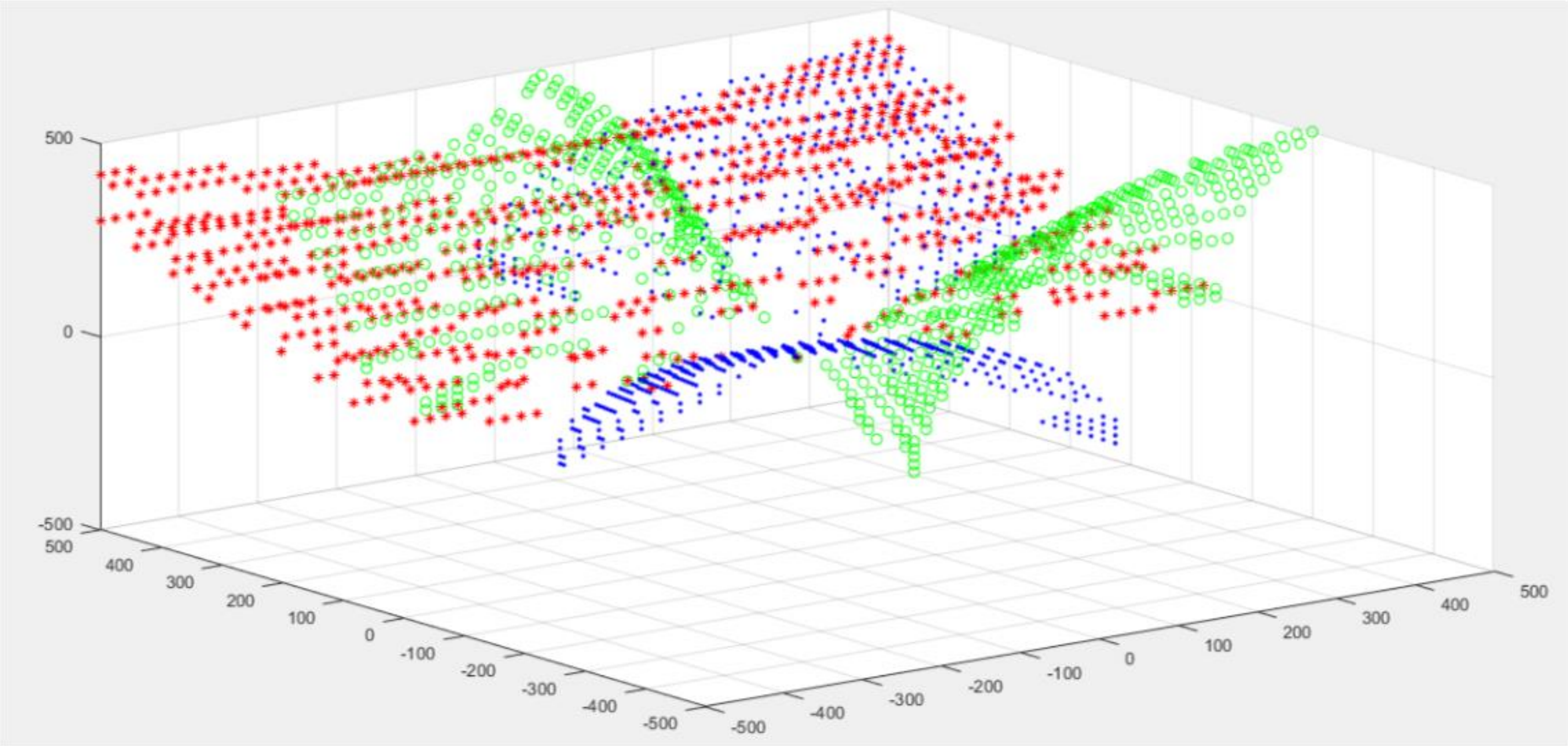
Delay3=130

Delay4=155

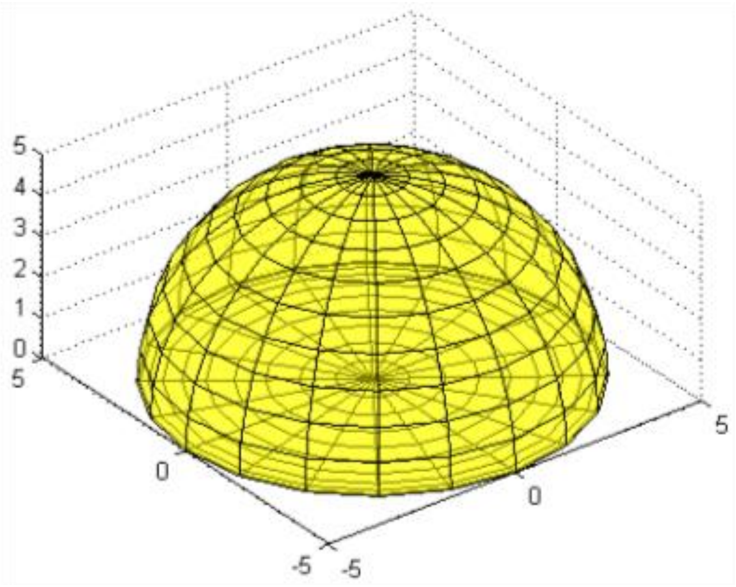
Error is very small. This virtually point is very close to sound position.

Calculations

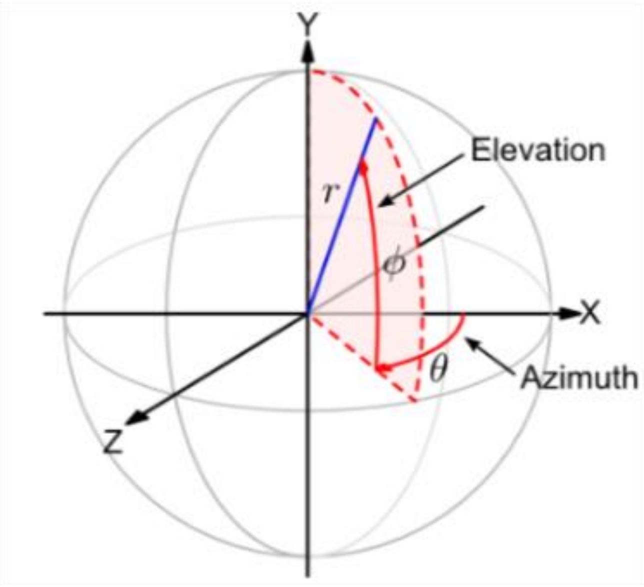
Figure:Matlab space scanning..



Showing Direction

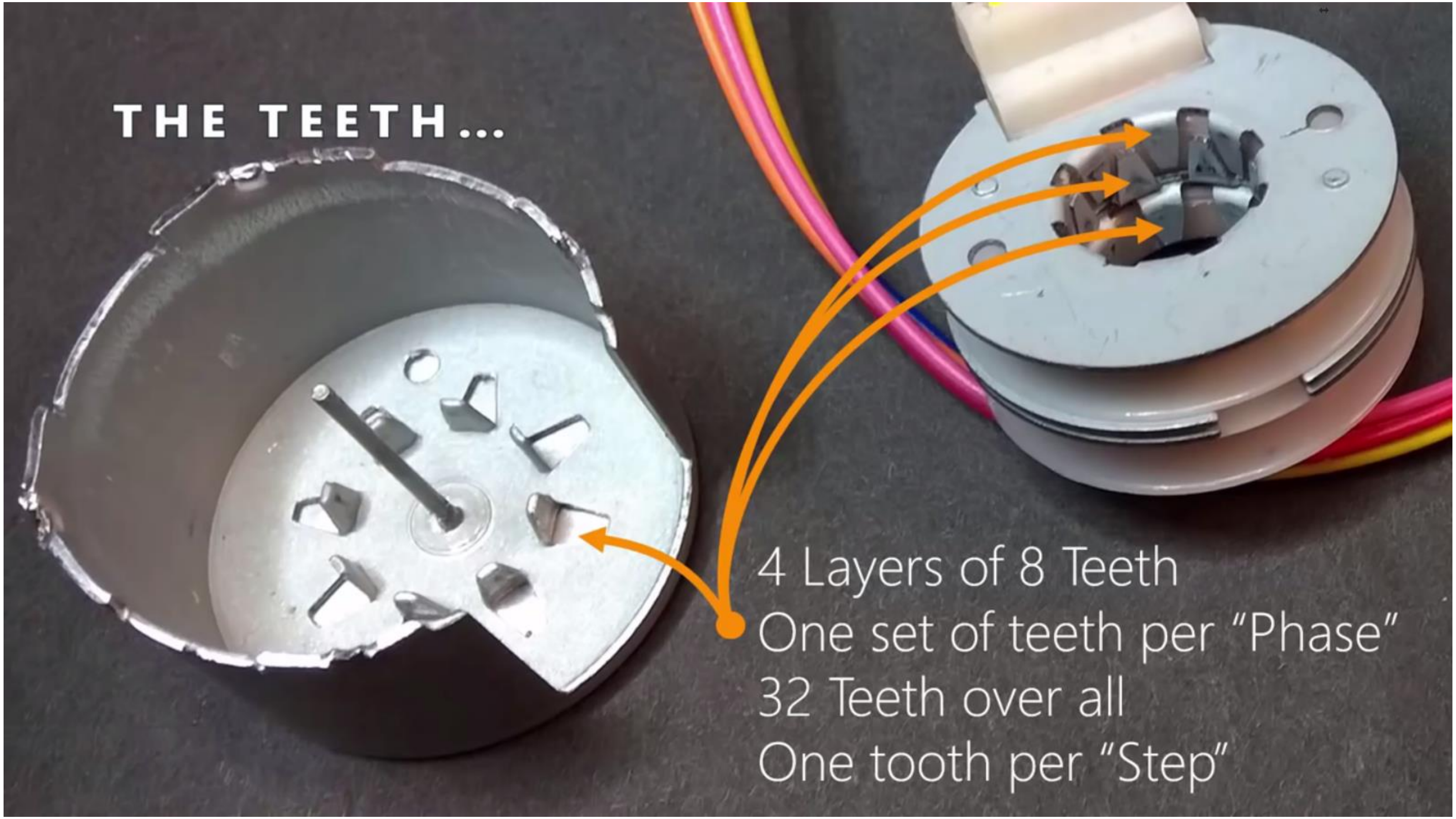


A dome as a scanning space



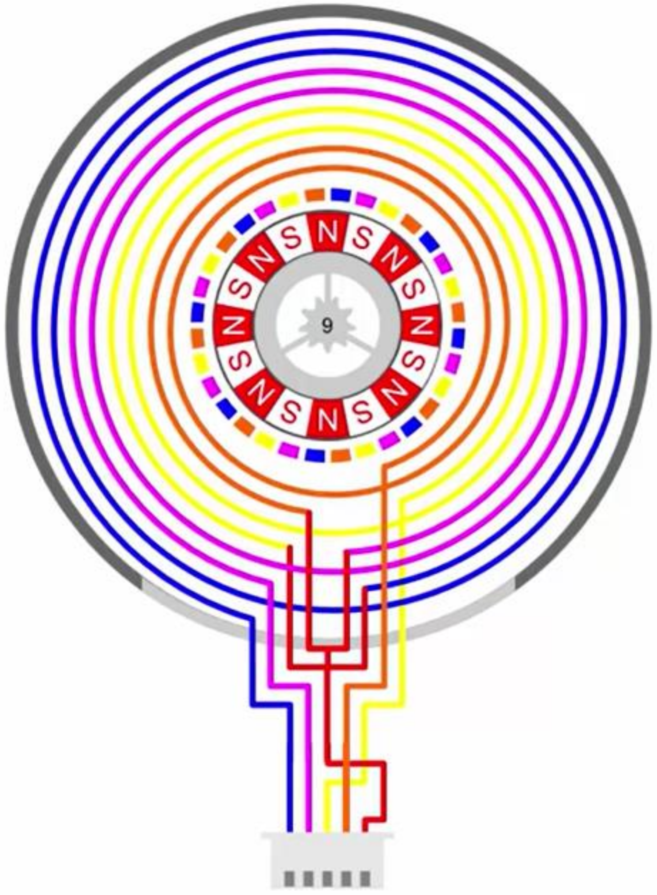
Polar and Cartesian coordinate systems. The orientation of these axes is used by calculating delays.

Showing Direction



Showing Direction

28BYJ-48 MOTOR ELECTORMAGNETICS



The 28BYJ-48 is a Unipolar Stepper Motor (as opposed to Bipolar).

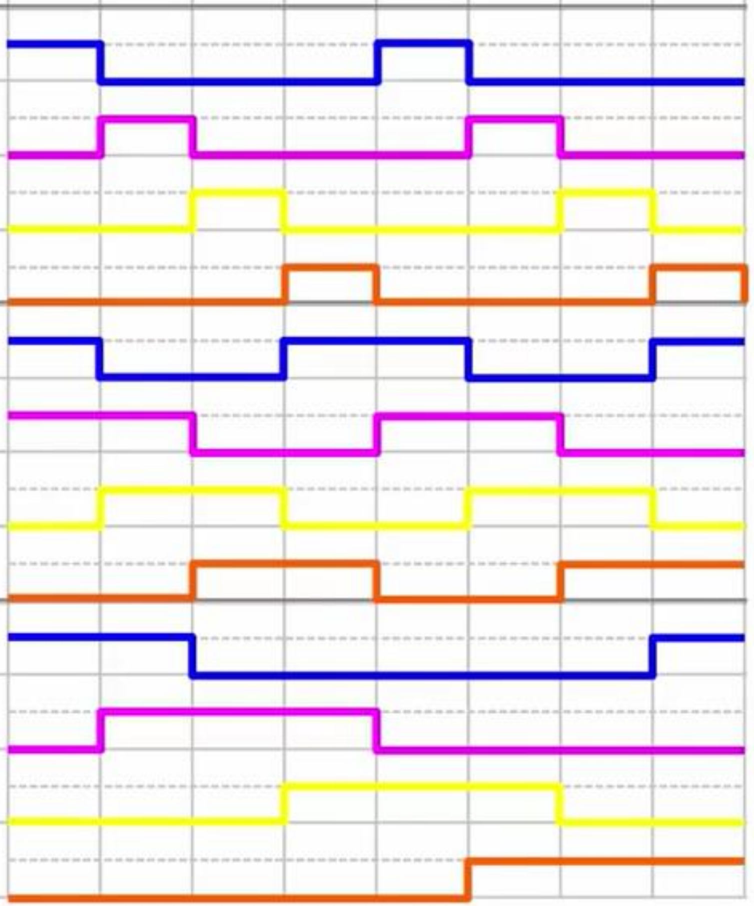
With Unipolar motors, you don't need to change the polarity of the voltages on any give lead. That means that you don't need an H-Bridge to reverse the polarity.

The common center taps are connected to +5VDC. You then use some circuitry (the ULN2003 Array in this case) to pull the appropriate coil ends to ground to energize their respective half of the coil.

STEPPING METHODS

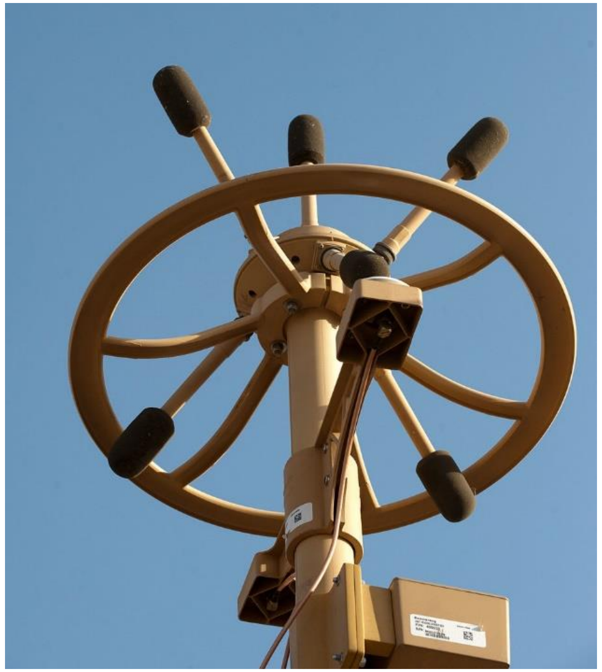
STEPS

METHODS	PHASES	1	2	3	4	5	6	7	8
WAVE DRIVE One phase at a time Simplest, but least used	BLUE								
	PINK								
	YELLOW								
	ORANGE								
FULL STEP Two phases at a time Strongest Torque	BLUE								
	PINK								
	YELLOW								
	ORANGE								
HALF STEP One, or two phases at a time Smallest step angle Medium torque	BLUE								
	PINK								
	YELLOW								
	ORANGE								



CONCLUSION

Military defense, tracking systems, security technology can be fields of application.



YANKI was developed by Aselsan

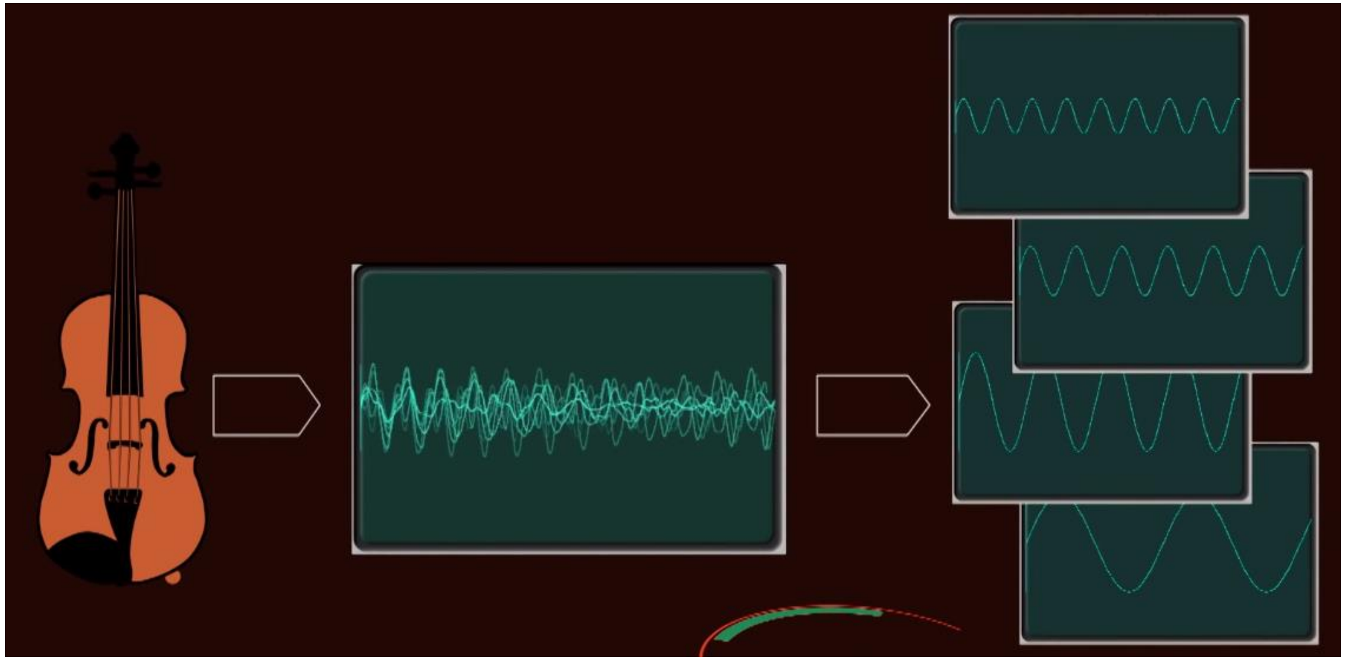
Boomerang III is used in Afghanistan by USA.
Boomerang Warrior X is wearable version.

A defense system can be triggered by a sniper gunshot.

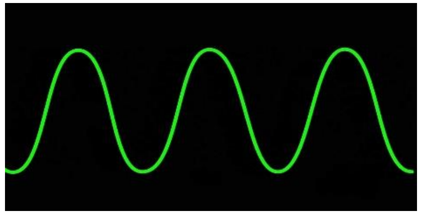
CONCLUSION

It can be used for tracking camera when a speaker talks.

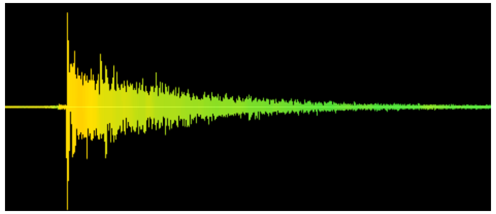
Future Work



Physicist Joseph Fourier

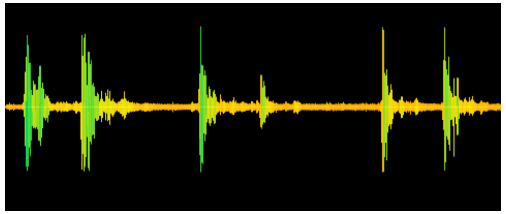


Sine wave



Shotgun

Thunders



Sniper gun

Thanks for listening