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Electronic Distance Measurement

Group No. D-3
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Abstract

This project is aimed at designing an electronic distance measurement system to aid collision detection for vehicles. We would be using microwaves and the principle of Frequency Modulated Continuous Wave RADAR to measure the distance between the two objects. Depending upon the change in distance and rate of change of distance we will make calculations to detect a possible collision

Contents

1. Introduction

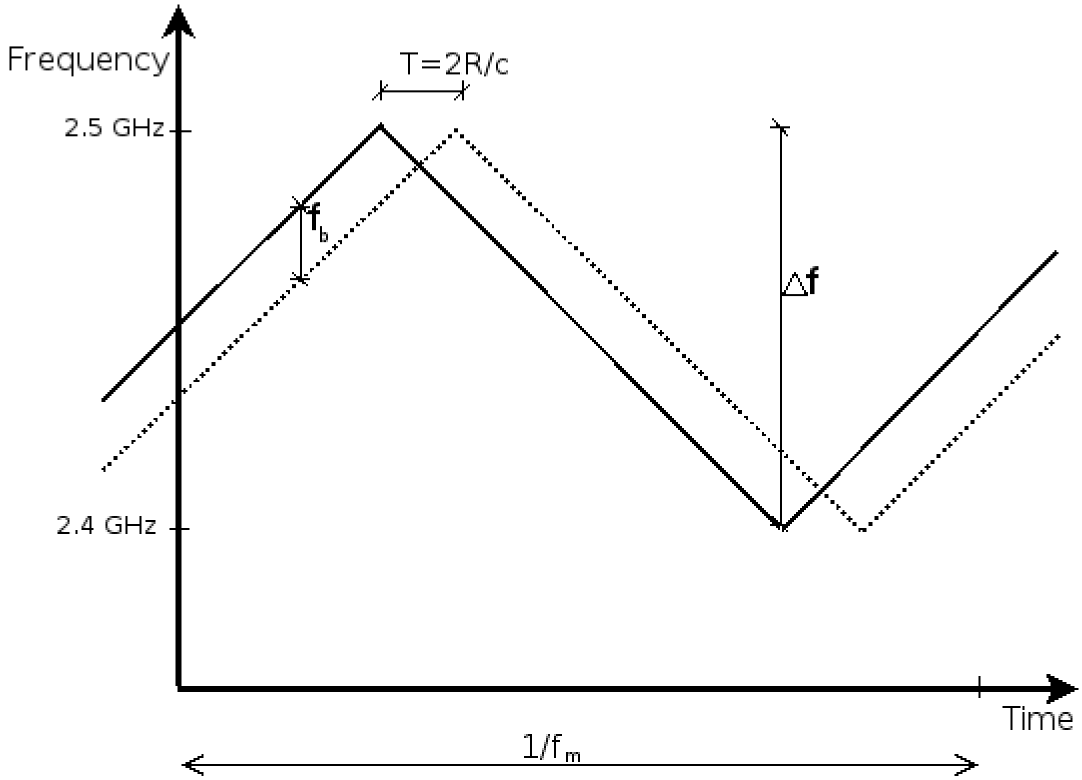
1.1. Objective

To measure distance between two vehicles using microwaves. We will be using the principle of Frequency Modulated Continuous Wave RADAR for the same. The transmitter and received waves are heterodyned and the distance is directly proportional to this beat frequency.

1.2. Principle of Working

The transmitter of the system transmits a wave in the range of 2.4 GHz to 2.5 GHz, which is modulated either by a sawtooth waveform or a triangular waveform.

The echo is heterodyned with the Local Oscillator signal and the *beat*



$$f_b = (2R/c)(\Delta f)/(1/2f_m)$$

$$f_b = (4R.\Delta f.f_m)/c$$

Figure 1: Range Calculation of FMCW radar

frequency is obtained. From the beat frequency we can obtain the range which is given by the formula

$R=(cf)/(4f_m\Delta f)$

where

R = the range of the target
c = the speed of light
f = the beat frequency that is measured
f_m = the frequency of the modulating waveform.
Δf = sweep in the VCO frequency

This formula is explained in Figure 1.

1.3. Main components used and Block diagram

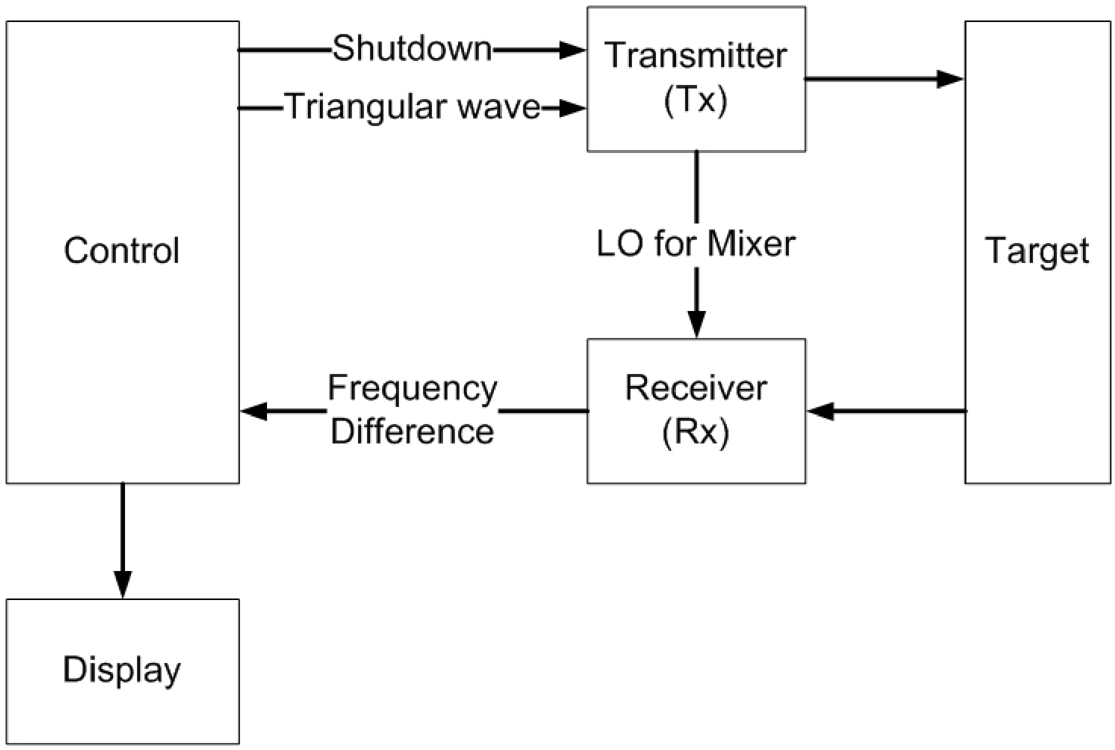


Fig 2 . Block Diagram of Circuit

- Voltage Controlled Oscillator (VCO) : The VCO is used in the generation of microwaves in the range of 2.4 GHz to 2.5 GHz. The VCO that we would be using is the MAX2750.
  The VCO has only 8 pins and the output frequency at pin 7 is proportional to the input voltage applied at pin 2. This VCO also has a power saving mode which enables the VCO to power down when not in use by making shutdown pin (pin 4) low when not in use. This VCO operates on a power supply between the range 2.7 V to 5.5 V

- Low Noise Amplifier (LNA) : The LNA is used to amplify the received signal to a level such that the mixer can detect and use it. The LNA used is the BGA430 which provides a 15dB gain at a frequency of 2450 MHz. This LNA operates on a power supply of upto 6.5 V It is a 6 pin IC with 3 pins as ground and one each for the supply RF input and RF output.

- Mixer : The mixer we have used is the AD8343 from Analog Devices. This is a high performance active mixer and operates upto 2.5 GHz. This is the component that will heterodyne the transmitted and received waveform to give the beat frequency. The mixer uses a single power supply of 5 V for operation

- Microcontroller : We use the microcontroller AT89c2051 to measure the input frequency and display it on an LCD display. This microcontroller will calculate the distance depending upon the frequency and output it to the LCD display. It will also control the VCO and set it to power down state when not in use. A single 5 V supply is needed for the operation of this microcontroller

- Triangular Wave Generator : We use XR8038 for generating a triangular wave. This IC uses a single power supply of 10V and will generate a triangular wave depending upon its configuration.

- Amplifier : We use OPA847 which is a high speed amplifier from Texas Instruments. This is needed to convert the sine wave input from the receiver into a square wave input to be fed to the micro controller. This is a surface mount chip which is available in the SOIC-8 package. It needs a power supply of upto 6.5 V.

- Resistors and Capacitors : We are using chip resistors and capacitors of the 0603 and 1812 package for our RF components.

2. Design Approach

The project is organized mainly into 3 parts. The transmitter section, the receiver section, and the microcontroller section (which mainly consists of calculating the received beat frequency).

We are using a VCO to generate a wave in the frequency range of 2.4 GHz to 2.5 GHz and the output of the VCO is coupled to a driver amplifier which in turn is connected to an antenna.

The Reflected wave is received by an antenna and then amplified using a low noise amplifier. This received wave is then heterodyned using a mixer and the output is passed through a band bass filter and then through a hard limiter which converts the sine wave into a square wave.

To measure the frequency of the wave we are using the microcontroller AT89c2051 and its two internal timers T0 and T1.

The VCO requires a triangular waveform input between 0.75 V and 1.75 volts we obtain the triangular wave from the XR8038 which is a triangle wave generator and to get it to the required limits we are using an OpAmp as an adder.

3. Design Of Main Circuit

The project is divided into three sections as mentioned earlier. Now we shall explain how each section has been implemented.

2.1. Transmitter System:

The transmitter system block diagram is shown in Figure 3.

The transmission system mainly consists of a voltage controlled oscillator (VCO), a driver amplifier and a power amplifier whose output is fed to a matched antenna (or else an impedance matching circuit is needed in between).

In out transmitter system we need the output frequency to be swept from 2.4 GHz to 2.5 GHz. So there is a triangular wave input which is given to the VCO which in turn modulates the frequency between 2.4 GHz and 2.5 GHz.

The output of the VCO is then fed to a T-junction Power splitter. This is done to split the signal into two, one of which is the transmitter output, while the other is used as an input to the mixer for detection purposes.

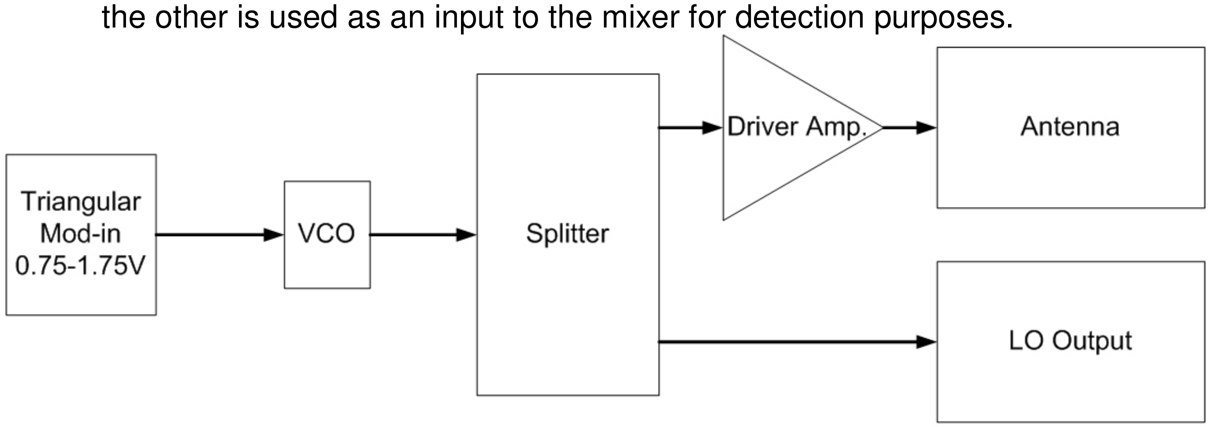


Fig 3. Block Diagram of transmitter

The driver amplifier and the power amplifier are used to further boost power before transmission. The power amplifier may or may not be used depending on our power needs.

The antenna is used as the final stage in transmission and should be matched to the internal circuit

The components used in this system are
1. VCO : MAX 2750 (2.4 GHz - 2.5 GHz VCO)
2. T-Junction Splitter : Designed on PCB board itself
3. Driver Amplifier : MMG3001NT1(High frequency transistor)
4. Antenna : High directivity antenna to be Provided by Prof. Girish Kumar.

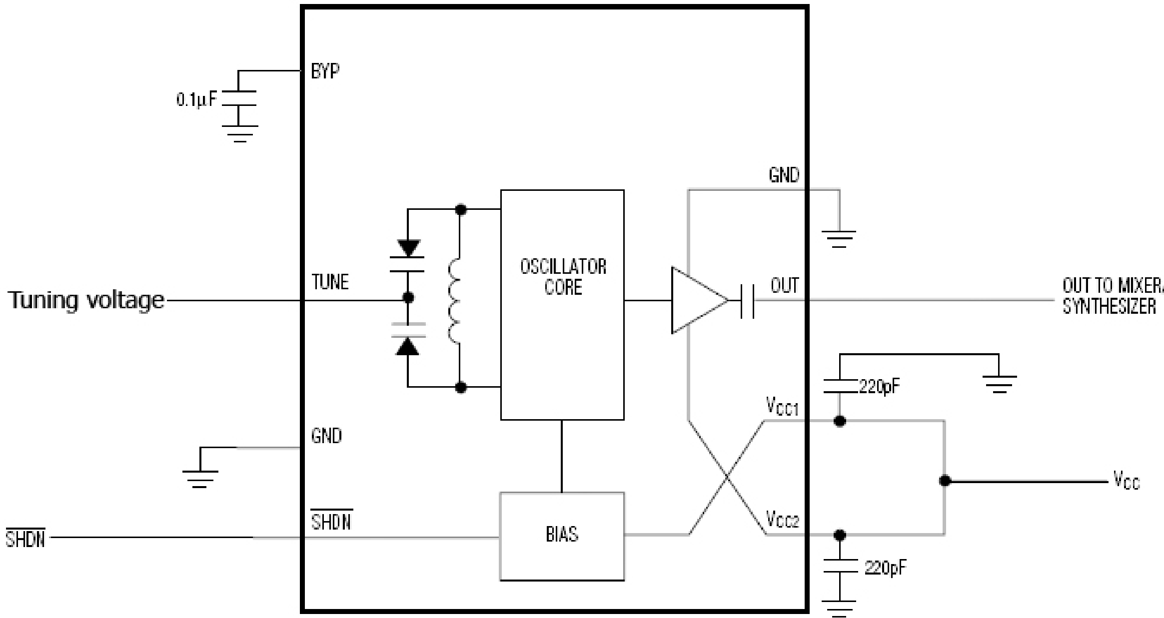


Fig 4. Circuit Diagram of VCO

2.2. Receiver system:

The block diagram of the receiver system is shown in Figure 5.

The receiver system consists of a receiving antenna, a low noise amplifier(LNA) a mixer and a band pass filter.

The antenna receives the signal and the passes it through to the low noise amplifier which amplifies the very low power signal to a higher value. This signal amplified to a larger level we can then feed this to the mixer,to which the other input is the signal generated by the VCO. Once these two signals are heterodyned and then passed through a band pass filter we can get the difference of the two frequencies.

This output is given to the microcontroller part which calculates the frequency and hence the distance as per the formula given before.

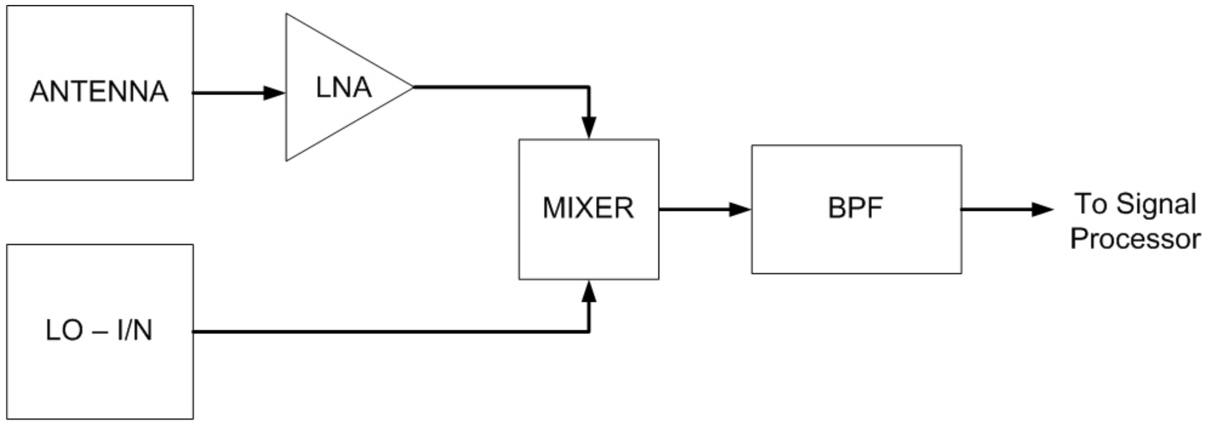


Fig 5. Block Diagram of Receiver

The components used in this section are :
1. LNA: MAX 2641
2. Mixer: AD8343
3. Band pass filter: designed to allow frequencies of 10 Hz to 500 kHz of the Butterworth type.

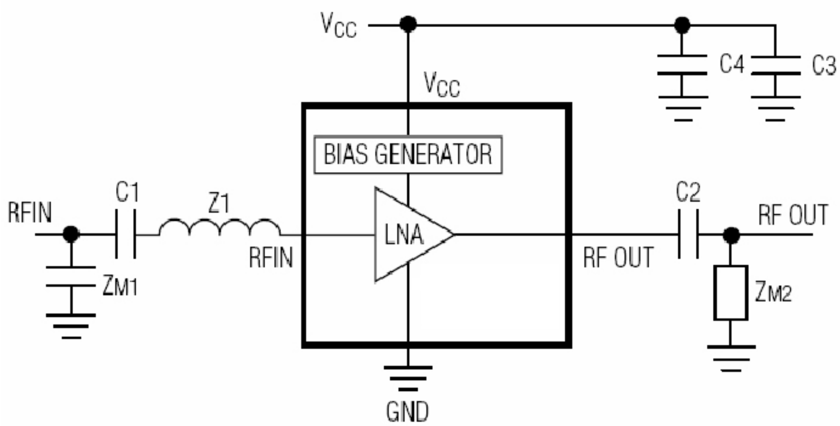


Fig 6. Circuit Diagram of LNA

2.3. Microcontroller System:

The block diagram for this is shown is Figure 7.

The microcontroller system has two functionalities, namely to generate the triangular waveform to be fed to the VCO and to measure the frequency from the receiver section.

The triangular waveform we need is from 0.75 V to 1.75 V. This is so that the VCO will oscillate between the frequencies of 2.4 GHz to 2.5 GHz. This is obtained by using XR8038 waveform generator, which is coupled to an OpAmp in adder configuration to get the waveform to the required level. This level can further be adjusted by the use of two precision pots.

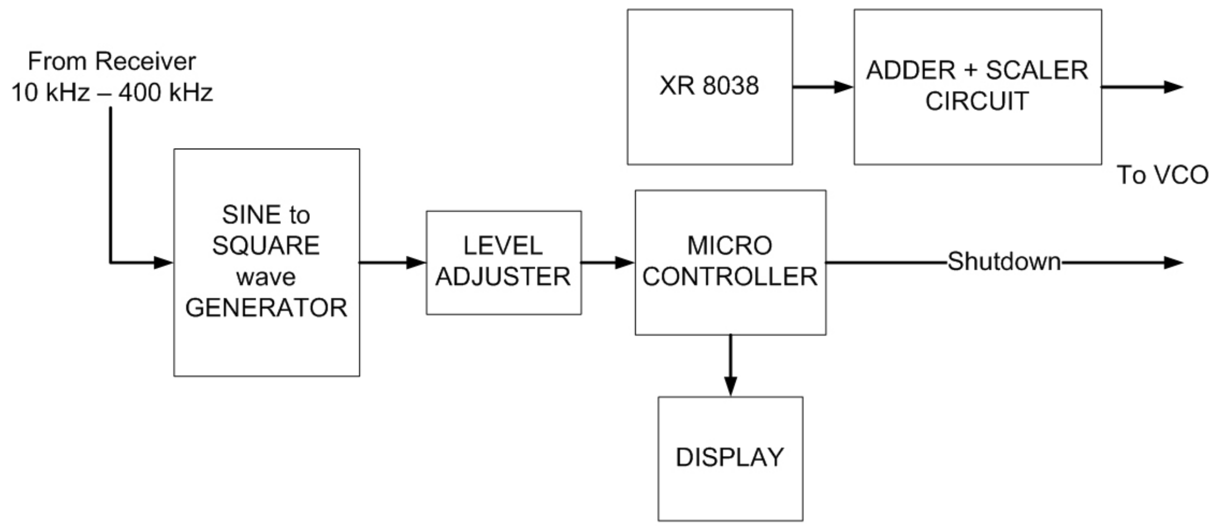


Figure 7. Control Block Diagram

The Frequency is measured by passing the received signal form the band pass filter to a high frequency comparator which gives us a square-wave which is then further passed though an OpAmp to bring its level down to 5V so that we can feed it directly to the microcontroller. The 89C52 microcontroller uses its internal counter to measure this frequency and the output shown on the LCD screen

The components used in this section are
1. Microcontroller 89C52
2. XR 8038 waveform generator.
3. Operational Amplifiers(depending on required speed)
4. LCD display.

4. Testing Of Blocks

The microcontroller PCB design is complete and the PCB has been soldered and tested.

For the testing of the PCB we used a dual power supply i.e -10 V , ground and +10 V. The input was provided from the function generator in form of a square wave and the ouput was displayed by the LCD. The following are the reading taken.

Input Frequency(kHz)	Binary Output	Decimal Output
5	0000 0101	5
10	0000 1010	10
20	0001 0011	19
25	0001 1001	25

32	0010 0000	32
40	0010 0111	39
50	0011 0001	49
60	0011 1011	59
70	0100 0011	67
80	0100 1100	76
90	0101 0110	86
100	0110 0001	97
120	0111 0011	115
150	1001 0010	146
172	1010 0110	166
200	1100 0001	193

Table 1. Frequency Readings

The VCO PCB design is complete and the PCB has been soldered and tested. The voltage shown was applied to pin no.2 and the output of the VCO is as shown below.

Tuning voltage (V)	Frequency (GHz)
0.75	2.39
1.1	2.43
1.4	2.46
1.75	2.50

Table 2 Output of the VCO

The LNA PCB design is complete and the PCB has been soldered and tested. Three PCBs have been soldered and tested and the following behavior was observed. An Input signal of -15 dB was applied and the gain was measured at 2.4 GHz and 2.5 GHz

Frequency (GHz)	LNA (PCB 1)	LNA (PCB 2)	LNA (PCB 3)
2.4	15 dB	10.1 dB	12.8 dB
2.5	15 dB	9.6 dB	12.7 dB

Table 3: Gain of LNA PCBs

5. Conclusions and future Work

5.1. Current Status:

- **Radio Frequency Part:**

1. PCBs for all the RF blocks have arrived and testing for the same is pending.
2.We need to test the mixer PCB.

- **Controller Part:**

1. PCBs of all blocks have been made, soldered and tested and are working
2. Final PCB which includes all control blocks has been made and

soldered

5.2. Conclusion

We have designed and obtain PCBs for all the blocks. The PCBs of the microcontroller blocks have already been soldered and are working. The PCBs of the VCO, LNA and Power Splitter are working. We need to make Mixer PCB operational.

5.3. Further Direction Of work:

1. Testing of the RF Mixer
2. Integrating the RF and microcontroller components together
3. Making a 'BOX' of all the components

6. Appendix

6.1 Components

S.No	Component	Type	Quantity	Remarks
	IC			
1	AT89c2051	Microcontroller	1	Measurement of frequency and overall control
2	XR 8038	Wave generator	1	To create a triangular wave at 10 kHz
3	LM741	Operational Amplifier	2	Level adjustment and Scaling(OpAmp as an adder)
4	OPA847	Operational Amplifier	1	Hardlimiter
5	MAX2750	VCO	1	Tunable output frequency in the range 2.4 GHz to 2.5 GHz
7	MMG3001NT1	Transistor	1	High speed transistor used as a

				driver amplifier
8	MAX 2641	Low Noise Amplifier	3	Used to amplify received signal
9	AD8343	Mixer	1	Mixes transmitter and received waveforms
10	LM7805	Voltage Regulator	1	To supply 5 V to microcontroller and RF chips
	Capacitors			
11	33 pF	Ceramic	2	
12	3.3 nF	Ceramic	1	
13	22 μF	electrolytic	1	
14	0.1 μF	Ceramic	1	
15	0.33 μF	Ceramic	1	
16	47 pF	SM, 0603	3	SMxxx : Surface mount, package, chip capacitor
17	0.01 μF	SM, 0603	1	
18	1000 pF	SM, 0603	1	
19	18 nF	SM, 0603	1	
20	9 nF	SM, 0603	1	
21	1 pF	SM, 0603	2	
22	470 pF	SM, 0603	2	
23	100 pF	SM, 0603	2	
24	0.1 μF	SM, 0603	1	
25	220 pF	SM, 0603	2	
26	10 nF	SM, 0603	7	
	Resistors(ohm)			
	1K		3	
	10K		2	
	100K		1	
	8.2K		1	
	82K		1	
	22K		1	
	50K	Trim pot	1	
	10K	Trim pot	1	
	5K	Trim pot	1	
	8.2	SM, 0603	1	

	Inductors			
	56 nH	SM, 1812	1	Surface mount inductors with package 1812
	22 μH	SM, 1812	1	
	45 μH	SM, 1812	1	
	1.65 nH	SM, 1812	1	
	Misc.			
	12 MHz Crystal		1	
	LCD		1	

6.2 References

C and Assembly coding for microcontroller 89c2051
http://www.atmel.com
http://www.keil.com
http://www.8052.com

The 8051 Microcontroller, Architecture, Programming and Application.
Kenneth J.Ayala   Penram Publications

Datasheet of 89c2051
http://atmel.com/dyn/resources/prod_documents/doc0368.pdf

Datasheet of XR8038
http://www.exar.com/products/xr8038a.pdf

Datasheet of LM741
http://www.national.com/ds/LM/LM741.pdf

Datasheet of THS3001
http://www.datasheetcatalog.com/datasheets_pdf/T/H/S/3/THS3001.shtml

Datasheet of BGA 430
www.chipcatalog.com/Datasheet/C83674B9F185751B1E47B992994A1B35.htm

Datasheet of MMG3001NT1
http://www2.hibbertgroup.com/freescale/main

Datasheet of MAX2641
www.maxim-ic.com.cn/pdfserv/en/ds/MAX2640EVKIT-MAX2641EVKIT.pdf

Datasheet of AD8343
www.analog.com/UploadedFiles/Data_Sheets/924558975AD8343_a.pdf

Datasheet of LM7805
http://www.national.com/ds/LM/LM7512C.pdf

6.3 PCB Layouts of all blocks

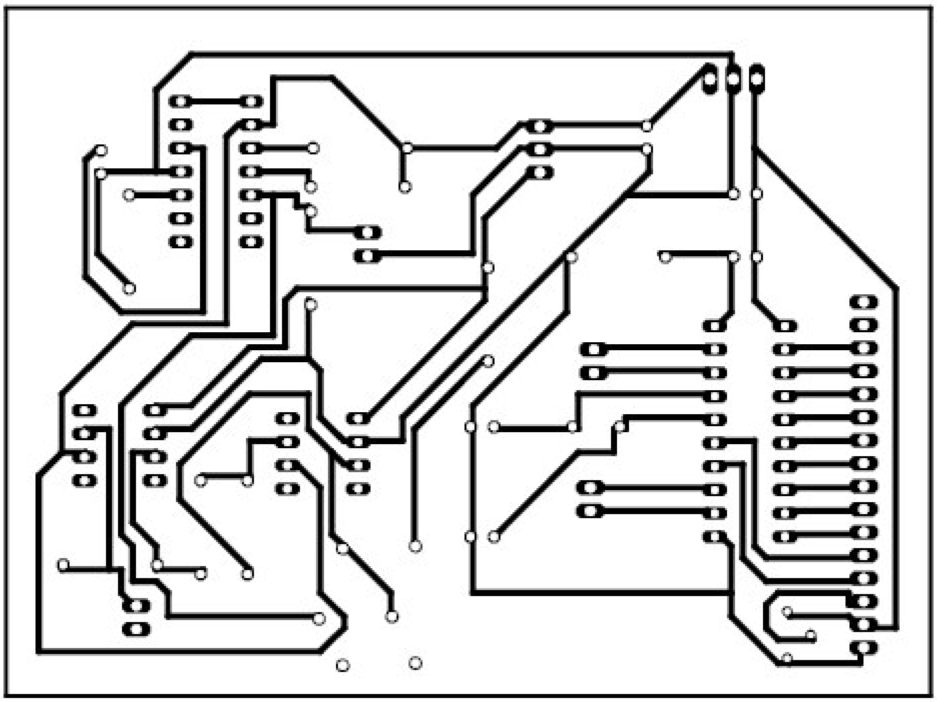


Fig 8a. Bottom Layer of controller PCB(Scale Factor 1)

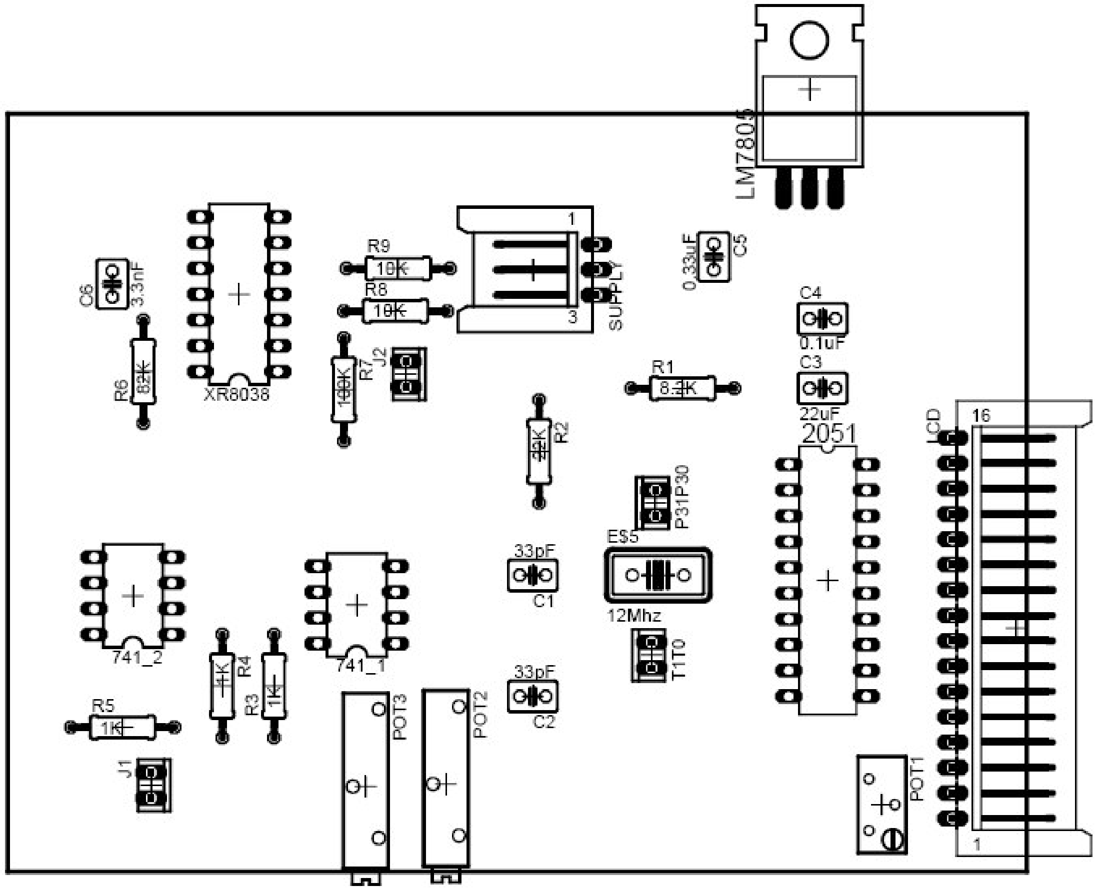


Fig 8b. Component Placement of controller PCB

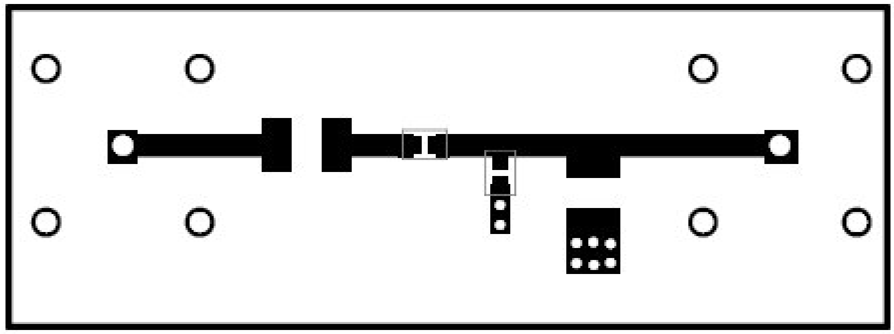


Fig 9a.. Top Layer of Band Pass Filter (Scale factor 2)

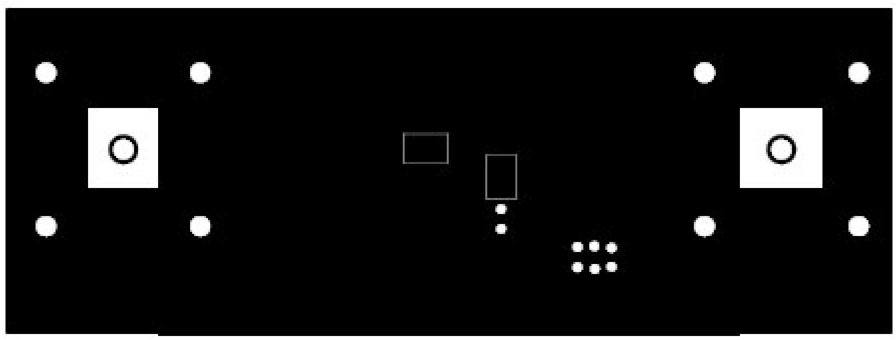


Fig 9b. Bottom Layer of Band Pass Filter(Scale factor 2)

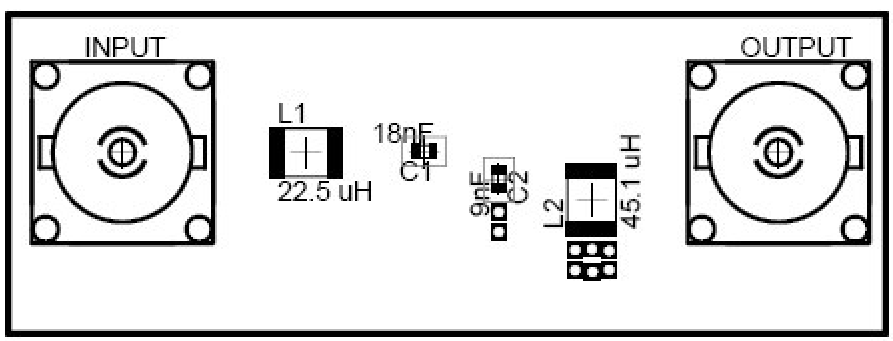


Fig 9c. Component Placement of Bandpass Filter(Scale factor 2)

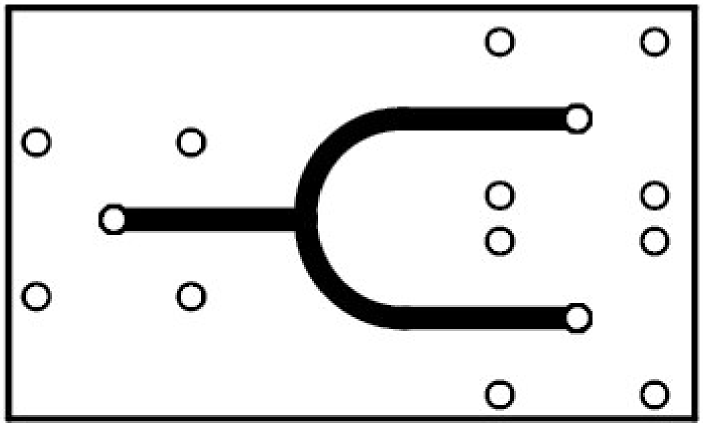


Fig 10a. Top Layer of power splitter PCB (Scale factor 2)

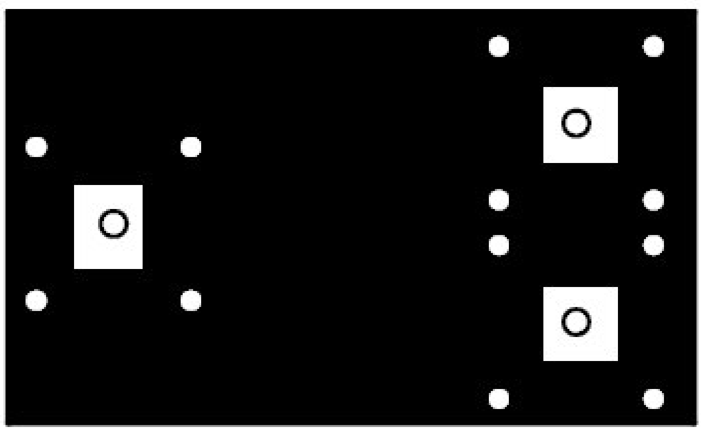


Fig 10b. Bottom Layer of power splitter PCB(Sale factor 2)

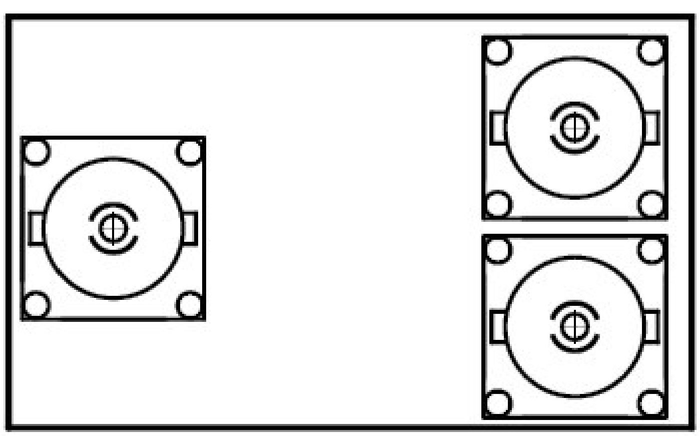


Fig 10c. Component Placement of Power Splitter(Scale factor 2)

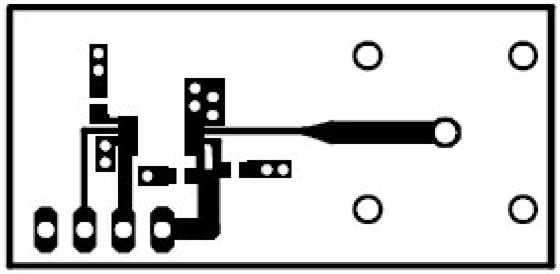


Fig 11a. Top layer of VCO PCB (Scale factor 2)

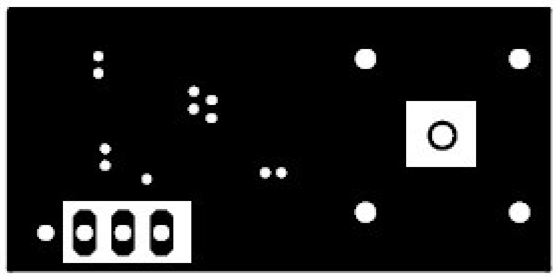


Fig 11b. Bottom layer of PCB (Scale factor 2)

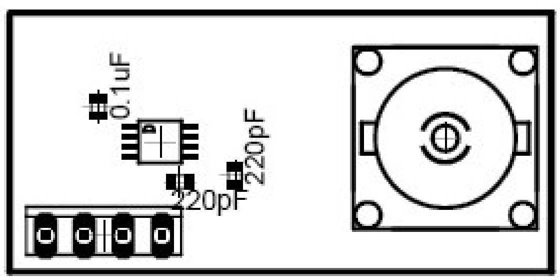


Fig 11c. Component Placement of VCO(Scale factor 2)

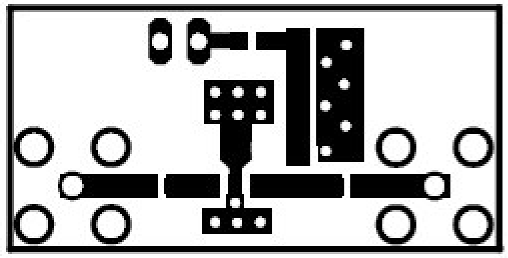


Fig 12a. Top layer of Driver amplifier (Scale factor 2)

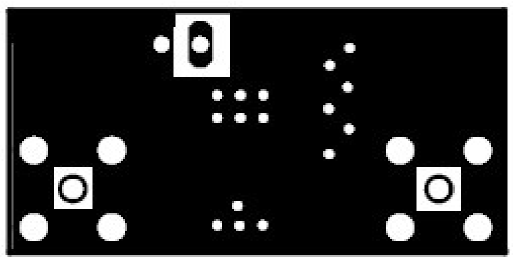


Fig 12b. Bottom layer of Driver amplifier (Scale factor 2)

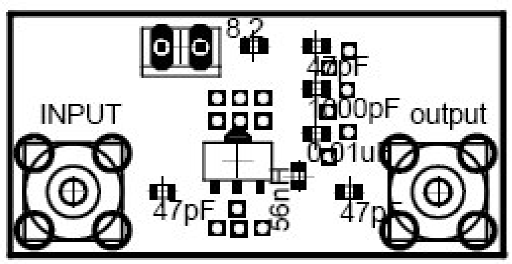


Fig 12c. Component Placement of Driver amplifier (Scale factor 2)