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CERTIFICATE

This is to certify that the Major project report entitled "**DESIGN AND ANALYSIS OF PREPOST SELECTOR FROM 30MHz TO 3000MHz** " is a bonafide work carried out by **Mr.PRANAVSESH V S** bearing Roll No. **2K14/MOC/12**, a student of Delhi Technological University, under the guidance of **Dr.RIYANKA JAIN** in partial fulfillment of the requirements for the award of Degree in **Master of Technology** in "**MICROWAVE AND OPTICAL COMMUNICATION ENGINEERING**".

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Candidate Declaration

I,**PRANAVSESH V S** here by declare that the work which is being presented in this thesis entitled "***DESIGN AND ANALYSIS OF PREPOST SELECTOR FROM 30 MHZ TO 3000MHZ "*** is my own work carried out under the guidance of Dr. Priyanka Jain , Assistant Professor, Department of electronics and communication engineering , Delhi Technological University. And Mr. Arun Verma scientist at EI wave digitech hyderabad .

I further declare that the matter embodied in this thesis has not been submitted for the award of any other degree or diploma.

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Abstract

A prepost selector improves the performance of any receiver. Typically it is tuned to have a narrow bandwidth centered on the operating frequency of the receiver .the signal which passes through the prepost selector is declined slightly ,but attenuates other signals reducing unwanted signals. A prepost selector may be designed so that in addition to mitigating the unwanted signals ,it protect the receiver from damage caused by the input voltage spikes.

In this research the idea is to design a prepost selector whiach can handle any signal within the frequency range 30MHz to 3000Mhz .which is realized using a set of tunable bandpass filters with constant fractional bandwidth(7.5%). Depending on the frequency of interest to be passed through the filter switches are used to select between the available filters . Each filter can handle a band of frequencies to pass through. Filters are made tunable by using reverse biased varactor diodes. Total 8 filters are used to cover the frequency range 30MHz to 3000MHz. First filter is a high pass filter remaining all filters are bandpass filters. Within the bandpass filters first 5 filters are lumped element structures and two of them are microstripline structures, since lumped elements will not give good response at high frequencies. All filters are simulated and verified before fabricating. Finally module is fabricated and tested. All the results of simulation and testing results are given in detail.

Chapter 1

Introduction

Filters play an important role in many applications RF / microwave. They are used to separate or combine different frequencies. The electromagnetic spectrum is limited and has to be shared; Filters are used to select or limit the spectrum RF / microwave within the limits assigned. Emerging applications such as wireless communications continue to challenge the filters RF / microwave with increasingly demanding requirements of higher performance, smaller size, lighter weight and lower cost. Depending on the requirements and specifications, filters RF / microwave may be designed as concentrated or distributed circuit elements elements;[1] , They can be made in various structures of transmission lines, such as a waveguide, the coaxial line and microstrip.

Filter type is defined with frequency, allowing or reject. There lowpass, highpass, bandpass and stopband filters with different types of performing frequency selectivity. Historically, filters were first discrete inductors (L) and capacitors (C) for applying radio frequency (RF). [2]Today, lumped element filters remain in use in the frequency range of 50 MHz to 2 GHz. The simplicity of design, production and low cost are the main advantages of using this type of filters. They can often be very compact compared to filters based on resonators half wave structures and have no "natural" appearing in modes other technologies such as planar filter resonator structures. [3]However, the output characteristics of lumped elements filters suffer from low quality factor (Q) components. Although the values of Q increase inductors and capacitors modern even hundreds, are kept well below Q of thousands that have cavity filters

The recent development of new materials and manufacturing technologies, including microwave monolithic integrated circuit (MMIC), micro-electro-mechanical system (MEMS), micro-machining, high superconducting temperature (HTS), and Cofired ceramic low temperature (LTCC), has stimulated the rapid development of new mi-crostrip and other filters. Meanwhile, advances in computer-aided design (CAD) tools as electromagnetic fullwave (EM) simulators have revolutionized the design of the filter. Many new filters microstrip with advanced filtering features have been demonstrated.[4]

Due to the emergence of multiple frequency bands in different regions and different applications requirement exists for tunable filters. It is important for the receivers and transceivers that operate throughout the frequency spectrum to have maximum tuning range and save filtering features While the frequency is tuned.

A preselector improves the performance of almost any receiver, but is especially useful for receivers with broadband front-end are prone to overload,: such as scanners and receivers consumers in the common market. Typically a preselector is tuned to have a narrow bandwidth centered on the operating frequency of the receiver. Preselection passes through the signal is tuned to only declined slightly, but attenuates other signals, reducing unwanted interference. A preselection may be designed so that in addition to mitigating interference from other frequencies, protect a sensitive receiver static damage caused by the input voltage spikes, and from signals from other overhead, transmitters nearby.

Chapter 2
Literature review

2.1 Bandpass filter

A bandpass filter only passes frequencies within a certain desired band and attenuates other signals whose frequencies are either below a lower cutoff frequency or above an upper limit cutoff frequency. The frequency range of a band pass filter allows to pass through is known as passband. A typical pass filter band can be obtained by combining a low pass filter and highpass filter or lowpass conventional application to bandpass transformation. The ideal pass filter band has a flat pass band where no gain or attenuation is there and all frequencies outside the passband are completely rejected. Overall state, there is no perfect pass filter band. Therefore, one can say that the filters do not attenuate all frequencies outside the desired frequency range.[4] This phenomenon is known as filter roll off and usually expressed in dB attenuation per octave or frequency decade. The circuits in series and parallel resonant LC combine to form a bandpass filter. LC resonant circuits series are used to allow only the desired frequency range to pass while the parallel resonant LC circuit is used to attenuate frequencies outside the passband by deriving them to the ground. Lumped components come with parasites. For example, an inductor is parasitic resistance and parasitic capacitance. As he approached high frequency (about 1 GHz), parasites begin to affect the frequency response of the filter. It is also very difficult to model a clustered component. Therefore, the filter circuit passing pooled component band becomes microstrip transmission line structure using various methods, such as transformation of Richard, Kuroda identities, investors Immitance and so on. Today, a transmission line or microstrip stripline is performing as a filter because of its behavior as a good resonator. micro strip lines give a better compromise in terms of size and performance lumped element filters. [7]The transmission lines comprise a microstrip conductor strip width (W) and thickness (t) and a wide earth plane separated by a dielectric layer (ε) thick (h).

2.2 Lumped Topologies of bandpass filter

schematics with a LC-resonator and a shunt series LC-resonator at the top of topologies are obtained with the transformation of aT-type and a Pi-type lowpass prototypes.. [10]They have a fairly large inductance and small capacitance in the series resonators shunt resonators but the situation is reversed. prototypes lowpass filter coupled give C-coupled inverter topologies and bypass filters resonators coupled L. In addition, the resonance filter capacitively coupled series can be constructed with the same shape. They are narrow band approaches a bandpass filter and have values of desirable components in this frequency. The topology is called tubular and consists of a series of inductors and capacitors is connected capacitively connected to ground. 7th structure is the structure of the LC resonator having control independent bandwidth. Which can be used to design the filter from low frequency to 2GHz with the values ??of capacitor and inductor embodiment, depending on the requirements bandwidth. Along with topologies also given its response to filters designed to center frequency 600MHz.

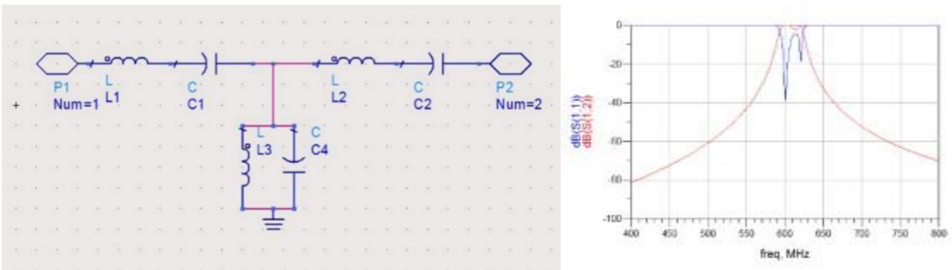


Fig 2.1 T-type 3rd order filter

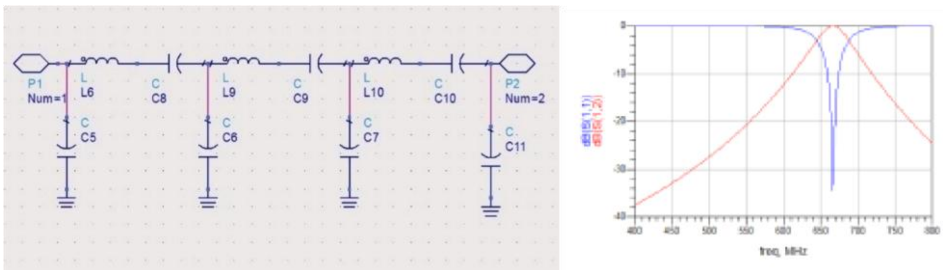


Fig 2.1 Shunt C-coupled 3rd order filter

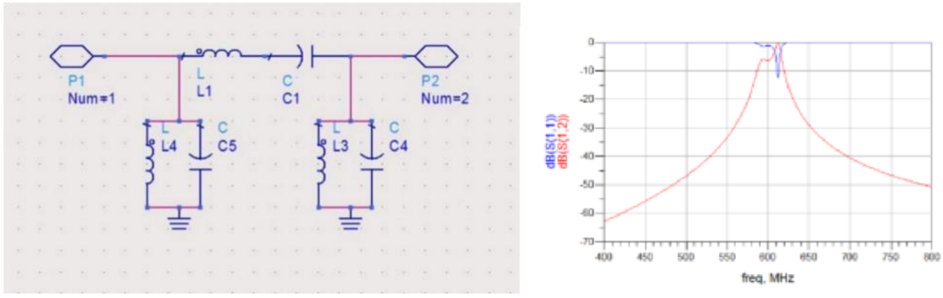


Fig 2.3 Pi-type 3rd order filter

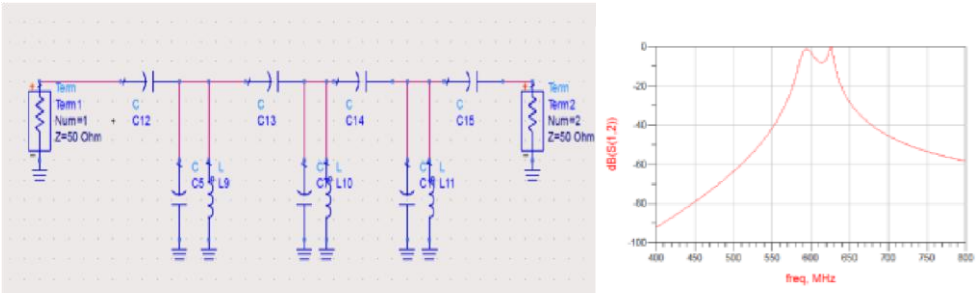


Fig 2.4 Top C-coupled 3rd order filter

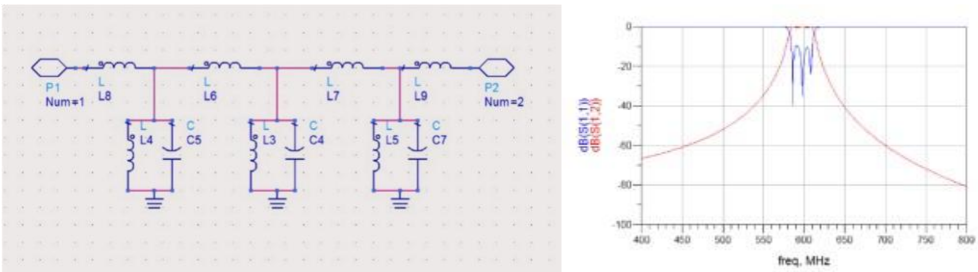


Fig 2.5 Top L-coupled 3rd order filter

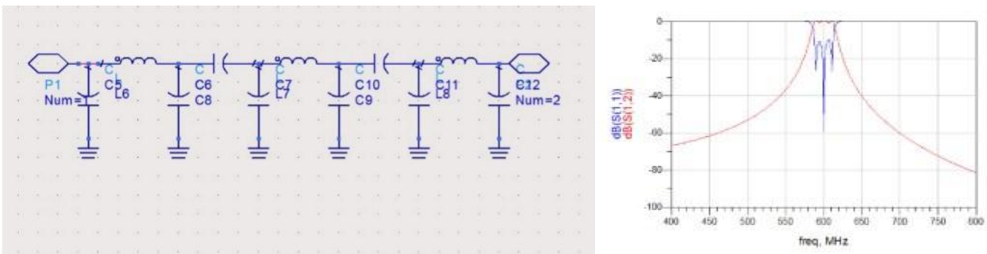


Fig 2.6 Tubular 3rd order filter

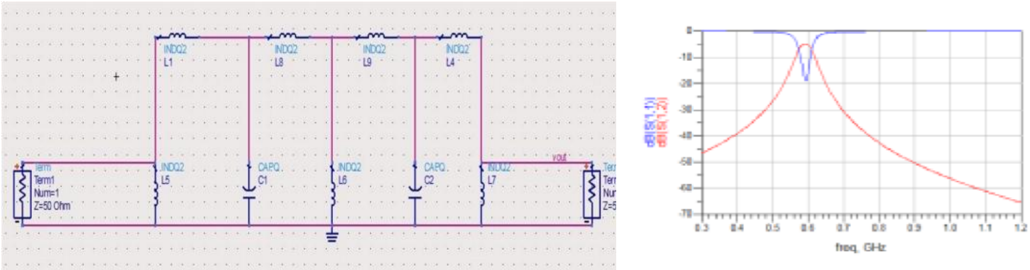


Fig 2.7 LC tank resonator with bandwidth control

All presented topologies upto 6th have good output response but values of components are sufficiently differ. So, in first two topologies capacitance values are too small to be realizable and inductance values are high meaning that the overall size of a filter will be large. Moreover, it is better to choose topologies with grounded inductors to diminish the influence of a parasitic parallel capacitance appearing with an inductance. The 7th topology is more realizable and more flexible.

2.3 Tunable filters

Because the demand for tunable filters for broadband interfaces and other applications, there are several methods to achieve this purpose. In this chapter the scientific work to better understand the current state of issues are discussed.

2.3.1 Tuning methods

Tuning in frequency range from the simplest single resonator filter of lumped elements requires a change in component values to change a resonance frequency. For filters with a higher order one all the resonator elements should be changed. In addition, the coupled elements must also be adjusted to maintain the bandwidth of a filter thereof. The main approach to the tuning frequency is electrically changing the capacitance of a filter. The reason is that the tuning of the coils is more complicated.[14] Today, different types of tunable capacitors are developed and can be successfully applied agile filters. There ferroelectric varactor diodes, capacitors, batteries digital switchable capacitors and RF MEMS (microelectromechanical systems).

Varactor diodes have a widespread application. The concept used in this type of tunable capacitor is based on changes in the width of the depletion region of the semiconductor diode and resulting changes in capacitance. The DC reverse bias voltage used to effect this change. Although varactor tunable filters have a small power consumption and relatively quick speed tuning, suffer from moderate value Q resonators. Another drawback of the varactor is the power capacity. Because varactor diodes are originally non-linear devices, the input signal generates large nonlinear unwanted distortions.

BST the ferroelectric material has a high Q and a wide range of adaptation; therefore, it is a good candidate for tunable varactors. As a paraelectric phase , BST exhibit large dielectric constant can be changed by an external bias voltage. Ferroelectric can be manufactured in a variety of substrates using standard manufacturing processes semiconductors.[36] Therefore, the tunable capacitors flat BST can be integrated directly into a filter circuit PCB. The second advantage is the very compact size due to a high value of material permittivity.[38]

Varactors are nonlinear and need the voltage control circuit makes more complicated filter design. Capacitor banks handled these problems and digitally tune a filter. Power range and harmonic tuning capability are better than those of the varactors. The DTC suffer from a low quality factor switches despite a high Q of the MIM capacitors fixed.

Among these variants, the RF MEMS components can be used in tunable filters. In these devices a DC voltage applied may result in a change of capacitance by employing movements micrometer level. MEMS capacitors have small size and zero energy consumption. Other advantages are that provide a low insertion loss and show a wide range of tuning. However, an RF MEMS suffer from a life cycle shortened considerably in contrast to purely electronic components diverted. Depending on the technology, the control of a RF MEMS component requires an analog voltage, and therefore a suitable control circuit.[25]

. Generally, based on various tuning elements used, tunable filters may be classified as semiconductor (varactor and pin diodes) tunable filters, RF (MEMS) tunable filters microelectromechanical systems, piezoelectric transducer (PET) tunable filters, and materials tunable filters ferroelectrics . A well known problem for tunable filters is the variation of bandwidth as the center frequency is tuned. Several techniques have been tried to overcome this problem, to achieve absolute band width constant over a wide tuning range using different tuning elements.[23]

2.3.2 lumped tunable bandpass filter

we have seen different topology of bandpass filters using lumped elements . Among them for designing a tunable bandpass filter we should have the freedom to tune the central frequency with minimum number of tunable capacitors . The best architecture to do that is the final structure from the topology section. Let us analyze the different flexibility of this particular architecture in detail. For analysis purpose let us use a 500Mhz to 1000Mhz tunable bandpass filter.

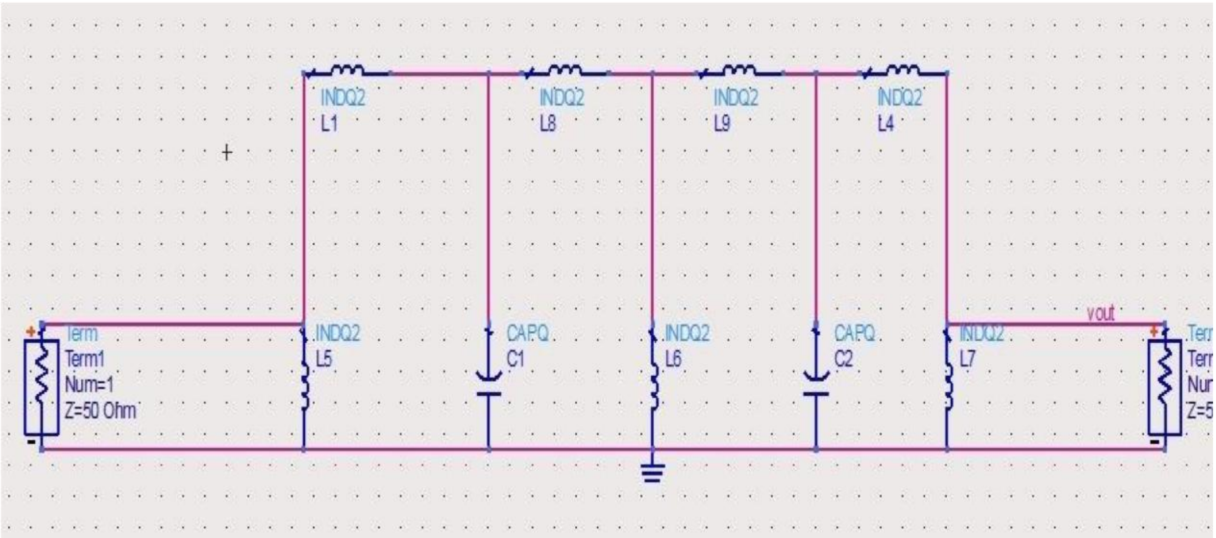


Fig 2.8 basic structure of lumped tunable bandpass filter

The figure shows the basic structure of the tunable bandpass filter .the structure is symmetric about the central inductor L6. Inductors L1,L5&C1 forms a tank circuit similarly C2,L4 & L7 forms a symmetric tank.L1,L8,L9& L4 are of same value which decides the central frequency of the filter along with the capacitors c1 and c2. L6 accounts for the bandwidth of the filter . which can be tuned to obtain the desired bandwidth. L5 and L7 should be designed to match the 50ohm impedance of the source. Changing the L5 and L7 values affects the return loss of thr filter . while designing the filter try obtain an optimum value for those inductors such that better return loss can be obtained.

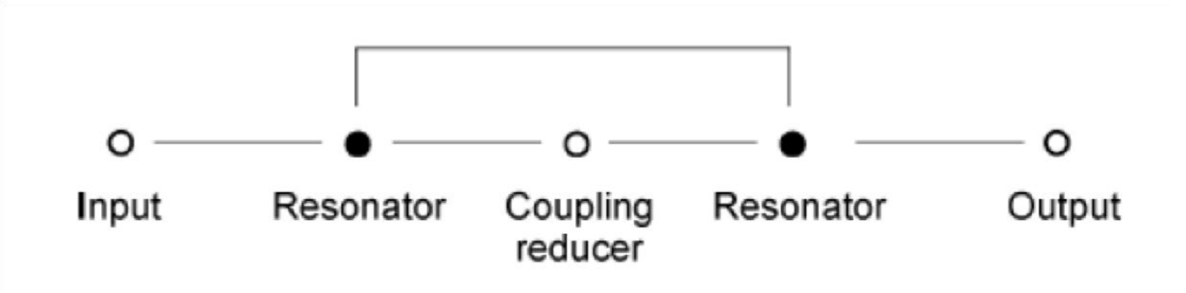


Fig 2.9 equivalent representation of filter structure

Central frequency tuning can be attained by changing the capacitors in the tank circuits. Since both capacitance are same value tuning can be done easily. Varactors can be used in place of capacitors to adjust the capacitor values.

Detailed analysis is done on the effects of individual components on the response of the filter .the tuning range depends on the type of the varactor. If varactor is able to tune the capacitance over a high percentage tuning range will also be high. But a limitation is that the return loss of the filter will not be good over a wide range of capacitance values . So while choosing the varactors these effects should also be taken into consideration . With the highest possible value of the varactor we will start the design .first try to optimize L1,L2,L9 and L4 to match the central frequency the keep L5 and L7 such that good return loss is obtained . Values are such that at the designed frequency the inductors will have an impedance of 50ohm . Increasing the values of L1,L2,L9 and L4 move the central frequency to lower values along with that return loss will also reduce . So while reducing theses values try to find optimum L5 and L7 values such that circuit is matched at 50 ohms. Increasing and decreasing the values of L5 and L7 will reduce the return loss of the filter . So try to obtain an optimum value .L6 is used to control the bandwidth . Increasing value of L6 will increase the bandwidth but there will be trade of between return loss . If return loss is reducing try to adjust the value of L5 and L7. Finally we can tune the central frequency using C1 and C2 .

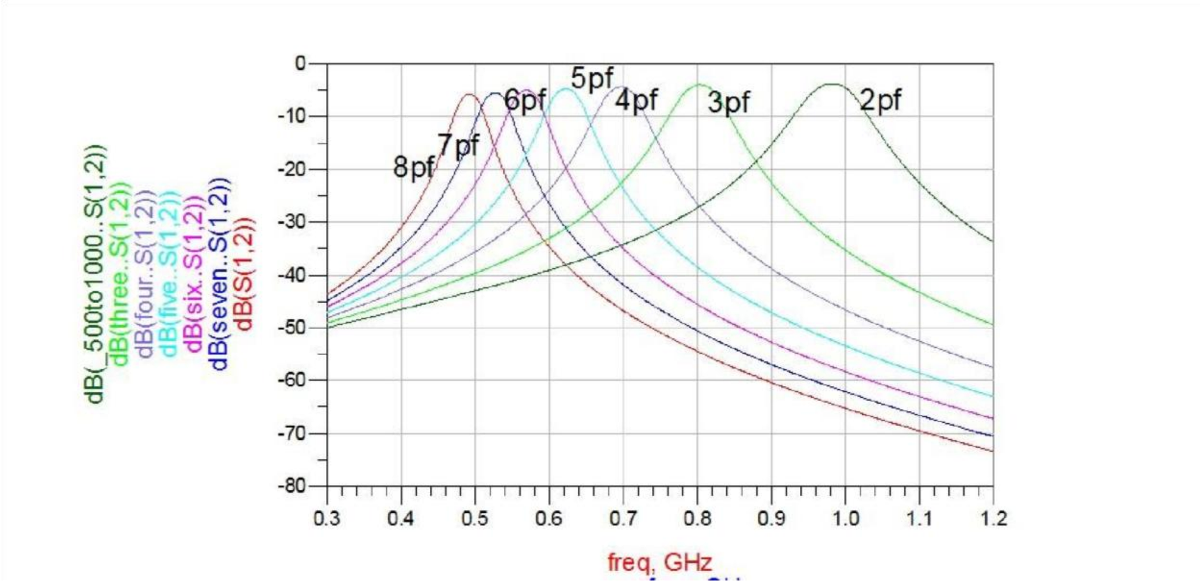


Fig 2.10 response of filter at different values of capacitors

Figure shows the response of the filter for different values of the capacitors with constant fractional bandwidth. As capacitance increases central frequency is decreasing. With 4 times increasing in capacitance 50% reduction in central frequency is obtained.

2.3.3 Microstripline tunable bandpass filter

Park et al. [14] introduced a filter with magnetic and electrical coupling independent method using the admittance matrix. The scheme independent magnetic and electrical coupling makes it possible to manipulate the coefficient variation frequency dependent coupling, and this leads to different predefined width variations versus frequency band. Based on the filter topology independent magnetic and electrical coupling, this document has three filters with three different variations of bandwidth; constant fractional bandwidth, decreased fractional bandwidth (absolute constant band width), and increasing fractional bandwidth. The proposed topology design is different from the line comb filter in which the three have identical electrical lengths, the same varactors and the same filter values. Due to the nature of a narrowband model grouped LC circuit, a design methodology using integrated circuits distributed admission matrices for the coupled resonators and broadband transformer is presented. specific design considerations for the design load and capacitive polarization are performed in order to achieve excellent insertion loss and tuning range.

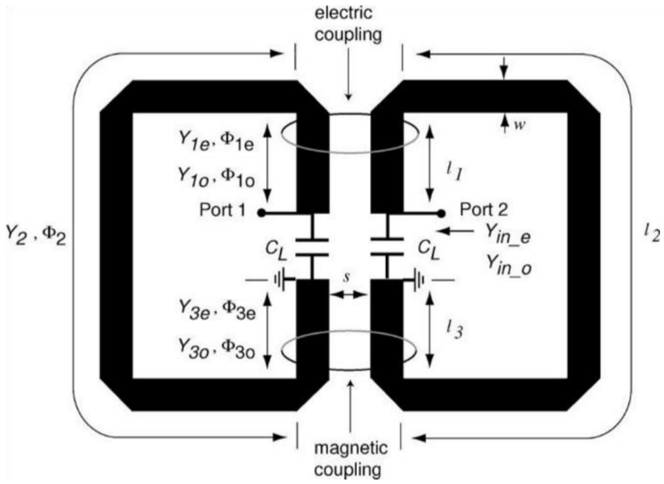


Fig 2.11 coupled line structure

2.3.3.1 Design

A. Admittance Matrix of the Filter

The input even- and odd-mode admittances are

$$Y_{\text{in\_}e} = j\omega C_L + Y_{re} \qquad (1)$$
$$Y_{\text{in\_}o} = j\omega C_L + Y_{ro} \qquad (2)$$

where

$$Y_{re} = Y_{1e}\frac{Y_2\dfrac{-jY_{3e}\cot\phi_{3e} + jY_2\tan\phi_2}{Y_2 + Y_{3e}\cot\phi_{3e}\tan\phi_2} + jY_{1e}\tan\phi_{1e}}{Y_{1e} + jY_2\dfrac{-jY_{3e}\cot\phi_{3e} + jY_2\tan\phi_2}{Y_2 + Y_{3e}\cot\phi_{3e}\tan\phi_2}\tan\phi_{1e}} \quad (3)$$

$$Y_{ro} = Y_{1o}\frac{Y_2\dfrac{-jY_{3o}\cot\phi_{3o} + jY_2\tan\phi_2}{Y_2 + Y_{3o}\cot\phi_{3o}\tan\phi_2} + jY_{1o}\tan\phi_{1o}}{Y_{1o} + jY_2\dfrac{-jY_{3o}\cot\phi_{3o} + jY_2\tan\phi_2}{Y_2 + Y_{3o}\cot\phi_{3o}\tan\phi_2}\tan\phi_{1o}}. \quad (4)$$

The overall admittance matrix of the capacitively loaded coupled resonators is

$$Y = \begin{bmatrix} \frac{Y_{\text{in\_}e} + Y_{\text{in\_}o}}{2} & \frac{Y_{\text{in\_}e} - Y_{\text{in\_}o}}{2} \\ \frac{Y_{\text{in\_}e} - Y_{\text{in\_}o}}{2} & \frac{Y_{\text{in\_}e} + Y_{\text{in\_}o}}{2} \end{bmatrix} \quad (5)$$

$$= \begin{bmatrix} j\omega C_L + Y_{r11} & Y_{r12} \\ Y_{r12} & j\omega C_L + Y_{r11} \end{bmatrix} \quad (6)$$

where

$$Y_{r11} = \frac{Y_{re} + Y_{ro}}{2} \quad Y_{r12} = \frac{Y_{re} - Y_{ro}}{2}. \quad (7)$$

B. Design of the Filter

1) Calculating the Loading Capacitor and the Even-Odd Mode Admittances, two conditions must be satisfied. One is the resonance condition and the other is coupling condition .

$$\text{Im}[Y_{11}(\Omega_0)] = 0 \quad \frac{\text{Im}[Y_{12}(\Omega_0)]}{b} = K_{12} \quad (8)$$

where

$$b = \frac{\omega_0}{2} \frac{\partial \text{Im}[Y_{11}(\omega_0)]}{\partial \omega} \quad k_{12} = \frac{\Delta}{\sqrt{g_1 g_2}}. \quad (9)$$

Previous design parameters can not be found uniquely by only the resonance conditions and load because the design parameters are eight degrees of freedom. Therefore, it is necessary independently choose parameters such as resonator impedance. For simplicity, the charging capacitor needs to be decoupled from (8) and which can be chosen after all other filter parameters are from the resonance condition im [Y11] = 0 it follows that

$$C_L = -\text{Im}\left[\frac{Y_{r11}(\omega_0)}{\omega_0}\right]. \quad (10)$$

With the above result, b can be defined by

$$b = \text{Im}\left[\frac{\omega_0}{2} \frac{\partial Y_{r11}(\omega_0)}{\partial \omega} - \frac{Y_{r11}(\omega_0)}{2}\right]. \quad (11)$$

The coupling condition in (8) can now be rewritten as

$$\frac{\text{Im}[Y_{r12}(\omega_0)]}{\text{Im}\left[\frac{\omega_0}{2} \frac{\partial Y_{r11}(\omega_0)}{\partial \omega} - \frac{Y_{r11}(\omega_0)}{2}\right]} = \frac{\Delta}{\sqrt{g_1 g_2}}. \quad (12)$$

sets of design parameters because the design parameters are not determined solely by (12). If the design parameters and are chosen first, satisfying (12) becomes a problem of selection of the sections of filter electric and magnetic coupling. These sections of electrical and magnetic coupling also have six degrees of freedom. Although all sets of design parameters give exactly the same frequency response, these coupling structures have different frequency variations as the resonance frequency is tuned.

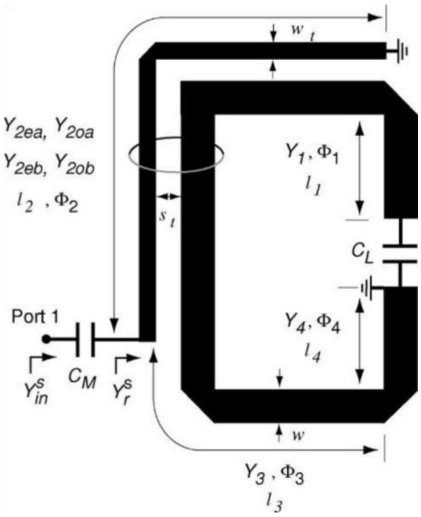


Fig 2.12 Electrical circuit model of the resonator with the external coupling circuit.

over the entire tuning range. In this study, the impedance transformer network in fig 2 suggested as an external coupling circuit . the resonator input admittance seen from the input port before the matching capacitor is

$$Y_r^s = y_{22}^s + y_{23}^s \frac{y_{34}^s y_{42}^s - y_{44}^s y_{32}^s}{y_{33}^s y_{44}^s - y_{34}^s y_{43}^s} + y_{24}^s \frac{y_{43}^s y_{32}^s - y_{33}^s y_{42}^s}{y_{33}^s y_{44}^s - y_{34}^s y_{43}^s} \quad (13)$$

where

$$y_{22}^s = -j\frac{Y_{2ea} + Y_{2oa}}{2}\cot\phi_2 \quad (14)$$

$$y_{23}^s = y_{32}^s = j\frac{Y_{2ea} - Y_{2oa}}{2}\csc\phi_2 \quad (15)$$

$$y_{34}^s = y_{43}^s = j\frac{Y_{2eb} + Y_{2ob}}{2}\csc\phi_2 \quad (16)$$

$$y_{42}^s = -j\frac{Y_{2ea} - Y_{2oa}}{2}\cot\phi_2 \quad (17)$$

$$y_{33}^s = -j\frac{Y_{2eb} + Y_{2ob}}{2}\cot\phi_2 + jY_1\frac{\omega C_L + Y_1\tan\phi_1}{Y_1 - \omega C_L\tan\phi_1} \quad (18)$$

$$y_{44}^s = -j\frac{Y_{2eb} + Y_{2ob}}{2}\cot\phi_2 + jY_3\frac{-Y_4\cot\phi_4 + Y_3\tan\phi_3}{Y_3 + Y_4\cot\phi_4\tan\phi_3}. \quad (19)$$

Chapter 3

Design and simulation of prepost selector

3.1 Prepost selector

A preselector improves the performance of almost any receiver, but is especially useful for receivers with broadband front-end that are prone to overload, such as scanners and receivers of consumers in the common market. A preselection is usually tuned to have a narrow bandwidth centered on the operating frequency of the receiver. Preselection passes through the signal is tuned to only declined slightly, but attenuates other signals, reducing unwanted interference. A preselector can be designed so that, in addition to the attenuation of interference other frequencies, protect a sensitive receiver damage caused by the static entry, voltage spikes, and overhead signals from other transmitters, nearby. However, a preselector not eliminate the interference in the same frequency as the receiver is tuned to. additional filtering may be useful because the first input stage (front end) receptor begins with at least an RF amplifier which has a limited capacity (dynamic range). Most RF amplifiers amplify all radio frequencies delivered to the antenna. Therefore off frequency signals are a waste load in the RF amplifier. Amplifier circuits also have a limit to the amount of energy that can handle incoming RF without overloading. When overloads front-end, receiver performance is drastically reduced, and in extreme cases can damage the receiver. In situations where the noisy and crowded bands, or when there are strong local stations, the dynamic range of the receiver can be quickly overcome. Additional filtering limits frequency range and power requirements that apply to all subsequent stages of the receiver, only loaded with signals within the chosen band.

tunable antenna preamplifiers (preamps) often incorporate a circuit preselection front-end to improve its function. The integrated device is both a preamplifier and a preselector, and can correctly refers either named. This ambiguity sometimes leads to confusion. thumbwheel liabilities that have no power and no internal amplifier work quite well with modern receivers with minimal signal loss, and preamplifiers do not need a preselection when fed a narrowband source, such as a loop antenna resonance tuned .

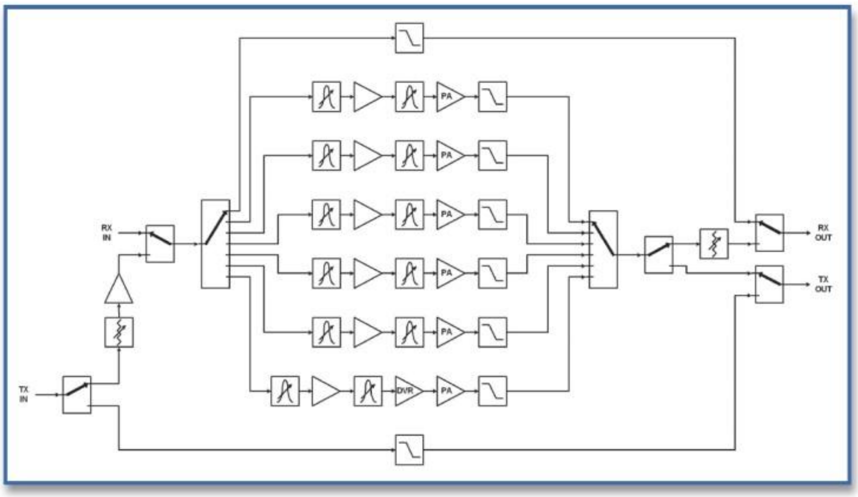


Fig 3.1 prepost selector block diagram

The figure shows the block diagram of a typical pre-post selector circuit. A switch is connected at the front end to to select between the transmitter and receiver sections . Later the signal is passed through set of bandpass filters to select the required band and reject the side bands . Amplifier stages are incorporated in between the filters to account for the loss resulting from the filters and the switching network.

Aim is to design a pre-post selector with filters which accounts minimum loss so as to avoid the amplifier stages and to reduce the complexity of the network. The requirements of the structures are

- Frequency of operation from 30MHz to 3000MHz.
- Miniaturized circuit using the smallest packages of components possible.
- Maximum power handling capability.
- Constant fractional bandwidth of individual filters 7.5%
- Filter structures with minimum loss.
- Return loss less than -10dB
- High IP3

In order to cover the 30MHz to 3000MHz frequency range ,the proposed structure occupies 8 filters . Which comprises of 7 tunable bandpass filters and one high pass filter. The block diagram of the structure is give below.

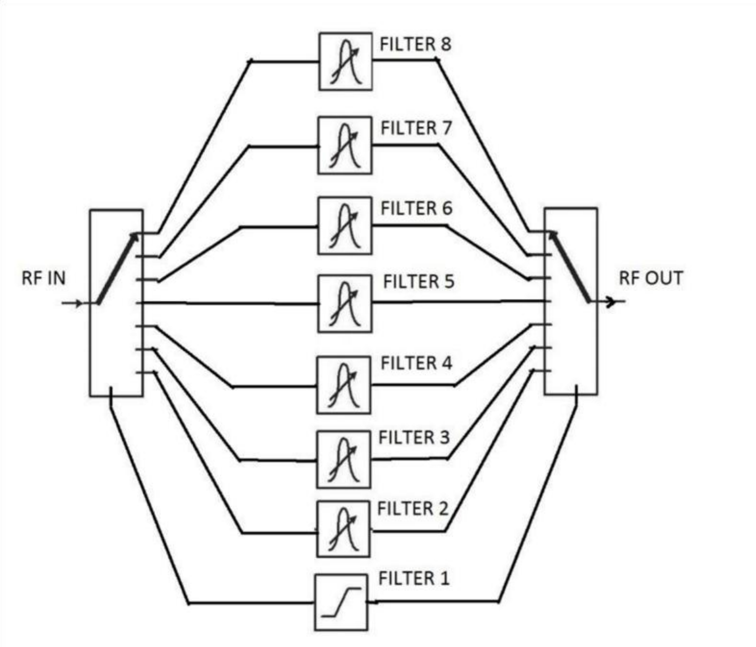


Fig 3.2 proposed block diagram

The figure shows the block diagram of the proposed prepost selector the RF signal will first pass through a switch which decides the filter through which signal should pass through . There are 8 filters . Both switches at the front and back of the filters are controlled by same signals ,combined action of both filters makes a complete path for the signal through one of the filters .

NAME	TUNING RANGE	DESCRIPTION	Type
Filter 1	2000 MHz to 3000Mhz	High pass filter	Lumped element
Filter 2	30 MHz to 107MHz	Tunable bandpass filter	Lumped element
Filter 3	88 MHz to 244 MHz	Tunable bandpass filter	Lumped element
Filter 4	242MHz to 410MHz	Tunable bandpass filter	Lumped element
Filter 5	405 MHz to 680 MHz	Tunable bandpass filter	Lumped element
Filter 6	625 MHz to 845 MHz	Tunable bandpass filter	Lumped element

Filter 7	809 MHz to 1400MHz	Tunable bandpass filter	Microstripline
Filter 8	1350MHz to 2000 MHz	Tunable bandpass filter	Microstripline

TABLE 3.1 proposed filters

3.2 schematic of rf circuit

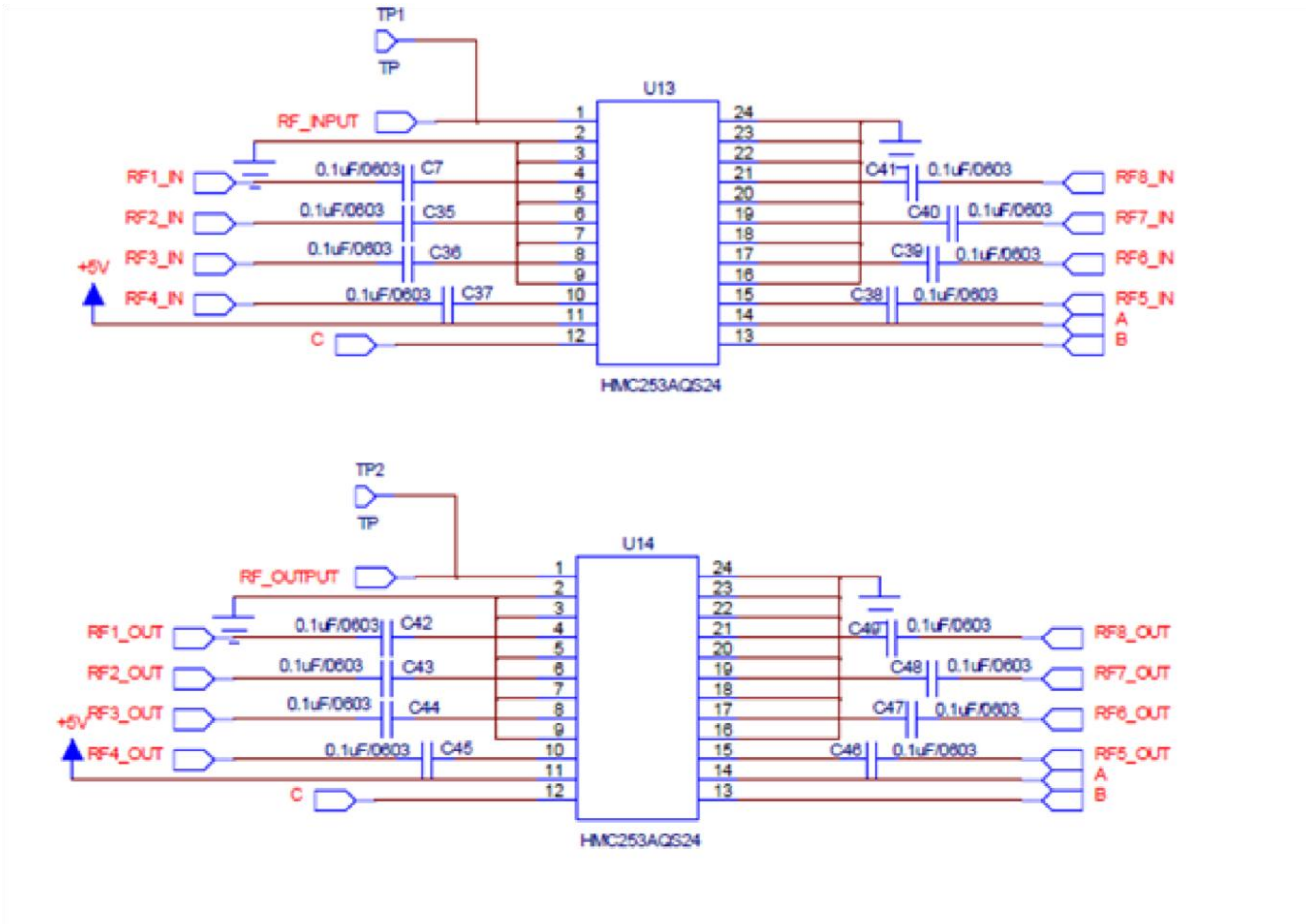


Fig 3.3 schematic of switches

HMC253 is an RF switch (SP8) for detailed information data sheet is given . First pin is connected to the RF INPUT which is connected to the source through an SMA connector . All filters are connected between the switches as given in the block diagram. Since the switches are controlled by DC signals DC blocking capacitors are connected at both input and output of the filters . There are 8 input pins for RF signals . Each filter is connected to each pins . A,B,C are the control pins used to select between the 8 available inputs. Control is done by microcontroller . Detailed schematic of the control board is given the digital board schematic.

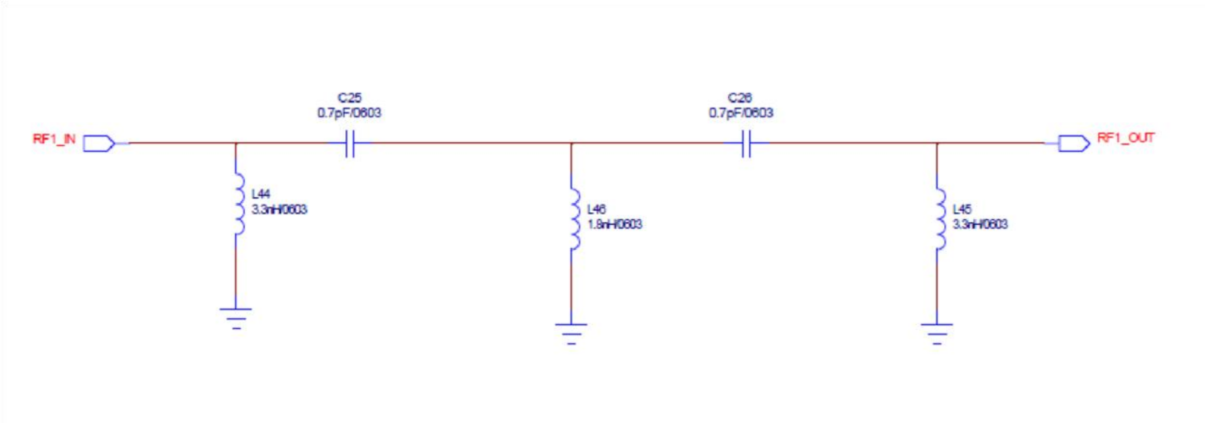


Fig 3.4 filter 1

Schematic of filter 1 .RF in is connected to the switch through dc blocking capacitor . Similarly RF out to second switch. It is a 5th order buttor worth high pass filter 2000MHz cut of frequency . Two capacitors are manufactured by johanson technologies . Inductors are from coilcraft . All are 0603 package.

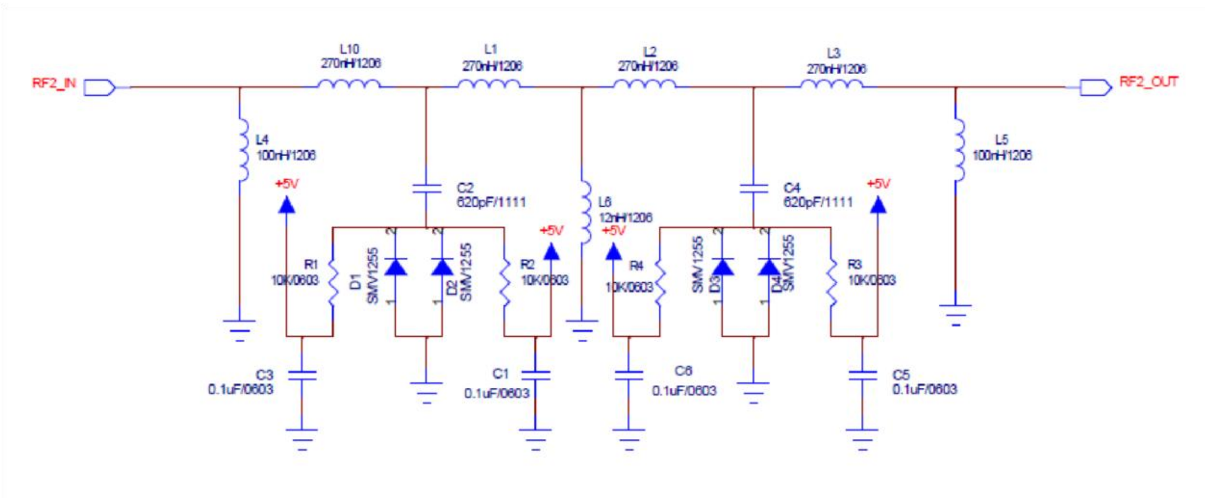


Fig 3.5 filter 2

Schematic of filter 2 .RF in is connected to the switch through dc blocking capacitor . Similarly RF out to second switch. It is a lumped tunable bandpass filter with 30MHz to 107 MHz frequency range. Inductors are 1206 package manufactured by coilcraft . Tunable capacitors are SMV1255 diode detailed information regarding the diodes are given in the data sheet, capacitamce will vary from 10 pf to 150 pf. The voltage control is done by digital to analog converter which is shown in the digital board schematic.

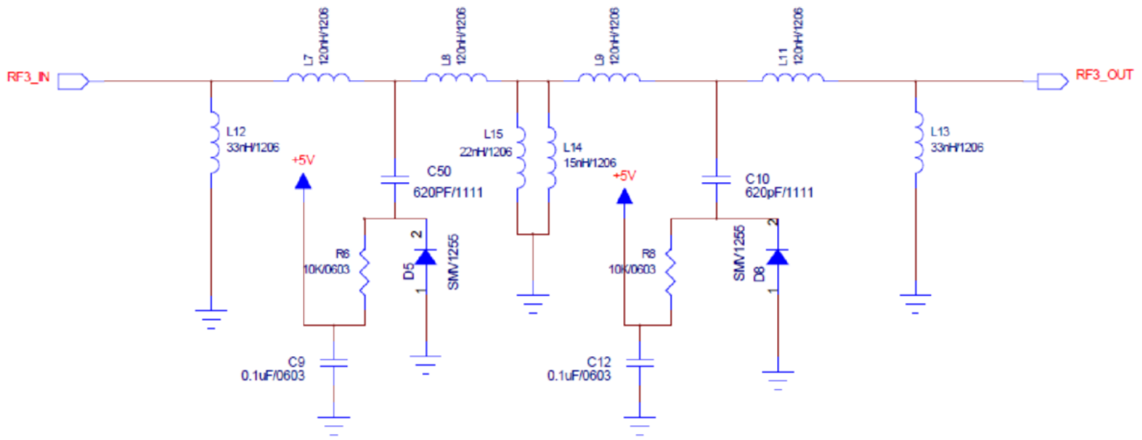


Fig 3.6 filter 3

Schematic of filter 3 .RF in is connected to the switch through dc blocking capacitor . Similarly RF out to second switch. It is a lumped tunable bandpass filter with 88MHz to 244MHz frequency range. Inductors are 1206 package manufactured by coilcraft . Tunable capacitors are SMV1251 diode detailed information regarding the diodes are given in the data sheet. The tunable capacitor values change from 3 pf to 45 pf . The voltage control is done by digital to analog converter which is shown in the digital board schematic.

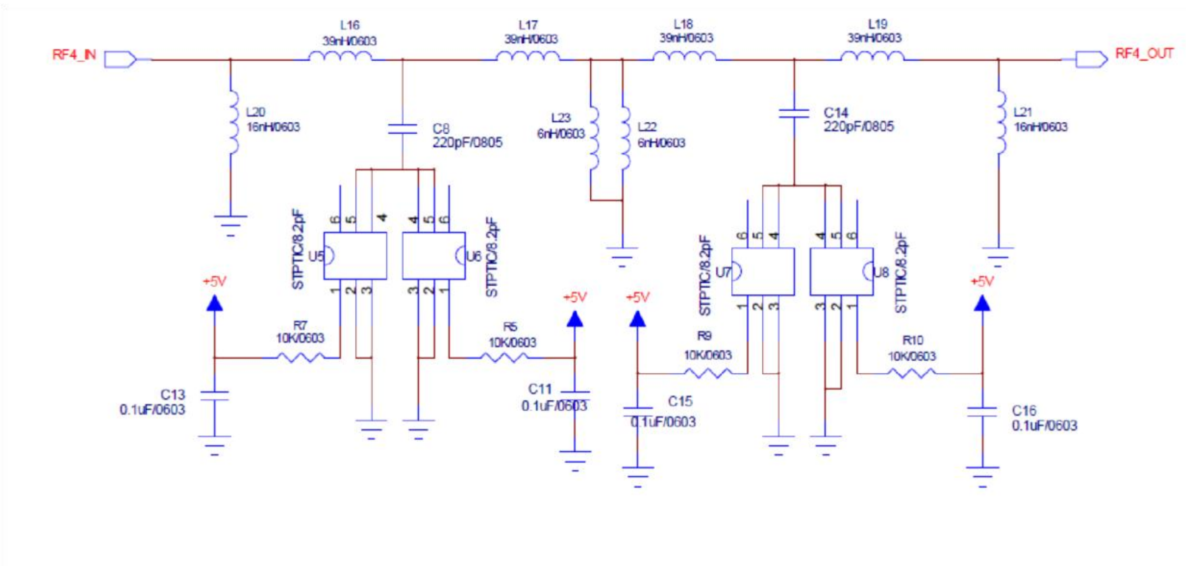


Fig 3.7 filter 4

Schematic of filter 4 .RF in is connected to the switch through dc blocking capacitor . Similarly RF out to second switch. It is a lumped tunable bandpass filter with 242 MHz to 410MHz frequency range. Inductors are 0603 package manufactured by coilcraft . Tunable capacitors are STPTIC-82F1M6 which is 6 pin passive tunable integrated circuit made of BST. detailed information regarding the diodes are given in the data sheet. The tunable capacitor values change from 4.2 pf to 16.4 pf . The voltage control is done by digital to analog converter which is shown in the digital board schematic.

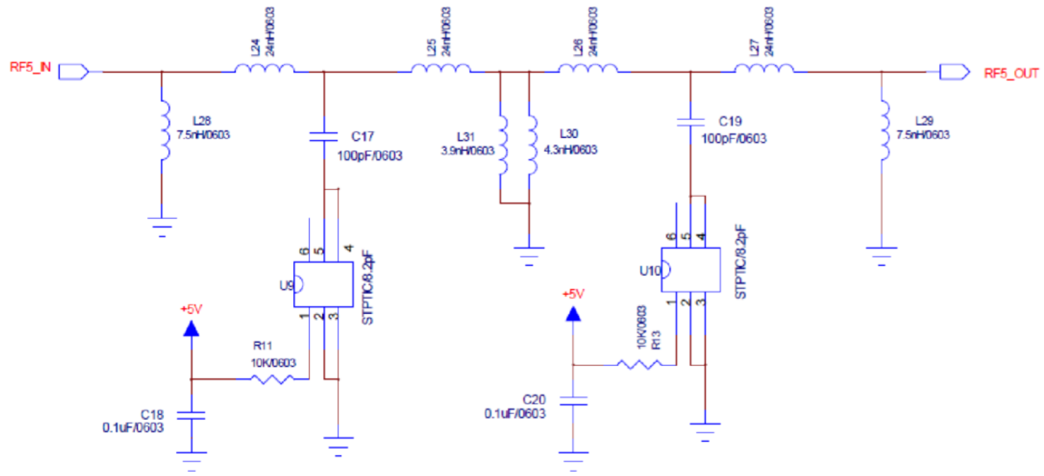


Fig 3.8 filter 5

Schematic of filter 5 .RF in is connected to the switch through dc blocking capacitor . Similarly RF out to second switch. It is a lumped tunable bandpass filter with 405 MHz to 680 MHz frequency range. Inductors are 0603 package manufactured by coilcraft . Tunable capacitors are STPTIC-82F1M6 which is 6 pin passive tunable integrated circuit made of BST. detailed information regarding the diodes are given in the data sheet. The tunable capacitor values change from 2.2 pf to 8.2 pf .The voltage control is done by digital to analog converter which is shown in the digital board schematic.

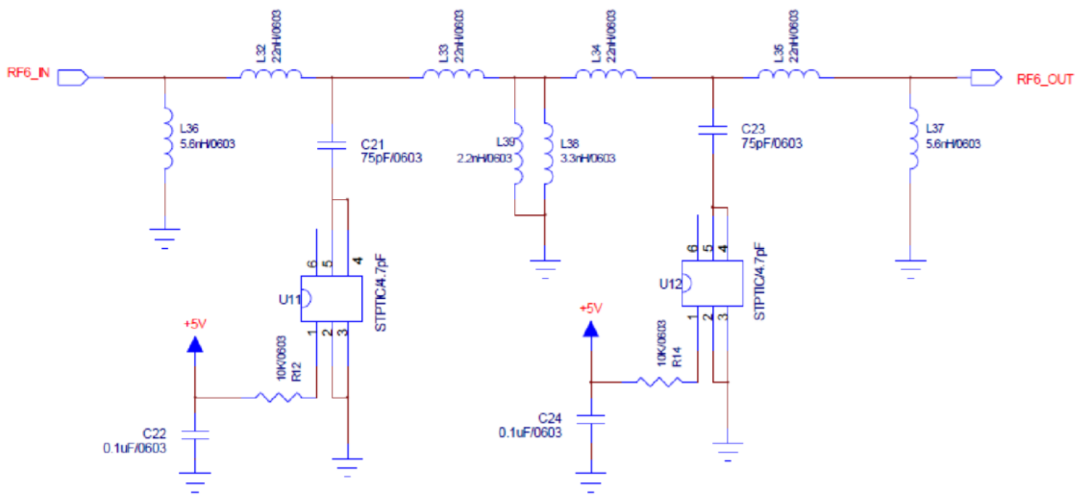


Fig 3.9 filter 6

Schematic of filter 6.RF in is connected to the switch through dc blocking capacitor . Similarly RF out to second switch. It is a lumped tunable bandpass filter with 625 MHz to 845 MHz frequency range. Inductors are 0603 package manufactured by coilcraft . Tunable capacitors are STPTIC-47F1M6 which is 6 pin passive tunable integrated circuit made of BST. The tunable capacitor values change from 1.3 pf to 3 pf .detailed information regarding the diodes are given in the data sheet. The voltage control is done by digital to analog converter which is shown in the digital board schematic.

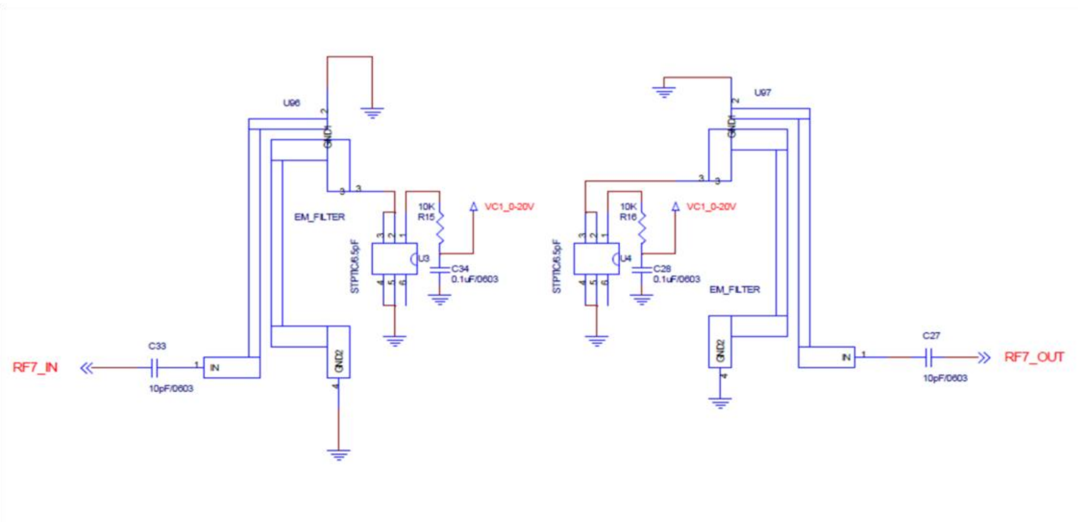


Fig 3.10 filter 7

Figure shows the schematic of filter 7 which is a microstripline tunable bandpass filter . Its detailed analysis is carried out in the previous section . Central frequency tuning i done by connecting tunable capacitor. STPTIC-82F1M6 is used . Its tunable capacitor values will change from 6.5 pf to 2 pf . Its tuning range is from 802 MHz to 1400MHz , tuning control is done by DAC . Which is explained in digital schematic.

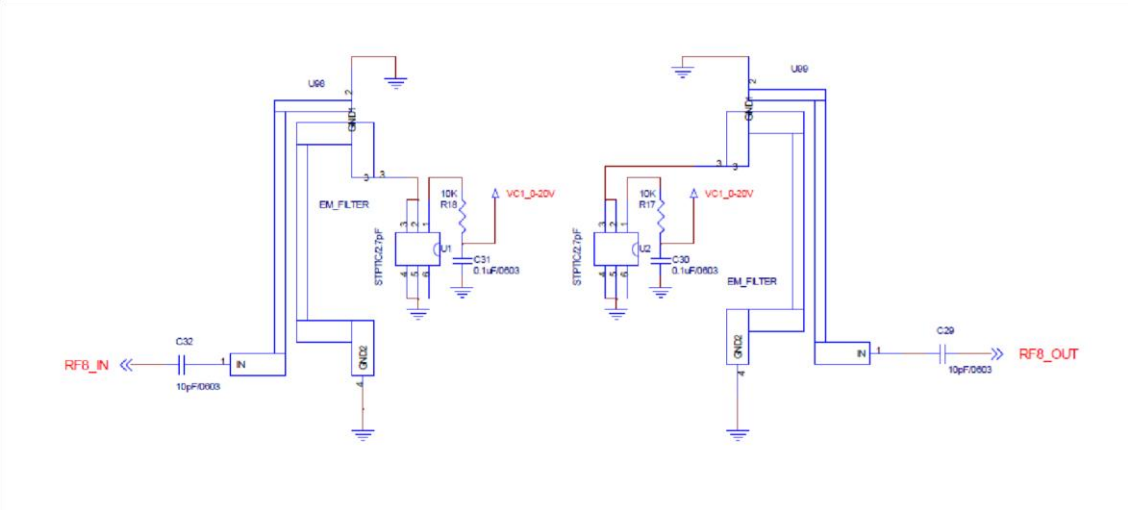


Fig 3.11 filter 8

Figure shows the schematic of filter 8 which is a microstripline tunable bandpass filter . Its detailed analysis is carried out in the previous section . Central frequency tuning i done by connecting tunable capacitor. STPTIC-27F1M6 is used . Its tunable capacitor values change from 0.7pf to 2.7 pf Its tuning range is from 1350MHz to 2000MHz , tuning control is done by DAC . Which is explained in digital schematic.

3.3 schematic of digital board

the RF schematic given in the previous section consists of filters and switches. They are all passive components. We have 8 filters which are connected to the switches. But how to select between the filters . There comes the digital board. A separate control board is designed to control the RF circuits. The detailed schematics and data sheets are given in the following sections.

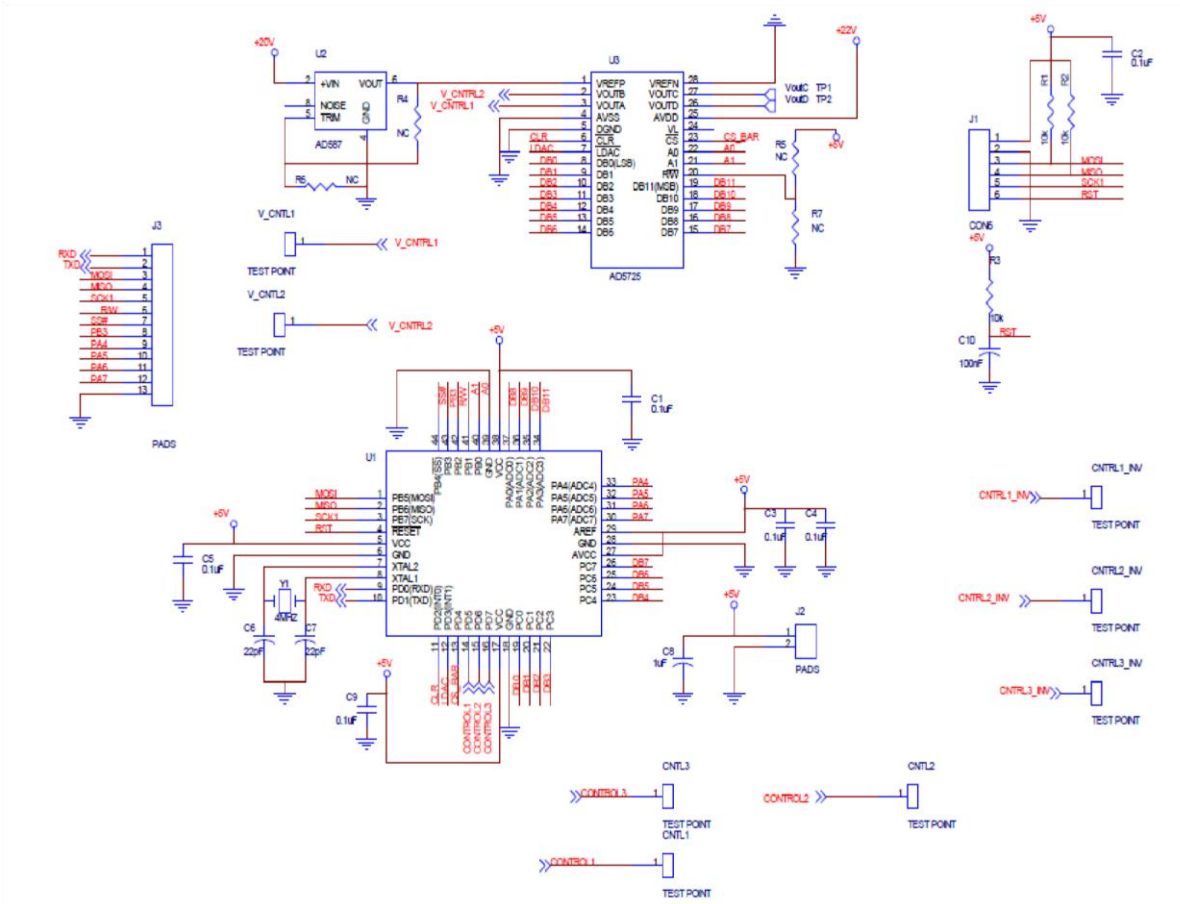


Fig 3.12 digital board schematic part 1

The AD5725 is a quad, 12-bit, parallel input, voltage output digital-to-analog converter that offers guaranteed monotonicity, integral nonlinearity (INL) of ±0.5 LSB maximum and 10 µs maximum settling time. Output voltage swing is set by two reference inputs, VREFP and VREFN. By setting the VREFN input to 0 V and the VREFP to a positive voltage, the DAC provides a unipolar positive output range. A similar configuration with VREFP at 0 V and VREFN at a negative voltage provides a unipolar negative output range. Bipolar outputs are configured by connecting both VREFP and VREFN to nonzero voltages. This method of setting output voltage ranges has advantages over the bipolar offsetting methods because it is not dependent on internal and external resistors with different temperature coefficients.

Digital input to the DAC is given through microcontroller.

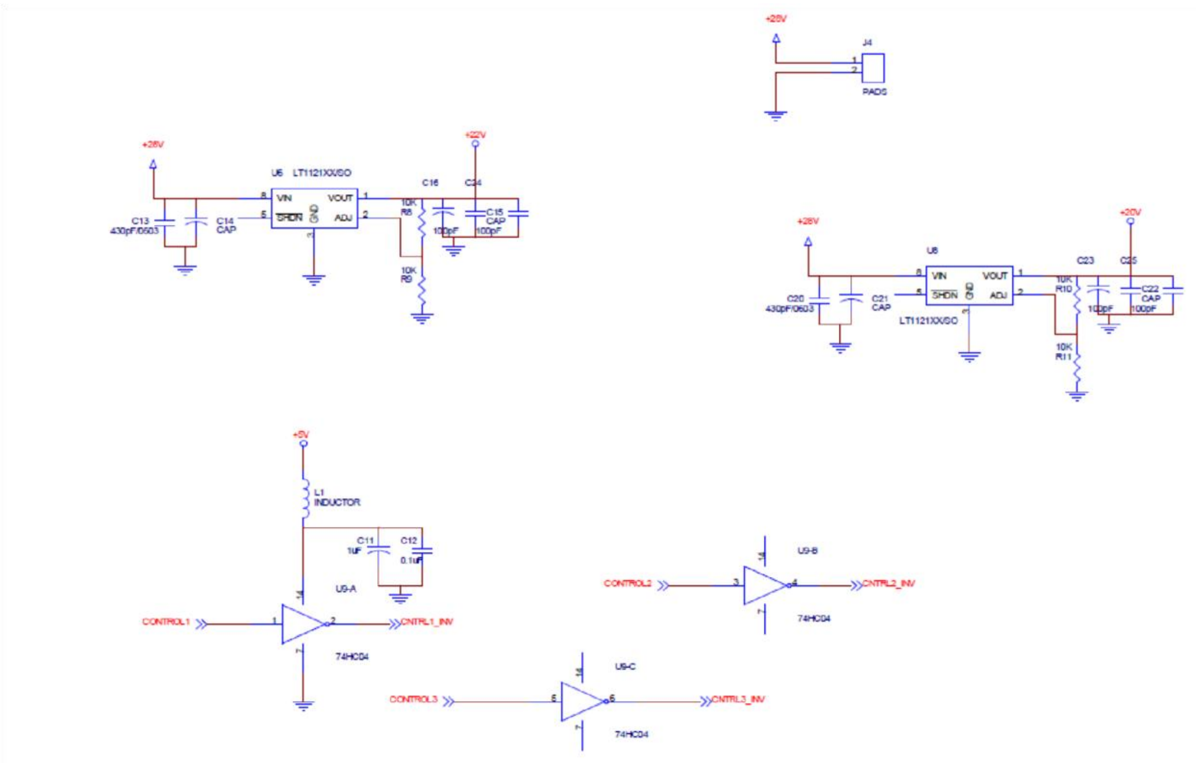


Fig 3.13 digital board schematic part 2

We are using 8-bit Microcontroller with 16K Bytes In-System Programmable F lash . Detailed description of the microcontroller is given in the data sheet. The switch in the rf board is controlled by the control1 , control2 and control3 from microcontroller. First switch is directly controlled by the control digital output , second switch is controlled by inverse of control voltages which are obtained through NOT gates .

3.4 Pcb designing

So far the schematic has been explained . The PCB comprises of two separate board for rf and digital circuits , the only way to include all of the circuits together is by designing a 4 layer layout. Since the the cost of production is high and is more complicated . Two two layer boards are designed and are connected in stacks through pins. Both boards are of same dimensions . The RF board will be placed on top and digital board at the bottom . Two SMA connectors are connected to the RF board for RF signal input and output. All the control voltages and power supplies are given in the digital board . Pin connections are used to pass signals between the boards. Following section will explain individual boards.

3.4.1 RF board pcb layout

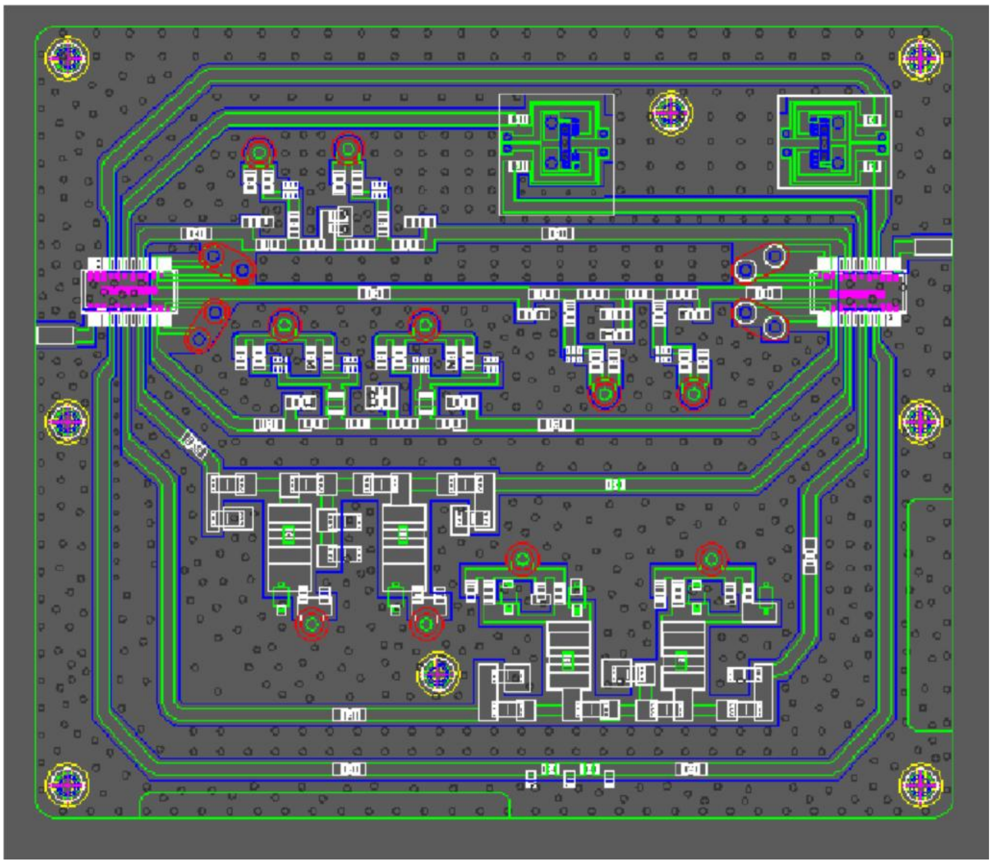


Fig 3.14 rf board layout with component masks

The figure shows the AUTOCAD of the RF circuit. Rogers RO4350B material is used with 0.5mm thickness .connections for SMA connectors are given at left and right edges. Switches are also given at both edges. Are filters are incorporated between the switches and 50ohm feed line connections are made. The control pins for the switches are given as via holes ,which will be connected to digital board through pins. Similarly control voltages for the varactors of the filters are given via holes to the bottom digital board. Two cut outs are given in the pcb at the right edge and bottom edge for the external connection pins which will be connected at the digital boards. 7 Mounting screw holes are given the board. The bottom plate of the pcb is ground.

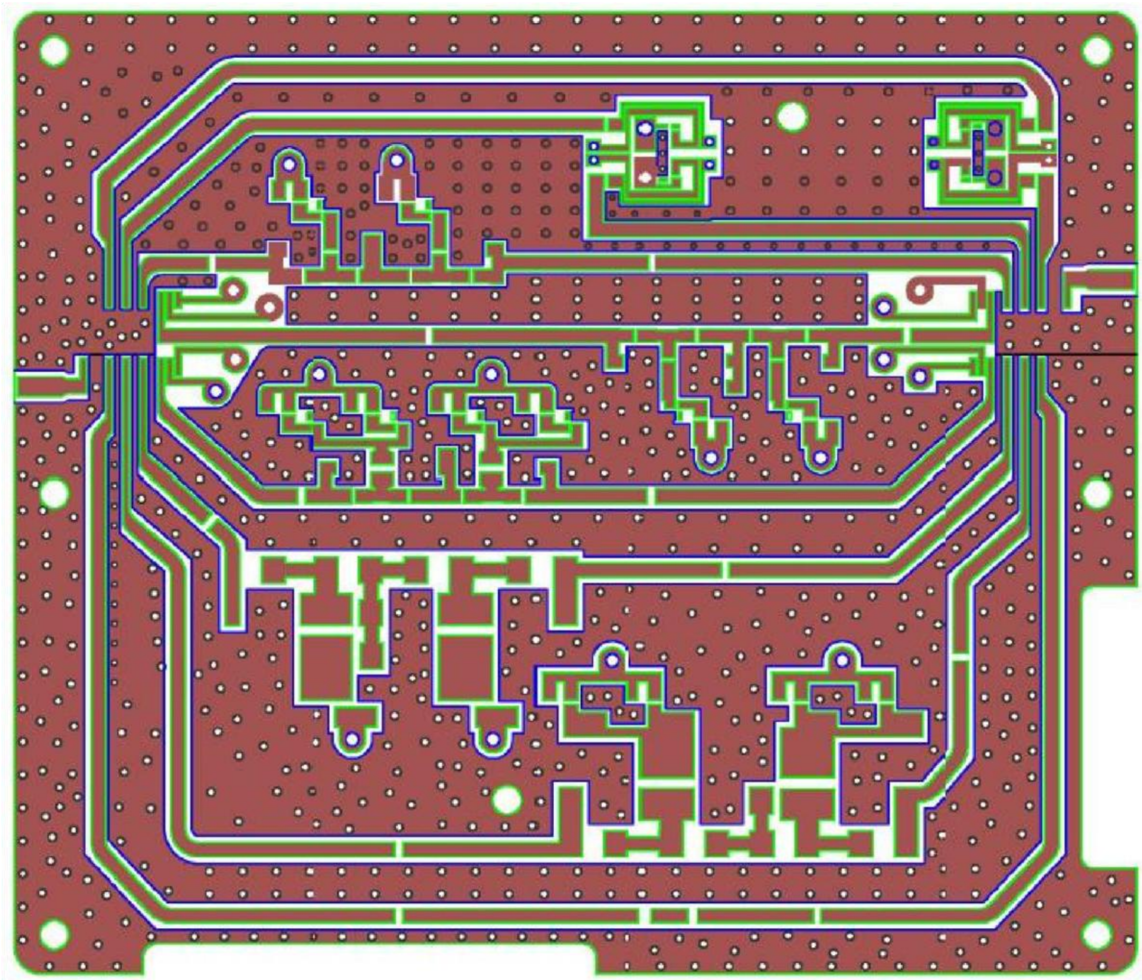


Fig 3.15 rf board layout without component masks

Figure shows the board layout without component masking. The holes throughout the boards are the rf grounds which will be connected to the bottom of the plate.

3.4.2 digital board pcb layout

For digital board material used is FR4 with 0.8mm thickness . All designs are carried out using PADS software .the figure shows the top plate of the board . All the components are placed on the top plate .via pin connections from the RF board will be connected to the digital boards in the yellow dots. The blue patches shows the pads of the components. Yellow pads the right and bottom edges of the boards are the control and power supply pins. Thick lines in the boards shows the power supply lines the big copper patches apart from connections lines are connected to ground through via holes.

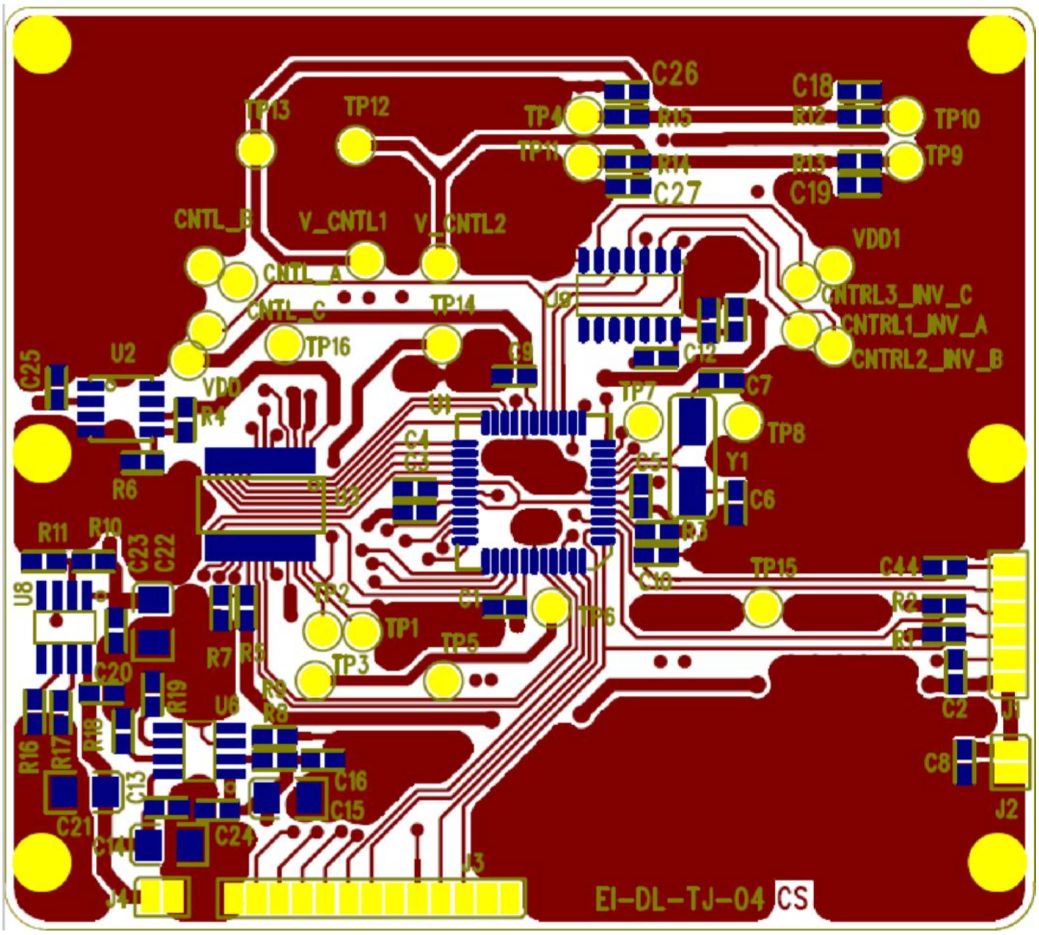


Fig 3.16 digital board layout with component masks

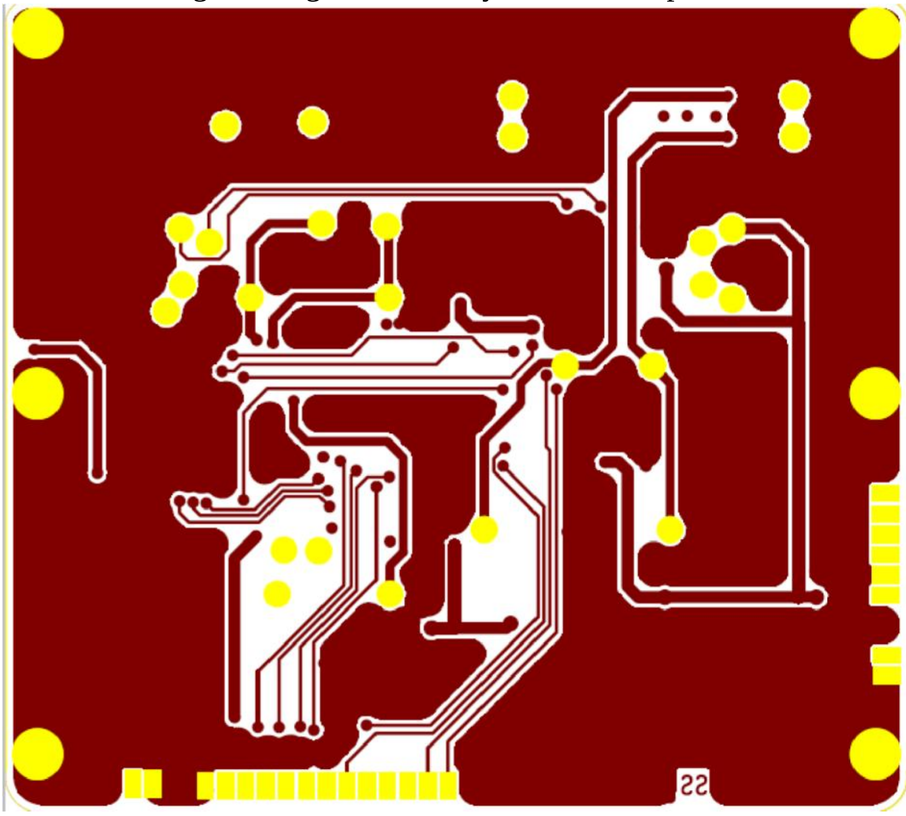


Fig 3.17 the bottom plate of the pcb

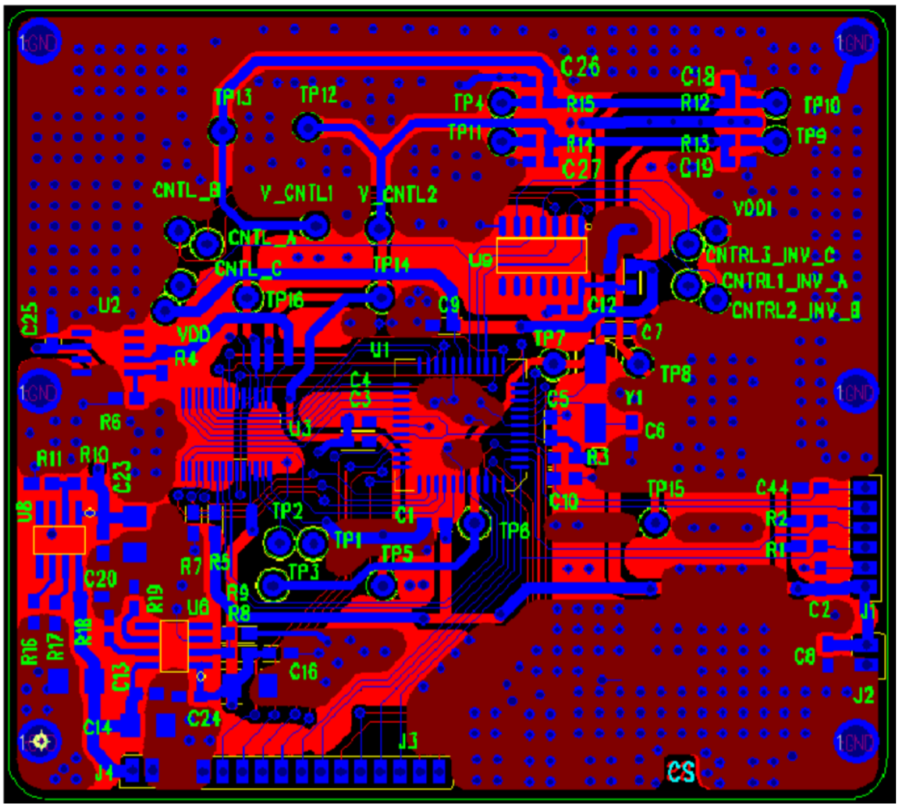


Fig 3.18 top and bottom plate combined

3.5 Simulation results

In this section we will see the results if the individual rf circuits compare the results with the specifications. All layouts are drawn in SONNET software and the results are plotted in AWR software.

3.5.1 filter 1

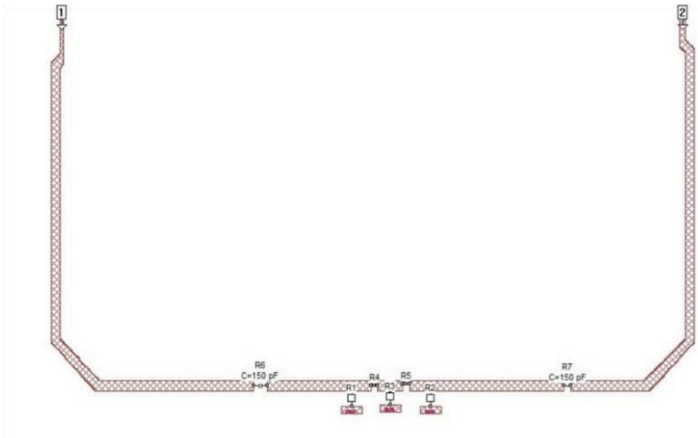


FIg 3.19 sonnet layout of high pass filter

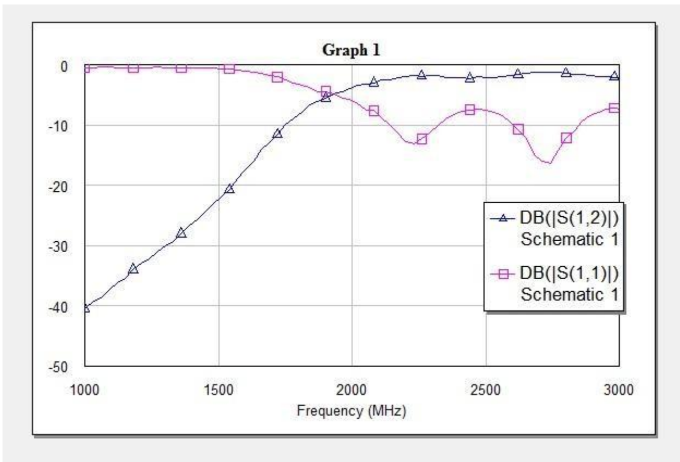


Fig 3.20 S-paramter results(IN db)

The high pass filter response shows a 3dB cut off frequency of 1900Mhz which is used to bypass the RF signal frequency above 2000 MHz.

3.5.2 filter 2

Tunable bandpass filter from 30Mhz to 100Mhz all the components used are datafiles imported from the specified manufacturers.

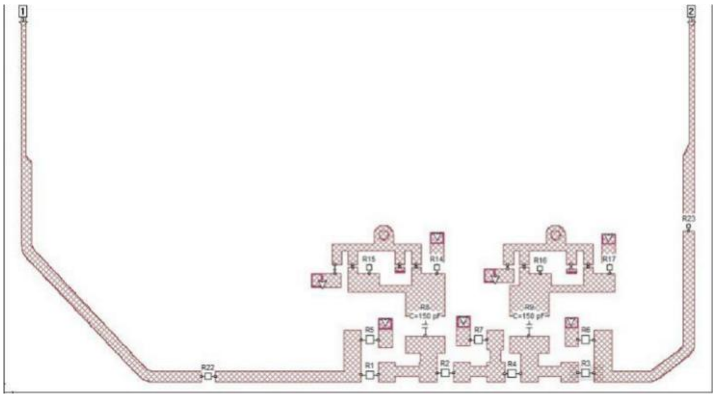


Fig 3.21 sonnet layout of filter2

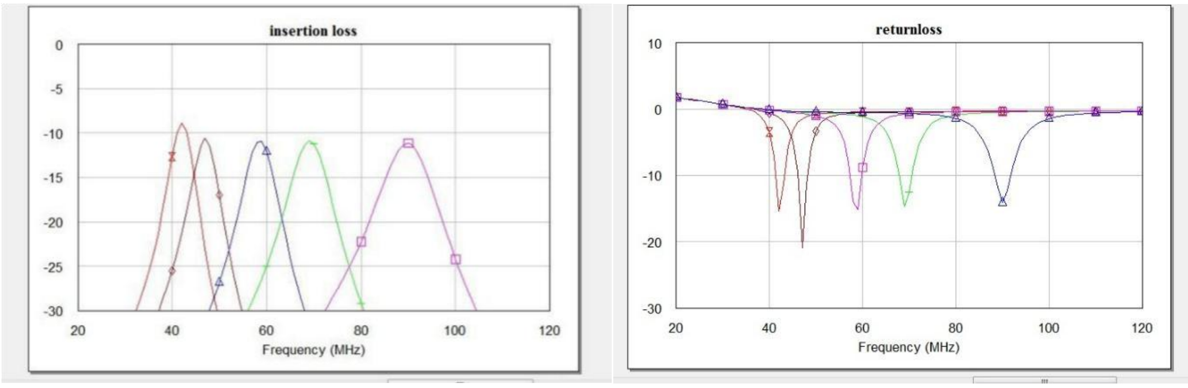


fig 3.22 s-parameter results (in db)

Since board size of the pcb was one of the constraints while designing the pcb , all designs are carried out using chip inductors . The insertions loss is less than 10dB for very low frequency is so quite expected. the filter is able to tune from 30MHz to 100MHz with the available tunable varactor with almost constant fractional bandwidth of 7.8%. The insertionloss response shows the filter output at different values of tunable capacitor. The return loss of the filter is also showing a good results which more than 10dB loss .

3.5.3 filter 3

Tunable bandpass filter from 88Mhz to 244Mhz all the components used are datafiles imported from the specified manufacturers.

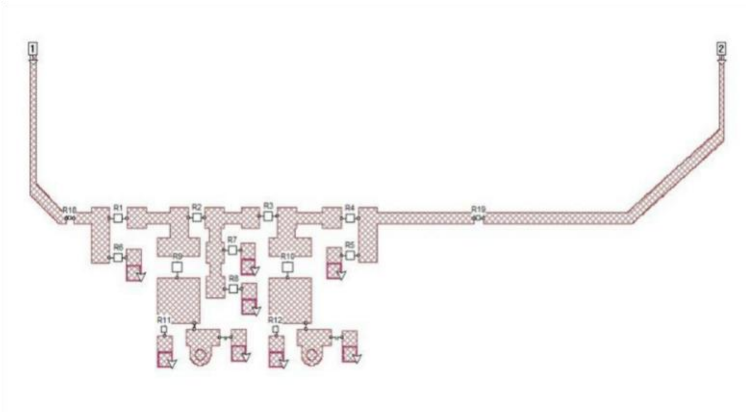


fig 3.23sonnet layout of filter3

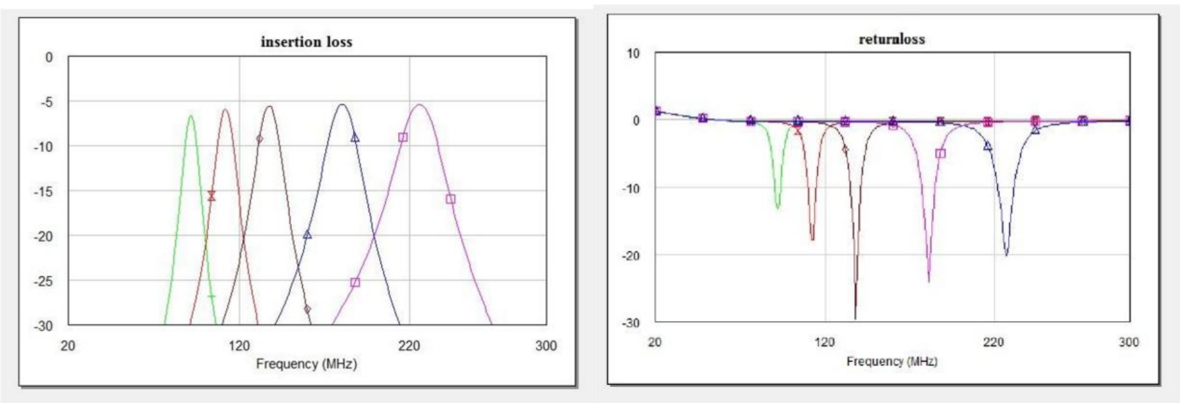


fig 3.24 s-parameter results (in db)

We can see that insertion loss is closer to 5dB throughout the band ,which is a good response . The filter is able to tune from 88MHz to 244MHz using the designed tunable capacitor.the fractional bandwidth is almost constant throughout the band with an average value of 7.5%. The return loss is also very good , with loss greater than 10db for all central frequencies.

3.5.4 filter 4

Tunable bandpass filter from 242Mhz to 410Mhz all the components used are datafiles imported from the specified manufacturers.

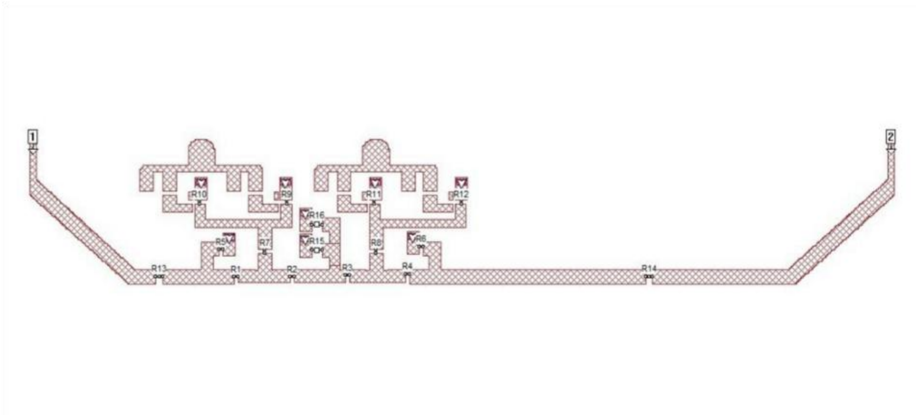


Fig 3.25 sonnet layout of filter 4

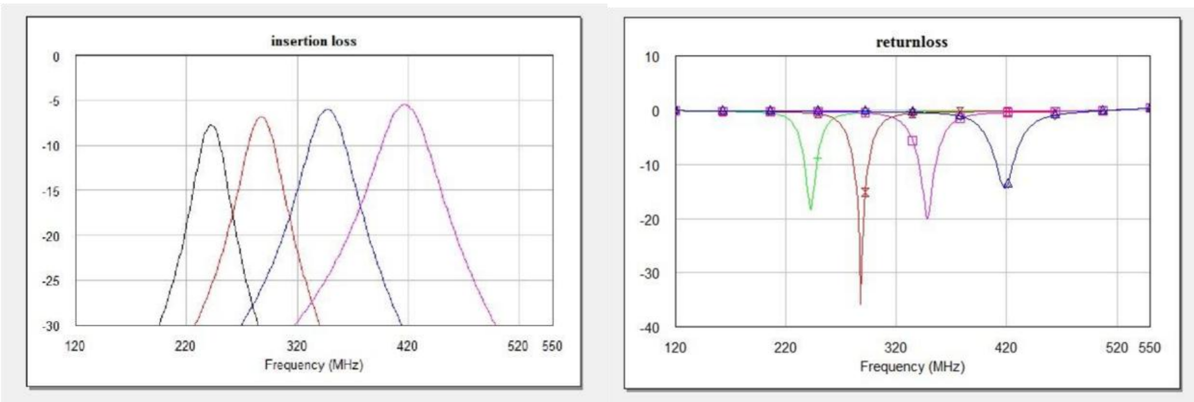


fig 3.26 s-parameter results (in db)

We can see that insertion loss is closer to 5dB throughout the band ,which is a good response . The filter is able to tune from 242MHz to 410MHz using the designed tunable capacitor.the fractional bandwidth is almost constant throughout the band with an average value of 7.5%. The return loss is also very good , with loss greater than 10db for all central frequencies.

3.5.5 filter 5

Tunable bandpass filter from 410Mhz to 680Mhz all the components used are datafiles imported from the specified manufacturers.

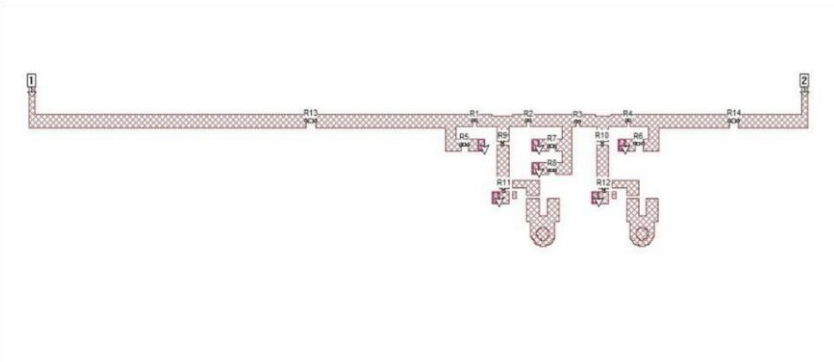
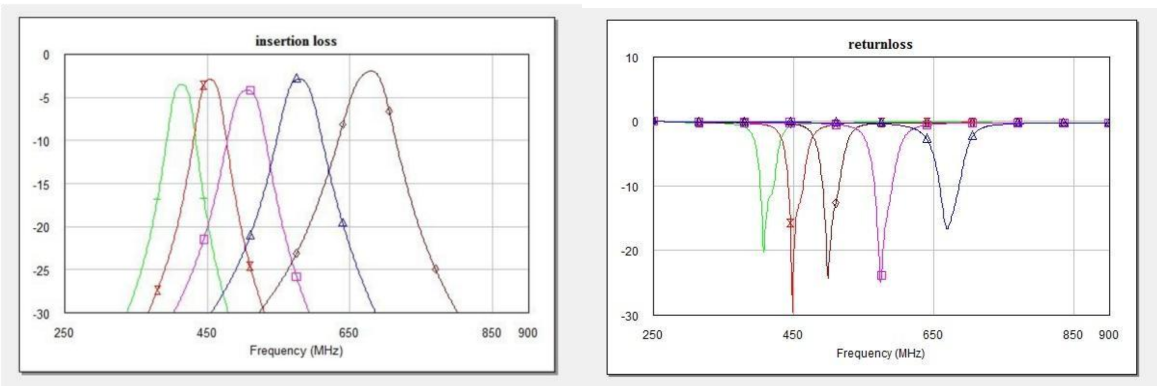


fig 3.27 sonnet layout of filter 5



S-

fig 3.28 s-parameter results (in db)

We can see that insertion loss less than 5dB throughout the band ,which is a good response . The filter is able to tune from 410MHz to 680MHz using the designed tunable capacitor.the fractional bandwidth is almost constant throughout the band with an average value of 7.4%.

The return loss is also very good , with loss greater than 10db for all central frequencies.

3.5.6 filter 6

Tunable bandpass filter from 625Mhz to 845Mhz all the components used are datafiles imported from the specified manufacturers.

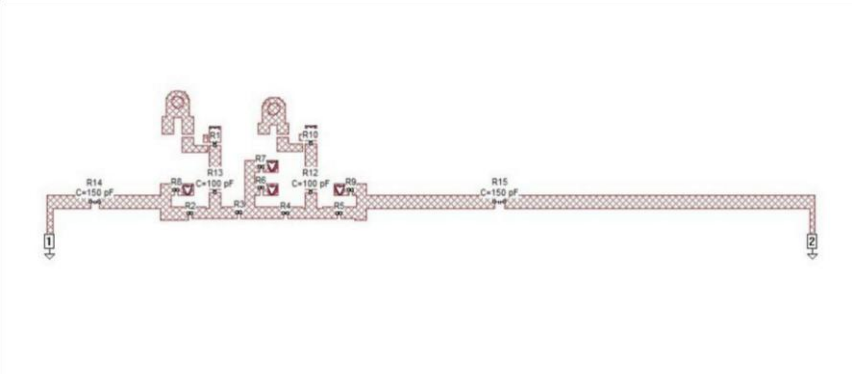


fig 3.29sonnet layout of filter 6

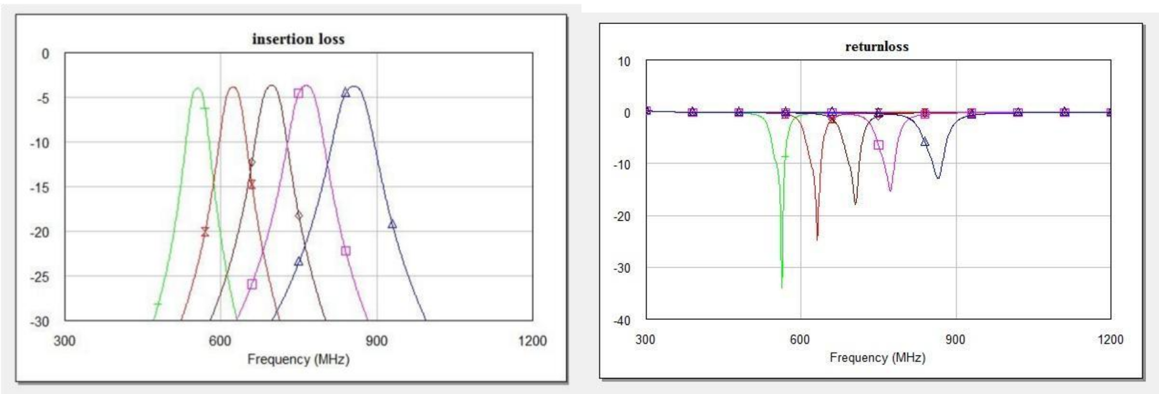


fig 3.30 s-parameter results (in db)

We can see that insertion loss is closer to 5dB throughout the band ,which is a good response . The filter is able to tune from 625 MHz to 845 MHz using the designed tunable capacitor.the fractional bandwidth is almost constant throughout the band with an average value of 7.7%. The return loss is also very good , with loss greater than 10db for all central frequencies.

3.5.7 filter 7

Tunable bandpass filter from 809Mhz to 1400Mhz all the components used are datafiles imported from the specified manufacturers.

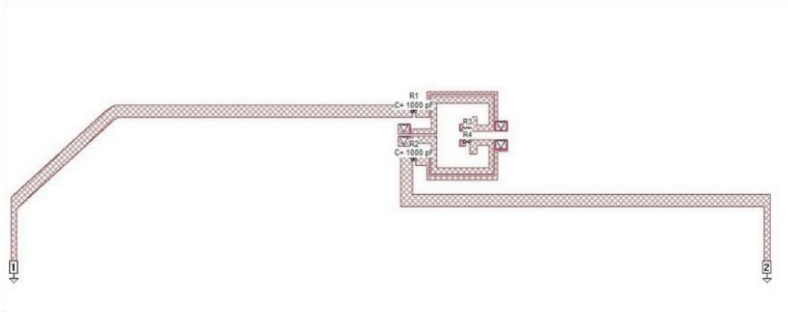


fig 3.31 sonnet layout of filter 7

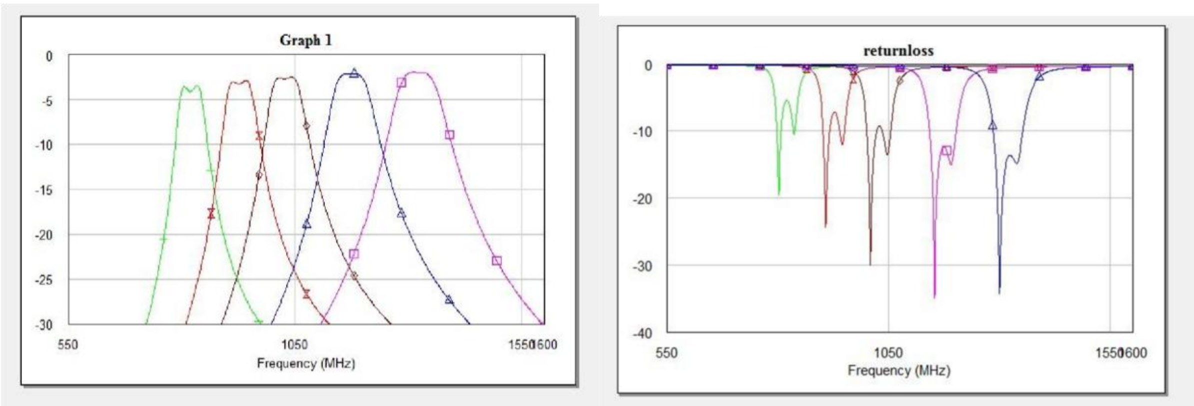


fig 3.32 s-parameter results (in db)

We can see that insertion loss is less than 5dB throughout the band ,which is a good response . The filter is able to tune from 809MHz to 1400MHz using the designed tunable capacitor.the fractional bandwidth is almost constant throughout the band with an average value of 7.4%. The return loss is also very good , with loss greater than 10db for all central frequencies.

3.5.8 filter 8

Tunable bandpass filter from 1350 Mhz to 2000Mhz all the components used are datafiles imported from the specified manufacturers.

fig 3.33 sonnet layout of filter 8

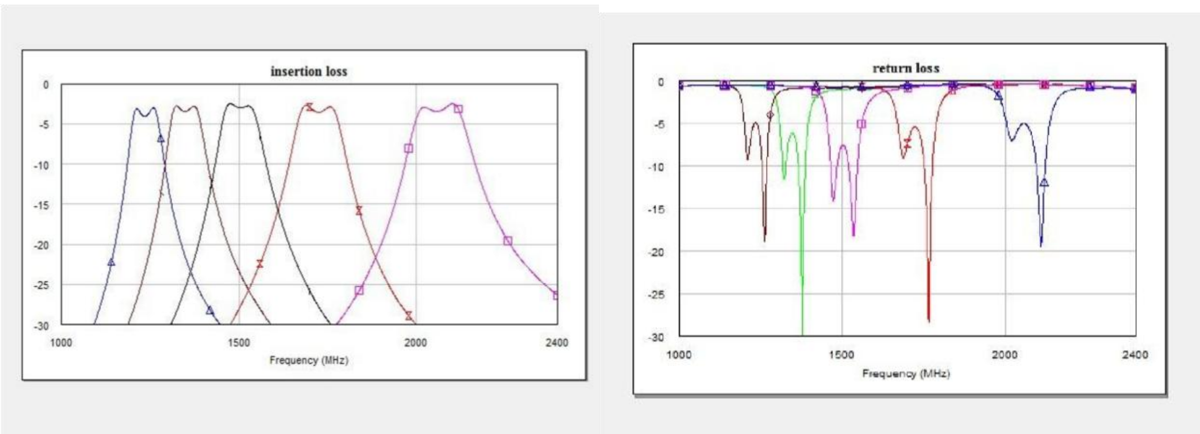


fig 3.34 s-parameter results (in db)

We can see that insertion loss is less than 5dB throughout the band ,which is a good response . The filter is able to tune from 1350 MHz to 2000 MHz using the designed tunable capacitor.the fractional bandwidth is almost constant throughout the band with an average value of 7.6%. The return loss is not very good , we can see that at it is not less greater that 10 dB at center frequency . This is due to the coupling line spacing which we have kept

0.2 mm for easiness of manufacturing , but by design it should have been 0.1 mm

Chapter 4

Fabrication and testing of prepost selector module

4.1 Fabrication and assembling

4.1.1 components used

SI.No	Qty	Part No	Description	Package	value	Supplier	manufacturer
1	2	HMC253AQS24E	SP8T SWITCH	24-SSOP	0	digikey	Hittite
2	1	ATMEGA16L-8AU-ND	MICRO CONTROLLER	44-TQFP	0	digikey	ATMEL
3	1	AD587KRZ-REEL7	High Precision 10 V Reference	8-SOIC	0	digikey	Analog devices
4	1	AD5725ARSZ-1500RL7	Voltage Output DAC	28-SSOP	0	digikey	Analog devices
5	1	SN74HC04DR	IC HEX INVERTER 14-SOIC	14-SOIC	0	digikey	TEXAS INSTRUMENTS
6	2	LT1121CS8-5#PBF	IC REG LDO 5V 0.15A 8SOIC	8-SOIC	0	digikey	LINEAR TECHNOLOGIES
7	4	SMV1255-079LF	DIODE VARACTOR 15V 20MA SC-79	SC-79, SOD-523	81.21pf	digikey	Skyworks Solutions Inc.
8	4	SMV1251-079LF	DIODE VARACTOR	SC-79, SOD-523	56.65pf	digikey	Skyworks Solutions Inc.

9	6	STPTIC-82F1M6	IC TUNABLE CAP RF BST 6UQFN	6-UQFN (1.6x1.2)	8.2pf	digikey	STMicroelectronics
10	4	STPTIC-47F1M6	IC TUNABLE CAP RF BST 6UQFN	6-UQFN (1.6x1.2)	4.7pf	digikey	STMicroelectronics
11	2	STPTIC-68F1M6	IC TUNABLE CAP RF BST 6UQFN	6-UQFN (1.6x1.2)	6.8pf	digikey	STMicroelectronics
12	4	STPTIC-27F1M6	IC TUNABLE CAP RF BST 6UQFN	6-UQFN (1.6x1.2)	2.7pf	digikey	STMicroelectronics
13	4	1206CS-271X_LB	RF chip inductor	1206	270nH	COIL CRAFT	COIL CRAFT
14	4	1206CS-121X_LB	RF chip inductor	1206	120nH	COIL CRAFT	COIL CRAFT
15	2	1206CS-101X_LB	RF chip inductor	1206	100nH	COIL CRAFT	COIL CRAFT
16	2	1206CS-330X_LB	RF chip inductor	1206	33nH	COIL CRAFT	COIL CRAFT
17	2	1206CS-220X_LB	RF chip inductor	1206	22nH	COIL CRAFT	COIL CRAFT
18	2	1206CS-150X_LB	RF chip inductor	1206	15nH	COIL CRAFT	COIL CRAFT
19	2	1206CS-120X_LB	RF chip inductor	1206	12nH	COIL CRAFT	COIL CRAFT
20	4	0603HP-39NX_LU	RF chip inductor	0603	39nH	COIL CRAFT	COIL CRAFT
21	4	0603HP-24NX_LU	RF chip inductor	0603	24nH	COIL CRAFT	COIL CRAFT
22	4	0603HP-22NX_LU	RF chip inductor	0603	22nH	COIL CRAFT	COIL CRAFT
23	2	0603HP-16NX_LU	RF chip inductor	0603	16nH	COIL CRAFT	COIL CRAFT
24	2	0603HP-7N5X_LU	RF chip inductor	0603	7.5nH	COIL CRAFT	COIL CRAFT

25	2	0603HP-6N0X_LU	RF chip inductor	0603	6.0nH	COIL CRAFT	COIL CRAFT
26	2	0603HP-5N6X_LU	RF chip inductor	0603	5.6nH	COIL CRAFT	COIL CRAFT
27	2	0603HP-4N3X_LU	RF chip inductor	0603	4.3nH	COIL CRAFT	COIL CRAFT
28	2	0603HP-3N9X_LU	RF chip	0603	3.9nH	COIL CRAFT	COIL CRAFT
			inductor				
29	2	0603HP-3N3X_LU	RF chip inductor	0603	3.3nH	COIL CRAFT	COIL CRAFT
30	2	0603HP-2N2XJLU	RF chip inductor	0603	2.2nH	COIL CRAFT	COIL CRAFT
31	4	0603HP-1N8XJLU	RF chip inductor	0603	1.8nH	COIL CRAFT	COIL CRAFT
32	4	201S42E621KV4E	CAP CER 620PF 200V NP0 1111	1111 (2828 Metric)	620pf	digikey	Johanson Technology Inc.
33	4	500R15N221JV4T	CAP CER 220PF 50V NP0 0805	0805 (2012 Metric)	220pf	digikey	Johanson Technology Inc.
34	2	251R14S101JV4T	CAP CER 100PF 250V NP0 0603	0603 (1608 Metric)	100pf	digikey	Johanson Technology Inc.
35	4	251R14S750KV4T	CAP CER 75PF 250V NP0 0603	0603 (1608 Metric)	75pf	digikey	Johanson Technology Inc.
36	4	251R14S100JV4T	CAP CER 10PF 250V NP0 0603	0603 (1609 Metric)	10pf	digikey	Johanson Technology Inc.
37	4	251R14S0R7AV4T	CAP CER 0.70PF 250V NP0 0603	0603 (1608 Metric)	0.7pf	digikey	Johanson Technology Inc.
38	14	GRM1885C1H151JA01D	CAP CER 150PF 50V NP0 0603	0603 (1608 Metric)	150pf	digikey	Murata Electronics North America

39	20	C0603C102K5RACTU	CAP CER 1000PF 50V X7R 0603	0603 (1608 Metric)	1000pf	digikey	Murata Electronics North America

Table 4.1 list of components used

4.1.2 digital board

Two separate boards were fabricated for RF and digital circuits,and tested separately before mounting to the housing. The following Images shows the fabricated circuit boards. Digital board was fabricated on an Fr4 0.5mm substrate controls from the digital board can be seen as 0.5mm diameter holes (PTH) 6 holes are given for connecting the rf board. Figure 4.1 shows the digital board with components assembled . on the right side six connector pins are given for programming the micro-controller through pony programmer. At the bottom 13 connector pins are given to control the micro controller . external connection to the computer is done through rx/tx pins of the controller .another 2 pins are given for power supply . 20V power supply can be connector to the supply input. Voltage regulators are used to down convert the voltages to match the specifications of other components.

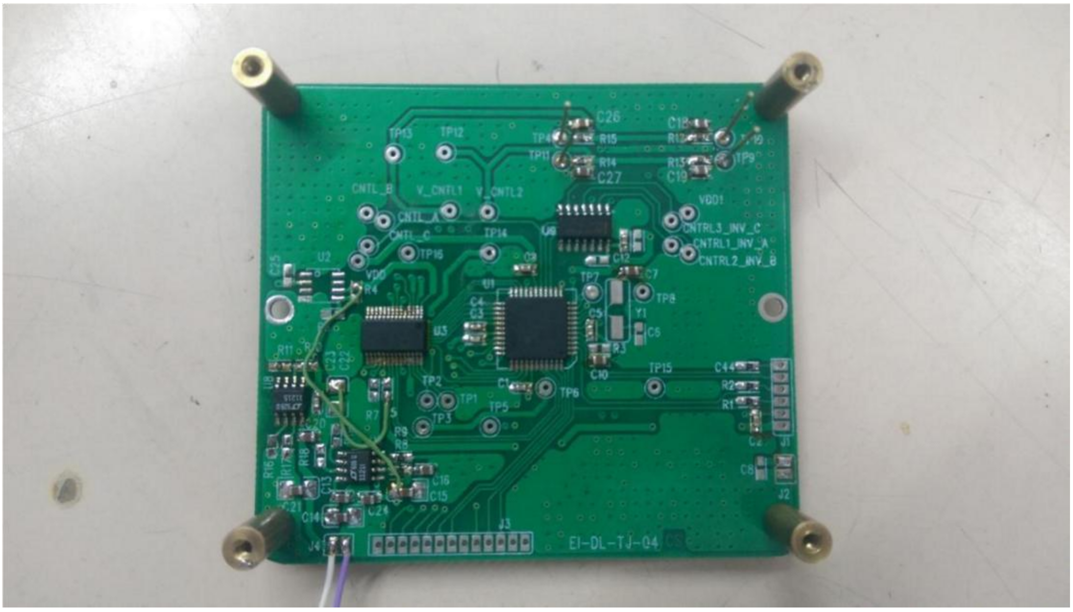


Fig 4.1 Digital board with components

4.1.3 RF board

Fig 4.2 shows the RF board with components assembled.RF board is fabricated on a 0.5mm thick Rogers4350 substrate Two IC’s at the left and right end of the board are the RF switches(HMC253) which has got one common RF input and 8 RF output pins . each filter is connected to each switch provisions . At the top two filters can be seen with rectangular shape , they are the odd and even mode coupled microstripline tunable bandpass filters. Voltage controls for the varactor diodes are connected through pins from the digital board which is to be connected at the bottom of the RF board.two cut outs are given at right and bottom ends of the boards for making connections to the connectors in the digital board easier.six 2mm diameter holes are given to mount the digital and RF boards in stacks. All the all other 0.4mm diameter holes are PTH which connects the grounds properly. Two pads are given at left and right ends near the switches for connecting theSMA connectors.

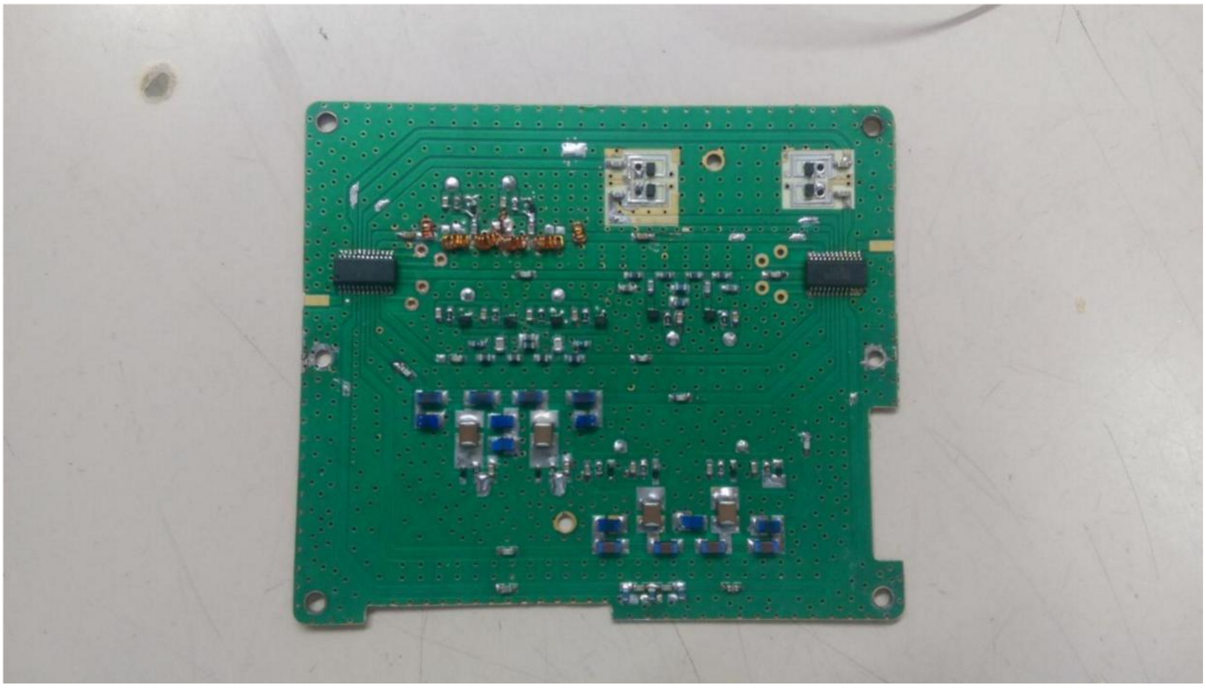


Fig 4.2 RF board with components

After testing individual boards separately they are connected through 1inch pins in stacks as shows in fig 4.3. SMA connectors are connected at the left and right ends for RF input anf output. A connector is given at the bottom of the board which contains power supply pins, microcontroller programming pins and microcontroller interface pins , finnally an housing is made to cover the module at cut outs are given for SMA connectors and other connectors.

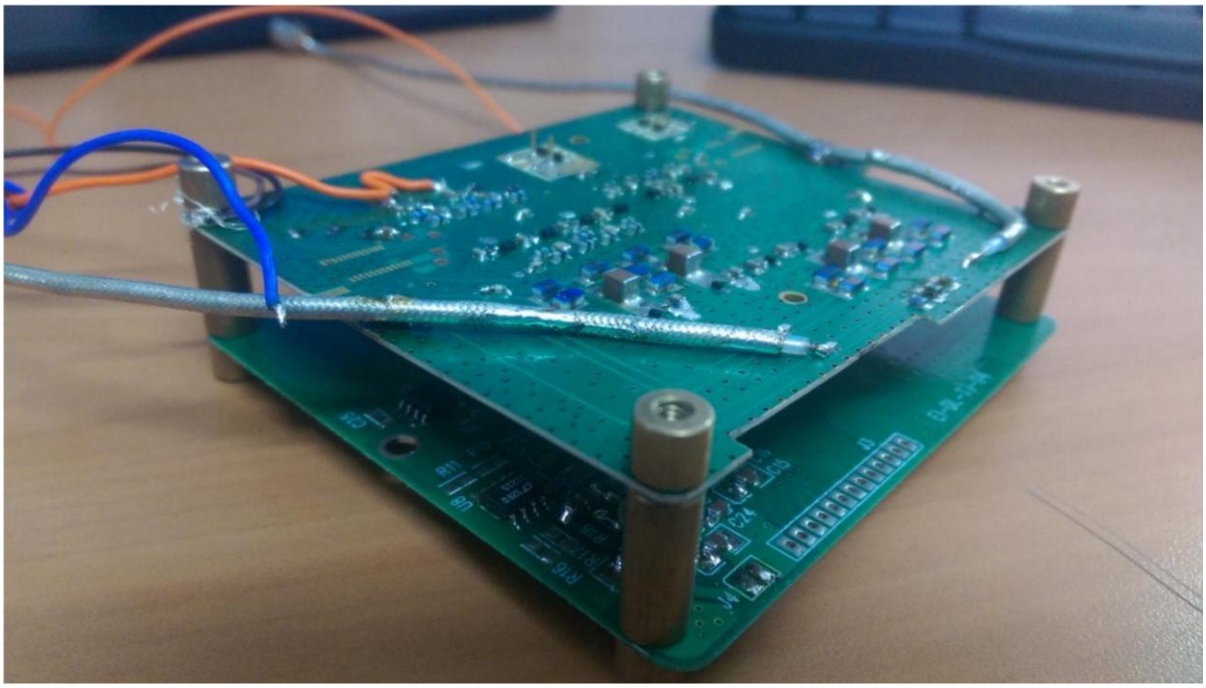


Fig 4.3 both RF and digital boards connected through pins

4.2 programming the microcontroller

The atmel16L microcontroller is used to select the frequency by controlling the RF switch and by supplying desired biasing voltage to the varactor diode. Two functions are used to control switch and voltage separately.

Program type : Application

Clock frequency : 8.000000 MHz

Memory model : Small

External SRAM size : 0

Data Stack size : 256

Chip type : ATmega16L

```
***********************************************
*
******/

#include <mega16.h>
 #include <stdlib.h>
 #include <string.h>
 #include<stdio.h>
 #include <delay.h>
#define RXB8 1
#define TXB8 0
#define UPE 2
#define OVR 3
#define FE 4
#define UDRE 5
#define RXC 7
#define FRAMING_ERROR (1<<FE)
#define PARITY_ERROR (1<<UPE)
#define DATA_OVERRUN (1<<OVR)
#define DATA_REGISTER_EMPTY (1<<UDRE)
#define RX_COMPLETE (1<<RXC)     eeprom
int switchpos=8,bw=500,fy=4000;
funcswitch(int val);
 funcdac(int ch ,int Volt);
// USART Receiver buffer #define
RX_BUFFER_SIZE 8 char
rx_buffer[RX_BUFFER_SIZE];


#if RX_BUFFER_SIZE<256 unsigned char
rx_wr_index,rx_rd_index,rx_counter;
#else
unsigned int rx_wr_index,rx_rd_index,rx_counter;
#endif bit
rx_buffer_overflow;
 int Freq[81]={30,35,40,45,50,55,60,65,70,75,80,90,100,
110,120,130,140,150,160,170,180,190,200,
220,240,260,280,300,320,340,360,380,400,
420,440,460,480,500,520,540,560,580,600,
          620,640,660,680,700,720,740,760,780,800,
          820,840,860,880,900,950,1000,1050,1100,
          1150,1200,1250,1300,1350,1400,1450,1500,

1550,1600,1650,1700,1750,1800,1850,1900,1950,2000};
void InterPolateData(int freqValue)
{
float Xval; int
j,val;
if(freqValue >=30 && freqValue < 80)
  {
    funcswitch(2);
delay_ms(1000);
    }
 else if(freqValue >=80 && freqValue < 200)
  {
    funcswitch(3);      delay_ms(500);
    }
 else if(freqValue >=200 && freqValue < 400)
  {
     funcswitch(4);       delay_ms(500);
     }
 else if (freqValue >=400 && freqValue <700)
   {
    funcswitch(5);       delay_ms(500);
    }
 else if(freqValue >=700 && freqValue < 900)
   {
    funcswitch(6);      delay_ms(500);
    }
 else if(freqValue >=900&& freqValue < 1300)
    {
    funcswitch(7);       delay_ms(500);
```

```
}
else if(freqValue >=1300&& freqValue < 2000)
{
funcswitch(8);      delay_ms(500);

}   else

funcswitch(1);      delay_ms(500);
}  char str[20];   char str1[20];
formatStr()

{   int i,val,Volt;    char
strtemp[10];
for(i=1;i<strlen(str);i+
+)    strtemp[i-
1]=str[i];    strtemp[i-
1]='\0';
puts(strtemp);
val=atoi(strtemp);
Volt=atoi(strtemp);
switch(str[0])

{      case
'w':

                    printf("IN    CASE    W");
InterPolateData(val);                    break;
case  'a':                    printf("IN CASE a");
//funcswitch(val);
switchpos=val;                              break;
case  'b':                    printf("IN CASE b");
//  funcdac(val);                         bw=val;
break;


   case 'c':               printf("IN CASE c");
str1[0]=str[1];
str1[1]=str[2];
str1[3]='\0';
Volt=atoi(str1);
printf("volt=%d\r\n",Volt);
funcdac(0,Volt);
funcdac(1,Volt);                          //fy=val;
break;


   default:  break;
}



                delay_ms(1000);
```

```
};

//switch function
#include <mega16.h>

funcswitch(int val)
{
DDRD=0xff;
val =val-1;

PORTD.5=val%2;
val =val/2;
PORTD.6= val%2;
PORTD.7=val/2;
}

//function funcdacc

#include "delay.h"
#include <mega16.h>
 #include <string.h>
 #include<stdio.h>
 #include <delay.h>
#define ldac PORTD.3
#define B0 PORTB.0
#define B1 PORTB.1
#define cs PORTD.4
#define C0 PORTC.0
#define C1 PORTC.1
#define C2 PORTC.2
#define C3 PORTC.3
#define C4 PORTC.4
#define C5 PORTC.5
#define C6 PORTC.6
#define C7 PORTC.7
#define A3 PORTA.3
#define clr PORTD.2

funcdac(int ch ,int Volt)
{
float val=16.0;  int C;   int
j,P,i=0,g,g1; double
cons,D; int
Arr_1[12],Arr[12];

clr=1; cs=1;
ldac=1;
ldac=0;

B0=ch%2;
B1=ch/2;

// B0=1;
// B1=0;

printf("volt2=%d\r\n",Volt);
cons=4096/16.0;
cons=cons/1;
D=(Volt*cons)/10; C=D;
printf("D=%d%",C); printf("
\r\n"); while(C>1)
{
 g=C%2;
 Arr[i]=g;
C=C/2;  i++;
g1=C;
}
```

```
#define A0 PORTA.0
#define A1 PORTA.1
#define A2 PORTA.2
```

```
g=C;
Arr[i]=g;
P=i;
while(i<=11)
{
i++;
Arr[i]=0;
printf("i=%d\r\n",i);
}
i=0;
printf("data=");
for(j=0;j<12;j++)
{
 printf("%d%",Arr[11-j]);

}
  printf("\r\n");
 A3=Arr[11];
A2=Arr[10];
 A1=Arr[9];
A0=Arr[8];
 C7=Arr[7] ;
C6=Arr[6] ;
C5=Arr[5] ;
C4=Arr[4] ;
C3=Arr[3] ;
C2=Arr[2] ;
C1=Arr[1] ;
 C0=Arr[0] ;

for(i=0;i<=11;i++)
cs=0; delay_ms(1);
cs=1; delay_ms(1);
ldac=1;
}
```

4.3 testing the module with network analyzer

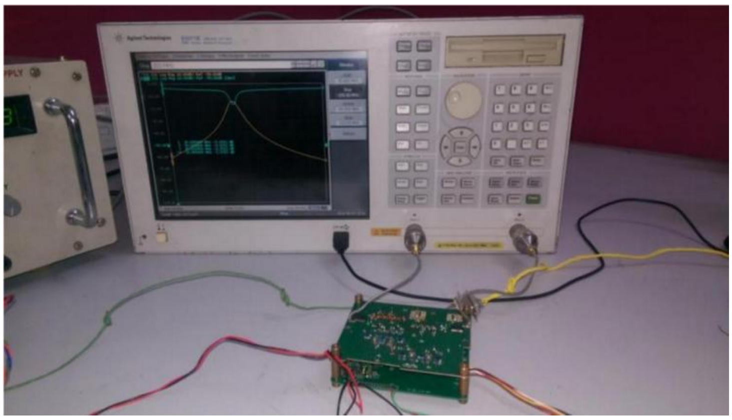


Fig 4.4 prepost selector module connected to network analyser for testing.

Figure shows the testing setup of the prepost selector module. For testing purpose coaxial connectors were soldered to the board and connected to network analyzer. Digital controls were given with wires soldered to the respective connectors . after connecting to the network analyzer the output obtained is given below. For each path two graphs were taken which is basically the starting and ending points of the respective path.

Filter	frequency(MHz)	Voltage (V)
Filter2	30	0.l
	40	1
	50	1.6
	60	2.1
	70	2.5
	75	2.7
	80	2.8

Filter	frequency(MHz)	Voltage (V)
Filter3	80	0.l
	90	0.5
	110	1.1
	120	1.4
	140	1.9
	160	2.3
	200	3.2

Table 4.2 filter 2 response with voltage

Filter	frequency(MHz)	Voltage (V)
	224	0.2
	230	0.9
	260	3.2
Filter4	305	7
	350	12
	380	16.3
	415	20.6

Table 4.3 filter 3 response with voltage

Filter	frequency(MHz)	Voltage (V)
	700	1.6
	750	1.9
	800	2.1
Filter6	825	2.4
	850	2.4
	875	2.5
	900	2.7

Table 4.4 filter 4 response with voltage

Table 4.6 filter 6 response with voltage

Filter	frequency(MHz)	Voltage (V)
	400	0.5
	450	2.4
	500	4.7
Filter5	575	8.7
	650	14.2
	675	16.4
	700	19.1

Table 4.5 filter 5response with voltage

Filter	frequency(MHz)	Voltage (V)
	830	1.6
	900	3
	1000	5
Filter7	1100	7.1
	1200	9.8
	1250	11
	1300	12.6

Table 4.7 filter 7 response with voltage

Filter	frequency(MHz)	Voltage (V)
Filter 8	1220	1.2
	1400	4.1
	1600	7.9
	1700	9.1
Filter8	1800	13.1
	1900	17.3
	1950	19.9

Table 4.8 filter 8response with voltage

Tables given above tabulated the frequency response of individual paths corresponding to bias voltage of the varactor . S-parameter response is given in the following figures .

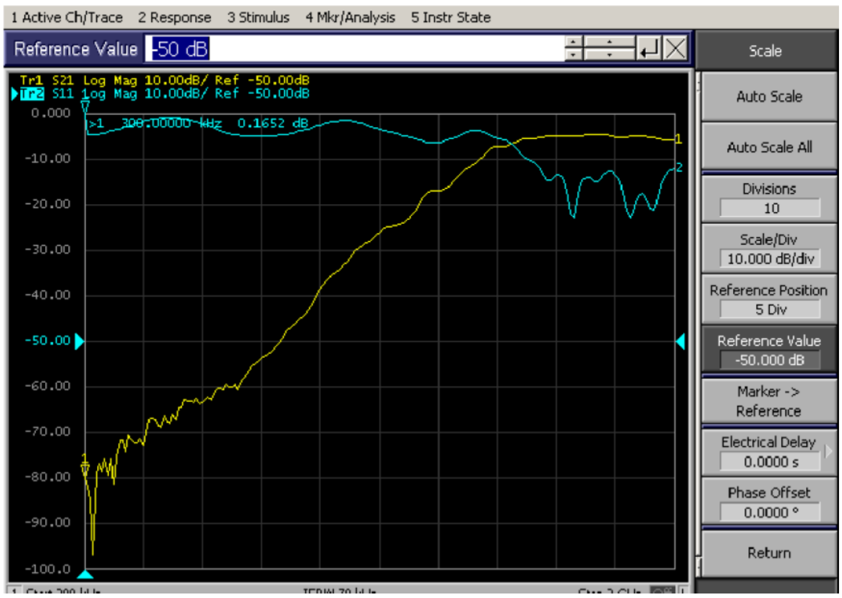


Fig 4.5 path1 ,high pass filter

Figure shows the s-parameter results of high pass filter ,yellow line shows insertion loss and blue line indicated return loss ,3dB cut off point is at 2GHz ,which is matching the simulated results

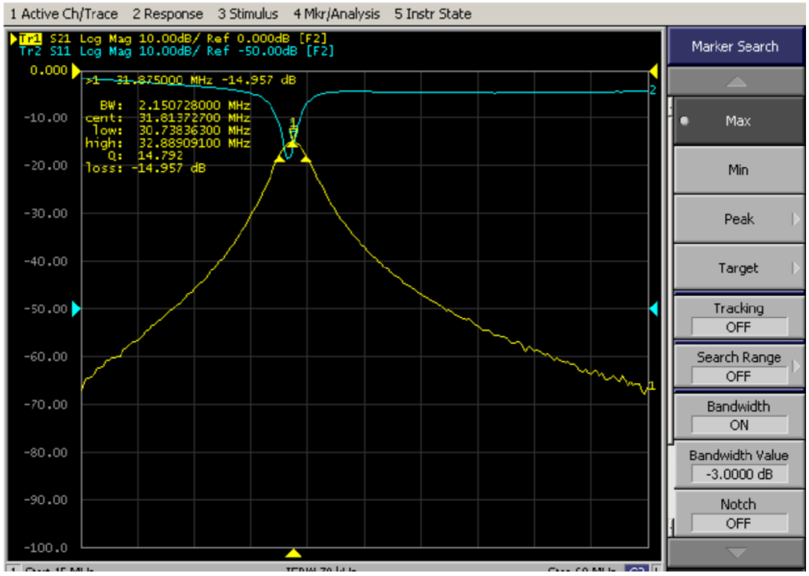


Fig 4.6 path2 ,first point

Figure 4.6 shows the response of filter 2 at 31.8 MHz , insertion loss is 14dB and absolute bandwith is 2.15Mhz. yellow line shows insertion loss and blue line indicated return loss

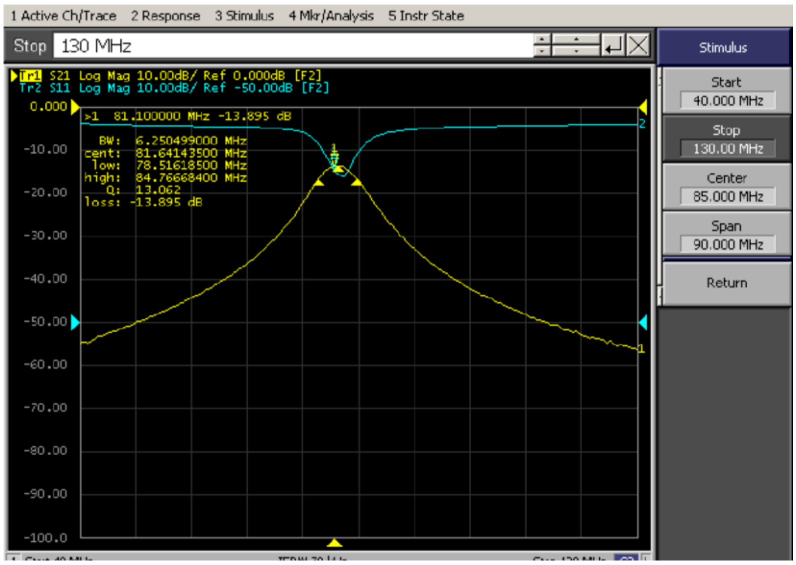


Fig 4.7 path2,second point

Figure 4.7 shows the response of filter 2 at 81.6 MHz , insertion loss is 13dB and absolute bandwith is 6.29Mhz. yellow line shows insertion loss and blue line indicated return loss

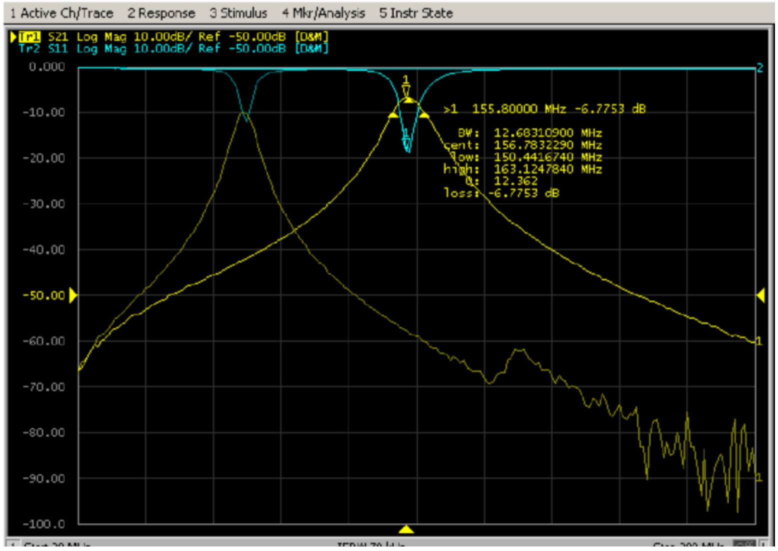


Fig 4.8 path3 ,first point

Figure 4.8 shows the response of filter 3 at 156.78 MHz , insertion loss is 6.77dB and absolute bandwith is 12.68 Mhz. yellow line shows insertion loss and blue line indicated return loss

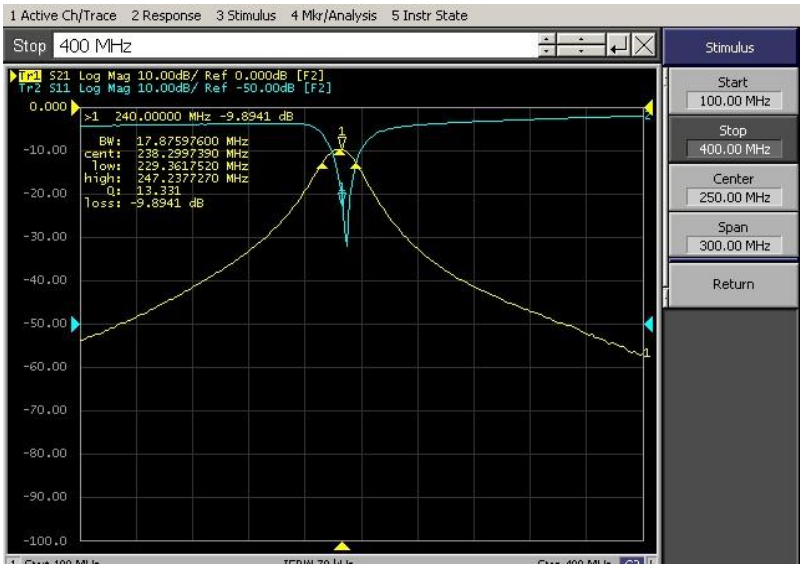


Fig 4.9 path3 ,second point

Figure 4.9 shows the response of filter 3 at 238.29 MHz , insertion loss is 9.8dB and absolute bandwith is 17.87 Mhz. yellow line shows insertion loss and blue line indicated return loss

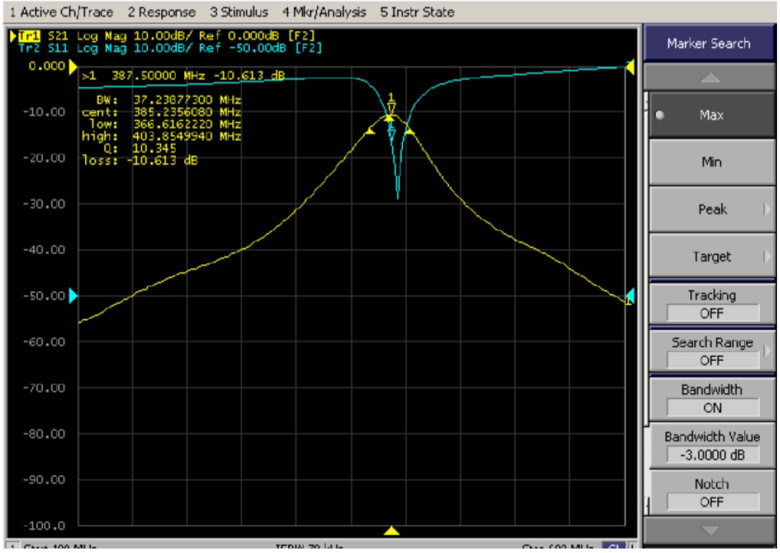


Fig 4.10 path4 ,first point

Figure 4.10 shows the response of filter 4 at 305.23 MHz , insertion loss is 10.63dB and absolute bandwith is 37.238Mhz. yellow line shows insertion loss and blue line indicated return loss

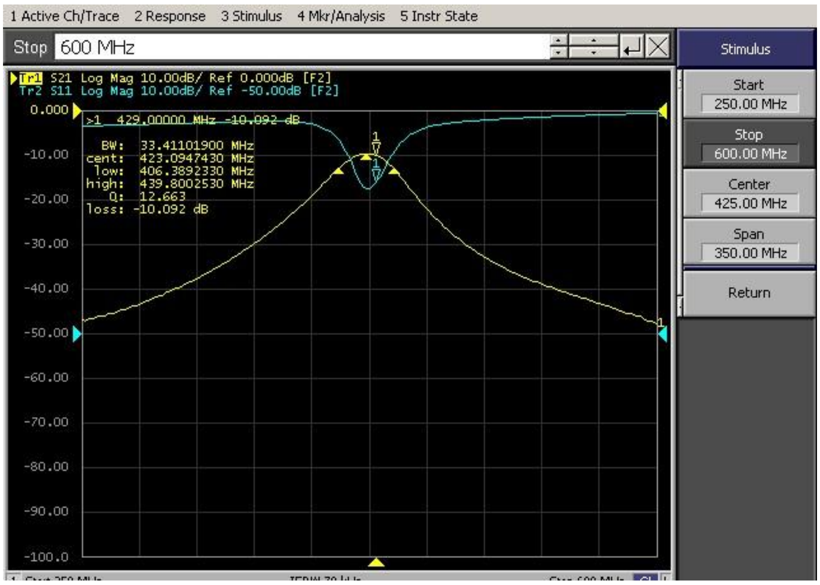


Fig 4.11 path 4 ,second point

Figure 4.11 shows the response of filter 4 at 423 MHz , insertion loss is 10.92dB and absolute bandwith is 33.41Mhz. yellow line shows insertion loss and blue line indicated return loss

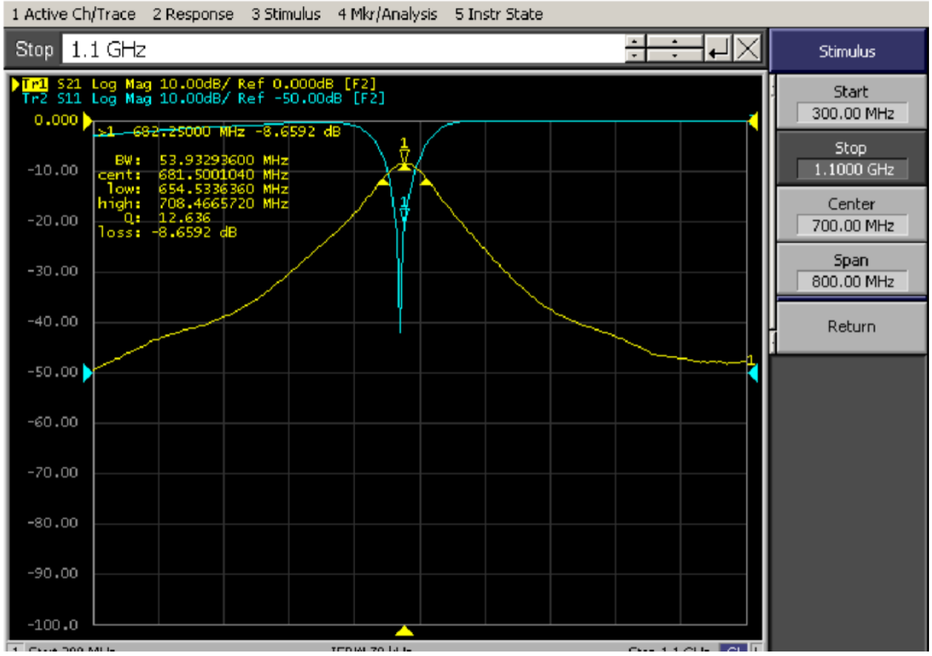


Fig 4.12 path 5 ,first point

Figure 4.12 shows the response of filter 5 at 681.5 MHz , insertion loss is -8.6592dB and absolute bandwith is 53.92. yellow line shows insertion loss and blue line indicated return loss

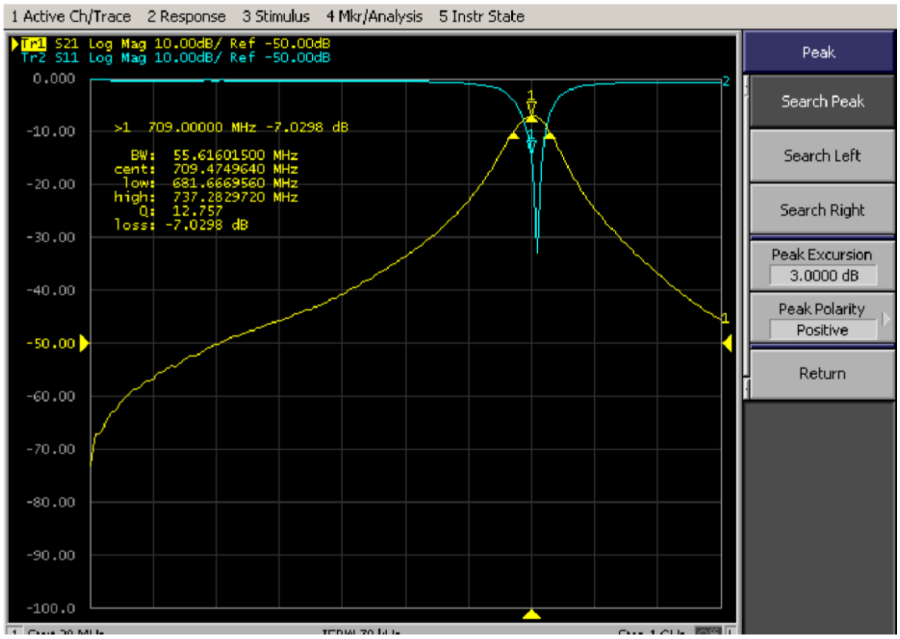


Fig 4.13 path 5,second point

Figure 4.13 shows the response of filter 5 at 709 MHz , insertion loss is -7.02dB and absolute bandwith is 55.61Mhz. yellow line shows insertion loss and blue line indicated return loss

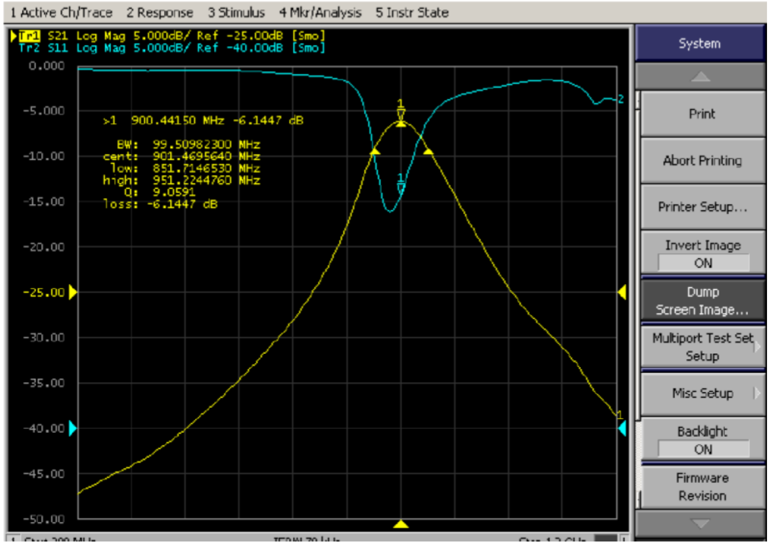


Fig 4.14 path 6 ,first point

Figure 4.14 shows the response of filter 6 at 901.46 MHz , insertion loss is 6.1447dB and absolute bandwith is 99.5Mhz. yellow line shows insertion loss and blue line indicated return loss

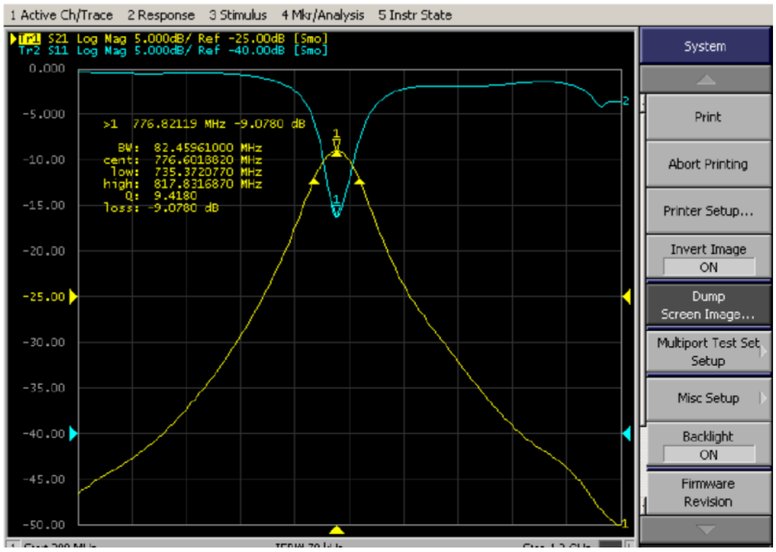


Fig 4.15 path 6 ,second point

Figure 4.15 shows the response of filter 6 at 776.60 MHz , insertion loss is 9.078dB and absolute bandwith is 82.45Mhz. yellow line shows insertion loss and blue line indicated return loss

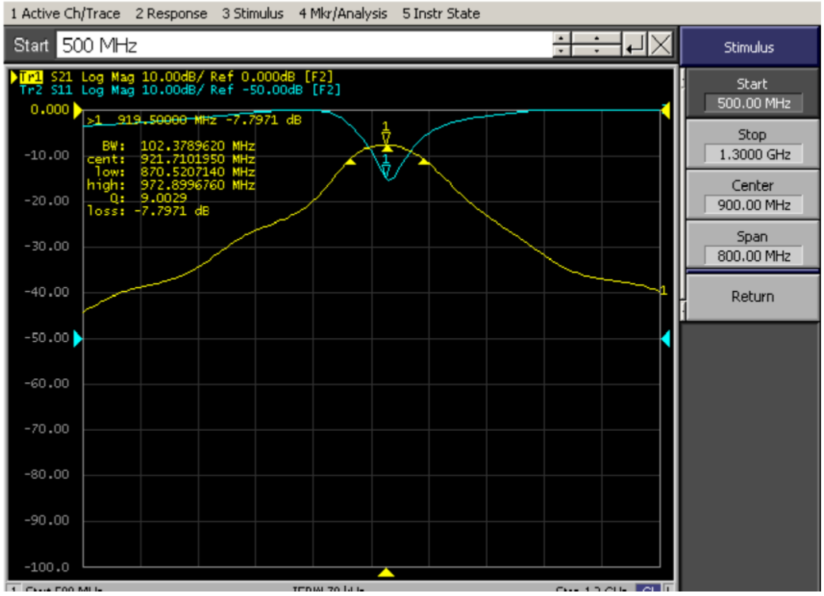


Fig 4.16 path 7,first point

Figure 4.16 shows the response of filter 7 at 921.71 MHz , insertion loss is -7.791 and absolute bandwith is 102.37Mhz. yellow line shows insertion loss and blue line indicated return loss

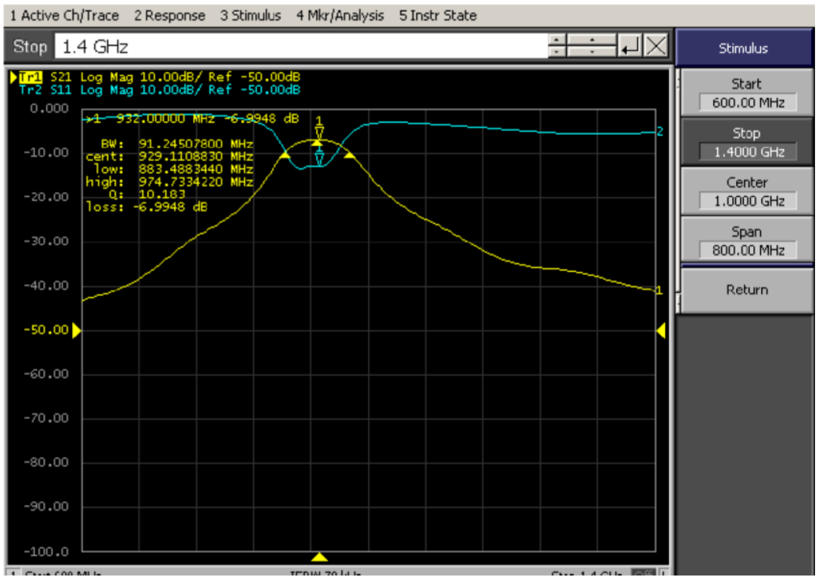


Fig 4.17 path 7,second point

Figure 4.17 shows the response of filter 7 at 929 MHz , insertion loss is -6.994dB and absolute bandwith is 91.24 Mhz. yellow line shows insertion loss and blue line indicated return loss

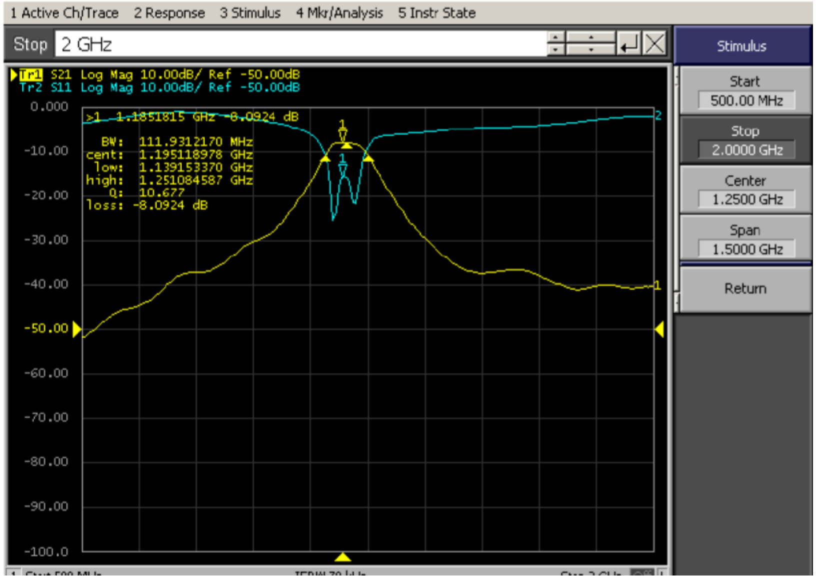


Fig 4.18 path 8 ,first point

Figure 4.18 shows the response of filter 8 at 1195.11 MHz , insertion loss is -8.092dB and absolute bandwith is 111.2Mhz. yellow line shows insertion loss and blue line indicated return loss

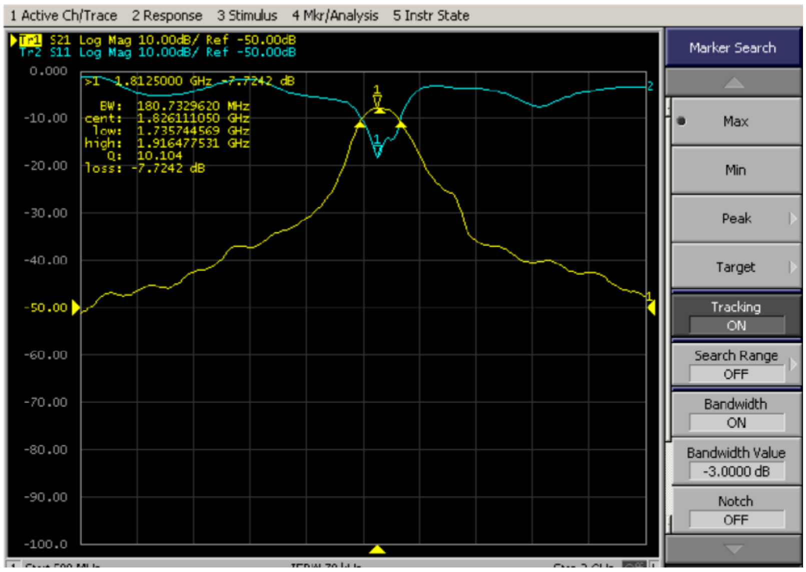


Fig 4.19 path 8 ,second point

Figure 4.19 shows the response of filter 6 at 1826.11 MHz , insertion loss is -7.721dB and absolute bandwith is 180Mhz. yellow line shows insertion loss and blue line indicated return loss

Chapter 5
Conclusion and summary

To begin with the design of a prepost selector module a prepost selector designed by polezero was inspirational . the specifications provided by them were approved by the US military applications ,my intension was to create something similar to their specifications. It was really challenging to create something which meets the industrial standards . compromises were made in the specs to save time and reduce complexity . initially different topologies of bandpass filters were analysed and implemented in agilent ADS. Lumped bandpass filters were found to misbehave at higher frequencies so decided to go for microstripline filter. May different types of filters were studied and implented and tested. Since ADS was not giving accurate results , I went for SONNET software , all the microstripline filters were designed and tested in SONNET software and it was giving accurate results. To go with tunable filters , from the vailable bandpass topologies the one which can be easily tuned by changing the capacitance was choosen. The topology was very flexible to meet the design specifications. Filters were designed to operate at constant fractional bandwidth ,which was achievable using the structure. Similarly for above 1GHz even and odd mode coupled bandpass filter was used , tuning was also possible with that structure. Apart from the variety of varactor dioded availabale in the market ,for research purpose ,we decided to go for two types of varactors ,SMV diodes and PTIC's. smv diodes have very high capacitance which was very apt at low frequencies ,at higher frequencies we went for PTIC(passive tunable intergrated circuit) which was very small 6 pin IC challenges were in soldering the IC, hot plates were used to solder .choosing the inductors were also a challenging tast, compromise has to done between the performance and size of the components, since we decided not to keep air core inductors and torroids which will be very big in size ,final selection was surface mount inductors with ceramic core. For lower frequencies 1206 shows better Q , since at higher frequencies 0603 package was also meeting the specifications , we went for coilcraft make inductors , S-parameters files were available on the websiite for simulation purpose. Simulations with S parameter files weere carried out in AWR software by National Instruments. Initially all filters were simulated and tested in

SONNET software, then AUTOCAD drawings were made. We went for Rogers 4350 ,0.5mm thick substrate to reduce loss . digital board was drawn in PADS . all components were assembled and tested before final mounting of two boards. Once the filters were tested , we went for microcontroller programming . In programming two functions were used first one to control the path and second one to set the varactor voltage . The we tested the module with automated control and results were plotted using network analyzer. With some compromise in insertion loss of the filters which was more than designed one , all other specifications were meeting the required one . For future improvement in the module , reduction in overall board size, improvement in insertion loss, better automation with the microcontroller programming will be considered.

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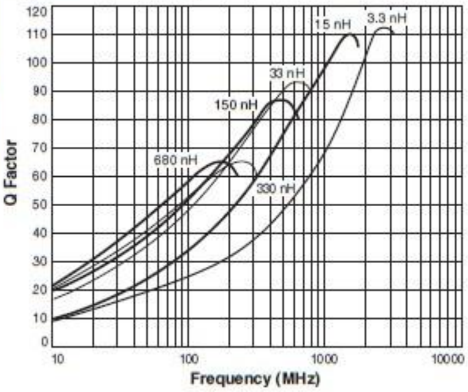
appendix

Data sheets of components used

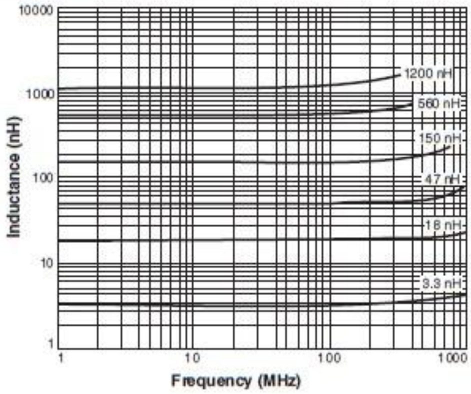
S-Parameter files ON OUR WEB SITE
SPICE models ON OUR WEB SITE

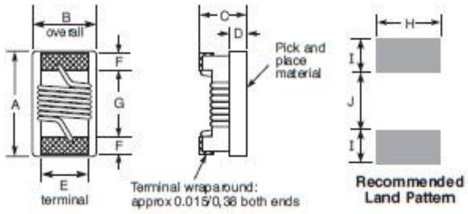
1206CS Series (3216)

Typical Q vs Frequency



Typical L vs Frequency





A max	B max	C max	D ref	E	F	G	H	I	J
0.140	0.085	0.060	0.020	0.056	0.020	0.080	0.076	0.040	0.070
3,56	2,16	1,52	0,51	1,42	0,51	2,03	1,93	1,02	1,78

Note: Height dimension (C) is before optional solder application. For maximum height dimension including solder, add 0.006 in / 0,152 mm.

Designer's Kit C320 contains 10 each of all 5% values
Core material Ceramic
Environmental RoHS compliant, halogen free optional
Terminations RoHS compliant silver-palladium-platinum-glass frit. Other terminations available at additional cost.
Weight 19.5 – 23.0 mg
Ambient temperature –40°C to +125°C with Irms current
Maximum part temperature +140°C (ambient + temp rise).
Storage temperature Component: –40°C to +140°C. Tape and reel packaging: –40°C to +80°C
Resistance to soldering heat Max three 40 second reflows at +260°C, parts cooled to room temperature between cycles
Temperature Coefficient of Inductance (TCL) +25 to +125 ppm/°C
Moisture Sensitivity Level (MSL) 1 (unlimited floor life at <30°C / 85% relative humidity)
Failures in Time (FIT) / Mean Time Between Failures (MTBF) One per billion hours / one billion hours, calculated per Telcordia SR-332
Packaging 2000/7″ reel; 7500/13″ reel. Plastic tape: 8 mm wide, 0.3 mm thick, 4 mm pocket spacing, 1.6 mm pocket depth
PCB washing Tested to MIL-STD-202 Method 215 plus an additional aqueous wash. See Doc787_PCB_Washing.pdf.

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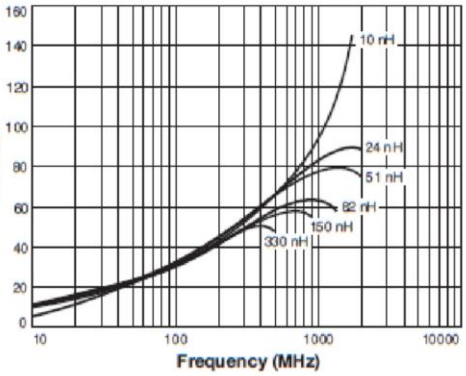
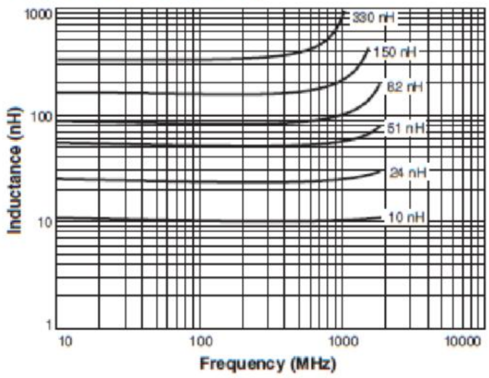
Chip Inductors – 0603HP Series (1608)

- Higher Q and lower DCR than other 0603 inductors
- Highest SRF values – as high as 16 GHz
- Excellent current handling capability – up to 2100 mA
- 54 inductance values from 1.8 to 390 nH

Typical Q vs Frequency



Typical L vs Frequency



Core material Ceramic

Environmental RoHS compliant, halogen free optional

Terminations RoHS compliant silver-palladium-platinum-glass frit. Other terminations available at additional cost.

Weight 2.0 – 3.2 mg

Ambient temperature –40°C to +125°C with Irms current

Maximum part temperature +140°C (ambient + temp rise).

Storage temperature Component: –40°C to +140°C. Tape and reel packaging: –40°C to +80°C

Resistance to soldering heat Max three 40 second reflows at +260°C, parts cooled to room temperature between cycles

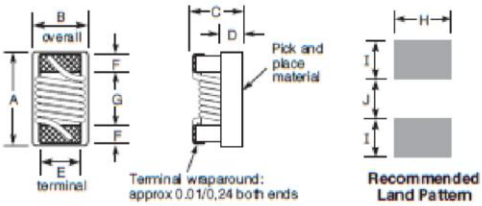
Temperature Coefficient of Inductance (TCL) +25 to +125 ppm/°C

Moisture Sensitivity Level (MSL) 1 (unlimited floor life at <30°C / 85% relative humidity)

Failures in Time (FIT) / Mean Time Between Failures (MTBF) One per billion hours / one billion hours, calculated per Telcordia SR-332

Packaging 2000 per 7″ reel. Paper tape: 8 mm wide, 1 mm thick, 4 mm pocket spacing

PCB washing Tested to MIL-STD-202 Method 215 plus an additional aqueous wash. See Doc787_PCB_Washing.pdf.



A max	B (min–max)	C max	D	E	F	G	H	I	J	
0.069	0.034–0.043	0.037	0.015	0.029	0.013	0.038	0.040	0.027	0.028	inches
1,75	0,86–1,09	0,94	0,38	0,74	0,33	0,96	1,02	0,69	0,71	mm

Note: Height dimension (C) is before optional solder application. For maximum height dimension including solder, add 0.006 in / 0,152 mm.

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SKYWORKS®

DATA SHEET

SMV1247-SMV1255 Series: Hyperabrupt Junction Tuning Varactors

Applications

- Low tuning voltage VCOs
- High-volume commercial systems

Features

- High capacitance ratio: $C_{0.3V}/C_{4.7V}$ = 12 typical
- Packages rated MSL1, 260 °C per JEDEC J-STD-020

Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04–0074.

Description

The SMV1247-SMV1255 group of silicon hyperabrupt junction varactor diodes is designed for use in Voltage Controlled Oscillators (VCOs) with a low tuning voltage operation. This group of varactors is characterized for capacitance and resistance over temperature.

Table 1 describes the various packages and markings of the SMV1247 to SMV1255 varactors.

Table 4. Capacitance vs Reverse Voltage

V_R (V)	C_T (pF)					
	SMV1247	SMV1248	SMV1249	SMV1251	SMV1253	SMV1255
0	8.86	22.62	37.35	53.65	69.32	81.21
0.5	6.17	16.32	25.88	38.23	50.23	58.28
1.0	4.37	12.33	18.18	28.09	37.07	43.27
1.5	2.96	9.12	12.08	20.13	27.57	31.49
2.0	1.88	6.27	7.27	13.55	19.37	21.50
2.5	1.22	3.93	4.44	8.60	12.39	13.40
3.0	0.95	2.57	3.40	5.78	7.77	8.51
3.5	0.83	1.95	2.96	4.57	5.77	6.51
4.0	0.77	1.71	2.72	3.95	4.86	5.58
4.5	0.73	1.59	2.51	3.58	4.34	5.07
5.0	0.70	1.49	2.38	3.33	4.01	4.76
5.5	0.68	1.44	2.30	3.16	3.78	4.58
6.0	0.67	1.40	2.24	3.03	3.62	4.46
6.5	0.66	1.36	2.19	2.94	3.50	4.39
7.0	0.65	1.33	2.14	2.88	3.41	4.33
7.5	0.64	1.31	2.09	2.83	3.34	4.29
8.0	0.64	1.30	2.03	2.79	3.28	4.26

Typical Performance Characteristics

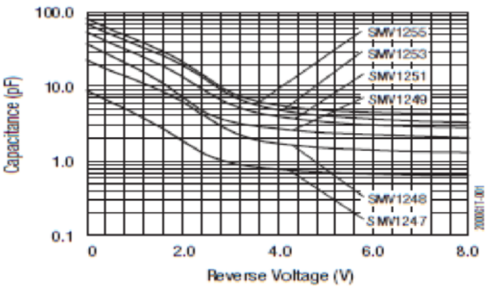


Figure 1. Capacitance vs Reverse Voltage

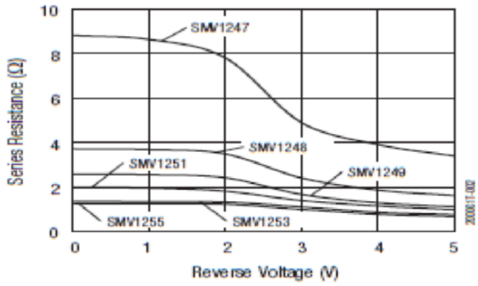


Figure 2. Series Resistance vs Reverse Voltage @ 500 MHz

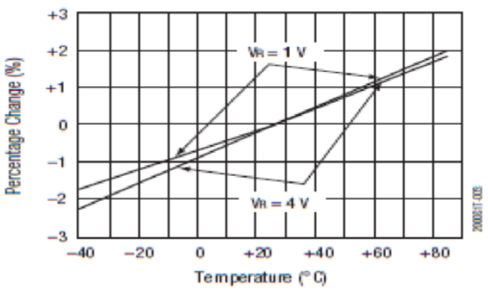


Figure 3. Relative Capacitance Change vs Temperature

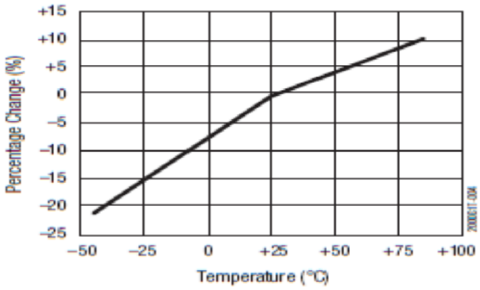


Figure 4. Relative Series Resistance Change vs Temperature @ 500 MHz

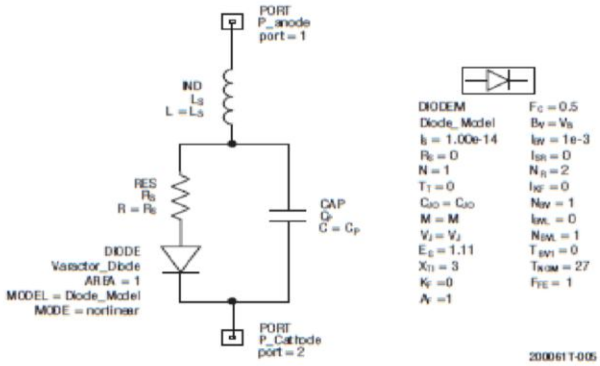


Figure 5. SPICE Model

Table 5. SPICE Model Parameters[1]

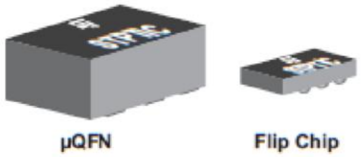
Part Number	CJO (pF)	VJ (V)	M	CP (pF)	RS (Ω)
SMV1247	8.47	80	70	0.54	4.9
SMV1248	22.12	138	100	0.87	2.4
SMV1249	36.40	80	70	1.68	1.7
SMV1251	52.48	100	76	2.00	1.4
SMV1253	51.8	73.6	48.7	2.7	1.1
SMV1255	80.00	135	100	2.74	1.0

[1] Model was designed to fit measured data in the range of up to 4 V.
For package inductance (Ls), refer to Table 1.
For more details, refer to the Skyworks Application Note, *Varactor SPICE Model for Approved RF VCO Applications*, document number 200315.

STPTIC

Parascan™ tunable integrated capacitor

Datasheet - production data



Features

- High power capability (+36 dBm)
- High tuning range (3.5/1)
- High quality factor (Q)
- High linearity device
- Low leakage current
- Capacitor bias is DC blocked
- Frequency of operation from DC to 3 GHz
- 8 values available: 1.2 pF, 2.7 pF, 3.3 pF, 3.9 pF, 4.7 pF, 5.6 pF, 6.8 pF and 8.2 pF
- Analog control voltage
- Compatible with high voltage control IC (STHVDAC series)
- Available in plastic molded package:
  - μQFN package 1.2 x 1.6 x 0.9 mm
  - Flip Chip 0.65 x 1.0 x 0.3 mm
  - Flip Chip 0.65 x 1.2 x 0.3 mm
- ECOPACK®2 compliant component

Benefit

- RF tunable passive implementation in mobile phones to optimize antenna radiated performances.

Applications

- Cellular Antenna open loop tunable matching network in multi-band GSM/WCDMA/LTE mobile phone
- Open loop tunable RF filters

Description

The ST integrated tunable capacitor, offers excellent RF performance, low power consumption and high linearity required in adaptive RF tuning applications. The fundamental building block of PTIC is a tunable material called Parascan, which is a version of barium strontium titanate (BST) developed by Paratek microwave.

BST capacitances are tunable capacitances intended for use in mobile phone application, and dedicated to RF tunable applications. These tunable capacitances are controlled through a bias voltage ranging from 2 to 20 V. The use of BST tunable capacitance in mobile phones enables significant improvement in terms of radiated performances making the performance almost insensitive to the external environment.

TM: Parascan is a trade mark of Paratek microwave Inc.

Representative performance data at 25°C for 8.2 pF WLCSP Package

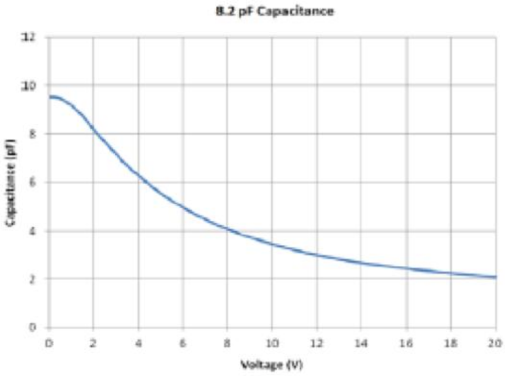


Figure 2. Capacitance

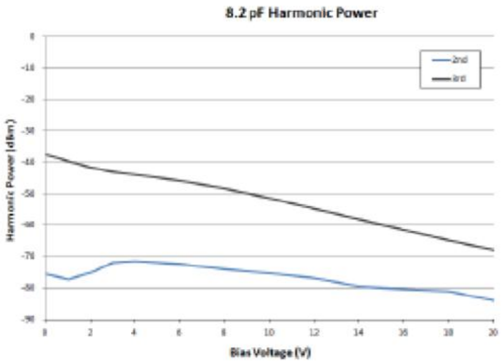


Figure 3. Harmonic Power*

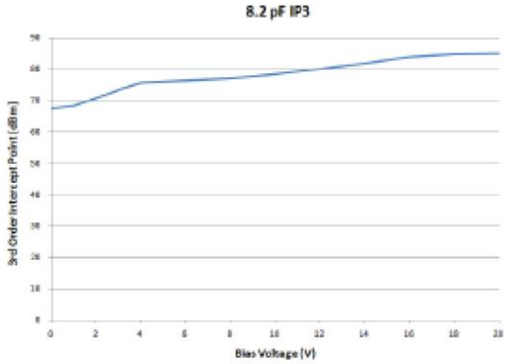


Figure 4. IP3*

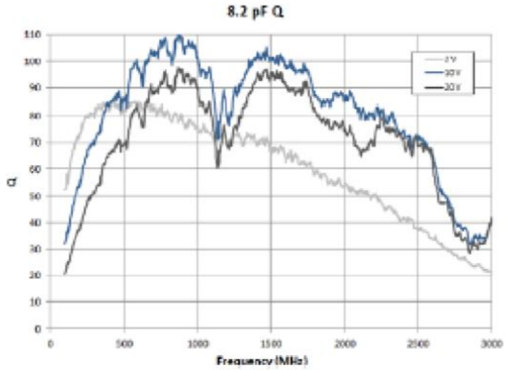


Figure 5. Q*

*The data shown is based on the TCP−1082N device performance, for reference only. The TCP−3082H performance data will be available in the Production Datasheet.

Table 3. ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Units
Input Power	+40	dBm
Bias Voltage	+25 (Note 5)	V
Operating Temperature Range	−30 to +85	°C
Storage Temperature Range	−55 to +125	°C
ESD − Human Body Model	Class 1A JEDEC HBM Standard (Note 6)	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.
5. WLCSP: Recommended Bias Voltage not to exceed 20 V
6. Class 1A defined as passing 250 V, but may fail after exposure to 500 V ESD pulse

Representative performance data at 25°C for 4.7 pF WLCSP Package

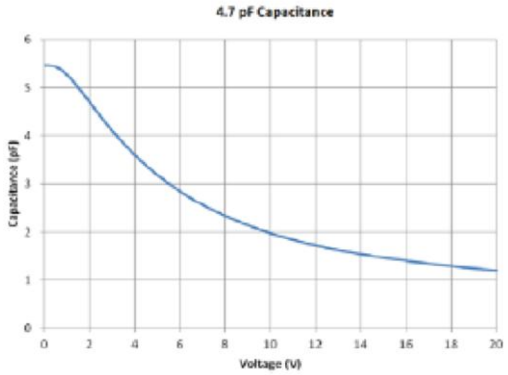


Figure 2. Capacitance

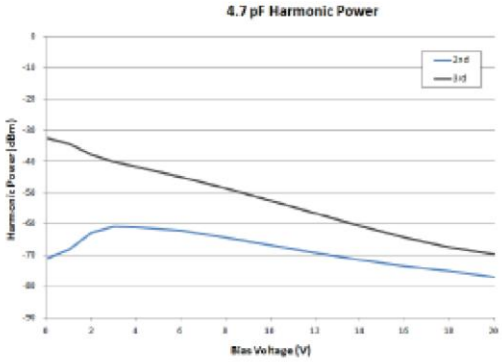


Figure 3. Harmonic Power*

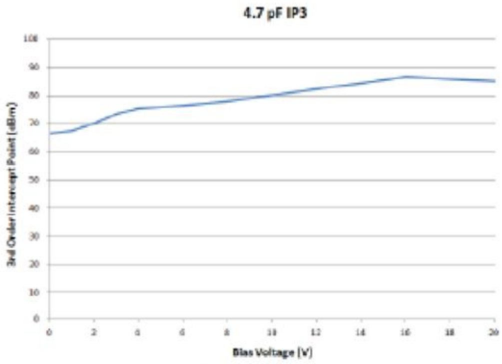


Figure 4. IP3*

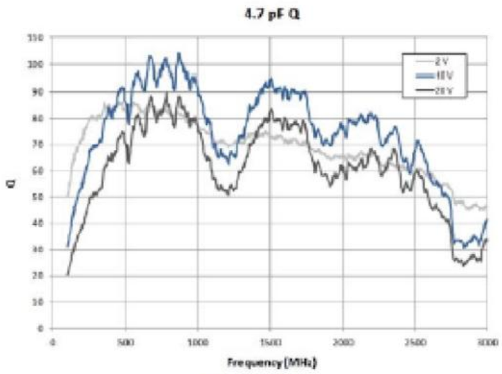


Figure 5. Q*

*The data shown is based on the TCP−1047N device performance, for reference only. The TCP−3047H performance data will be available in the Production Datasheet.

Table 3. ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Units
Input Power	+40	dBm
Bias Voltage	+25 (Note 5)	V
Operating Temperature Range	−30 to +85	°C
Storage Temperature Range	−55 to +125	°C
ESD − Human Body Model	Class 1A JEDEC HBM Standard (Note 6)	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

5. WLCSP: Recommended Bias Voltage not to exceed 20 V
6. Class 1A defined as passing 250 V, but may fail after exposure to 500 V ESD pulse

Representative performance data at 25°C for 2.7 pF WLCSP Package

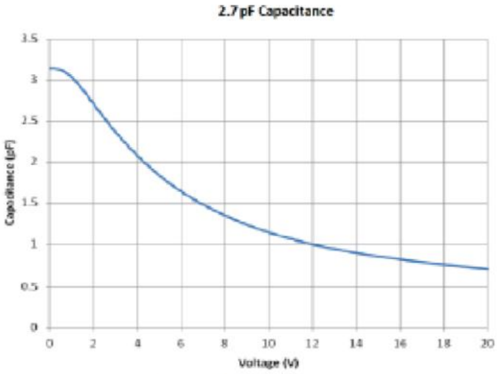


Figure 2. Capacitance

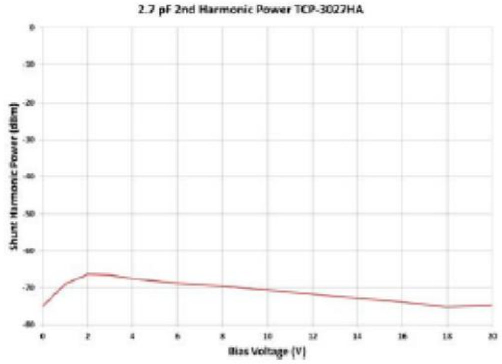


Figure 3. 2nd Harmonic Power

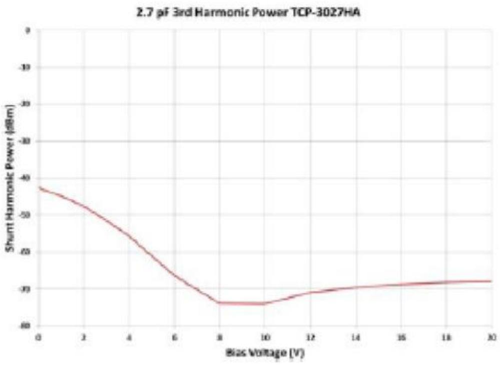


Figure 4. 3rd Harmonic Power

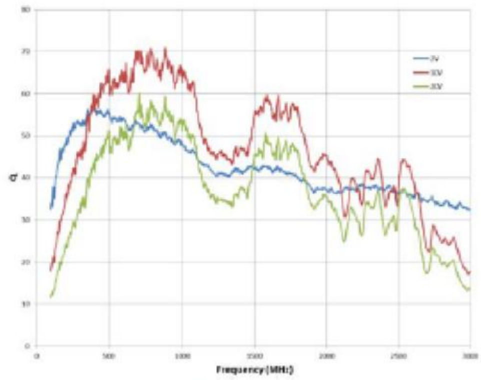


Figure 5. Q

Table 3. ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Units
Input Power	+40	dBm
Bias Voltage	+25 (Note 6)	V
Operating Temperature Range	−30 to +85	°C
Storage Temperature Range	−55 to +125	°C
ESD − Human Body Model	Class 1A JEDEC HBM Standard (Note 7)	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

6. WLCSP: Recommended Bias Voltage not to exceed 20 V
7. Class 1A defined as passing 250 V, but may fail after exposure to 500 V ESD pulse

ANALOG DEVICES
HITTITE MICROWAVE PRODUCTS

HMC253AQS24 / 253AQS24E

v01.1015

GAAS MMIC SP8T NON-REFLECTIVE SWITCH, DC - 2.5 GHz

Typical Applications

The HMC253AQS24 / HMC253AQS24E is ideal for DC - 2.5 GHz applications:

- CATV/DBS
- CDMA
- Cellular/PCS

Features

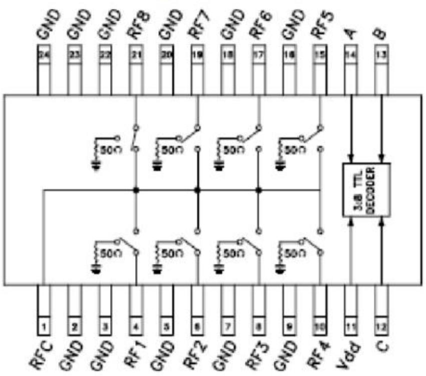
Low Insertion Loss (2 GHz): 1.1dB

Single Positive Supply: Vdd = +5V

Integrated 3:8 TTL Decoder

24 Lead QSOP Package

Functional Diagram



General Description

The HMC253AQS24 & HMC253AQS24E are low-cost non-reflective SP8T switches in 24-lead QSOP packages featuring wideband operation from DC to 2.5 GHz. The switch offers a single positive bias and true TTL/CMOS compatibility. A 3:8 decoder is integrated on the switch requiring only 3 control lines and a positive bias to select each path. The HMC253AQS24 & HMC253AQS24E SP8T will replace multiple configurations of SP4T and SPDT MMIC switches.

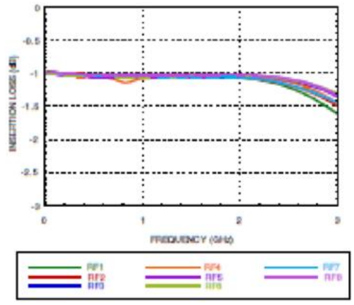
Electrical Specifications, T_A = +25° C, For TTL Control and Vdd = +5V in a 50 Ohm system

Parameter		Frequency	Min.	Typ.	Max.	Units
Insertion Loss		DC - 1.0 GHz DC - 2.0 GHz DC - 2.5 GHz		1.0 1.1 1.4	1.5 1.7 2.1	dB dB dB
Isolation		DC - 1.0 GHz DC - 2.0 GHz DC - 2.5 GHz	35 30 28	40 35 33		dB dB dB
Return Loss	"On State"	DC - 1.0 GHz DC - 2.0 GHz DC - 2.5 GHz		21 20 16		dB dB dB
Return Loss (RF1-8)	"Off State"	0.3 - 2.5 GHz 0.5 - 2.5 GHz		8 13		dB dB
Input Power for 1 dB Compression		0.3 - 2.5 GHz	20	23		dBm
Input Third Order Intercept (Two-Tone Input Power = +10 dBm Each Tone)		0.3 - 2.5 GHz	41	46		dBm
Switching Characteristics tRISE, tFALL (10/90% RF) tON, tOFF (50% CTL to 10/90% RF)		0.3 - 2.5 GHz		 20 90		 ns ns

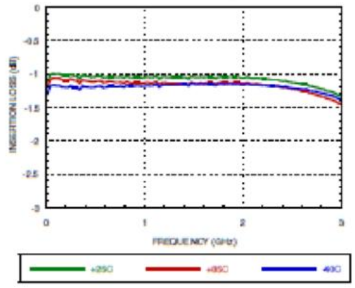
For price, delivery, and to place orders: Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106
Phone: 781-329-4700 • Order online at www.analog.com
Application Support: Phone: 1-800-ANALOG-D

GAAS MMIC SP8T NON-REFLECTIVE SWITCH, DC - 2.5 GHz

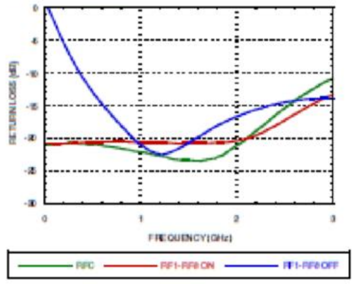
Insertion Loss



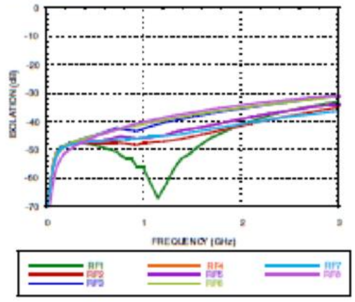
Insertion Loss vs. Temperature



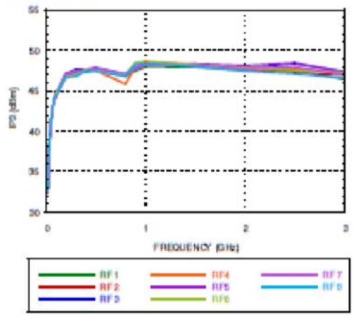
Return Loss



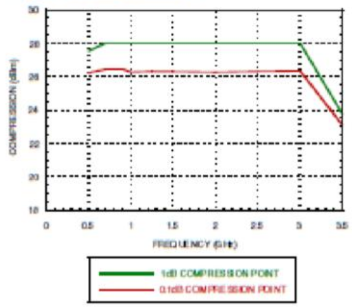
Isolation



Input IP3



Input Compression



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Features

- High-performance, Low-power Atmel® AVR® 8-bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single-clock Cycle Execution
  - 32 × 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory segments
  - 16 Kbytes of In-System Self-programmable Flash program memory
  - 512 Bytes EEPROM
  - 1 Kbyte Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C[1]
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - Programming Lock for Software Security
- JTAG (IEEE std. 1149.1 Compliant) Interface
  - Boundary-scan Capabilities According to the JTAG Standard
  - Extensive On-chip Debug Support
  - Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Four PWM Channels
  - 8-channel, 10-bit ADC
    8 Single-ended Channels
    7 Differential Channels in TQFP Package Only
    2 Differential Channels with Programmable Gain at 1x, 10x, or 200x
  - Byte-oriented Two-wire Serial Interface
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated RC Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
- I/O and Packages
  - 32 Programmable I/O Lines
  - 40-pin PDIP, 44-lead TQFP, and 44-pad QFN/MLF
- Operating Voltages
  - 2.7V - 5.5V for ATmega16L
  - 4.5V - 5.5V for ATmega16
- Speed Grades
  - 0 - 8 MHz for ATmega16L
  - 0 - 16 MHz for ATmega16
- Power Consumption @ 1 MHz, 3V, and 25°C for ATmega16L
  - Active: 1.1 mA
  - Idle Mode: 0.35 mA
  - Power-down Mode: < 1 µA

8-bit AVR® Microcontroller with 16K Bytes In-System Programmable Flash

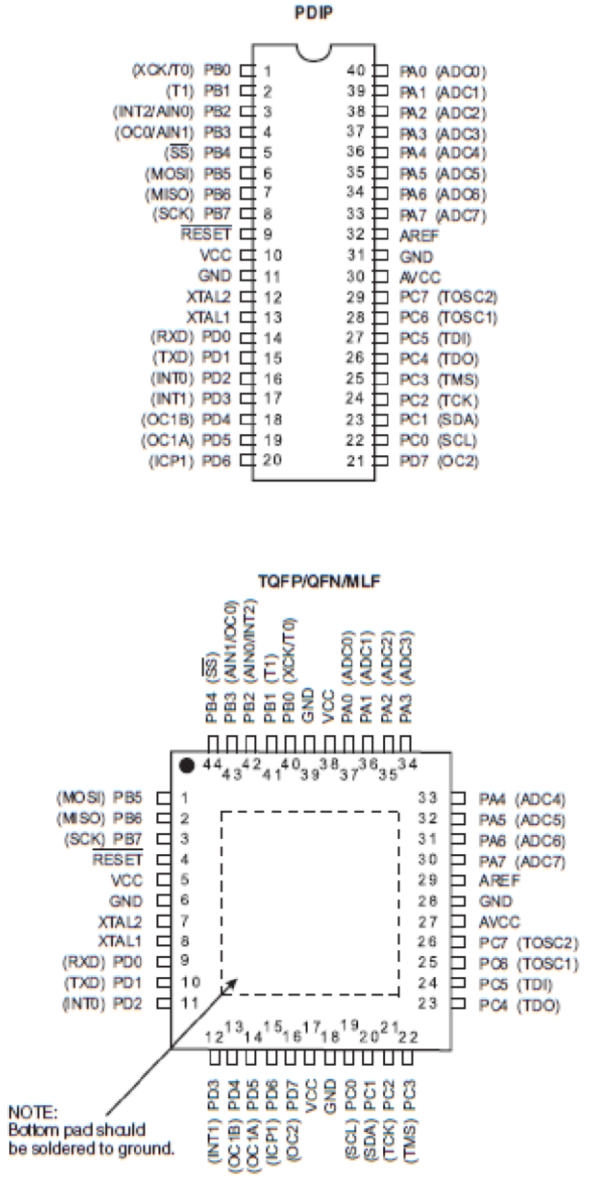
ATmega16
ATmega16L

Summary

Rev. 2466TS–AVR–07/10

Pin Configurations

Figure 1. Pinout ATmega16



Disclaimer

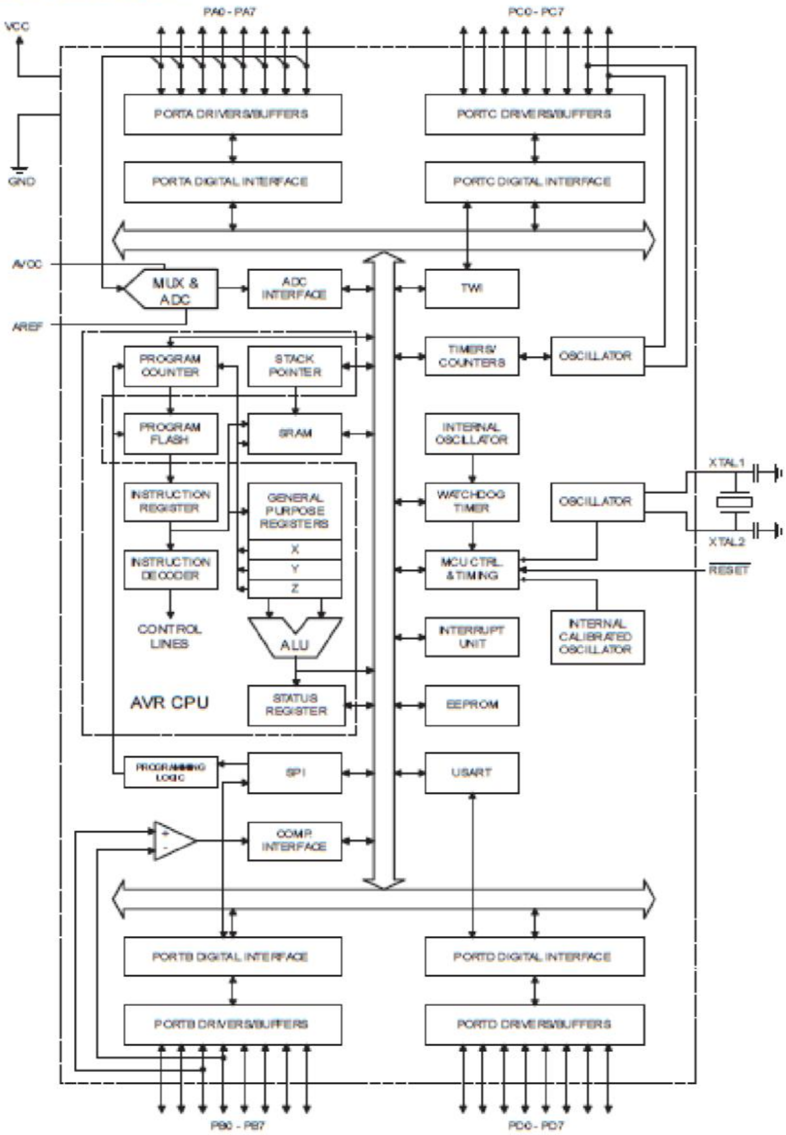
Typical values contained in this datasheet are based on simulations and characterization of other AVR microcontrollers manufactured on the same process technology. Min and Max values will be available after the device is characterized.

Overview

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Block Diagram

Figure 2. Block Diagram



Quad, 12-Bit, Parallel Input, Unipolar/Bipolar, Voltage Output DAC

Data Sheet **AD5725**

FEATURES

- +5 V to ±15 V operation
- Unipolar or bipolar operation
- ±0.5 LSB max INL error, ±1 LSB max DNL error
- Settling time: 10 µs max (10 V step)
- Double-buffered inputs
- Simultaneous updating via $\overline{LDAC}$
- Asynchronous $\overline{CLR}$ to zero/midscale
- Readback
- Operating temperature range: −40°C to +85°C
- *i*CMOS® process technology

APPLICATIONS

- Industrial automation
- Closed-loop servo control, process control
- Automotive test and measurement
- Programmable logic controllers

FUNCTIONAL BLOCK DIAGRAM

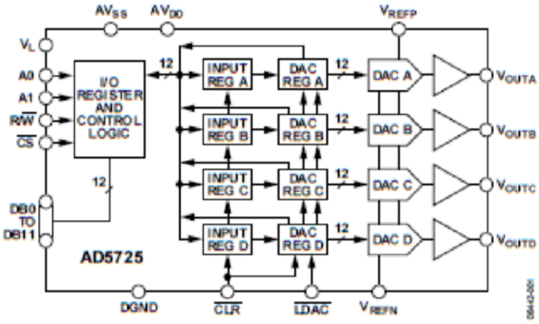


Figure 1.

GENERAL DESCRIPTION

The AD5725 is a quad, 12-bit, parallel input, voltage output digital-to-analog converter that offers guaranteed monotonicity, integral nonlinearity (INL) of ±0.5 LSB maximum and 10 µs maximum settling time.

Output voltage swing is set by two reference inputs, V_{REFP} and V_{REFN}. By setting the V_{REFN} input to 0 V and the V_{REFP} to a positive voltage, the DAC provides a unipolar positive output range. A similar configuration with V_{REFP} at 0 V and V_{REFN} at a negative voltage provides a unipolar negative output range. Bipolar outputs are configured by connecting both V_{REFP} and V_{REFN} to nonzero voltages. This method of setting output voltage ranges has advantages over the bipolar offsetting methods because it is not dependent on internal and external resistors with different temperature coefficients.

Digital controls allow the user to load or read back data from any DAC, load any DAC, and transfer data to all DACs at one time.

The AD5725 is available in a 28-lead SSOP package. It can be operated from a wide variety of supply and reference voltages, with supplies ranging from single +5 V to ±15 V, and references from +2.5 V to ±10 V. Power dissipation is less than 270 mW with ±15 V supplies and only 40 mW with a +5 V supply. Operation is specified over the temperature range of −40°C to +85°C.

*i*CMOS® Process Technology
For analog systems designers within industrial/instrumentation equipment OEMs who need high performance ICs at higher-voltage levels, *i*CMOS is a technology platform that enables the development of analog ICs capable of 30 V and operating at ±15 V supplies while allowing dramatic reductions in power consumption and package size, and increased ac and dc performance.

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PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

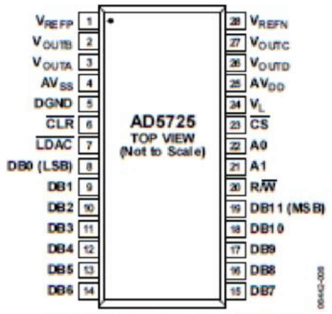


Figure 6. Pin Configuration Diagram

Table 6. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	V_{REFP}	Positive DAC Reference Input. The voltage applied to this pin defines the full-scale output voltage. Allowable range is AV_{DD} – 2.5 V to V_{REFN} + 2.5 V.
2	V_{OUTB}	Buffered Analog Output Voltage of DAC B.
3	V_{OUTA}	Buffered Analog Output Voltage of DAC A.
4	AV_{SS}	Negative Analog Supply Pin. Voltage ranges from 0 V to –15 V.
5	DGND	Digital Ground Pin.
6	$\overline{CLR}$	Active Low Input. Sets input registers and DAC registers to zero scale (0x000) for the AD5725-1 or midscale (0x800) for the AD5725.
7	$\overline{LDAC}$	Active Low Load DAC Input.
8	DB0	Data Bit 0 (LSB).
9	DB1	Data Bit 1.
10	DB2	Data Bit 2.
11	DB3	Data Bit 3.
12	DB4	Data Bit 4.
13	DB5	Data Bit 5.
14	DB6	Data Bit 6.
15	DB7	Data Bit 7.
16	DB8	Data Bit 8.
17	DB9	Data Bit 9.
18	DB10	Data Bit 10.
19	DB11	Data Bit 11 (MSB).
20	R/$\overline{W}$	Read/Write Pin. Active low to write data to DAC; Active high to read back previous data at data bit pins with V_L connected to +5 V.
21	A1	Address Bit 1.
22	A0	Address Bit 0.
23	$\overline{CS}$	Active Low Chip Select Pin.
24	V_L	Voltage Supply for Readback Function. Can be left open circuit if not used.
25	AV_{DD}	Positive Analog Supply Pin. Voltage ranges from +5 V to +15 V.
26	V_{OUTD}	Buffered Analog Output Voltage of DAC D.
27	V_{OUTC}	Buffered Analog Output Voltage of DAC C.
28	V_{REFN}	Negative DAC Reference Input. The voltage applied to this pin defines the zero-scale output voltage. Allowable range is AV_{SS} to V_{REFP} – 2.5 V.

LT1121/LT1121-3.3/LT1121-5

Micropower Low Dropout Regulators with Shutdown

FEATURES

- 0.4V Dropout Voltage
- 150mA Output Current
- 30μA Quiescent Current
- No Protection Diodes Needed
- Adjustable Output from 3.75V to 30V
- 3.3V and 5V Fixed Output Voltages
- Controlled Quiescent Current in Dropout
- Shutdown
- 16μA Quiescent Current in Shutdown
- Stable with 0.33μF Output Capacitor
- Reverse Battery Protection
- No Reverse Current with Input Low
- Thermal Limiting
- Available in the 8-Lead SO, 8-Lead PDIP, 3-Lead SOT-23 and 3-Lead TO-92 Packages

APPLICATIONS

- Low Current Regulator
- Regulator for Battery-Powered Systems
- Post Regulator for Switching Supplies

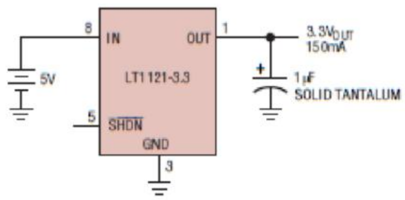
DESCRIPTION

The LT®1121/LT1121-3.3/LT1121-5 are micropower low dropout regulators with shutdown. These devices are capable of supplying 150mA of output current with a dropout voltage of 0.4V. Designed for use in battery-powered systems, the low quiescent current, 30μA operating and 16μA in shutdown, makes them an ideal choice. The quiescent current is well-controlled; it does not rise in dropout as it does with many other low dropout PNP regulators.

Other features of the LT1121/LT1121-3.3/LT1121-5 include the ability to operate with very small output capacitors. They are stable with only 0.33μF on the output while most older devices require between 1μF and 100μF for stability. Small ceramic capacitors can be used, enhancing manufacturability. Also the input may be connected to ground or a reverse voltage without reverse current flow from output to input. This makes the LT1121 series ideal for backup power situations where the output is held high and the input is at ground or reversed. Under these conditions only 16μA will flow from the output pin to ground.

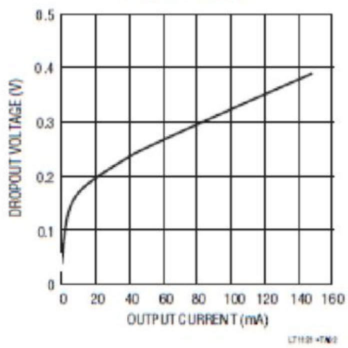
TYPICAL APPLICATION

5V Battery-Powered Supply with Shutdown



$V_{\overline{SHDN}}$ (PIN 5)	OUTPUT
<0.25	OFF
>2.8	ON
NC	ON

Dropout Voltage



ABSOLUTE MAXIMUM RATINGS

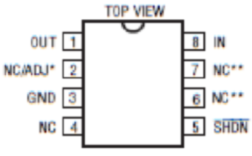
(Note 1)

Input Voltage
- LT1121 .... ±30V
- LT1121HV .... +36V, –30V

Output Pin Reverse Current 10mA
Adjust Pin Current 10mA
Shutdown Pin Input Voltage (Note 2).......... 6.5V, –0.6V
Shutdown Pin Input Current (Note 2) 20mA
Output Short-Circuit Duration .... Indefinite
Operating Junction Temperature Range (Note 3)
- LT1121C-X.. 0°C to 125°C
- LT1121I-X .... –40°C to 125°C

Storage Temperature Range ....–65°C to 150°C
Lead Temperature (Soldering, 10 sec).................. 300°C

PIN CONFIGURATION

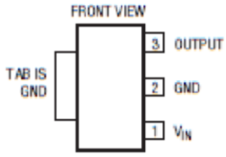


N8 PACKAGE
8-LEAD PDIP
S8 PACKAGE
8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 120°C/W (N8, S8)
T_{JMAX} = 150°C, θ_{JA} = 70°C/W (AS8)

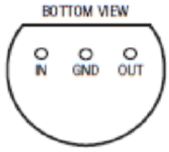
*PIN 2 = NC FOR LT1121-3.3/LT1121-5
= ADJ FOR LT1121

**PINS 6 AND 7 ARE FLOATING (NO INTERNAL CONNECTION) ON THE STANDARD S8 PACKAGE.
PINS 6 AND 7 CONNECTED TO GROUND ON THE A VERSION OF THE LT1121 (S8 ONLY). CONNECTING PINS 6 AND 7 TO THE GROUND PLANE WILL REDUCE THERMAL RESISTANCE. SEE THERMAL RESISTANCE TABLES IN THE APPLICATIONS INFORMATION SECTION.



ST PACKAGE
3-LEAD PLASTIC SOT-223

T_{JMAX} = 150°C, θ_{JA} = 50°C/W



Z PACKAGE
3-LEAD PLASTIC TO-92

T_{JMAX} = 150°C, θ_{JA} = 150°C/W

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LT1121CN8#PBF	LT1121CN8#TRPBF	LT1121CN8	8-Lead Plastic PDIP	0°C to 125°C
LT1121CN8-3.3#PBF	LT1121CN8-3.3#TRPBF	LT1121CN8-3.3	8-Lead Plastic PDIP	0°C to 125°C
LT1121CN8-5#PBF	LT1121CN8-5#TRPBF	LT1121CN8-5	8-Lead Plastic PDIP	0°C to 125°C
LT1121IN8#PBF	LT1121IN8#TRPBF	LT1121IN8	8-Lead Plastic PDIP	–40°C to 125°C
LT1121IN8-3.3#PBF	LT1121IN8-3.3#TRPBF	LT1121IN8-3.3	8-Lead Plastic PDIP	–40°C to 125°C
LT1121IN8-5#PBF	LT1121IN8-5#TRPBF	LT1121IN8-5	8-Lead Plastic PDIP	–40°C to 125°C
LT1121CS8#PBF	LT1121CS8#TRPBF	1121	8-Lead Plastic SO	0°C to 125°C
LT1121CS8-3.3#PBF	LT1121CS8-3.3#TRPBF	11213	8-Lead Plastic SO	0°C to 125°C
LT1121CS8-5#PBF	LT1121CS8-5#TRPBF	11215	8-Lead Plastic SO	0°C to 125°C
LT1121HVCS8#PBF	LT1121HVCS8#TRPBF	1121HV	8-Lead Plastic SO	–40°C to 125°C
LT1121IS8#PBF	LT1121IS8#TRPBF	1121I	8-Lead Plastic SO	–40°C to 125°C
LT1121IS8-3.3#PBF	LT1121IS8-3.3#TRPBF	121I3	8-Lead Plastic SO	–40°C to 125°C
LT1121IS8-5#PBF	LT1121IS8-5#TRPBF	121I5	8-Lead Plastic SO	–40°C to 125°C
LT1121HVIS8#PBF	LT1121HVIS8#TRPBF	121HVI	8-Lead Plastic SO	–40°C to 125°C
LT1121ACS8#PBF	LT1121ACS8#TRPBF	1121A	8-Lead Plastic SO	0°C to 125°C
LT1121ACS8-3.3#PBF	LT1121ACS8-3.3#TRPBF	1121A3	8-Lead Plastic SO	0°C to 125°C
LT1121ACS8-5#PBF	LT1121ACS8-5#TRPBF	1121A5	8-Lead Plastic SO	0°C to 125°C

1121fg