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DEVELOPMENT OF 4W SOLID STATE AMPLIFIER IN THE FREQUENCY RANGE OF 40±6MHZ

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Abstract- This paper presents broad-band 4W solid-state power amplifier operating at RF 40±6MHz frequencies in the class AB mode of operation. This amplifier stage will be used as a driver to another solid state amplifier of more than 40W output in the given frequency range. The amplifier is over current and over voltage protected by using the regulated dc power supply. The stability of MRF 134 is improved by parallel resistive loading. This amplifier can deliver 4 W to 50-ohm load with 55% efficiency and 18 dB gain. The toroidal ferrite transformer is used to implement a broadband matching network. The simulation work is done using Tina 9 – TI software. Numerous parameters like Frequency response, power gain and output waveform etc. related to solid state amplifier have been rigorously substantiated.

Keywords - Broadband amplifier, class AB mode of operation, Transformer matching.

I. INTRODUCTION

In RF and microwave circuits, transducers provide weak signals which need to be amplified. This amplification of power is done by using a vacuum tube or the transistor. Amplifiers are used to increase the power of an RF signal by converting dc power to RF power[7]. This RF power output from radio frequency oscillators or amplifiers can be used to generate plasma at various frequencies. Ion cyclotron resonance heating System is an integral part of the future fusion reactors. For fusion reactors the power level required are of the order of tens of megawatt in the frequency range of 10-100MHz. The RF frequency bands for industrial, scientific and medical (ISM) utilization are 13.56 MHz, 27.12 MHz, and 40.68 MHz [3]. Solid state power amplifiers are highly used as a driver stage at RF power heating application in plasma generation where the reflection of wave is predictable and not much higher. Efficiency and optimum power transfer are the main factors that must be considered while designing an amplifier. There are other parameters also like return loss at both the side of transistor and gain of the amplifier over entire frequency band. At most of the places, solid state devices are widely used for amplification of power since it is consecrated with various advantages like high voltage gain, mechanical strength, light-weight etc.

The most important parameters in the power amplifier design are operating frequency, linearity, efficiency, power output, gain and bandwidth, while designing a power amplifier, a trade-off between bandwidth and gain is made because improving any one of them would degrade the other.

Amplifiers topology simply includes biasing of amplifier and matching network at input and output side of the transistor for maximum power transfer. The DC biasing circuit is fairly standard; it does not involve any microwave constraints [6]. There are number of different biasing strategies followed by the transistor, that strategies known as a classes of an amplifier which ranges from class A to class G. most commonly used classes are A, AB, B and C. choice of operating class of an amplifier depends on the requirement of gain and efficiency.

The M/A-COM make RF MOSFET MRF134 is selected out of the available choices from various manufacturers due to expected optimized performance as per requirement. MRF134 is an RF power N–Channel enhancement-mode field– effect transistor (FET) designed especially for HF and VHF power amplifier applications. This n–Channel enhancement mode amplifier application is limited up to 400 MHz for this transistor. Output power engendered is 5.0 watts[10].

Amplifier is designed using available transistors. It is not surprising that in most of the cases the transistor is unstable at given frequency. Unstable transistor leads to the oscillation of an amplifier. Fluctuation in gain is affected by the oscillation in amplifier. If the innermost two-port of MOSFET is stable, then the amplifier in which it is embedded will be stable. The stability of this MOSFET is improved by the parallel loading with resistors, 1k at input side and 1.8 k at output side of the transistor.

This amplifier is made to operate in class AB mode of operation. Efficiency of the class AB power amplifier is found between 25% to 50%.The power dissipation is lesser than the class A and more than that of class B power amplifier

II. IMPEDANCE MATCHING USING FERRITE TRANSFORMER

Maximum power transfer is the main objective in the RF and microwave circuit design. Source impedance should look like load impedance, that's why there is a matching network between source and load at input side and output side of the transistor. This transfer the maximum power to the load and minimize the loss due to mismatch. Various type of matching networks is used in circuit design like single stub matching, transformer matching and L- section matching. In this paper transformer matching is used as a matching network. In the transformer matching, appropriate selection of ferrite core needs to be done for stable operation. The core losses will increase with self-heating. In practical design application, this becomes important to acknowledge heating as an important design limitation. The stability can be calculated for any ferrite core by below given equation.

$$B_{\max\,(ac)} = \frac{E_{rms} \times 10^4}{4.44 f N_p A_e} = 0.205 \text{ gauss} < 2500 \qquad (1)$$

The B_{max} is affected by the change in the frequency. Lowering frequency while keeping the core same and number of turns greatly elevate the B_{max}. This also depends on the E_{peak} voltage and area of the core (A_e).

1) TRANSFORMER DESIGN

transformer has some advantages over L section matching like device size will be reduced, ferrite permeability is higher than air core so that coil turns will be reduced. There will be an isolation between input and output matching circuit which would further reduce the fluctuation of power. In MRF134 The value of input impedance zin is **28 - j25 Ω**and output impedance is **25 – j60 Ω.** In this paper NiZn toroidal ferrite core is used and has application up to 100 MHz. Here auto-transformer is fabricated for the input matching circuit. The turns ratio defined by

$$\left(\frac{N_1}{N_2}\right) = \sqrt{\frac{Z_S}{Z_L}} \qquad (2)$$

Here Z_S is the source impedance and Z_L is the load impedance, N_1 is the turns ratio at primary side and N_2 at secondary side.

Figure 1: Transformer with turns ratio 9:6 ratio

AT resonate frequency $X_L = X_C$

$$X_L = X_C = \frac{1}{(2\pi f c)} \qquad (3)$$

Where f is the frequency 40 MHz and c is the internal capacitance at both side of transistor. By using this equation one can find the inductance that should be matched with the transformer inductance. Calculated inductance of MOSFET at input side is 0.1 **μH.** Here output side of the transistor is already matched and turns ratio at input side is 9:6. Fluctuation in power will be reduced between input and output side using transformer matching.

Below graph shows the resistance and inductance over frequency band 25MHz to 50MHz of fabricated toroidal ferrite auto-transformer, the values of this transformer is matched with the calculated values of MOSFET. The design of dc bias circuit of an amplifier

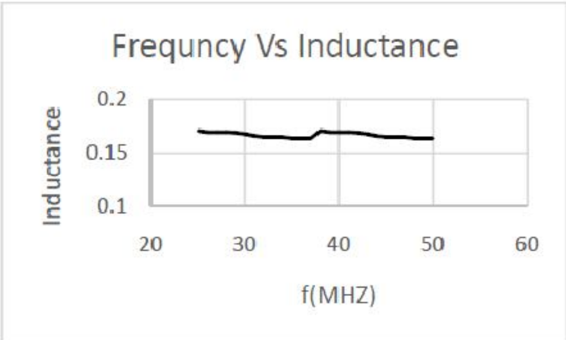

Figure 2. Graph of measured inductance of transformer

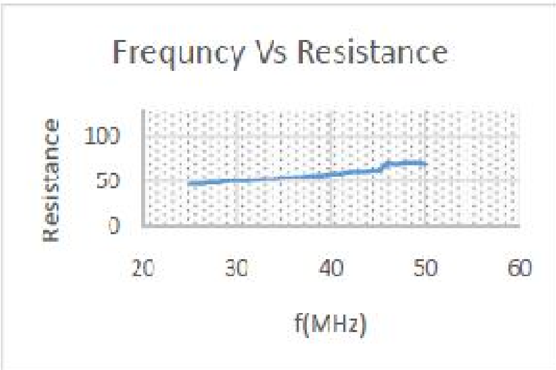

Figure 3. graph of measured Resistance of transformer

The design goal of a good DC bias circuit is to choose the appropriate static working point and keep the static working point constant in the range of transistor parameters and temperature change [9].

Below figure shows variable voltage divider circuit. This circuit output varies from 1.19 V to 3.57 V. Output varies by varying the 1 k potentiometer. The simulated and fabricated results are shown in table below. The transistor used in this biasing circuit is 2N2222. This NPN switching transistor is used for low voltage application (max. 40V). In this circuit 1N4733 zener diode is used as a breakdown voltage regulator. This will not allow voltage greater than 5.1V at the base of transistor 2N2222 in this circuit.

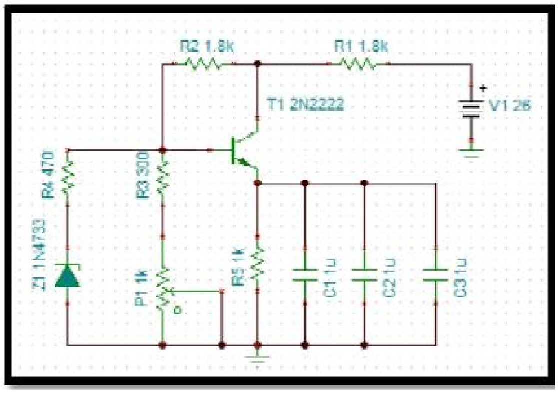

Figure 4. DC gate biasing circuit of MRF 134

Result	Applied voltage	Potentiometer ratings		
		0%	50%	100%
Simulated	25	3.57 V	2.37 V	1.18 V
Fabricated	25	3.48 V	1.98 V	0.91

Table 1. Comparison between simulated and tested result of gate biasing circuit

III. SIMULATION AND FABRICATION RESULTS

The input and output circuits are fabricated on 1mm thick G10 insulation sheets on which the MOSFET is mounted. Following figure shows the fabricated 4W power amplifier using transformer matching. Output of this amplifier is connected to the 50-ohm dummy load. This circuit gives 4W output from 10MHz to 70MHz. Here circuit gives 4W output power and flat gain when input power is 60mW and gate supply voltage is 3.5. Here RF drain current is 340mA. Here in the drain biasing the capacitors of the value of 10 pF and 100 pF are placed in parallel with the output for resonance matching.

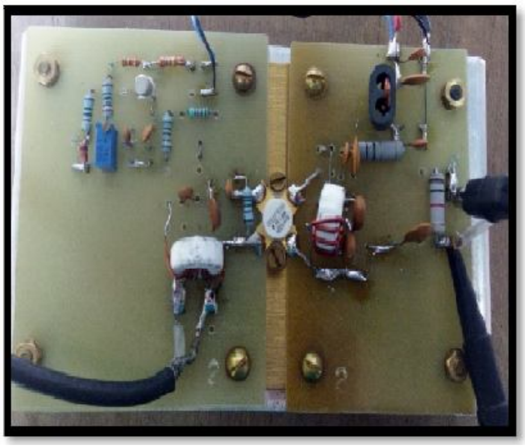

Figure 5. 4W broadband amplifier circuit

Below figures shows the output power and gain. The expected gain was 17 dB and the outcome is nearly 18 dB. As increasing the gate biasing voltage up to 4V the output power increases up-to 5W but the gain decreases.

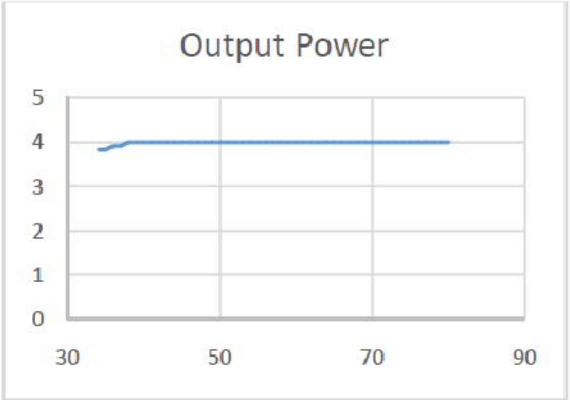

Figure 6. Frequency Vs Output Power

As shown in above graph, the response of output power is flat from 38MHz to 80MHz

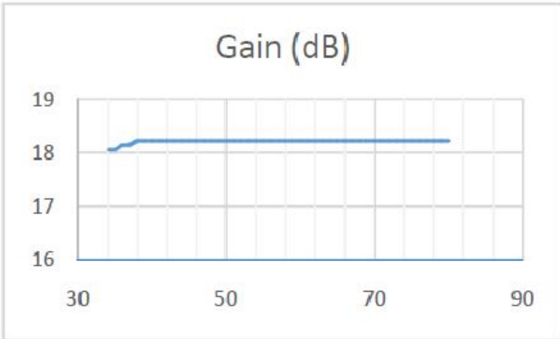

Figure 7. Frequency Vs Gain

CONCLUSION

As discussed in the project report, we successfully compared the different techniques of the parameters of power amplifiers like power gain, efficiency, class of amplifier, operating frequency etc. Matching technique has been studied in detail with the two different techniques i.e. L-section matching and transformer matching. We have verified the stability of MOSFET which is k=1.01. In L section matching technique, the change in frequency results change in power. All the respective changes have been shown in simulation results. This achieved targeted results are useful for the power amplification. Transformer matching is also done and result shows that transformer perfectly match at the input and output side of selected transistor MRF134.

The fabricated amplifier circuit is tested with the help of Standard Signal Generator, RF Power Amplifier, Dummy Load, DC Power Supply, Digital Storage Oscilloscope and Multimeter in the required frequency bandwidth of 40±6MHz. After proper optimization of the matching circuit the desired output of more than 4W is obtained at 40MHz. The response of gain is 18dB over the specified bandwidth. Thus, aim of the project is successfully completed.

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