DEVELOPMENT OF 25W SOLID STATE BROADBAND AMPLIFIER IN THE FREQUENCY RANGE OF 38±8 MHz

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ABSTRACT

This paper presents the development procedure for MOSFET based cwrf output amplifier. The active device should be operating in common emitter class B mode of operation. The output stage amplifier of more than 25W output and gain 16dB minimum needs development at 38 MHz and testing in the frequency range of 38±8 MHz. The amplifier module must be over current and over voltage protected by using regulated dc power supply during testing and operation. The MOSFET is mounted on a heat sink for protecting the device in case of overheating. The developed amplifier needs testing for the frequency response, power gain, output wave shapes etc.by using a set of appropriate instruments

Keyword: - *DC Biasing, Impedance matching, L section network, MOSFET, Solid State Power Amplifier***.** *Key word1*

1. INTRODUCTION

A radio frequency (RF) power amplifier is a type of circuit that converts a low-power radio-frequency signal into a higher power signal. Amplifiers play a vital role in the development of high performance and low-cost solutions for front end of the RF and microwave systems. Early RF & microwave amplifiers were the exclusive province of vacuum tube devices such as triodes, tetrodes, Klystrons, TWT amplifiers and magnetrons but today amplification is dominated by solid state amplifiers except for application at high output powers i.e. more than 100W for microwave and more than 1KW for RF. Amplifier circuits are generally identified with a class designation depending on the relation between the input and output signals. At RF/microwave frequencies amplifiers are defined to operate in class A, B, AB, C, D, E and F..

2. DESIGN METHODOLOGY OF 25W SSPA

Table 1. Specification requirement of the 25W SSPA

S.NO	PARAMETERS	VALUES
1	**Frequency**	**38MHz**
2	**Bandwidth**	**16MHz**

3	**Output Power**	**25W**
4	**Gain**	**16dB**
5	**Efficiency**	**More than 60%**
6	**Harmonics**	**Less than 20 dB**

The specifications of commercially available MOSFETS in the required frequency range and having appropriate power ratings are studied. The MACOM make n-channel enhancement type MOSFET MRF137 is selected due to its suitable ratings for development. The stability factor of this MOSFET is found to be 3.1

3. DESIGN OF AMPLIFIER CIRCUIT

From the manufacturer's data of MRF137, input impedance Zin = (4-j15) Ω and R_G = 50Ω. The source impedance is 50Ω and the load impedance is Zout = (14-j2.5) Ω.

A. Input Side

L-section is used for the impedance matching.

As $R_G > R_L$. As $Q = \sqrt{\frac{R_G}{R_L} - 1}$

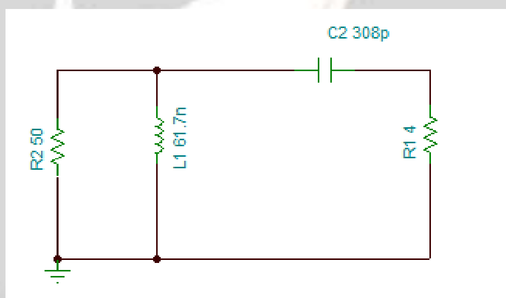

Figure 1: Circuit of Input side Impedance matching

So by doing calculation we get Q=3.39.

Now, $X_C = Q * R_L = 3.39 * 4 = 13.56\Omega$

and $C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi * 38 * 10^6 * 13.56} = 308\text{pF}$

Now,$X_L = \frac{R_G}{Q} = \frac{50}{3.39} = 14.74\Omega$,

and $L = \frac{X_L}{2\pi f} = \frac{14.74}{2\pi * 38 * 10^6} = 61.7\text{nH}$

B. Output Side

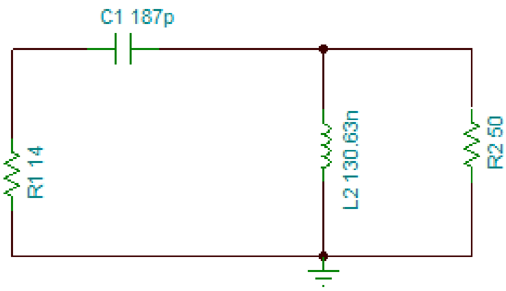

Figure 2: Circuit of Output side Impedance matching

So by doing calculation we get Q=1.60.

Now, $X_C = Q * R_L = 1.60 * 14 = 22.44\Omega$

and $C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi * 38 * 10^6 * 22.47} = 187\text{pF}$

Now, $X_L = \frac{R_G}{Q} = \frac{50}{1.60} = 31.25\Omega$

and $L = \frac{X_L}{2\pi f} = \frac{31.25}{2\pi * 38 * 10^6} = 130\text{nH}$

4. AMPLIFIER SIMULATION WITH TINA

A. Input Side

Due to usage of L-section impedance matching we got L1 as 61.7nH and C2 as 308pF and this will provide the maximum power transfer at the frequency of operation. We had provided power input Pin= 2W and we found that power at MOSFET input is 1.93W at the center frequency 38 MHz. The simulation shows that maximum power has been transferred and hence impedance is matched. At the 50Ω source impedance when V_{peak} = 14.15V then power = $V_{peak}^2/50$ = $(14.15/\sqrt{2})^2/50$ = 2W.At the 4Ω load impedance we received $V_{peak\ to\ peak}$= 7.86V so, the power = $Vp\text{-}p^2/8R = 7.86^2/(8X4)$ =1.93W.

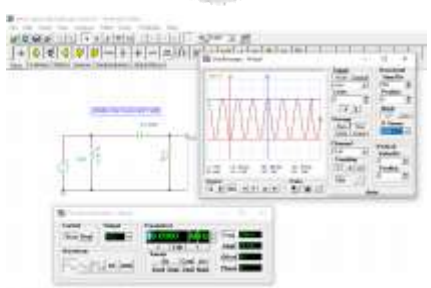

Figure 3: Simulation of Input circuit

B. Simulation of Output Side

Due to usage of L-section impedance matching we got L1 as 130.63nH and C2 as 187Pf. The simulation shows that maximum power is transferred at the frequency of operation hence impedance is matched.We had provided power input Pin= 2W and we found that power at MOSFET output is 1.94W at the center frequency 38 MHz. At the 50Ω source impedance when V_{peak} = 14.15V then power = $V_{peak}^2/50$ = $(14.15/\sqrt{2})^2/50$ = 2W.At the 4Ω load impedance we received $V_{peak\ to\ peak}$= 14.75V so, the power = $Vp\text{-}p^2/8R$ = $14.75^2/(8X14)$ =1.94W.

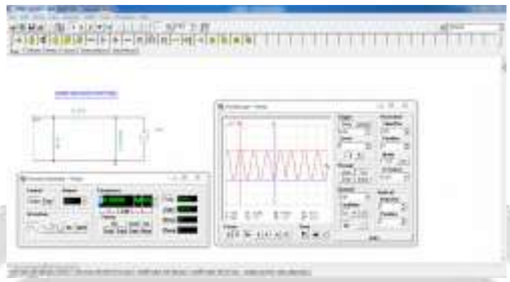

Figure 4: Simulation of Output circuit

5. DESIGNING AND SIMULATION OF BIASING CIRCUITS

Combining the biasing circuit of the input and output as shown above and simulated as shown in figure 7. The circuit has been provided with a dc voltage of 25V and the simulation has been carried out in the given frequency range.

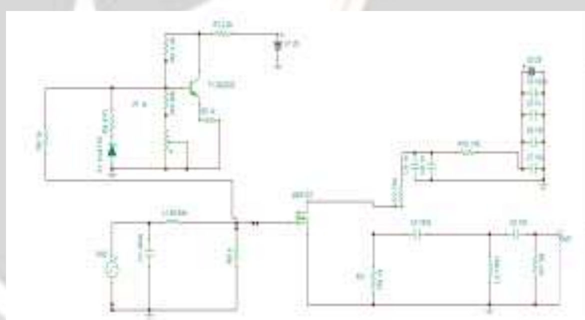

Figure 5: Schematic of 25W SSPA circuit

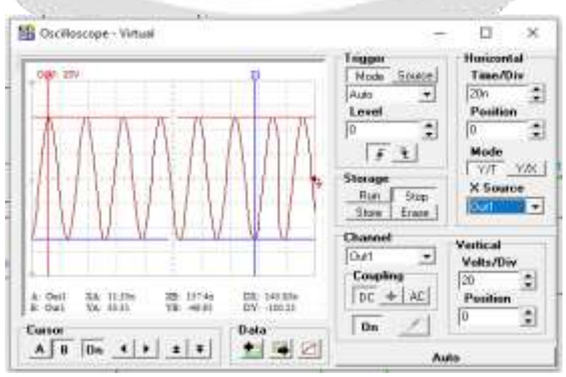

Figure 6: Simulation results of the SSPA circuit

In the simulation results we get the Vpp = 100.25V at 38 MHz. So, Pout = $Vpp^2/8*R = 100.25^2/8*50 = 25.125W$.

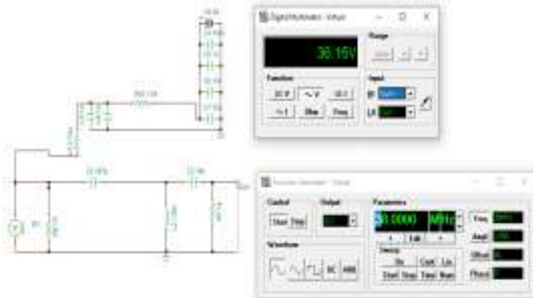

Figure 7: Output matching and output biasing circuits in the TINA TI software.

Here, R = 50Ω and Output power = 25W
As $P = (V^2/R)$ therefore $25 = (V^2/50)$ so V =35.35V.
I_P = 2.05A and therefore $I_{rms} = I_p/\sqrt{2}$ = 1.44A.
When IG1(rms) = 1.44A, the output voltage across 50Ω load = 35.35V.
Trans conductance (ΔI/ΔV) for MRF137 =.75A/V thus,.75 = (2.05/ΔV) , ΔV_p = (2.05/.75) = 2.733V and
ΔV_{rms} = 1.9V

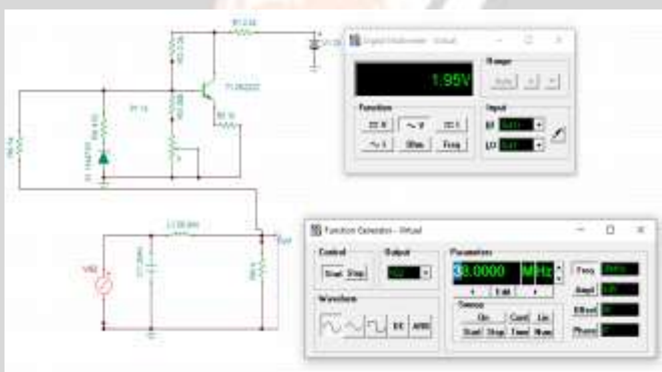

Figure 8: Input matching and input biasing circuits in the TINA TI software

VG1 (P) = 9.8V thus, VG1 (rms) = (VG1 (P)/√2) = (10/√2) = 6.929V.
Pin = $(Vin^2/R) = (6.929)^2/50$ = .96W.
Pout = 25W.
Gain = 10 × log (Pout/Pin) = 14.15dB.
Pin (dc) = VDD × ID = 24 ×1.74 = 41.90W.
Efficiency = Pout (ac) / Pin(dc) = 59.66%.

6. FABRICATION OF 25W SSPA.

The equation for finding the dimensions of an air coiled inductor is,

$$L(\mu H) = \frac{d^2 * n^2}{18d + 40l}$$

Where d = coil diameter in inches
l = coil length in inches
and n = number of turns

We got the following values

Inductors	Value
Input side	61.7Nh
Output side	130Nh
At Drain	2.74µH

The circuit is fabricated with MOSFET MRF137 mounted on a heat sink. G10 insulation sheets of 1mm thickness and dimensions 11mm X 9mm for input and output circuits are shown in figure 10.

Figure 9: View of the 25W SSPA hardware

Signal generator, RF power amplifier, DSO, Dummy load and 25W SSPA are connected accordingly for the testing purposes.The result of fabricated 25W SSPA in the DSO has been shown in fig 12. Peak to peak voltage of 100V has been received at the center frequency of 38 MHz.

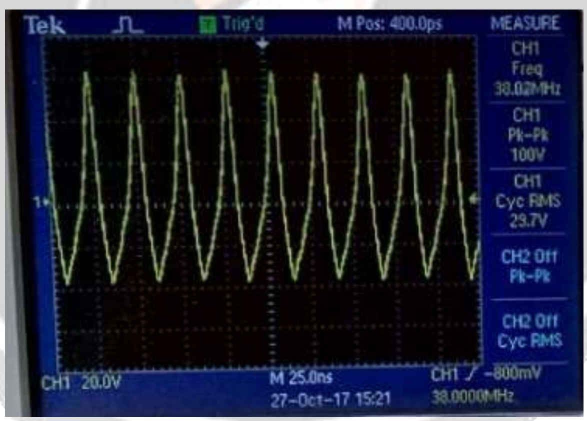

Figure 10: Waveform at 38MHz with output Vpp = 100V in the DSO.

The SSPA has been tested for the frequency range of 38±8 MHz. The SSPA has been tested for various input values from 0.1W to 2W and the required results are obtained for 0.4W input whose values are mentioned in table II.
From the Table II, the Pout (ac) = 25W and the Pin (dc) = 25×1.74 = 43.5W at the 38MHz.
Therefore, The efficiency = Pout (ac)/ Pin(dc) = 59.66% and the power dissipation = 43.5-25 = 18.5W at the 38MHz

TABLE II. TABLE OF THE CIRCUIT PARAMETERS AT PIN OF .4W

Freq. in (MHz)	Input voltage Vpp	Output voltage Vpp	ID (DC) (A)	Pin (W)	Pout (W)	Gain (dB)
30	12.64	125	2.8	.4	39.06	19.89
31	12.64	122	2.8	.4	37.21	19.68
32	12.64	119	2.6	.4	35.40	19.46
33	12.64	116	2.56	.4	33.64	19.24
34	12.64	114	2.4	.4	32.49	19.09
35	12.64	111	2.22	.4	30.80	18.86
36	12.64	110	2.084	.4	28.62	18.54
37	12.64	106	2.018	.4	28.09	18.46
38	12.64	101	1.746	.4	26.01	18.13
39	12.64	97.6	1.656	.4	23.81	17.74
40	12.64	95.8	1.598	.4	21.99	17.40
41	12.64	91.2	1.544	.4	20.79	17.15
42	12.64	88	1.44	.4	19.36	16.84
43	12.64	84	1.34	.4	17.64	16.44
44	12.64	80.8	1.264	.4	16.32	16.10
45	12.64	77.6	1.188	.4	15.05	15.75
46	12.64	74.4	1.066	.4	13.83	15.38

7. CONCLUSION

The assigned project work i.e. 25W broadband amplifier is successfully developed. The detailed design including simulation of the amplifier by using “input and output” within two halves has been completed using TINA tool. The needed value of all the specifications that were targeted were accomplished. The SSPA is fabricated as per simulation and systematically tested.

8. REFERENCES

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