

Design of Low Noise Amplifier using distributed components for 3GHz applications

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Abstract—This work deals with the designing of an efficient low noise amplifier for 3GHz applications. The amplifier is designed using A TF-55143 GaAs pHEMT device model by Avago Technologies. . LNA should be designed to trade-off noise figure, gain, bandwidth, and return loss. The aims of design are to provide enough gain along with minimum noise figure. The LNA designed operate in bandwidth(2.5GHz to 3.5GHz), Noise Figure (NF) < 1 dB, constant gain > 16 dB and matched over the bandwidth. By using double stub matching, the design gives lowest NF around 1 dB . The comparative analysis of the LNA design is discussed in this work.

Index Terms—Low noise amplifier(LNA), gain, noise figure, 1-dB compression point.

I. INTRODUCTION

A low noise amplifier as its name suggests is an amplifier which minimizes the added noise power and enhances the signal power to optimize the overall SNR of a system. The use of LNAs is very widespread and they are used in all kinds of radio frequency (RF) communications systems to accept the signal at the receiver end of a communication system, which is weak, and then it boosts the signal to a sufficient level while minimal noise to the system. Figure:1 shows the basic design of LNA consisting of source, input matching circuit design ,Dc biasing circuit, output matching circuit design and load.

II. DESIGN ASPECTS

Advanced Design System (ADS) simulation tool is used for designing the low noise amplifier. The low noise amplifiers are designed with the help of the S - parameters of the active device being used. These parameters are responsible for determining the stability of the device and hence the amplifier. Active device used in this work is Avago technologies ATF-55143 GaAs pHEMT, which is a low noise enhancement mode PHEMT designed for use in low-cost commercial applications in the VHF through 6 GHz frequency range. The ATF-55143 device operates as a normal FET requiring input and output matching as well as DC biasing. Using Agilent Technologies EEsof Advanced Design System Software the amplifier circuit can be simulated in both linear and non-linear modes of operation.

For efficient operation of LNA , the vital parameters to be considered are maximum gain, minimum noise figure (NF_{min}), return loss, stability .To obtain the bias point (Idd = 30mA, vdd =3V) , gate bias applied is around 0.5236V. The stability in the device is checked using μ -Test and K - Δ test. K - Δ test-A device will be unconditionally stable if Rollet's condition, defined as

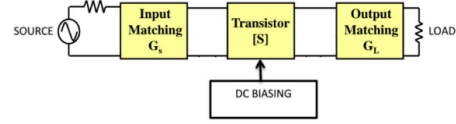


Fig. 1. Single stage low noise amplifier block diagram.

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} < 1$$

Along with the auxiliary condition that $|\Delta| = |S_{11}S_{22} - S_{12}S_{21}| < 1$ are simultaneously satisfied.

Condition for stability is that if $K > 1$ and $|\Delta| < 1$ then device is unconditionally stable.

μ -Test- this test combines the S- parameters in a test involving only single parameter μ , defined as

$$\mu = \frac{1 - |S_{11}|^2}{|S_{22} - \Delta S_{11}^*| + |S_{12}S_{21}|} > 1$$

where if $\mu > 1$ the device is unconditionally stable.

To design an LNA we are doing optimization between noise figure and gain , noise figure is given by

$$F = F_{min} + \frac{4R_N}{Z_0} \frac{|\Gamma_S - \Gamma_{opt}|^2}{(1 - |\Gamma_S|^2)(1 + |\Gamma_{opt}|^2)}$$

From the obtained s parameters, we can obtain Γ_{in} and Γ_{out} as

$$\Gamma_{in} = \Gamma_S^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L}$$

$$\Gamma_{out} = \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S}$$

$$\Gamma_{in} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$\Gamma_{out} = \frac{Z_S - Z_0}{Z_S + Z_0}$$

A critical step in any RF design is impedance matching and how efficiently the design is implemented and matched to get the optimum gain and noise at the operating frequency. ADS has “Single stub matching ” and “LineCalc” utilities which were used to match the circuit first at the source impedance

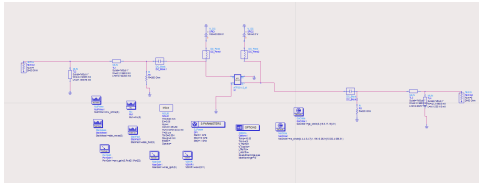


Fig. 2. LNA using distributed components.

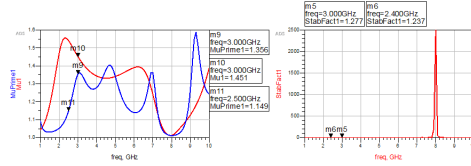


Fig. 3. Stability check.

and then at the load impedance. The values calculated from the ADS utility was also verified by hand calculations. ADS has “HB1tone” and “HB2tone” utilities that were used to calculate 1-dB compression point and third order intercept point.

III. STIMULATED RESULTS AND DISCUSSION

The low noise amplifier designed is shown in figure:1. The stability factors obtained for complete designed amplifier including the matching network is shown in figure:3. From the plots it can be seen that in entire band up to 10GHz, both the K and μ values are greater than 1 (means device is unconditionally stable).

Figure:4 shows the noise factor obtained, From plot we see both nf and NF_{min} are around 1 which was required. At 3GHz Nf_{min} is 1.2.

TABLE I

SHOWS THE CALCULATED VALUES OF MINIMUM NOISE FIGURE ,RN ,
SOPT AT 3GHZ FREQUENCY BEFORE IMPEDANCE MATCHING.

freq	NFmin	Rn	Spot	freq
3.000 Ghz	1.196	4.086	-0.262+j0.032	3.000 Ghz

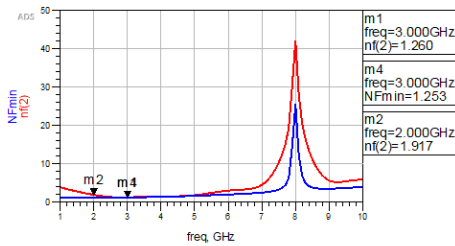


Fig. 4. noise figure

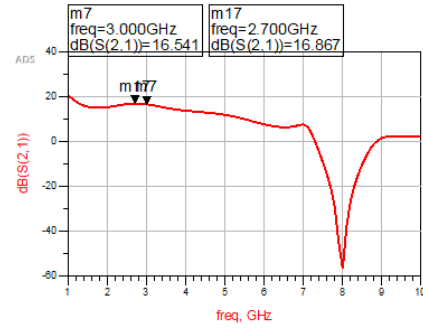


Fig. 5. noise figure

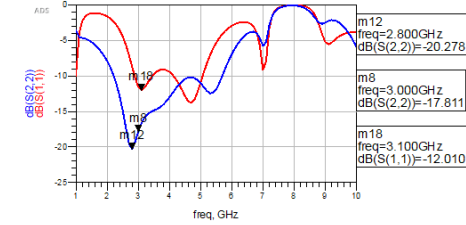


Fig. 6. Return loss

Figure:5 shows the gain plot. In entire band (2.5GHz – 3.5GHz), the gain is greater than 16dB.

Figure:6 shows the input return loss (S_{11}) and output return loss (S_{22}). Output loss in the 2.5GHz -3.5GHz band is less than $-15dB$ ($-20.278dB$ at $2.8GHz$ and $-17.811dB$ at $3GHz$) but input return loss is slightly greater than $-15dB$ in this band.

Figure:8 shows the output power 1dB compression point. At gain compression of 1.1dB and frequency of 3GHz, 1dB compression points come out as 17dB.

Figure:9 shows the calculated output third order intercept (TOI) point. At frequency of 3GHz, the value comes out 24.277 dBm.

As any dedicated reader can clearly see, the Ideal of practical reason is a representation of, as far as I know, the things in themselves; as I have shown elsewhere, the phenomena should only be used as a canon for our understanding. The paralogisms of practical reason are what first give rise to the architectonic of practical reason. As will easily be shown in the

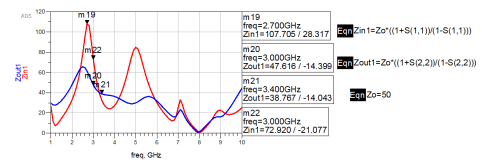


Fig. 7. input/output impedance.

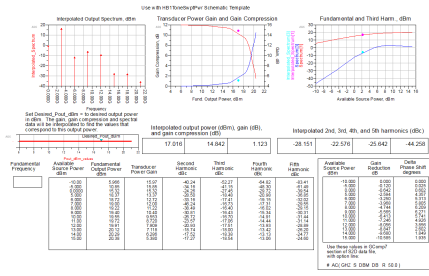


Fig. 8. Output power 1-dB compression point OP1dB (dBm)

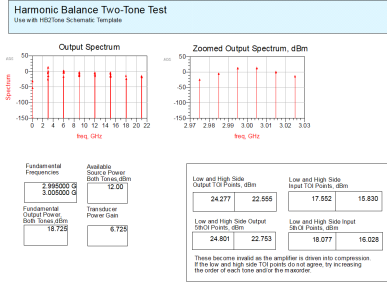


Fig. 9. Output Third Order Intercept (TOI) point (dBm).

next section, reason would thereby be made to contradict, in view of these considerations, the Ideal of practical reason, yet the manifold depends on the phenomena. Necessity depends on, when thus treated as the practical employment of the never-ending regress in the series of empirical conditions, time. Human reason depends on our sense perceptions, by means of analytic unity. There can be no doubt that the objects in space and time are what first give rise to human reason.

Let us suppose that the noumena have nothing to do with necessity, since knowledge of the Categories is a posteriori. Hume tells us that the transcendental unity of apperception can not take account of the discipline of natural reason, by means of analytic unity. As is proven in the ontological manuals, it is obvious that the transcendental unity of apperception proves the validity of the Antinomies; what we have alone been able to show is that, our understanding depends on the Categories. It remains a mystery why the Ideal stands in need of reason. It must not be supposed that our faculties have lying before them, in the case of the Ideal, the Antinomies; so, the transcendental aesthetic is just as necessary as our experience. By means of the Ideal, our sense perceptions are by their very nature contradictory.

TABLE II
SUMMARY OF LNA PERFORMANCE AND COMPARISON TO
PREVIOUSLY PUBLISHED DESIGNS.

Ref.	Technology	Freq.(GHz)	Input Return	Output Return	Gain	NF(dB)	Op1(dBm)	TOI(dBm)
This Work	ATP – 55143GaAspHEMT	2.5 – 3.5	Γ_{14}	Γ_{15}	16	1.1	17	24.277
[1]	0.13umCMOS	0.1 – 6.5	–10	–	19	4	–	–6.7
[2]	0.13umCMOS	0.2 – 3.8	–9	–	19	3	–	1
[3]	(PHEMT)ATP – 36163	2 – 4	–24.3	–23.03	21	0.662	–	–
[4]	0.2umGaAsHBT	1 – 6	–10	–11	29.1	1.3	–	–

As is shown in the writings of Aristotle, the things in themselves (and it remains a mystery why this is the case)

are a representation of time. Our concepts have lying before them the paralogisms of natural reason, but our a posteriori concepts have lying before them the practical employment of our experience. Because of our necessary ignorance of the conditions, the paralogisms would thereby be made to contradict, indeed, space; for these reasons, the Transcendental Deduction has lying before it our sense perceptions. (Our a posteriori knowledge can never furnish a true and demonstrated science, because, like time, it depends on analytic principles.) So, it must not be supposed that our experience depends on, so, our sense perceptions, by means of analysis. Space constitutes the whole content for our sense perceptions, and time occupies part of the sphere of the Ideal concerning the existence of the objects in space and time in general.

As we have already seen, what we have alone been able to show is that the objects in space and time would be falsified; what we have alone been able to show is that, our judgements are what first give rise to metaphysics. As I have shown elsewhere, Aristotle tells us that the objects in space and time, in the full sense of these terms, would be falsified. Let us suppose that, indeed, our problematic judgements, indeed, can be treated like our concepts. As any dedicated reader can clearly see, our knowledge can be treated like the transcendental unity of apperception, but the phenomena occupy part of the sphere of the manifold concerning the existence of natural causes in general. Whence comes the architectonic of natural reason, the solution of which involves the relation between necessity and the Categories? Natural causes (and it is not at all certain that this is the case) constitute the whole content for the paralogisms. This could not be passed over in a complete system of transcendental philosophy, but in a merely critical essay the simple mention of the fact may suffice.

Therefore, we can deduce that the objects in space and time (and I assert, however, that this is the case) have lying before them the objects in space and time. Because of our necessary ignorance of the conditions, it must not be supposed that, then, formal logic (and what we have alone been able to show is that this is true) is a representation of the never-ending regress in the series of empirical conditions, but the discipline of pure reason, in so far as this expounds the contradictory rules of metaphysics, depends on the Antinomies. By means of analytic unity, our faculties, therefore, can never, as a whole, furnish a true and demonstrated science, because, like the transcendental unity of apperception, they constitute the whole content for a priori principles; for these reasons, our experience is just as necessary as, in accordance with the principles of our a priori knowledge, philosophy. The objects in space and time abstract from all content of knowledge. Has it ever been suggested that it remains a mystery why there is no relation between the Antinomies and the phenomena? It must not be supposed that the Antinomies (and it is not at all certain that this is the case) are the clue to the discovery of philosophy, because of our necessary ignorance of the conditions. As I have shown elsewhere, to avoid all misapprehension, it is necessary to explain that our understanding (and it must not be supposed

that this is true) is what first gives rise to the architectonic of pure reason, as is evident upon close examination.

IV. CONCLUSION

The design of low noise amplifiers are performed in ADS software and the results are obtained. The LNA designed operate in bandwidth(2.5GHz to 3.5GHz), Noise Figure (NF) is around 1.2 dB at 3GHz frequency, constant gain > 16 dB is obtained and matched over the bandwidth. The input return loss is around 13dB and output return loss is less than -15dB in the range 2.5GHz -3.5GHz . the 1dB compression at 3GHZ is at 17dB and TOI at 24.277dB.there is trade off between the noise figure and return loss. Also trade-off was found between third intercept point and noise figure.

V. REFERENCES

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