

TN1031

Medium Power Wideband Amplifier for MMDS Application

Introduction

Designers of high-volume commercial microwave subsystems share common goals: high performance, low cost and ease of manufacturability. This technical note describes the process by which design engineers choose their devices to fulfill system constraints based on the specifications of an application. While this design may not yield the optimum design solution for all wideband applications, it does introduce a few RF and microwave techniques that can be applied to other wideband designs.

Design Consideration

The design for this medium power IF wideband amplifier used in a Multichannel Multipoint Distribution System (MMDS) is defined by the specifications in **Table 1**. The amplifier will be used as the output of a downconverter that provides a 33 video channel signal fed directly into a television set (similar to a CATV amplifier). Therefore, the amplifier will have to exhibit a reasonable output inter-modulation point and low inter-channel modulation distortion.

FREQUENCY RANGE (MHz)	GOALS (50-550)	SIMULATION (50-850)
Gain (dB)	12 min.	13 min.
Gain Flatness (dB)	1.5 dB Peak to Peak	1.0 dB Peak to Peak
P1dB Compression point (dBm)	17dBm	Not Simulated
Output IP3 (dBm)	27 dBm min.	Not Simulated
Input Return Loss (dB)	-10 min.	-10 min. up to 550 MHz
Output Return Loss (dB)	-12 min.	-12 min. up to 900 MHz
Bias Condition (mA)	10 V, 50 mA	10 V, 50 mA
Price in 100 K Quantities (US \$)	\$1	N/A

Table 1. Maximum Gain Design Performance Comparison: Goals and Simulation.

The device chosen for this design is the NE461M02, a NPN silicon epitaxial bipolar transistor specially designed for medium power and high dynamic range applications.

The transistor is also housed in the new M02 package (see **Figure 6**) which is optimized for high gain with its two emitter leads, good thermal dissipation and a sizable collector pad. In the band of operation, this device exhibits sufficient gain at the high end (12 dB up to 900 MHz) when biased at 10 V, 50 mA, while also providing a minimum of 23 dBm for one dB compression point (P1dB). Since the power performance is well above the specified requirement, a linear simulation was chosen to optimize the other design parameters.

Broadband Match

The purpose of designing a broadband amplifier is to synthesize an input and output matching network to the device that will achieve the desired transducer power gain (refer to **Table 2** and **Figure 1** for the NE461M02 S-Parameters and maximum available gain (MAG)). Since the device has a naturally sloped response of 6 dB/octave (**Figure 2**), these networks will have to compensate for the roll-off of the transistor within the passband. In this case, the design also requires a very good return loss, therefore simply mismatching the device will not allow the amplifier to meet the specifications. The final topology adopted (**Figure 3**) was a matching that combines three different design techniques to achieve the desired bandwidth (over a 1 to 10 ratio). The design includes series feedback on the emitter, parallel feedback from the collector to the base, and lossy matching networks both on the input and the output. The series feedback is used to offset the internal package feedback, bring unconditional stability at lower frequencies (below 500 MHz) and reduce the gain slope below 1 GHz. Once the 5 Ω resistive emitter feedback was applied, a flat gain over the band could easily be fine-tuned using the parallel feedback. However, meeting the desired return loss performance involved considerable design efforts and could only be achieved with a lossy network (which may affect the linear behavior of the device). In the simulation, all design parameters were eventually met (**Figures 4 and 5, Table 3**) except for the power parameters, which were not simulated. However, with a bias of 10 V, 50 mA, the amplifier would have to run below 10% efficiency to not meet the power specifications. Finally, stability was optimized with K (Stability factor) close to 1 in and around the active band. The circuit was simulated up to 4 GHz with good stability results.

Note:

1. Technical notes are proof of concepts based on CEL's device characterization and simulations to provide RF and microwave engineers with a starting point for their designs.

TYPICAL SCATTERING PARAMETERS (TA = 25°C)

VCE = 10 V, IC = 50 mA

FREQUENCY (GHz)	S11		S21		S12		S22		K	MAG ¹ (dB)
	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG		
0.10	0.599	-137.2	23.210	109.9	0.031	48.0	0.455	-97.0	0.482	28.743
0.20	0.602	-162.2	12.353	95.7	0.042	51.4	0.335	-125.3	0.751	24.685
0.30	0.603	-173.1	8.358	88.6	0.053	56.7	0.305	-137.6	0.892	21.978
0.40	0.601	179.8	6.307	83.5	0.066	60.0	0.295	-143.9	0.962	19.803
0.50	0.601	174.4	5.072	79.2	0.078	61.8	0.291	-147.3	1.008	17.594
0.60	0.599	169.8	4.248	75.4	0.091	62.8	0.292	-149.2	1.033	15.580
0.70	0.598	165.7	3.659	71.8	0.104	63.0	0.293	-150.1	1.047	14.132
0.80	0.596	161.9	3.220	68.4	0.117	63.0	0.295	-150.6	1.058	12.927
0.90	0.593	158.4	2.880	65.2	0.130	62.5	0.298	-150.6	1.064	11.906
1.00	0.591	155.0	2.609	62.1	0.144	61.9	0.301	-150.7	1.064	11.041
1.25	0.585	147.0	2.130	54.7	0.176	59.7	0.311	-150.1	1.064	9.284
1.50	0.577	139.5	1.818	47.8	0.207	57.0	0.321	-149.3	1.060	7.936
1.75	0.568	132.4	1.602	41.4	0.239	53.9	0.330	-148.7	1.049	6.913
2.00	0.557	125.5	1.444	35.3	0.270	50.7	0.340	-148.3	1.038	6.084
2.50	0.535	111.7	1.235	23.9	0.331	43.7	0.357	-148.4	1.013	5.010
3.00	0.515	97.5	1.101	13.5	0.388	36.0	0.372	-150.1	0.995	4.530
3.50	0.502	83.0	1.006	4.0	0.442	28.0	0.386	-153.7	0.981	3.572
4.00	0.498	69.2	0.931	-4.8	0.488	19.7	0.396	-159.7	0.977	2.805
4.50	0.501	56.9	0.874	-12.7	0.527	11.5	0.400	-167.1	0.979	2.197
5.00	0.507	46.6	0.828	-19.9	0.560	3.6	0.396	-175.8	0.985	1.698
5.50	0.510	37.9	0.794	-26.6	0.590	-4.2	0.384	175.1	0.994	1.290
6.00	0.506	30.9	0.772	-33.1	0.619	-12.1	0.360	165.5	1.003	0.617

Note:

1. Gain Calculations:

$$MAG = \frac{|S_{21}|}{|S_{12}|} (K \pm \sqrt{K^2 - 1})$$

When $K \leq 1$, MAG is undefined and MSG values are used. $MSG = \frac{|S_{21}|}{|S_{12}|}$, $K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2 |S_{12} S_{21}|}$, $\Delta = S_{11} S_{22} - S_{21} S_{12}$

MAG = Maximum Available Gain

MSG = Maximum Stable Gain

Table 2. NE461M02 S-Parameters and Maximum Available Gain.

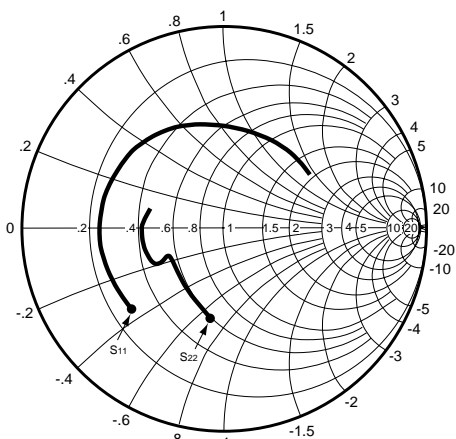


Figure 1. NE461M02 Input and Output S-Parameters from 0.1 to 6 GHz.

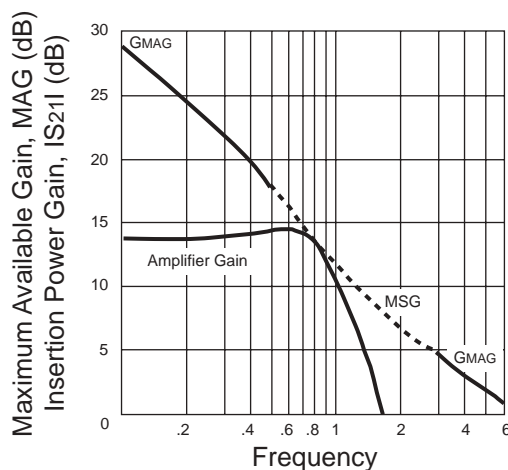
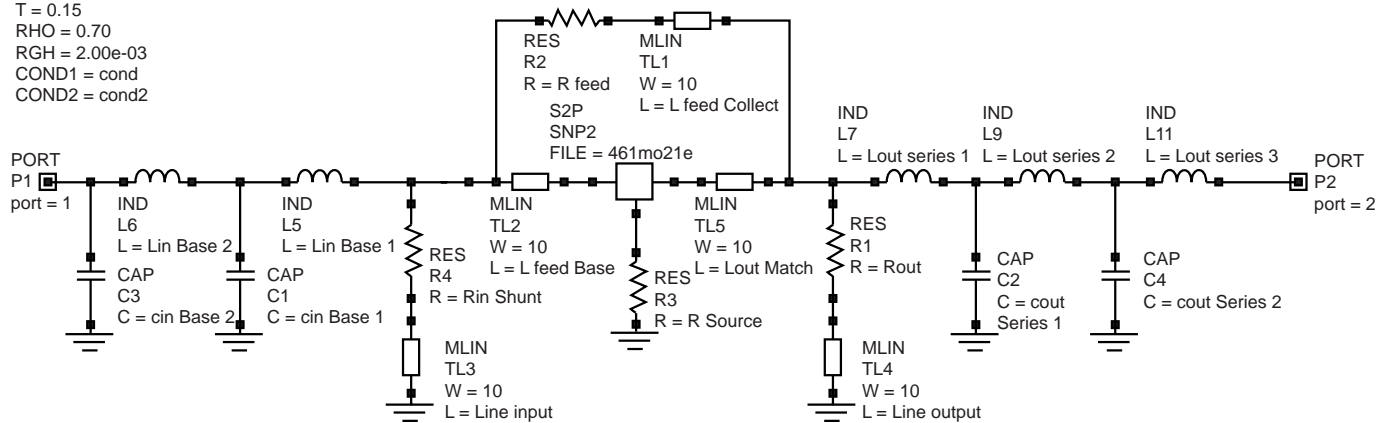


Figure 2. NE461M02 Maximum Available Gain to be matched and flattened.

DATA

MSUB
 MSUB1
 ER = 4.74
 H = 62
 T = 0.15
 RHO = 0.70
 RGH = 2.00e-03
 COND1 = cond
 COND2 = cond2

DIEL1 = diel
 DIEL2 = diel2
 HOLE = hole
 RES= resi



Var. Eqn.

VAR
 Lout Shunt = 11
 Line output = 2100
 Line input = 2500
 Lin Base 1 = 6
 Lin Base 2 = 10
 cin Base 1 = 7
 cin Base 2 = 3

L feed Collect = 1000
 L feed Base = 20
 Lout Match = 350
 Lin Shunt = 1100
 Rin Shunt = 400
 Lout Series 1 = 3.50
 Lout Series 2 = 10

Lout Series 3 = 4
 cout Series 1 = 6
 cout Series 2 = 3.50
 Rout = 500
 R feed = 250
 R Source = 5

Figure 3. Final Topology of the Amplifier.

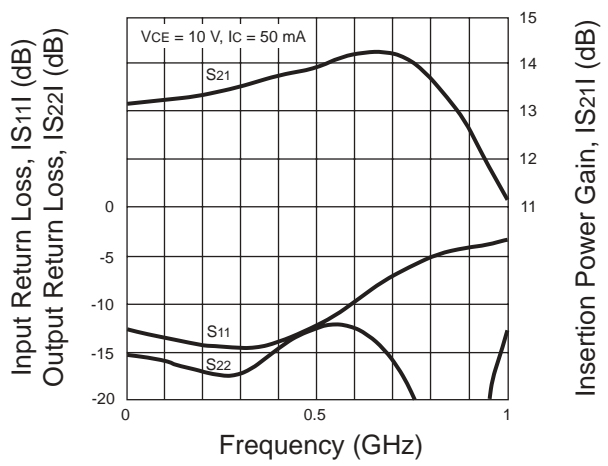


Figure 4. The NE461M02 Wideband Performance as an Amplifier.

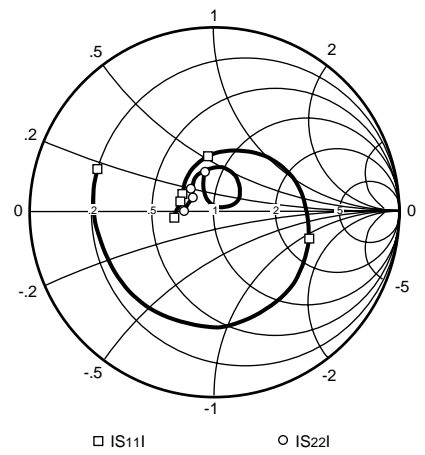


Figure 5. Matching of the NE461M02 in a Wideband Amplifier Application.

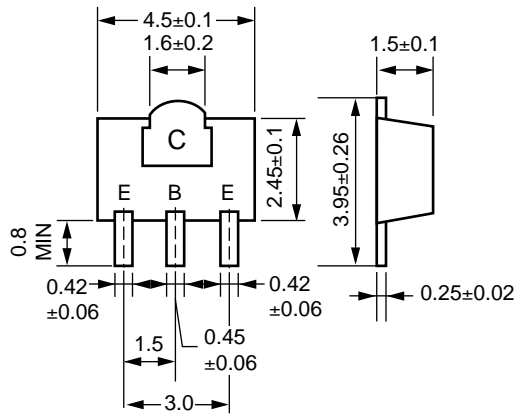


Figure 6. M02 Package.

Additional Design Features

In addition to exceeding the minimum specifications, a sensitivity study was performed to verify the robustness and repeatability of the design. S-Parameter files with different bias points were simulated to demonstrate that the design is

not very sensitive to bias changes in terms of gain and return loss. Along with the consistency of the NE461M02, this should be a key parameter to ensuring ease of manufacturability.

Additionally, some inductive elements were simulated using a 10 mil wide printed line to allow for tuning once the design is released to manufacturing. These lines should be laid out in a U-shape to vary the length by adding or cutting connecting traces, assisting with minor production tuning. However, chips inductors were used for the input and output matching filters since the values of such inductors would make printed line length impracticable for use at low frequencies.

Conclusion

This technical note describes the design process of a wideband medium power amplifier for high volume commercial applications using the NE461M02. Some insights on design considerations that address both performance and ease of manufacturability were exposed. Finally the simulation results provide the expected performance and proposed topology of the circuit.

NE461M02 IF AMPLIFIER, MMDS APPLICATION (WIDEBAND FLAT GAIN AMPLIFIER)

FREQUENCY (GHz)	S ₁₁ (dB)	S ₂₁ (dB)	S ₁₂ (dB)	S ₂₂ (dB)	K
0.10	-13.5455	13.3009	-18.2934	-15.9308	1.1358
0.15	-13.8542	13.3361	-18.0786	-16.6360	1.1148
0.20	-14.1782	13.3812	-17.8565	-17.3272	1.0907
0.25	-14.4979	13.4374	-17.5775	-17.6868	1.0626
0.30	-14.5689	13.5083	-17.2864	-17.1554	1.0319
0.35	-14.3491	13.5847	-16.9079	-15.9782	0.9989
0.40	-13.8667	13.6660	-16.5082	-14.4314	0.9675
0.45	-13.0010	13.7726	-16.0777	-13.1658	0.9381
0.50	-12.0087	13.9098	-15.5797	-12.2893	0.9112
0.55	-10.8936	14.0574	-14.9969	-12.0018	0.8904
0.60	-9.6308	14.2168	-14.4079	-12.4607	0.8766
0.65	-8.2480	14.2905	-13.8180	-13.9277	0.8705
0.70	-7.0084	14.2104	-13.3522	-16.4136	0.8692
0.75	-5.9386	13.9751	-12.9442	-19.8124	0.8690
0.80	-5.0457	13.6350	-12.6127	-23.9760	0.8648
0.85	-4.3373	13.1942	-12.2687	-28.2969	0.8519
0.90	-4.0006	12.7030	-11.9404	-29.1165	0.8414
1.00	-3.3922	11.1630	-11.6131	-12.2278	0.8415
1.25	-0.1703	-5.0108	-22.7718	-2.3392	0.9615
1.50	-0.0252	-22.3995	-35.7408	-0.7279	1.1476
1.75	-0.0117	-37.6498	-48.0402	-0.1658	1.2482
2.00	-0.0047	-50.7017	-59.4895	-0.0334	1.1520
2.25	-0.0025	-61.7557	-69.6489	-0.0076	1.2631
2.50	-0.0012	-70.8463	-78.1089	-0.0024	1.3206

Table 3. Simulated Performance of the Amplifier.

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