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AN-G001: ATF -13136 Demonstration Amplifier

INTRODUCTION

This Applications Note describes a one stage low noise amplifier designed using Hewlett-Packard's ATF-13136. The amplifier demonstrates the capabilities of this 1.2 dB noise figure GaAs FET as a front end device for Ku band Direct Broadcast Satellite (DBS) television systems.

AMPLIFIER DESIGN AND PERFORMANCE

The amplifier is designed from the catalog S and noise parameters of the ATF-13136. The topology selected uses a shorted stub tuning element to establish the input noise match and open stub tuning elements for the output gain match. A schematic for the amplifier is shown in Figure 1.

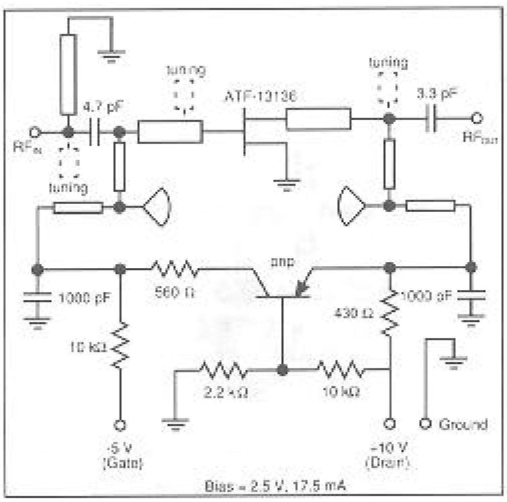

Figure 1. ATF-13136 Demonstration Amplifier

The amplifier is built on 20 mil thick RT/Duroid 5880. This substrate is used for its low loss, and because 50 Ohm transmission lines on this board are of a width close to that of the transistor leads. Figure 2 shows a scaled drawing of the layout.

Table 1 lists the performance of an amplifier built using this design. The data shows amplifier performance from 11.3 to 12.3 GHz in 0.1 GHz steps, giving both the noise figure in dB and the corresponding noise temperature in K. The associated gain at noise figure and total current draw are also listed.

The data shows that typical performance using this amplifier design is 1.7 dB (140 K) noise figure across 11.7 to 12.2 GHz, with 8 dB associated gain. This should correlate to a typical waveguide launched system noise figure performance of about 1.54 dB (123 K)—see SYSTEM NOISE FIGURE, below. Noise performance is quite flat, with slightly better performance on the band edges than is seen midband. There is approximately 0.5 dB gain roll off on the high end of the band.

Table 1. ATF-13136 Demonstration Amplifier Typical Performance

f (GHz)	NF (dB)	NF (K)	Ga (dB)
11.3	1.62	131	8.47
11.4	1.62	131	8.46
11.5	1.66	135	8.44
11.6	1.67	136	8.42
11.7	1.69	138	8.41
11.8	1.70	139	8.44
11.9	1.69	138	8.43
12.0	1.69	138	8.31
12.1	1.66	135	8.20
12.2	1.64	133	8.05
12.3	1.64	133	7.88

Bias with V_{dd} = +10 V; V_{gg} = −5 V; I_d = 17.07 mA

Although the original design range is 11.7 to 12.2 GHz, the match is reasonably broadband, and good performance is seen across at least 11.3 to 12.3 GHz.

BIAS

Two external power supplies are required to bias the amplifier: a +10 V supply for the drain and a −5 V supply for the gate. The gate feed is on the same side of the amplifier as the RF input; the drain feed is on the same side as the RF output and ground lug.

To turn the amplifier on:

1. First apply −5 V to the gate terminal "G"
2. Then apply +10.0 V to drain terminal "D"

Altering the voltage applied to the drain terminal will change the bias point by adjusting both V_d and I_d. To repeat the factory data, this voltage should be exactly 10.0 V. Only very small adjustments to bias can be accomplished by changing the voltage applied to the gate terminal because of the active bias scheme used.

The nominal transistor bias point used for the demonstration amplifier is 2.5 V, 17.5 mA. Recent testing has shown that this bias gives slightly superior noise performance to the data sheet characterization bias of 3 V, 20 mA. The improvement varies from wafer run to wafer run, and is on the order of 0.1 dB reduction in noise figure. (Note: a bias of 2.5 V, 20 mA yields performance that is typically less than .05 dB higher in noise, but 0.5 dB higher in gain than what is achieved at 2.5 V, 17.5 mA. Analysis of the noise measure of the particular system being designed is needed to determine which of these two bias points is preferable.) The S and noise parameter characterizations at 3 V, 20 mA can still be used for design, as the small bias changes discussed here do not appreciably alter device characterization.

The demonstration amplifier incorporates an active bias circuit to establish the operating point of the FET. For details on the construction and function of this bias circuit, see HP's *Appli-*

cations Note AN-A002, Design of a 4 GHz LNA for a TVRO System. Bias is critical to performance. The variability in pinchoff voltage from device to device does not allow for a passive two supply bias with fixed voltages to be successful in production. In addition, the two supply bias will not maintain a stable bias point over temperature; an active bias will.

If the goal is to obtain absolutely the lowest noise LNB possible with the ATF-13136, each first stage FET should be individually set to its empirically determined optimum bias (V_d between 2.0 and 3.0 V, I_d between 10 and 25 mA). The improvement in noise figure from the nominal bias (2.5 V, 17.5 mA) to the true optimum bias for any given ATF-13136 is typically 0.1 dB.

RF MATCHING AND TUNING

"Tabs"—open stubs, typically .020-in. wide and up to .100-in. long—can be used to tune the amplifier. Cut off pieces of transistor lead work well for this purpose.

The small stub at the gate of the device is the most critical tuning element, and has a strong effect on both gain and noise figure. This element helps most at the lower frequency end of the band; too large a stub will destroy high frequency noise performance. Occasionally a tab placed opposite the shorted stub tuner (sst) on the input circuit will improve high frequency gain and noise performance. (Note: adding a stub here effectively adjusts the length of the sst.) A small tab on the output near the blocking capacitor will usually improve the midband gain, but can also roll off the high frequency gain.

SYSTEM NOISE FIGURE

For convenience of testing, the demonstration amplifier uses SMA connectors instead of the waveguide launch found in most production systems. The measured loss of a pair of these connectors (plus a length of 50 ohm transmission line equal to the entire circuit length) is 0.50 dB at 12 GHz. Thus the demonstration amplifier has at least 0.20 dB of noise contribution from the input connector. The connectorized amplifier also requires an input blocking capacitor to prevent the generator impedance from affecting the gate bias voltage applied to the GaAs FET. This component, even though high Q, contributes an additional 0.10 dB to the noise figure of the demonstration amplifier due to its associated loss.

Note that the amplifier exhibits in-band noise performance as low as 1.65 dB. Correcting 0.20 dB for the input connector, 0.10 dB for the blocking capacitor, allowing 0.05 dB loss for the input portion of the pc matching structure and 0.10 dB degradation in noise performance due to broadband matching, we arrive at a minimum device noise figure of 1.20 dB. This agrees with the 1.2 dB typical, 1.4 dB maximum noise specification of the ATF-13136.

In an actual LNB, the observed noise figure should be better than what is displayed by the demonstration amplifier. A waveguide launch with approximately 0.05 dB loss will replace the input connector, and allow the removal of the input blocking capacitor from the design. Although there will be an additional noise contribution from the latter stages of the system, for a second stage with a 1.5 dB maximum noise figure and 9 dB of gain, and assuming an 8 dB noise figure for the mixer, this noise contribution is calculated to be 0.24 dB. The losses for the pc board remain about 0.07 dB. Thus systems with noise figures around 1.54 dB (123 K) can be achieved using the ATF-13136 in the 11.7 to 12.2 GHz band. Noise performance for the 10.95 to 11.7 GHz European DBS band is typically 0.1 dB better due to the lower frequency of operation.

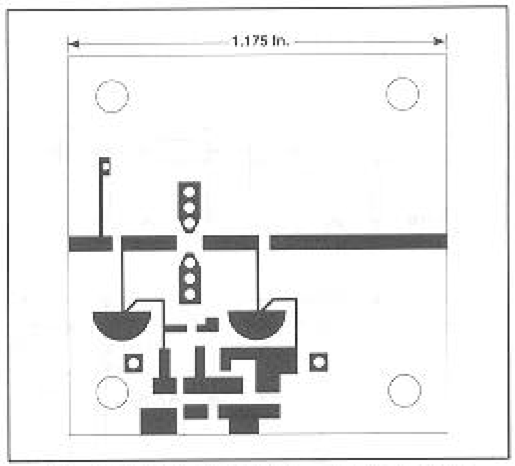

**Figure 2. ATF-13136 12 GHz Demonstration Amplifier
2X Scale Drawing
PC Board :20 mil RT/Duroid (ε = 2.5)**

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