Low Noise Amplifiers for 2304, 3456, 5760, and 10368 MHz using the ATF-36077 PHEMT

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INTRODUCTION

The Hewlett-Packard ATF-36077 PHEMT device is described in a series of low noise amplifiers for 2304, 3456, 5760, and 10368 MHz. Single stage amplifiers are described for 2304, 3456, and 5760 MHz while a two stage amplifier is described for 10368 MHz. The goal for these amplifiers was to establish a common printed circuit board size that would ultimately allow all LNAs to be built into a common aluminum waterproof enclosure.

LNA DESIGN

All LNAs were designed for ER=2.2 dielectric material. The 10368 MHz LNA was designed for .015 inch thickness material to minimize radiation losses while the lower frequency LNAs were designed for .031 inch thickness material. I have used both Taconics TLY-5 and Rogers D5880 material with very good success. All LNAs make use of plated through holes to obtain good high frequency grounding of the PHEMT devices.

All 4 LNAs use microstripline matching except for the noise match of the 2304 and 3456 MHz LNAs where a wire inductor was used for lower loss. Quarterwave bias decoupling lines are used to provide gate and drain bias to each stage. 50 Ω resistors are used along with the bias decoupling lines to provide low frequency terminations for the devices. On the 3 low frequency units a resistor in series with the drain is used to improve stability.

Each LNA will be described separately in the following sections

2304 MHz LNA

The 2304 MHz LNA including component placement is shown in Figure 1. The LNA uses a wire inductor for the input noise match and a microstripline match for the output with a small resistor in series with the drain to lower gain and improve stability.

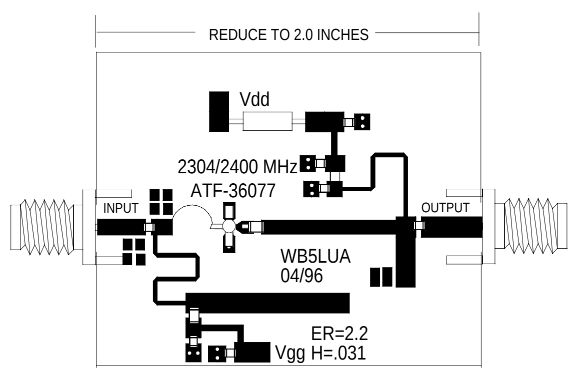

Figure 1. 2304 MHz LNA showing component placement

Although the ATF-36077 is capable of "device only" noise figures of nearly 0.2 dB at 2 GHz, the losses of the input network limit actual LNA noise figures to around 0.4 dB. I described another 2304 MHz LNA[1] that used wire inductors for both the noise match and the input bias decoupling line. This technique allowed the LNA to achieve a noise figure of 0.4 dB or slightly less. Since this LNA was designed to be mounted in a standard enclosure I included some additional input etch which raised the noise figure slightly. The prototype LNAs I built were mounted in a box made from brass strips 1 inch tall. The SMA connectors were soldered directly to the printed circuit board and the brass walls. I was able to achieve 0.4 to 0.5 dB noise figures on all units built to date. Associated gain is 15 to 16 dB typically. Bias point is Vds =2 volts and Ids = 15 mA.

The schematic diagram for both the 2304 MHz and 3456 MHz LNAs is shown in Figure 2. The parts list is shown in Figure 3.

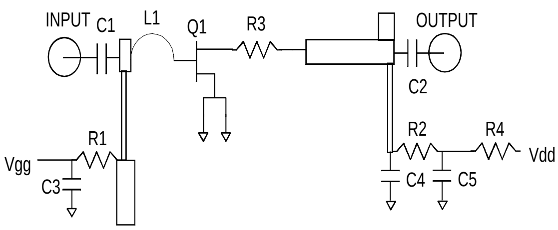

Figure 2. Schematic Diagram for 2304 and 3456 MHz LNAs

C1,C2, C4	8.2 to 10 pF chip capacitor
C3,C5	1000pF // .01uF chip capacitor
L1	2304 MHz , length = .5 inch 3456 MHz, length = .3 inch .007"diameter with .075" soldered to input etch and .025" soldered to gate lead. Adjust for best NF
Q1	Hewlett-Packard ATF-36077 PHEMT
R1,R2	50 Ω chip resistor
R3	10 to 27 Ω chip resistor (effects gain and stability)
R4	For operation from a power supply voltage of 5 volts, R4 = 200Ω - R3 - R2

Figure 3. Parts list for 2304 and 3456 MHz LNAs

3456 MHz LNA

The 3456 MHz LNA including component placement is shown in Figure 4. The LNA design is very similar to the 2304 MHz LNA. It also uses a wire inductor for the input noise match and a microstripline match for the output network. A small resistor in series with the drain is used to lower gain and improve stability.

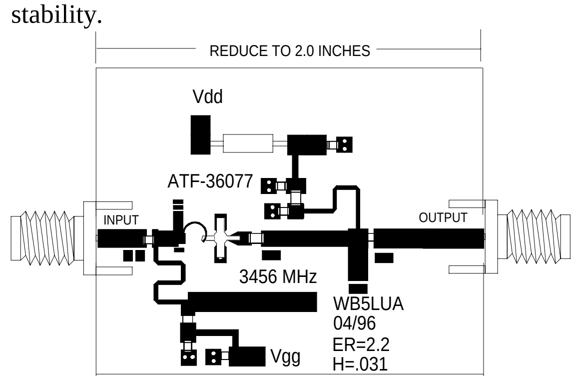

Figure 4. 3456 MHz LNA showing component layout

The prototype 3456 MHz LNAs were installed in brass housings similar to the 2304 MHz LNA. Noise figures of 0.6 to 0.7 dB were obtained along with 13 to 14 dB gain. The resistor in series with the drain can be lowered in value to increase gain and lower noise figure slightly. Somewhat lower noise figure could possibly be obtained by cutting off the input 50 Ω microstripline and placing the input connector adjacent to the input blocking capacitor. Bias point is Vds =2 volts and Ids = 15 mA.

5760 MHz LNA

The 5760 MHz LNA including component placement is shown in Figure 5. The LNA uses microstripline matching networks for both the input noise match and output gain match. Some resistive loading in the drain circuit is required for unconditional stability, according to the computer analysis. However, several LNAs have been built without this resistor with no problems experienced.

The prototype 5760 MHz LNAs were installed in brass housings similar to the other LNAs. Noise figures of 0.7 to 0.8 dB were obtained along with 12 to 13 dB gain. Somewhat lower noise figure could possibly be obtained by cutting off the input 50 Ω microstripline and placing the input connector adjacent to the input blocking capacitor. Bias point is Vds =2 volts and Ids = 15 mA.

The schematic diagram and parts list are shown in Figures 6 and 7.

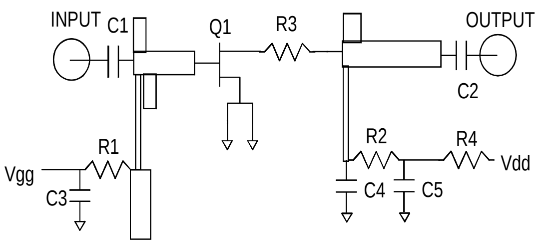

Figure 6 Schematic Diagram of 5760 MHz LNA

C1,C2,	1 pF chip capacitor (1-2 pF OK)
C4	10 pF chip capacitor
C3,C5	1000pF // .01uF chip capacitor
Q1	Hewlett-Packard ATF-36077 PHEMT
R1,R2	50 Ω chip resistor
R3	10 to 27 Ω chip resistor (effects gain and stability)
R4	For operation from a power supply voltage of 5 volts, R4 = 200Ω - R3 - R2

Figure 7. Parts list for 5760 MHz LNA

10368 MHz LNA

The 10368 MHz LNA was designed as a 2 stage LNA in an attempt to lower "low frequency" gain which became a problem when mating an earlier design single stage unit with a waveguide input configuration. With a single stage LNA, gain peaking in the 7 GHz frequency range coupled with the rolloff of the high pass nature of WR-90 produced some instabilities.

The 2 stage 10368 MHz LNA is shown in Figure 8. The LNA uses microstripline matching throughout the amplifier. The input network provides the noise match. Both the output matching network and the interstage

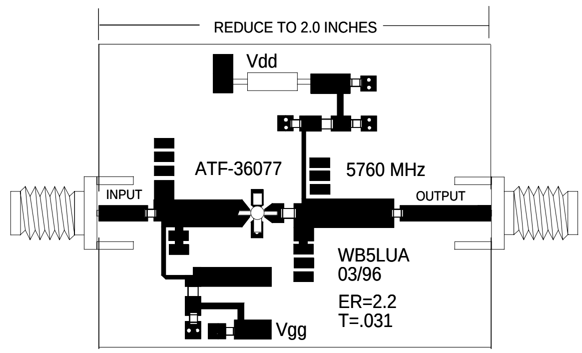

Figure 5. 5760 MHz LNA showing component placement

matching network were design for reasonable gain at 10368 MHz while providing some low frequency rolloff.

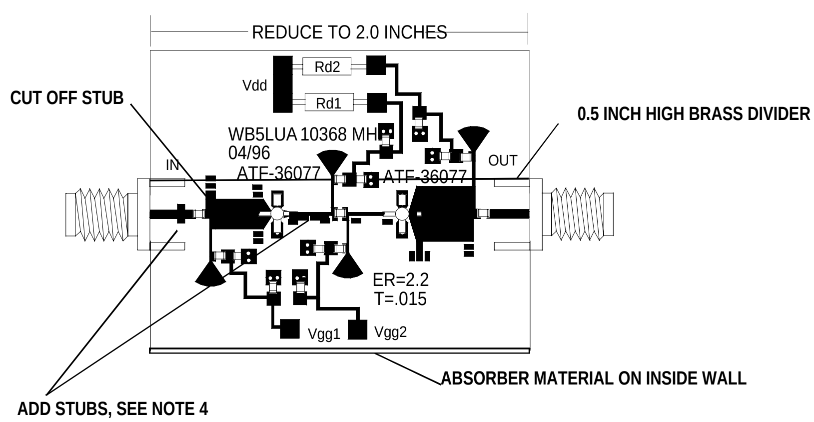

Figure 8. 10368 MHz LNA showing component placement

The prototype 10368 MHz LNAs were installed in brass housings. I used .75 inch wide brass for the 4 walls. With the higher gain of the 2 stage amplifier, the effect of the housing became more noticeable especially when attaching a cover to the box. I made use of a .5 inch wide piece of brass as a divider down the middle of the amplifier. This is shown in Figure 8. The .5 inch wide piece of brass is placed .85 inch in from the side of the box. This makes it slightly offset from being run directly down the middle of the box. The divider is soldered to the walls of the box in such a way that it will make contact with the cover and be about .2 inch above the printed circuit board etch. This divider tends to break up the waveguide effect of the enclosure which tends to help propagation of unwanted waves through the box., causing undesired feedback. I also made use of some absorber material as shown in Figure 8.

Some tuning of the initial design was necessary. I used .04 by .1 inch stubs cut from some transistor leads. Place 1 stub as shown on the input line. See Figure 8. This may necessitate some tuning depending on the type and quality of the SMA connectors you have in your junk box. Use 2 more stubs to widen the output etch as shown on Q1.

Noise figures of 0.7 to 1.0 dB were obtained along with 23 dB gain. Bias point is Vds =1.5 volts and Ids = 15 mA per device. The schematic diagram and parts list are shown in Figures 9 and 10..

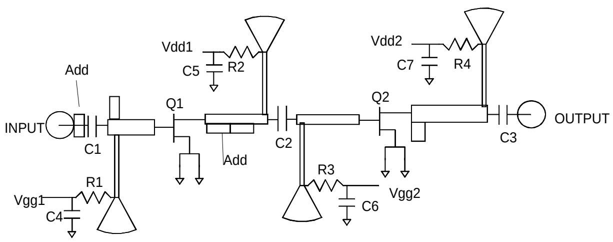

Figure 9. Schematic Diagram of 2 stage 10368 MHz LNA

C1	0.6 pF chip capacitor (0.5-1 pF OK)
C2,C3	1 pF chip capacitor (1-2pF OK)
C4,C5, C6,C7	1000pF // .01uF chip capacitor
Q1,Q2	Hewlett-Packard ATF-36077 PHEMT
R1,R2, R3,R4	50 Ω chip resistor
RD1 RD2	For operation from a power supply voltage of 5 volts, RD1=RD2 = 180Ω

Figure 10. Parts list for 10368 MHz LNA

Biasing

I use passive biasing in most of my amplifiers with good success. I use a regulated 5 volt source which also feeds the dc-dc converter which generates the negative voltage .. I use a potentiometer off the negative source to set the proper gate voltage required to sustain 10 to 15 mA drain current. The resistance between the 5 volt power supply and the drain of the device is calculated based on a 3 volt drop to the drain. The actual dc bias point of the device is not that critical. Vds can be anything from 1.5 to 2 volts and drain current can be between 10 and 15 mA. DC to DC converters and various passive and active bias schemes are covered in other articles.[23].

Downeast Microwave offers both single and dual stage power supplies for powering up FETs. (Part numbers PPS-1 and PPS-2) A potentiometer is used to set the gate voltage. The important thing to remember is to set the gate voltage at about -0.2 v before applying the drain voltage or before installing the bias resistors on the board. The worst thing you can do to a fet is to apply a high enough negative voltage to the gate that it "pinches off the drain" and causes no current to flow. With several volts negative on the gate and 5 volts positive on the drain, the device is history, even before it even thought about operating!. It is best to pre-set the gate voltage to where there is some drain current being pulled through the drain bias resistors. The gate voltage can then be set for optimum drain current which should coincide with maximum gain and nearly minimum noise figure. A good test for an LNA is to determine if optimum gain and noise performance occur coincidentally within the range of the specified bias point. If the LNA is oscillating, then as one increases drain current and drain voltage, the amplifier performance, i.e. gain, will peak at a much lower bias point. This signifies that the device is oscillating and going into a self-bias mode because of oscillations.

Enclosures

My preferred choice for an enclosure is normally a box made from brass strips.. This allows gold plated SMA connectors and the printed circuit board to be soldered directly to the brass. This provides a good RF tight box. Unfortunately when the box surrounds the circuit board, it begins to look like a piece of waveguide when viewed from either the input or output connector. The best solution would be to design the circuit board to be very narrow as viewed from the end. This will tend to look like a piece of higher frequency waveguide and will tend to rolloff lower frequencies and consequently attenuate signals that are propagating through the box and not the circuit.

Solutions to the 'waveguide effect" problem include the use of dividers to break up this phenomena. I described this technique in the section on the 10368 MHz amplifier. I have also used this same technique for the lower frequency amplifiers on occasion. If you come across an amplifier that does not seem to like having a cover placed on it, then try this divider on top of or slightly offset from the centerline of the circuit. The top of the divider should hit the lid and the bottom should be about .2 inches above the microstrip. The divider is parallel to the side walls. Be careful not to drop it on the circuit when finding the sweet spot.

Another solution is the use of absorber along at least one of the side walls. This tends to minimize unwanted reflections off the side walls which are the primary source of trouble. It was brought to my attention by Bill Janssen, K7NOM, back in 1995 that suitable microwave absorber can be found locally. In fact, Bill says there is a large supply of this stuff alongside most highways in the form of old rubber from truck tires. Sure enough, it does have some microwave absorption properties!. So if you get desperate, check the highways, but be careful! Bill attributes the absorbing properties to the carbon added to improve the ultra-violet resistance.

An alternative to the brass box approach is the aluminum housing approach that I mentioned earlier. I designed the amplifiers to fit inside an aluminum housing that is available from Downeast Microwave, part number "Rose-S". Steve makes a special pallet out of .25 inch thickness aluminum that spans the distance between the input and output connectors. It makes a tight fit in the enclosure and the SMA connectors thread into the edge of the inner pallet. The circuit board is then installed onto the aluminum pallet. I use small 4-40 hardware to hold the board down to the pallet

I have also found that the liberal use of conductive epoxy insures that the ground plane of the printed circuit board makes good RF connection along the entire surface of the aluminum pallet. I have used "Circuit Works Conductive Epoxy" part number 2400 with good success. It is a 2 part mix and once the tubes have been opened once, it appears that shelf life is not very long, so it is best to do several amplifiers at one time. Steve at Downeast Microwave uses shim stock to help enhance the RF connection between the pallet, circuit board, and the inside surface of the enclosure which then mates with the RF connectors.

Based on several amplifiers built to date it appears that the noise figure of the units built in the aluminum housings are within a 0.1 dB of the brass box units. I have also noticed that none of the aluminum housing units seem to have any stability issues when installing the covers. This could be due to the fact that the sides of the aluminum pallet and therefore the sides of the printed circuit board are suspended in the housing. As I mentioned before, it is the side walls of the amplifier that give rise to the "waveguide effect" problem. With the aluminum housing units, there is a gap or discontinuity between the side edge of the board and the inside edge of the housing.

Closing

Hopefully, these LNAs will provide a boost to both your terrestrial and moonbounce systems as they have to mine.

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09-09-97

References

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2. A.J. Ward, "Simple Low Noise Preamplifiers", QST, May, 1989, pg 31-36
3. Using the ATF-10236 in Low Noise Amplifier Applications in the UHF through 1.7 GHz Frequency Range, Hewlett Packard Application Note 1076, publication number 5963-3780E(3/95)