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# L and S Band Amplifiers using the ATF-36163 Low Noise PHEMT

## Application Note 1097

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### Introduction

The ATF-36163 PHEMT device has numerous applications as a low noise amplifier in the 900 MHz through 12 GHz frequency range. The ATF-36163 has a tested 12 GHz noise figure of 1.4 dB maximum with 1.2 dB being typical. At lower frequencies, such as 4 GHz, the ATF-36163 has a typical noise figure of 0.6 dB decreasing to about 0.5 dB at 2 GHz and below. With proper circuit design, the ATF-36163 can be successfully used as a low noise amplifier in the L and S band frequency ranges.

This paper describes the use of the Hewlett-Packard ATF-36163 in a low noise amplifier providing a 0.8 dB noise figure from 2.0 to 2.4 GHz with 16 dB of gain. The circuit can be easily modified to provide low noise performance for GPS, IMMARSAT, WEFAX, and PCS and other applications in the 1 to 2 GHz frequency range. The ATF-36163 is housed in a plastic surface mount SOT-363 (SC-70) package offering low noise performance in a low cost package.

### LNA Design

The LNA was designed using EESOF's Touchstone™ for

Windows and published S and Noise parameters.

The reference plane for both the S and Noise parameters is shown in Figure 1.

Unlike the customary ceramic microwave type package, the plastic SC-70 package has its reference plane for both S and Noise parameters at the end of the device leads and not at the package to lead interface.

The ATF-36163 has 4 source leads, all of which need to be well grounded for proper RF performance. The S Parameters were measured in a test fixture designed specifically for the SOT-363 package. The effects of source grounding in the fixture have been de-embedded so that the designer can add circuit

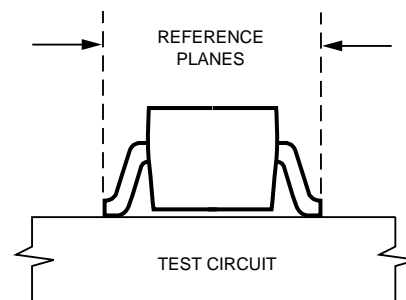


Figure 1. Reference Plane for S and Noise Parameters.

grounds such as plated through holes and any associated source lead length.

Since the ATF-36163 is a rather small, 200 micron gate width device, the typical application would generally be in the 4 GHz and higher frequency range. At lower frequencies, the device is still capable of very low noise figures and higher gain. Whenever a device is capable of greater than about 18 dB of gain at the desired operating frequency, the circuit should be designed to limit the gain in order to guarantee stable operation. When the ATF-36163 is used as a low noise amplifier at 12 GHz, the input can be matched for minimum noise figure and the output matched for maximum gain and the circuit will be unconditionally stable at 12 GHz. At lower frequencies, the gain of the device can approach 18 to 20 dB and higher with similar matching criteria. Although more gain may be desirable, it is not without compromise. This phenomena is characteristic of all state of the art low noise 12 GHz devices and must be dealt with properly to achieve desired performance at the lower frequencies.

The use of resistive loading in the

drain circuit and inductance between the source and ground are two good methods for enhancing low frequency stability. Both of these techniques have been covered in detail [1].

The use of source inductance between each of the source leads and ground provides series feedback whose effect varies with frequency. At higher frequencies, such as 12 GHz, adding source inductance makes the device regenerative which increases gain and causes instabilities. At lower frequencies, source inductance makes the device degenerative, thereby reducing gain and improving stability. The trick is to add a limited amount of source inductance that ensures that the device is unconditionally stable at frequencies significantly higher than the frequency of operation. Although this may not make the device unconditionally stable at the frequency of operation, it does improve inband stability. Resistive loading on the drain side can improve the inband stability even more.

Resistive loading in series with the drain or shunt with the drain is the easiest and most practical way of achieving broadband stability. The only disadvantage would be decreased power output since some of the power is lost in the resistive termination.

The circuit design presented here includes a shunt resistor in series with a short microstripline to terminate the device. With the aid of the computer, it was found that

the device cannot tolerate very much source inductance before instabilities are created in the X band frequency range. However small the inductance of the plated through holes appears to be, the inductance does limit the amount of additional inductance that could be added to help low frequency stability.

Source inductance can be derived from several components, all of which need to be modeled properly in order to achieve the desired performance. Start with modeling the plated through holes, one for each source lead. Thinner circuit board, i.e., 0.031 inch thickness, is preferred. Next, model the source lead length between the edge of the plated through hole and the reference plane at the device. The third item would be to model the bypass capacitor(s). This may be associated with RF bypassing the source resistor if self biasing were to be used. In the case of the ATF-36163, the device is unable to tolerate the inductance associated with even the best quality microwave chip capacitors. It is therefore recommended that the source leads of the device be dc grounded to minimize the additional inductance that would be added if bypass capacitors were used. This dictates that a negative voltage be used to bias up the gate. The nominal gate voltage is only -0.2 volts at less than 100 microamps.

The input noise match, consisting of a single series inductor, provides a low Q broadband noise match in the 1.8 to 2.8 GHz frequency range. With a low Q matching circuit, the effects on the circuit due to device-to-device variations is minimized. The inductor is a single piece of wire bent into a U shape. The bias

decoupling network consists of a series microstripline bypassed with a 10 pF chip capacitor. Low frequency stability is achieved by using an additional 50  $\Omega$  resistor bypassed with a 1000 pF chip capacitor. The output network was designed solely for broadband stability and gain. The resultant circuit board artwork is shown in Figure 2. The artwork shown in Figure 2 includes a space for a resistor in series with the drain of the device. This can be used to further enhance stability and reduce gain. Suggested value would be no greater than 33  $\Omega$ . Greater values of resistance will tend to increase noise figure.

Component placement is shown in Figure 3 and a schematic diagram is shown in Figure 4.

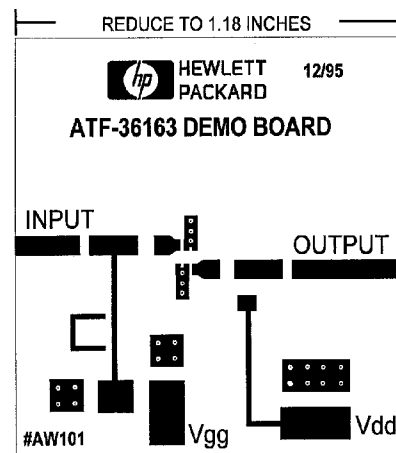


Figure 2. Artwork for 1 stage ATF-36163 LNA

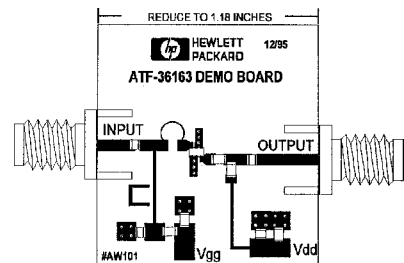


Figure 3. Component Layout for ATF-36163 LNA

#### Notes:

- [1]. *Using the ATF-10236 in Low Noise Amplifier Applications in the UHF through 1.7 GHz Frequency Range*, Hewlett-Packard Application Note 1076, Pub No. 5963-3780E(2/95)

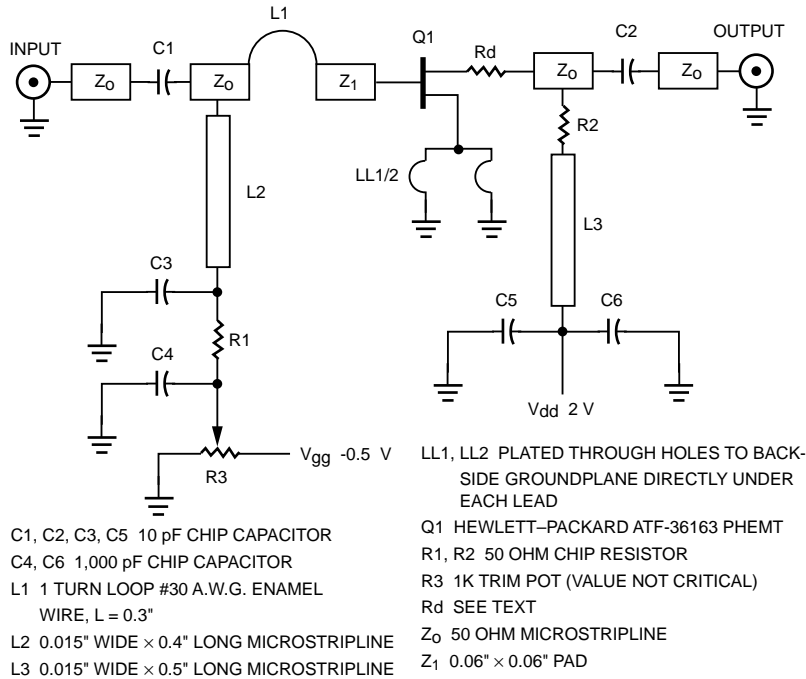


Figure 4. Schematic Diagram of ATF-36163 amplifier.

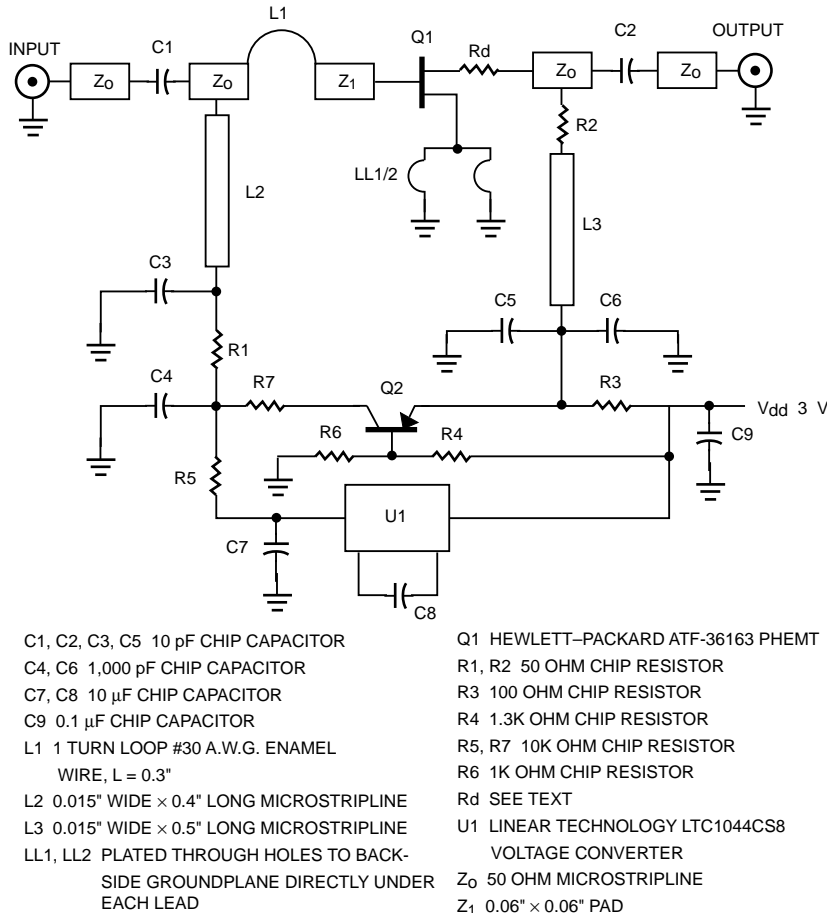


Figure 5. Schematic Diagram of ATF-36163 amplifier using dc-dc converter and active bias.

The graph in Figure 6 shows gain versus frequency of the completed amplifier. Gain is a nominal 16 dB from 2 GHz to 2.4 GHz. Noise figure, shown in Figure 7, is nominally 0.8 dB over the same frequency range. The frequency at which maximum gain occurs generally coincides with the frequency where minimum noise figure occurs. Therefore, increasing or decreasing the value of inductor L1 will either lower or raise the operating frequency of the amplifier. For lower frequency operation down to 1 GHz, L2 can be increased in length by tapping in the additional line length shown on the printed circuit board.

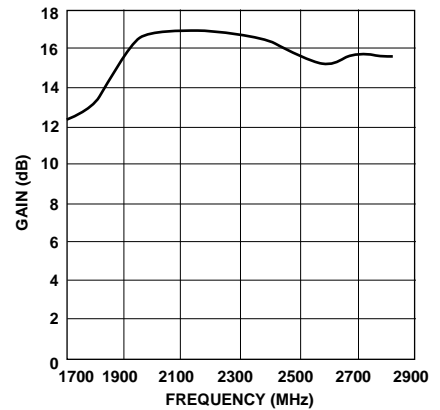


Figure 6. Gain vs. Frequency

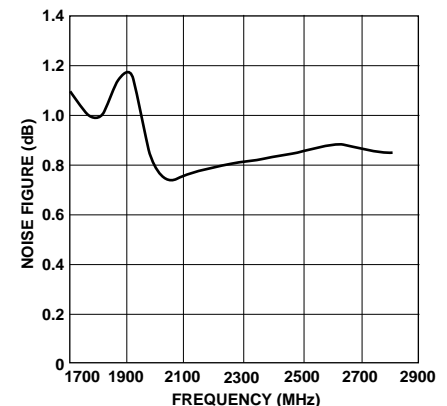
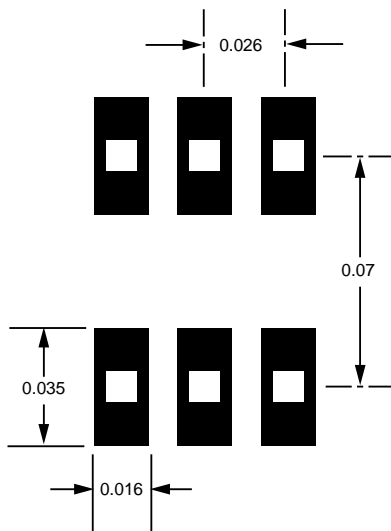


Figure 7. Noise Figure vs. Frequency

## General Design Considerations

### SOT-363 PCB Layout

A PCB pad layout for the miniature SOT-363 (SC-70) package is shown in Figure 8. Dimensions are in inches. The layout is shown with a nominal SOT-363 package footprint superimposed on the PCB pads.



**Figure 8. PCB Pad Layout (dimensions in inches)**

It is important to properly model the PCB pad layout when doing the design to get best correlation between simulation and actual performance. The pads add shunt capacitance at the drain and gate leads of the device. It is also best to add plated through holes as close as possible to the 4 source lead pads. Excessive source lead length, i.e., 0.050", can cause gain peaking in the 13 GHz range, which can ultimately produce instabilities.

### Biasing

For best performance, the ATF-36163 should be operated with the

source leads dc grounded. This requires a negative voltage on the gate to "bias-up" the device. Nominal gate voltage is a (negative) -0.20 volts for 10 mA drain current and somewhat less negative for a drain current of 15 mA. Typical operation for best gain performance would be at a  $V_{ds}$  of 2.0 volts and an  $I_d$  of 15 mA. With a 50  $\Omega$  resistor in the drain bias decoupling network, a supply voltage of 2.75 volts will be required.

### Enclosures

The LNA is usually installed in some sort of conductive or RF "reflective" enclosure or housing. The housing has various effects on the overall performance. The addition of walls and a cover can actually reduce radiation losses with the "good" result of lowering noise figure by 0.1 dB and raising gain by a dB or so.

Now for the "bad" effect. Depending on the height and width of the enclosure, as viewed from the end of the LNA, a waveguide effect can occur. Depending on the width of the cavity versus operating frequency and the ability of any component on the circuit board to launch a wave into the "waveguide", various other undesired phenomena can occur. The most obvious is instability resulting in oscillations. The ability of the LNA plus enclosure to oscillate is generally determined by the frequency where maximum gain occurs and this may even occur at a frequency lower than the desired operating frequency. A good idea is to measure the swept gain of the LNA just to make sure that there is no excessive gain peaking out-of-band which could potentially cause trouble. The use of the lowest possible value blocking capacitors helps provide a highpass response to roll-off low

frequency gain. Adjusting the impedance of the inductors used for bias decoupling can also be another means of providing a more highpass gain response.

### Conclusion

The ATF-36163 in a low cost surface mount package provides a nominal 0.8 dB noise figure and 16 dB of associated gain in the 2 to 2.4 GHz frequency range.

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