Agilent Technologies
Innovating the HP Way

L Band Amplifier using the ATF-36077 Low Noise PHEMT

Application Note 1128

Introduction

The Agilent Technologies ATF-36077 PHEMT device is described in a low noise amplifier that can be easily optimized for any spot frequency in the 900 through 1800 MHz frequency range. The ATF-36077 is intended to be used as a low noise amplifier in 12 GHz DBS applications providing 0.5 dB noise figures. The device is capable of noise figures below 0.4 dB at frequencies below 2 GHz. Although the device has an inherent noise figure of around 0.2 dB, actual circuit losses limit the minimum noise figure that can be obtained at about 0.3 dB.

Design

Achieving the associated gain of which the device is capable is difficult since the device is not inherently stable at the desired operating frequency. It is not enough that the amplifier be stable at the operating frequency – it must be stable at all frequencies. Any out-of-band oscillation will make the amplifier unusable.

The simplest technique to ensure broad-band stability is to resistively load the drain. Resistive loading produces a constant impedance on the device over a wide frequency range. In the case of the ATF-36077, a 50 ohm resistor and a small amount of series inductance is used to provide shunt loading of the device. The series inductance also provides some impedance matching. An additional series resistor directly off the drain is also used to enhance stability. This circuit topology produces acceptable gain while ensuring a good output match and retaining stability over as wide a bandwidth as possible.

Obtaining the lowest possible noise figure from the device requires that the input matching network convert the nominal 50 ohm source impedance to Γ opt. In the case of the ATF-36077 at 1.3 GHz, a series inductor provides a good noise match.

The source leads of the ATF-36077 must be grounded with minimal source inductance. The use of the customary bypassed source resistor technique for biasing a typical MESFET such as the ATF-10136 will not work very well with a PHEMT device. Excessive source inductance will cause the device to oscillate at frequencies around 20 to 22 GHz. The ATF-36077 will perform very well if plated through holes are placed directly under the source leads adjacent to the package and if the printed cir-

Table 1. ATF-36077 LNA Performance

Frequency (MHz)	Gain (dB)	Noise Figure (dB)
1100	19.5	0.53
1150	20.8	0.60
1200	22	0.44
1250	22.4	0.38
1300	22.6	0.33
1350	22	0.31
1400	21.2	0.28
1450	20.5	0.28
1500	19.5	0.30
1550	18.6	0.30
1600	17.5	0.40

cuit board thickness is kept at 0.031 inch or less.

A schematic diagram and parts list are shown in Figure 1. The schematic diagram suggests the use of active biasing to preset the bias point. The device is biased at a nominal Vds of 1.5 Volts and an Ids of 10 mA. Its operation will be explained in the next section.

Passive biasing can be used but it will require that a potentiometer be connected to the output of the dc to dc converter U1 to set the gate voltage bias required for nominal drain current.

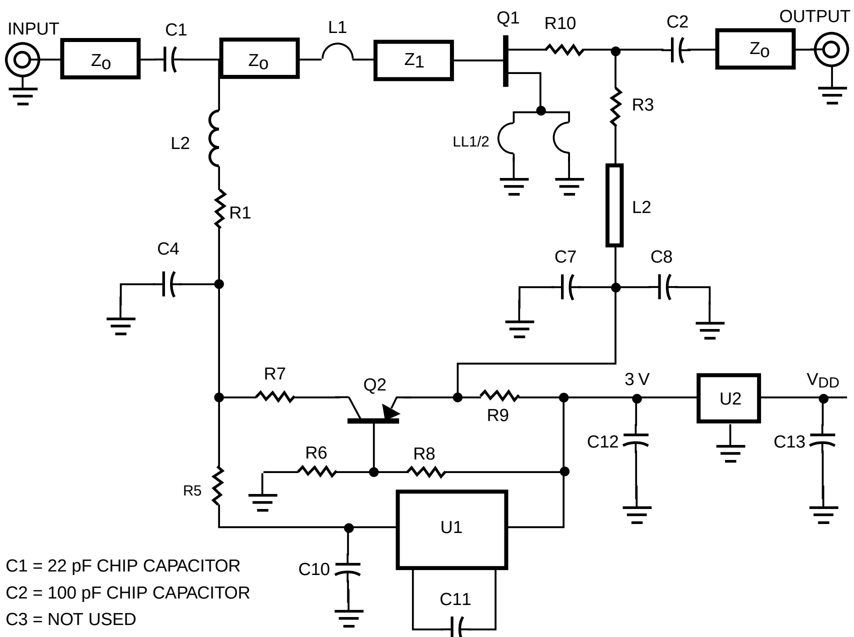
Performance

The performance of the amplifier is shown in Table 1. Since the loss of the input microstripline can add appreciable loss which adds directly to noise figure, the breadboard amplifier was built without any significant microstrip etch in the input network. The optimum noise figure is about 0.3 dB and this occurs over about a 100 MHz bandwidth, centered at 1400 MHz. The noise figure rises to 0.4 dB at 1600 MHz and 0.44 dB at 1200 MHz making the amplifier usable for broadband GPS applications. The amplifier can be tuned for other frequencies in the 900 through 1800 MHz frequency range by either increasing or decreasing the value of inductor L1.

Biasing

The preferred method of biasing FETs is the use of an active bias network as described in Figure 1. Although active biasing does add cost by requiring extra components, including a way of generating a negative voltage, the advantages generally outweigh the disadvantages. Active biasing offers the advantage that variations in pinchoff voltage and Idss will not necessitate a change in either the source or drain resistor value for a given bias condition. The active bias network automatically sets Vgs for the desired drain current.

The typical active biasing scheme for FETs requires that the source leads be grounded and an additional supply be used to generate the negative voltage required at the gate for typical operation. Referring to Figure 1, resistors R6 and R8 provide a regulated voltage at the base of Q2. The voltage is increased by 0.7 volts by virtue of the emitter-base junction of Q2 and then applied to the drain of Q1. Since R3 and R10 are in series with the drain, the voltage drop



C1 = 22 pF CHIP CAPACITOR
C2 = 100 pF CHIP CAPACITOR
C3 = NOT USED
C4, C7 = 1000 pF CHIP CAPACITOR
C5, C6 = NOT USED, GROUND SOURCES DIRECTLY
C9 = NOT USED
C8, C12, C13 = 0.1 µF CHIP CAPACITOR
C10, C11 = 10 µF CHIP CAPACITOR
L1 = 6T 0.007" DIA. WIRE, 0.050" ID, 0.14" LENGTH
L2 = 0.18 TO 0.33 µH RFC
LL1, LL2 = PLATED THROUGH HOLES TO BACKSIDE GROUNDPLANE DIRECTLY UNDER EACH LEAD
Q1 = AGILENT TECHNOLOGIES ATF-36077 PHEMT
R1 = 100 OHM CHIP RESISTOR
R2 = NOT USED
R3 = 50 OHM CHIP RESISTOR
R4 = NOT USED
R5, R7 = 10 k OHM CHIP RESISTOR
R6 = 1.3 k OHM CHIP RESISTOR
R8 = 2.7 k OHM CHIP RESISTOR (SETS DRAIN VOLTAGE)
R9 = 270 OHM CHIP RESISTOR (SETS DRAIN CURRENT)
R10 = 16 OHM CHIP RESISTOR (UP TO 27 OHMS OK)
U1 = LINEAR TECHNOLOGY LTC1044CS8 VOLTAGE CONVERTER
U2 = 5 VOLT REGULATOR TOKO TK11650U
U3 = OPTIONAL MMIC AMP - NOT USED
Z_O = 50 OHM MICROSTRIPLINE, MINIMIZE LENGTH ON INPUT TO MINIMIZE LOSS AND EFFECT ON NOISE FIGURE

Figure 1. Schematic and Parts List for ATF-36077 LNA

across R3 and R10 must be taken into account when designing the bias circuitry. Resistor R9 is connected between two regulated voltage points and therefore sets the drain current. Q1 gate is connected to a voltage divider consisting of R5 and R7 connected between the collector of Q2 and a negative voltage converter. The gate voltage can then assume a value necessary to sustain the desired drain current.

GaAsFET Demo Board

A typical printed circuit board built on 0.031 inch FR-4/G-10 is shown in Figures 2 and 3. This board is described in detail in Application Note 1076. The input 50 Ω microstripline has significant loss which can mask some of the device noise figure. The measured loss of the input microstripline excluding the blocking capacitor C1 is 0.3 dB at 1600 MHz and 0.15 dB at 900 MHz. Keep this loss in mind when evaluating the devices as most computer simulations appear to be optimistic about dielectric board losses and therefore give an optimistic (lower) prediction of noise figure.

In order to best evaluate the noise performance of the ATF-36077 without excessive input etch losses, the board shown in Figures 2 and 3 was modified. The input connector was soldered to the bottom groundplane and installed as close as possible to the input inductor L1. This allowed for the removal of most of the input etch. The performance shown in Table 1 reflects the changes to the demo board as described above.

An earlier version of the artwork had the locations of R1 and L2 reversed. When R1 is nearest the 50 Ω microstripline, the capacitive effect of the mounting pad at the junction of R1 and L2 shunts R1 to ground. The net result is increased noise figure. It is therefore better to have the inductor first then followed by the resistor since the impedance of the choke is higher than that of the resistor.

It is very difficult to obtain very low noise, high gain and unconditional stability with a high performance HEMT at L Band frequencies. Therefore, resistor R10, shown in Figure 1, is used in series with the drain to reduce gain and improve stability. Increasing this resistor much beyond 50 Ω will have an adverse effect on noise figure, i.e. >0.2 dB.

In Case of Difficulty

Generally the noise figure should be within a couple of tenths of a dB of that indicated in the performance table and gain within a few dB. If the noise figure or gain is not as expected then check the bias conditions. Is the Vds between 1.5 and 2 volts and drain current about 10 mA? If the bias voltage and current are adjustable, does performance maximize at the rated bias conditions or at some other set of values? If so,

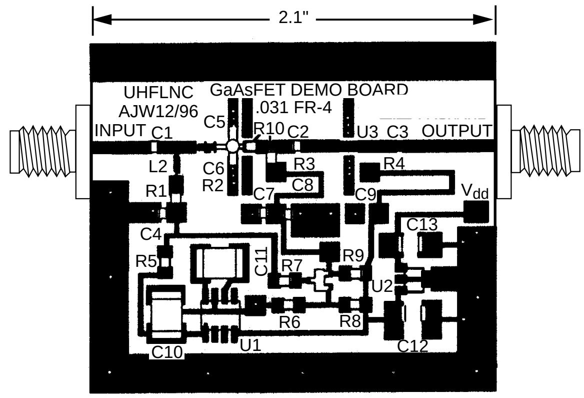


Figure 2. GaAsFET Demo Board showing component placement

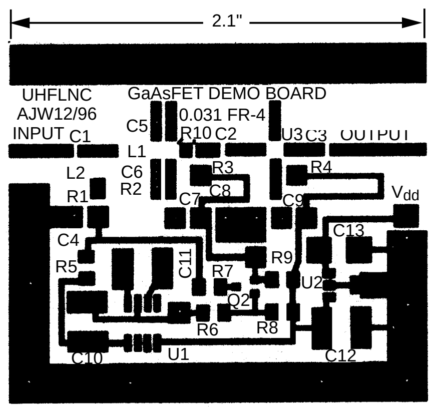


Figure 3. GaAsFET Demo Board 1x Artwork

then the problem may be excessive source inductance which is causing a high frequency oscillation. If a device is oscillating at any frequency, even an out of the band frequency, it may be difficult to obtain rated performance. Make sure the plated through holes are as close to the device as possible, i.e., 0.02 to 0.03 inch may be too long.

If the problem is inband stability, then the solution is to add series resistance between the drain and output connector. Increase the value of R10. Additional gain reduction can also be had by decreasing the length of the shunt output inductor in series with R3.

In some cases, higher than expected noise figure can be attributed to noise from the dc to dc converter or the PNP transistor used for active biasing. Use of a 0.1 µF bypass capacitor in parallel with C4 and at location C8 should help.

The use of a lossy or low Q RF choke for L2 can contribute to an increase in noise figure. The use of a small molded RF choke for L2 works well in prototypes. For surface mount applications be sure to choose a high Q wire wound choke such as those made by CoilCraft.

In some instances, the enclosure can cause undesirable feedback across the circuit board which can cause instabilities. This phenomena is true of any amplifier design. A cross sectional view of the housing can be viewed as a piece of waveguide whose dimensions, both width and height, determine the band of frequencies that it may pass with minimal attenuation. A combination of the amplifier response along with the housing response could contribute to instabilities if not controlled. The use of low profile surface mount components will minimize this effect.

Making sure that the cover is no closer to the printed circuit board than is necessary will minimize coupling from the cover. It is preferred to have the cover at least 0.3 to 0.5 inches above the circuit board. The use of ECOSORB™ can be used on the cover to minimize reflections if the cover has to be in close proximity to the board. The use of a metal divider hanging down from the cover is also another method of breaking up enclosure effects.

Conclusion

The ATF-36077 can provide less than 0.4 dB noise figures over several hundred MHz of bandwidth at L Band frequencies. A simple circuit has been shown that provides stable L Band operation. The single-element input matching network provides very good performance in this frequency range and offers the greatest bandwidth and least sensitivity to manufacturing tolerances. The resistive loading in the output network provides the best broadband stable performance by sacrificing some in-band gain.

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Data subject to change.

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