ALM-1106 as a 1.575 GHz GPS Low Noise Amplifier

Application Note 5240

Introduction

Many of today's GPS receiver LNA designs are based on discrete transistors rather than using MMICs because designs using discrete transistors result in amplifiers with lower Noise Figure (NF). Figure 1 shows a typical GPS LNA employing a discrete solution. Obviously, the discrete solution has higher component count, occupying larger PC board area and is generally more difficult to design. In today's portable applications where both circuit compactness and extremely quick time-to-market are required, circuits with discrete transistors are fast becoming less attractive. While it is true that discrete designs still offer the best NF performance, new MMICs provide nearly as good noise performance while offering many benefits such as:

- Integrated current mirror simplifies the biasing network design.
- Internal feedback makes impedance matching easier across a wider bandwidth.
- High linearity and low noise are achieved with low current consumption.
- Enhancement mode FET requires only a single positive supply.

An example of such MMIC is the Avago Technologies' ALM-1106, specifically designed for battery operated GPS LNA application. The ALM-1106 uses Avago Technologies' proprietary GaAs Enhancement-mode pHEMT process to achieve high gain operation with very low NF, high linearity and is capable of operating under supply condition of down to 1 V.

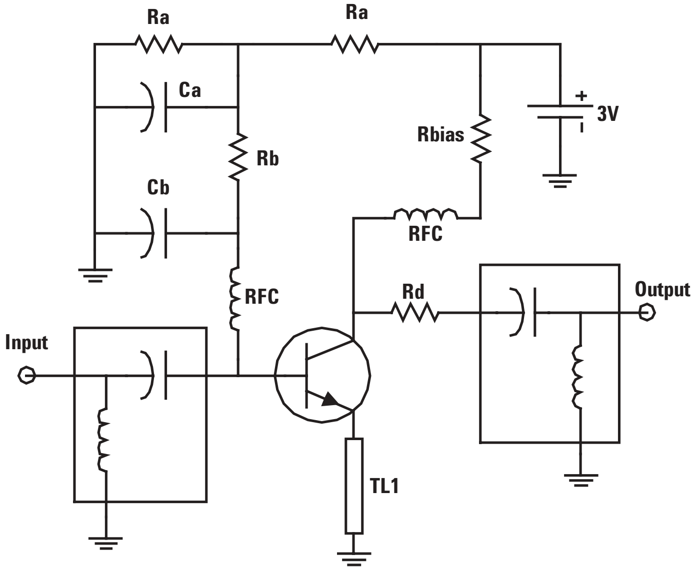

Figure 1. A typical GPS LNA solution with discrete transistor.

Impedance Matching for Low Noise Operation

As the prime consideration in designing this GPS LNA is low Noise Figure, the input matching of the LNA is tuned to achieve lowest possible Noise Figure. In this case, the LNA input return loss takes a backseat. At 1.575 GHz, the 4 Noise Parameters of ALM-1106 which are Γ_{opt}, F_{min} and r_n (Normalized Noise Resistance) give values of $0.71\angle 47.4°$, 0.8 dB and 0.24 Ω respectively. Based on these values, constant Noise Figure circles are plotted and shown in Figure 2.

It can be easily seen from Figure 2 that a series inductor followed by a shunt inductor are needed to transform the 50 Ω port impedance to somewhere close to Γ_{opt} in order to minimize the LNA's NF. At 1.575 GHz, the effect of the length of microstrip lines joining the matching inductors and the device input pin should be considered although this does not drastically change the matching circuit topology as commonly seen in high frequency designs. For example, the input series inductor does not transform the 50 Ω port impedance along the 50 Ω constant resistance circle when seen from the position of the following shunt inductor. The effect of the microstrip joining the series and shunt inductors will rotate the transformed impedance clockwise. This is graphically shown in Figure 2. Figure 3 gives a simple input matching circuit that will transform the port impedance close to Γ_{opt}.

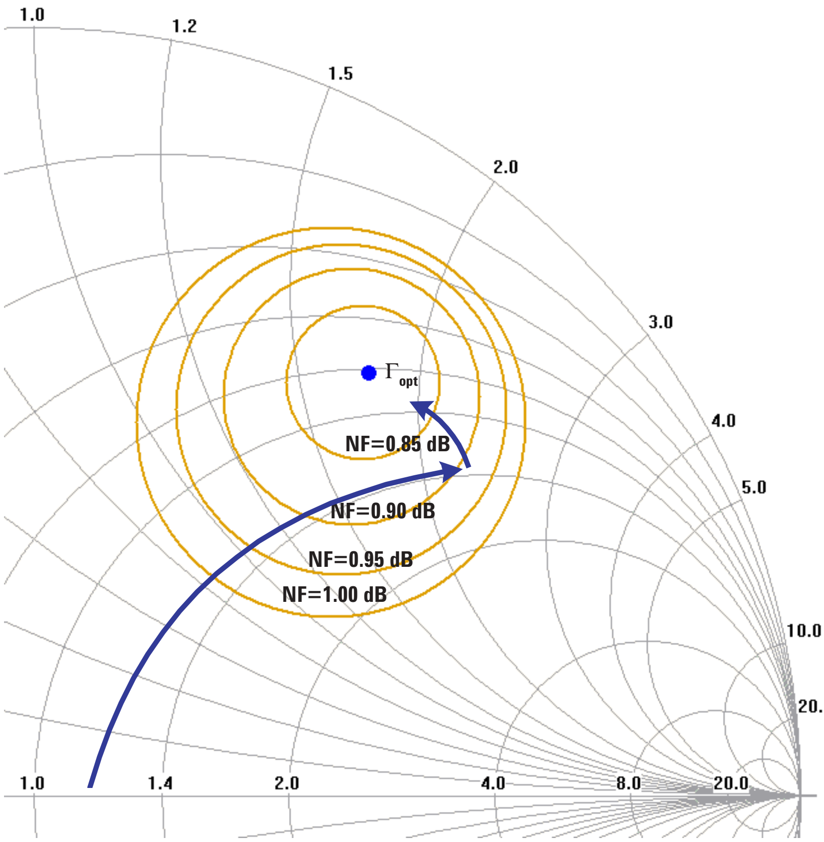

Figure 2. ALM-1106 constant NF circles at 1.575 GHz.

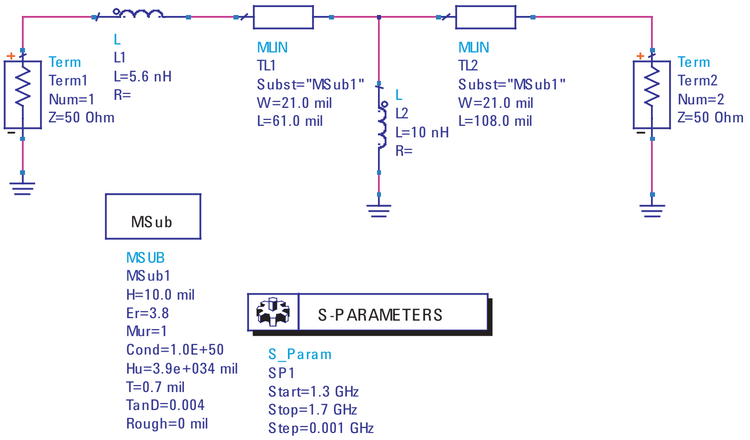

Figure 3. An input matching network consisting of a series inductor followed by a shunt inductor to tune the LNA input for low noise.

A GPS LNA with ALM-1106

Figure 4 below shows a typical circuit of an ALM-1106 configured to operate in the 1.575 GHz GPS band. It is clear that the circuit is more compact compared to the discrete transistor solution shown in Figure 1. Due to the need to maintain a low NF_{min}, the internal feedback employed in the device is kept to a minimal. In order to maintain unconditional stability, some external damping is necessary as provided by the 12 Ω resistor.

The 1.575 GHz GPS LNA is constructed on a 10 mil thick RO4350B PCB. The low NF required in the GPS LNA suggests the use of a low loss PCB material to demonstrate the low noise figure achievable with the ALM-1106. The demoboard PCB is reinforced with an additional layer of FR4 for mechanical strength and rigidity. Figure 5 shows a completed ALM-1106 demoboard and the board stacking structure is shown in Figure 6.

The ALM-1106 biasing current can be set using external resistor R1. In this application, R1 is empirically determined to be 18 kΩ to set the biasing current to about 10 mA while the LNA supply voltage is +2.85 V. The value of R1 needs to be re-determined when the control voltage driving the SD pin (pin 5) via R1 is not +2.85 V. There are no input and output DC blocking capacitors required in the circuit as the ALM-1106 incorporates these DC blocking capacitors internally to minimize external component count.

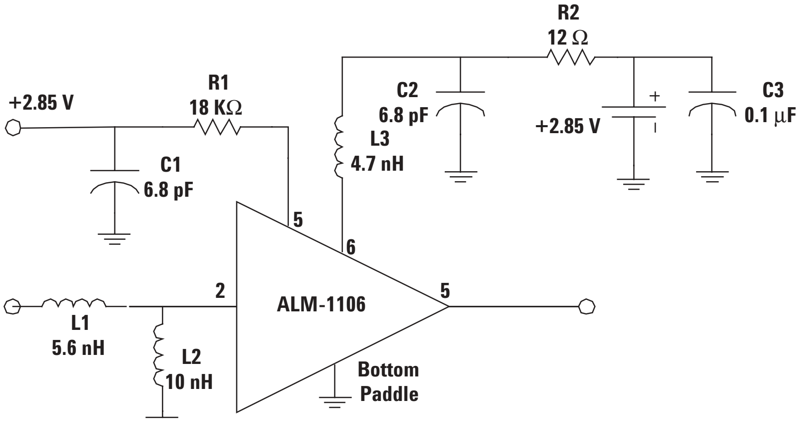

Figure 4. ALM-1106 application circuit configured to operate as 1.575 GHz GPS LNA.

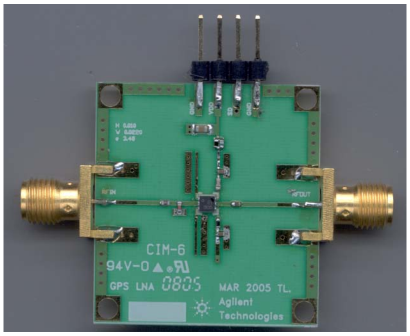

Figure 5. Completed ALM-1106 demoboard.

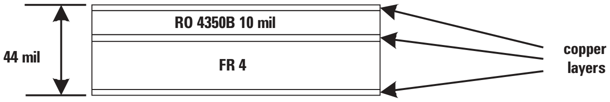

Figure 6. Demoboard PCB layers.

Table 1. Demoboard component list.

Component Designator	Manufactuer and Part Number			
C1, C2	6.8 pF	0402	ROHM	MCH155A6R8DK
C3	0.1 µF	0603	MURATA	GRM40X7R104K25PL
C4	100 pF	0402	ROHM	MCH155A101JK
L1	5.6 nH	0402	TOKO	LLP1005-FH5N6C
L2	10 nH	0402	TOKO	LLP1005-FH10NC
L3	4.7 nH	0402	TOKO	LLP1005-FH4N7NC
R1	18 KΩ	0402	ROHM	MCR01J183
R2	12 Ω	0402	ROHM	MCR01J120

Figure 7 shows the demoboard PCB layout. Note that C4 was originally included as part of output matching network. It was later found to be unnecessary and is not shown in the schematic in Figure 4. In real application, C4 can be replaced with a short using microstrip. Table 1 shows the list of components required to build the ALM-1106 1.575 GHz demoboard.

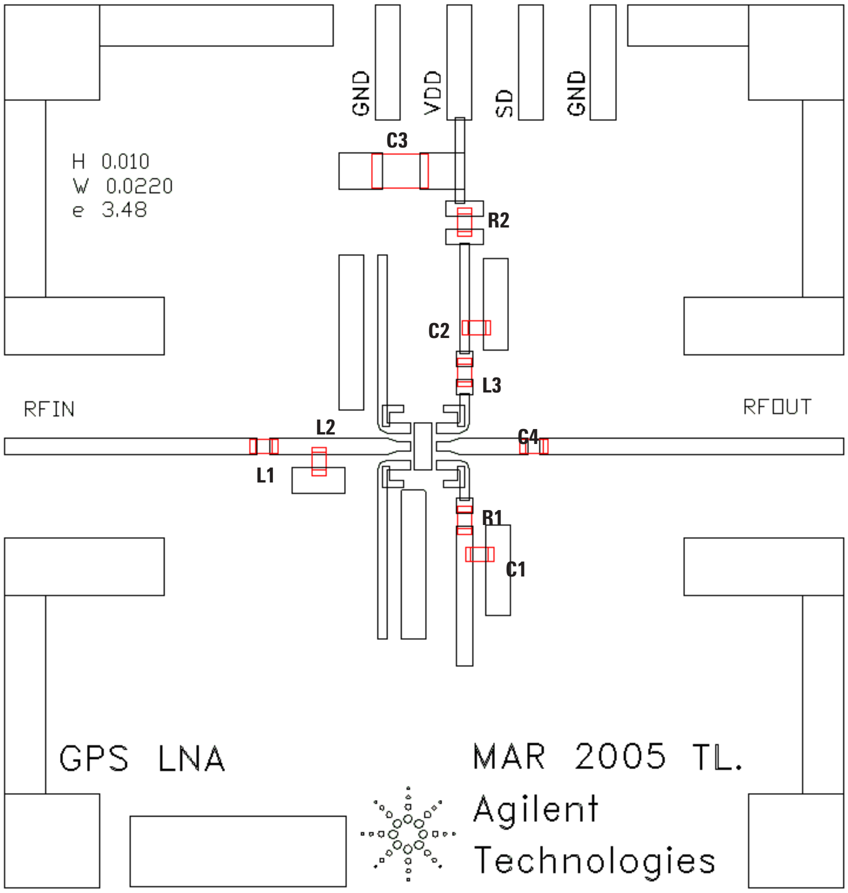

Figure 7. Demoboard layout and component placement.

RF Performance

The completed demoboard LNA gives approximately 14.5 dB while achieving return loss of better than 10 dB on both input and output port. Figure 9 shows the gain measured on the demoboard while Figure 8 gives the measured input and output return loss.

Since the LNA input is tuned for lowest NF, the measured NF on the demoboard is around 0.9 dB which agrees well with the value of F_{min} when board loss and connector loss are taken into consideration. Figure 10 gives the variation of NF across the frequency band.

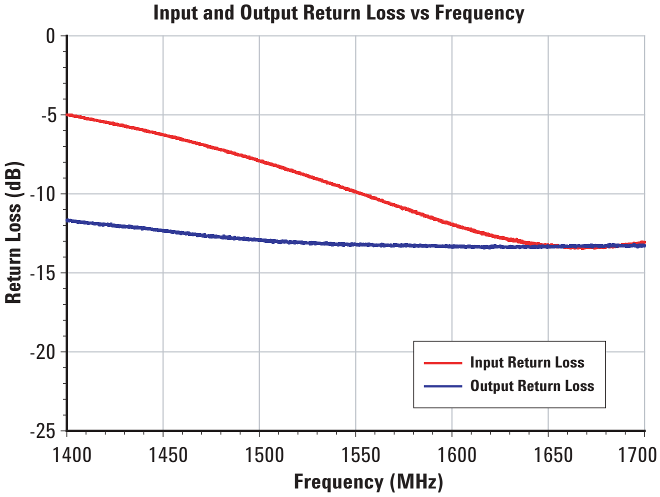

Figure 8. Measured input and output return loss on ALM-1106 demoboard.

Implementing Shutdown Control

In portable applications where battery power must be conserved, it is desirable that the receiver LNA can be shutdown and switched on under software control. Figure 11 shows a suggestion on how the ALM-1106 LNA can be placed under software control allowing it to be shutdown and turned on via a microcontroller output port. The suggested scheme here employs a P-Channel Enhancement Mode MOSFET transistor with its Gate connected to a microcontroller output pin. Assuming that the microcontroller is capable of raising its output pin level to that of Vdd (typically +2.85V), the MOSFET transistor can then be turned off when its Gate is at Logic High and thus turning off the ALM-1106 LNA. A Logic Low turns on the MOSFET switch and in turn switches on the LNA. Since P-Channel MOSFETs are available with low $R_{DS(on)}$($<0.5\ \Omega$), the voltage drop across these MOSFETs is negligible and introducing such a switch will not make much changes to the biasing of the ALM-1106 as discussed in this application note.

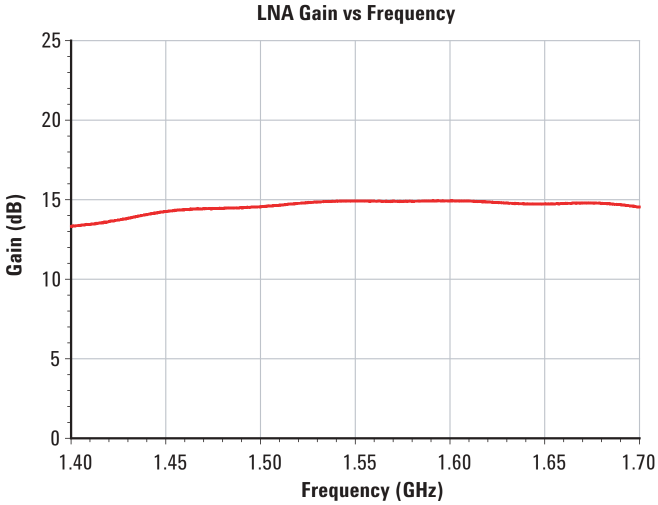

Figure 9. Measured small signal gain on the ALM-1106 demoboard.

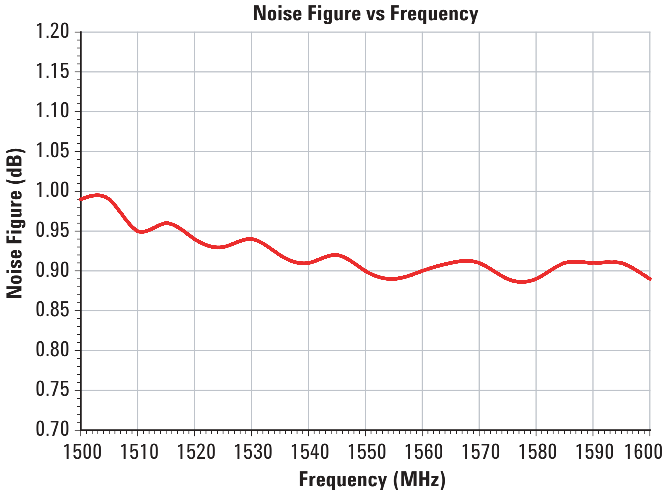

Figure 10. Measured NF on demoboard.

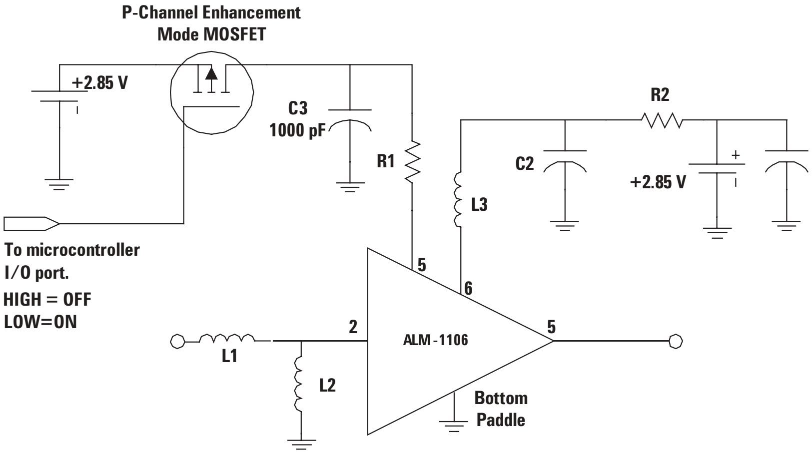

Figure 11. A possible scheme to place the ALM-1106 LNA under software control.

In cost sensitive application, the LNA can be directly controlled from a microcontroller I/O pin. This is suggested in Figure 12 and can be implemented in certain microcontrollers capable of delivering sufficient output current into pin 5 of ALM-1106. However, this scheme suffers from a few drawbacks such as :

- Substantial L-C filtering on the control line is required to remove digital noise spikes from microcontrollers.
- Variation of Logic HIGH level is significant among similar microcontrollers which in turn may cause variation in the ALM-1106 biasing current.
- Logic LOW level from microcontroller may not be sufficiently low to completely turn off the LNA.

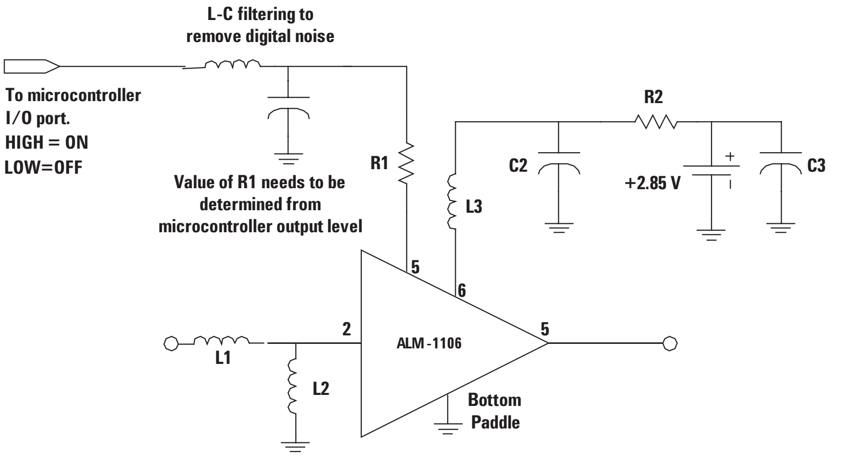

Figure 12. Another possible scheme of directly controlling the LNA from a microcontroller I/O port.

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

5989-3560EN - June 27, 2006