

TECH BRIEF

5 Key MMIC LNA Choices That Can Make or Break a Receiver Design





Introduction

Low Noise Amplifier (LNA) MMICs are a critical component in virtually all radar, wireless communication and instrumentation systems. There are a wide range of options and tradeoffs an engineer must consider when picking an LNA MMIC for a particular system design. The noise figure is often the feature of primary focus, as noise figure defines the sensitivity of the receiver — a critical system requirement. After noise figure, other project specific needs related to performance and size, weight, power and cost (SWaP-C) are then considered. Often these features are not heavily weighted, but they can make a big difference in advanced microwave applications.

The goal of this technical brief is to describe additional selection criteria commonly overlooked during the initial evaluation phase of an LNA. Keeping these additional parameters in mind may help an engineer save time during the design cycle, save money during assembly, and enhance a product's competitive advantage, leading to valuable contract wins.

Pinpointing the LNA in the Microwave Signal Chain

Receiver sensitivity and signal-to-noise (SNR) are two of the most critical electrical performance considerations for modern wireless communications, radars, instrumentation, and satellite communications. Largely, the noise performance of the receiver is defined by the performance of the LNAs used in these circuits.

Advanced applications, such as electronically steered arrays (AESAs) for military applications and phased array antennas for 5G wireless communication systems, require massive numbers of T/R modules, with each receive channel requiring an LNA.



Phased array and AESA radar systems are being retrofitted into both commercial and military aircraft. They employ dozens of low noise amplifier MMICs that are relied on for receiver sensitivity and optimal signal-to-noise ratio (SNR).

In radar systems, wideband LNAs can be used in the receiver modules, and their performance will impact the range and accuracy of the radar system.

To choose the best overall LNA designers should consider the importance of these five additional characteristics after they've identified the frequency band and noise figure combination required.



1. Input Power Survivability

Specifically in military and aerospace radar and communications applications, where electronic countermeasures (ECMs) may be used to overwhelm a receiver, a receiver must be capable of withstanding high levels of input power for varying intervals of time. Active or passive jamming can cause levels of noise and frequency bursts that couple large amounts of microwave energy into a receiver. Moreover, in many systems there is often a high-power transmitter in close proximity to the receiver, which can also lead to substantial power into the receiver front end.

Many of the latest applications, such as wideband and multi-band communications transceivers, and Low Probability of Intercept/Low Probability of Detection (LPI/LPD) radar (often employing frequency hopping) use extremely wide bandwidths of spectrum for transmission and reception. These factors lead to greater noise power coupled into the receiver, and less protection from the aggressive filtering possible in narrowband receivers. If the amount of noise or interference exceeds certain limits, a receiver may be overloaded and unable to function as designed.

If the receiver is exposed to these power levels for too long, the components within a receiver may suffer accelerated aging, performance degradation, or outright destructive failure.

A common method to reduce the impact of critically high input powers to a receiver is to include a limiter or circulator on the input of a receiver chain. An unfortunate side effect of adding anything prior to the LNA in the receiver is the degradation of the overall system noise figure.

This circuit will reduce the sensitivity of the receiver, which may shorten communications range, throughput, radar range and accuracy, and cause delays in acquiring mission critical information. For example, a superior system noise figure of 1 dB can rise to 2 dB or more when a limiter is added.

Therefore, it is very important to consider an LNA's highest input power handling (or input survivability) when choosing a component. Most LNAs can handle only 10 dBm pulsed on their input, but some can now survive 20 dBm continuously and 23-25 dBm pulsed. Such protection levels can in many cases eliminate the limiter.

Ratings of a Typical LNA MMIC

Parameter	Rating
Drain Voltage, V_{dd}	5.0 V
RF Input Power	+20 dBm
Channel Temperature, T_{ch}	150° C
Power Dissipation, P_{diss}	540 mW
Thermal Resistance	120° C/W
Operating Temperature	-40 to 85° C
Storage Temperature	-55 to 150° C
ESD Sensitivity (HBM)	Class 1A

Conditions of a Typical LNA MMIC

Parameter	Min	Typ	Max	Units
V_{dd}	2.0	3.0	4.5	V
I_{dd}		52		-mA

Understanding and carefully operating LNA MMICs to their specified maximum power ratings and operating conditions is critical to ensuring reliability and long life.



2. Gain Flatness and Gain Stability over Temperature

Gain flatness with frequency is essential for wideband communications systems to achieve the required inter-symbol-interference (ISI) levels of complex digital modulations schemes. Similarly, gain flatness can impact the range performance of radar systems. Equalizers are often employed to compensate for the gain slope of typical LNAs. It is important to note many LNA suppliers use different bandwidths to characterize gain flatness, often without indicating what the gain flatness is across the entire band.

Another factor to consider about LNA performance, which is often omitted from datasheets, is the gain stability over temperature (*Figure 1*). In applications such as aerospace communications and Satcom, the operating temperature variations can exceed 180° F within a short time window.

Temperature changes that are significant can affect an LNA by more than just changing the noise figure of the device and system; they can vary the frequency dependent gain of the LNA. For example, large phased array antennas may have thousands of TR modules, with many of the modules exposed to a variety of temperature gradients. If the communications system relies on gain stability throughout the TR modules, and the LNA's gain variation over temperature is too large, the system may suffer a loss in performance that impacts the bottom line of the deployment.

Recognizing this, system designers should opt for LNA designs that exhibit both superior gain flatness *and* gain stability over temperature.

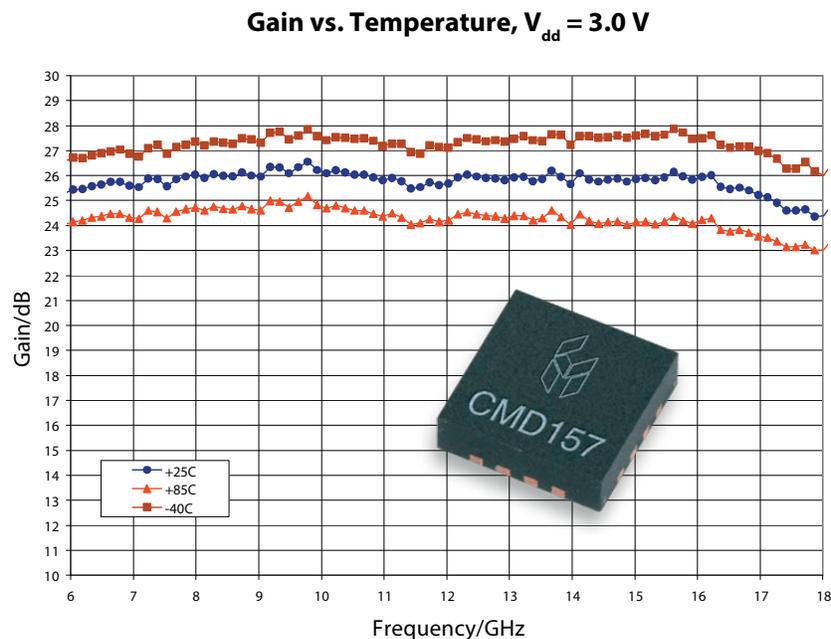


FIGURE 1.

This 6-18 GHz LNA exemplifies how gain flatness and gain stability over temperature are possible in a single device.



3. Supply Voltage

Properly biasing a MMIC amplifier is critical to achieving adequate device performance. Depending upon the particular LNA design, the biasing circuitry could be composed of a positive and negative biasing circuit with temperature compensation. With such a dual bias scheme, the positive and negative voltage supply must be provided in the correct sequence, or else device failure can result.

When designing at a system level for a large RF or microwave assembly, many different voltage supplies may be required. Certain design constraints may also limit the noise and stability performance of those power supplies, which may impact the practical LNA performance due to limited power supply rejection ratio (PSRR). To avoid this, additional circuitry may be used to condition the voltage supplies for a given LNA MMIC. Each of these circuits and connection points

introduces a potential failure mode to the voltage supplies, and thus impacts system reliability. These supply-voltage circuits also consume valuable assembly real estate and power, contribute to the overall size/weight of the assembly, add costs, and of course, consume design and test time.

In order to reduce the infrastructure necessary to integrate a MMIC LNA into a microwave assembly, Custom MMIC has applied innovative circuit-design techniques. The approach has resulted in MMICs which only require a single positive voltage supply enabling a wide range of voltage input options for greater flexibility. All of the necessary circuitry to properly bias these LNAs is integrated into the MMIC itself. Ultimately, when your MMIC requires only a single positive supply voltage it reduces your bill-of-material, overall system complexity, failure modes, and overall system SWaP-C.

Related Resources

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Simplify Amplifier Biasing Using Positive Bias pHEMT MMICs

APPLICATION NOTE

Biasing Scheme for Dual Positive Supply Amplifiers



4. Power Consumption

For many ground-based and stationary RF communications and radar systems, the power consumption of an LNA is not a significant consideration. However, the latest AESAs, phased-array antennas, and multi-input multi-output (MIMO) RF systems may require tens, hundreds, and even thousands of LNAs integrated into T/R modules. Many Satcom, military, automotive, and 5G wireless communication systems are also looking to these extremely complex antenna transceiver systems to solve the performance challenges innate in transmitting and receiving at high microwave and millimeter-wave frequencies.

In mobile platforms, including aerospace and satellite communications, power constraints are a system-wide limitation that often dictate what solutions can be used. Moreover, for these applications, the power requirements of the components directly lead to the overall size and cost of the power generation circuits, and hence, the total system SWaP-C. Some systems may have a power budget limit, and performance sacrifices must be made to meet that limit. With the importance of reliable communications in the modern battlefield, time to market may be impacted in order to design within the power budget while producing dependable communications.

An example of this concept is seen with satellite communications. The power required by a phased-array antenna must be generated by solar cells mounted on the satellite, which is one of the largest contributing factors of a satellite's weight and size.

At Custom MMIC, we have analyzed each of our LNA designs to ensure that their power consumption

(bias current and bias voltage) is as efficient as possible. MMICs designed in this way also derive the benefit of lower power draw. They are also typically smaller, demonstrate better temperature performance, and provide improved SNR at lower power levels.



As launching satellites costs thousands to tens of thousands of dollars per kilogram, reducing the weight of a satellite system can directly influence the cost-per-bit of high-speed satellite communication services.

5. Value of Time Saved in the Development and Production of your System

The SWaP-C parameters of an LNA are important in the component selection cycle. In addition, an often neglected factor is savings in time. Such time factors include design, assembly, test, qualification, support, and documentation. Choosing less efficient LNA MMICs, which might increase one or more time element, can cause project delays and cost overruns. Therefore, selecting LNAs that exhibit characteristics discussed in this brief will save time in addition to size, weight, power and cost.



Conclusion

Real-world receiver design challenges are often impacted by what is not featured in a product datasheet. Considering more than just noise figure when selecting an LNA therefore can make or break a project. Giving serious thought to survivability, gain flatness/stability, supply voltage, power consumption, and the impact of time hold the keys to success in modern radar, Satcom and communications systems.

Next Steps

[Complete Low Noise Amplifier Data](#)

[Support and Technical Resources](#)



Custom MMIC strives to make success achievable through innovative MMIC design, thorough product specifications, and fast delivery of evaluation boards. Learn more at www.custommmic.com.