Custom MMIC

TECH BRIEF

5 Key LNA MMIC Factors that Can Make or Break a Receiver Design

Introduction

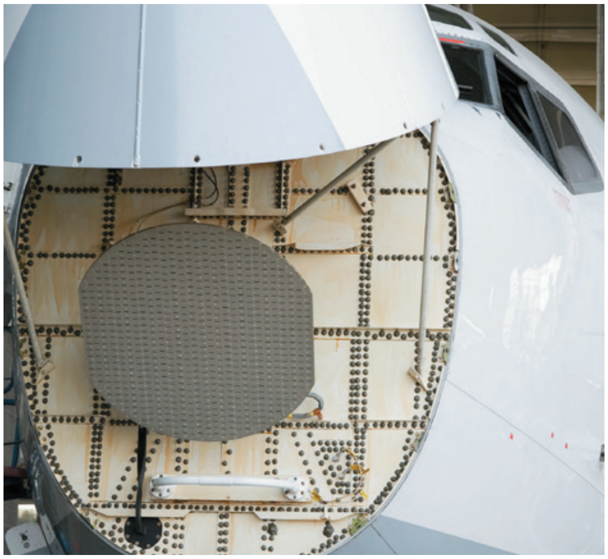
Low Noise Amplifier (LNA) MMICs are a critical component in virtually all radar, wireless communications and instrumentation systems. There are a wide range of options and tradeoffs an engineer must consider when picking an LNA MMIC for a particular circuit design. The noise figure (NF) performance is often the feature of primary focus, as noise figure defines the sensitivity of the receiver — a critical system requirement. After NF, 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 low-noise amplifiers (LNAs) used in these circuits. Many of the emerging 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.

LNA performance can also be a contributing factors in bit-error-rate (BER) and error-vector magnitude (EVM) for high-speed wireless communications if used in local oscillator chains. Similarly for radar, wideband



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).

LNAs can be used to amplify the output of the local oscillator (LO) in the transmitter or receiver modules, which impact the range and range-accuracy performance of a radar system.

To get it all right across your entire signal chain in applications like these, consider the importance of these 5 additional characteristics of your LNAs after you've found the band and noise figure combination you need.

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 broadband or frequency-selective interference into a receiver. Moreover, in these applications there is often a high-power transmitter in close proximity to the receiver, which can lead to substantial coupling and power ingress into the receiver front end.

Many of the latest applications, such as wide band 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 aggressive filtering possible in narrowband receivers. If the amount of noise or intentional/unintentional interference exceeds certain limits, a receiver may be overloaded and unable to isolate intended communications. Beyond this limit, or 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. These signal chain additions reduce the sensitivity of the receiver, which may shorten communications range, throughput, radar range and accuracy, and cause delays in acquiring mission critical information. A great 1 dB system noise figure can effectively become 2 dB or more when adding protection circuitry.

It's thus very important to consider an LNA's highest input power handling (or input survivability). Most LNAs can handle only 10-15 dBm pulsed on their input, but the highest achievers are now surviving 20 dBm continuously and 23-25 dBm pulsed, and can help you eliminate the protection network.

Ratings of a Typical LNA MMIC

Parameter	Rating
Drain Voltage, V_{dd}	5.0 V
RF Input Power	+20 dBm
Channel Temperature, Tch	150° C
Power Dissipation, Pdiss	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.

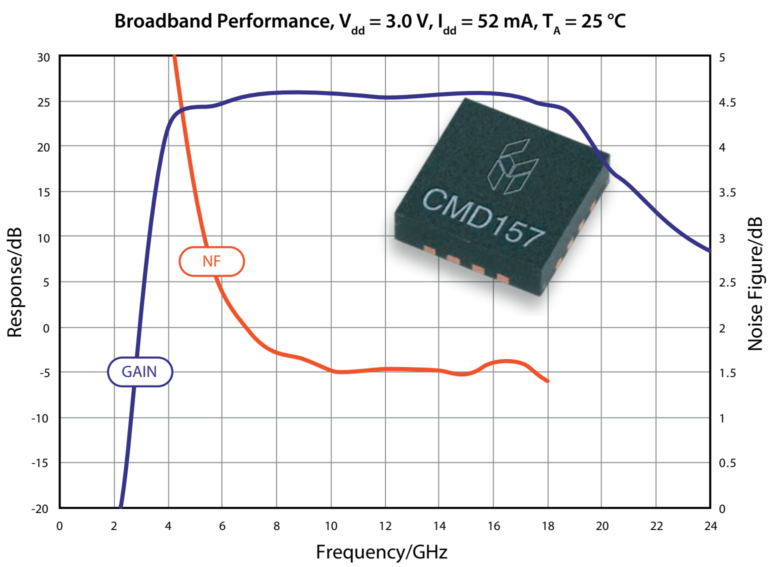
2. Gain Flatness and Gain Stability over Temperature

Gain flatness across the required band is essential for wideband communications systems to achieve the required inter-symbol-interference (ISI) levels of complex digital modulations schemes. Similarly, gain flatness directly impacts 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. In applications such as aerospace communications, and SatCom, the operating temperature variations can exceed 180° F of temperature variations 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 stability is temperature dependent, the system may suffer a loss in performance that impacts the bottom line of the deployment.

Recognizing this, advanced MMIC engineers will ensure that their LNA designs exhibit both superior gain flatness and gain stability over temperature.



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. Some LNA MMICs have the biasing and compensation circuitry built in, but a positive and negative voltage supply must be provided to the exact specification for the biasing network to operate properly.

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.

Download our Tech Brief "Throw out complex bias sequencers along with the negative supply" and learn more about designing with single or all positive supply MMICs.

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 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 dictates 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.

MMIC engineers who critically analyze each of their LNA designs to ensure that their power consumption (bias current and bias voltage) is as efficient as possible, also derive the benefit of lower power draw compared to other LNAs. MMICs designed in this way are also derive the benefit of lower power draw and also derive the benefit of lower power draw and are typically smaller, demonstrate better temperature performance, and provide improved SNR at lower power levels.

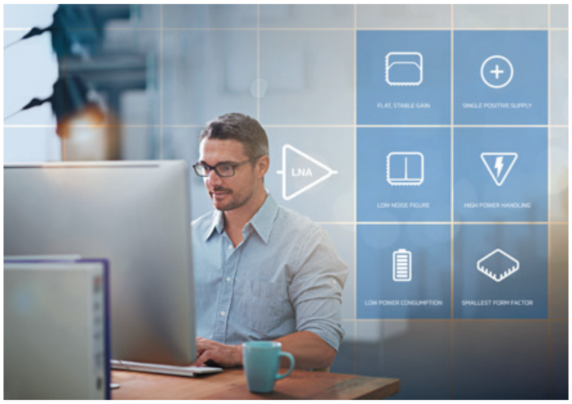
As launching satellites costs thousands to tens of thousands of dollars per kilogram, reducing the weight of a satellite system can directly influence the cost-per-bit of high-speed satellite communication services.

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

Size, weight, power and cost (so called SWaP-C) are important component selection criteria for an engineer during their design cycle, which of course should be taken into consideration when selecting an LNA. In addition, an often neglected factor is savings in time. 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 can make or save 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.



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

To review data and download S-parameters on our Low Noise Amplifiers visit http://www.custommmic.com/low-noise-amplifiers/

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