Application Note

Design Considerations for Ensuring Amplifier Stability

AN007

Simply put, an amplifier is said to be unconditionally stable if there are no passive source or load impedances which can induce an oscillation. Unfortunately, this terminology results in occasional misconceptions among design engineers.

What follows is a brief practical look at "unconditional stability" for *small-signal amplifiers* from an applications engineering perspective. Power amplifiers have the same issues, but they are addressed differently since few lab setups have the capability of accurately measuring large-signal S-parameters.

Derived from S-parameters, stability indices such as the Rollett Stability K-factor or the geometric stability factors (Mu or Mu Prime) define an unconditionally stable 2-port network when their value is ≥1.0. The key thing to note is that these stability indices are derived from measured S-parameters. Why does this matter?

It is more accurate to say that *a set of S-parameters for an application circuit and associated bias condition indicate unconditional stability* than it is to say that a particular amplifier is unconditionally stable.

Here are some common circumstances that will change an amplifier's S-parameters and potentially degrade the stability of an amplifier:

- Insufficient ground vias in the layout which increase RF inductance to ground. This inductive feedback can often degrade stability indices and/or create an oscillation.
- RF routing issues that increase coupling from the RF input to the RF output.
- Significant changes in bias current. Often a device which is unconditionally stable under typical bias conditions is only conditionally stable at very low current. This is sometimes observed in TDD applications in which the device is continuously turned on and off. These ramps represent transient conditions. Often the S-parameters at the intermediate states between off and on do not show unconditional stability.
- Changes in ambient temperature. Many devices show degraded stability at low temperatures since the gain usually increases as temperature decreases. This means that it is essential to check S-parameter data sets over temperature to evaluate stability.

The bottom line is that care must be taken when using the term "unconditional stability." In real-world applications, there are many ways in which amplifier S-parameters can change, and these must be accounted for in any stability analysis.

The idea that unconditional stability is an inherent characteristic of an amplifier, and that it can never oscillate, is incorrect. Consider the following:

As long as an amplifier has sufficient gain, it can be placed into an application schematic which purposefully introduces frequency-selective feedback from the RF output to the RF input. In this situation, the "unconditional stability" of the amplifier is a big "don't care." With sufficient gain and appropriate phase shift from output to input the circuit will oscillate. In fact, this is exactly how oscillator circuits are designed!

The Guerrilla RF applications engineering team is happy to assist you in selecting the most effective solution to address your system requirements. If you have application-specific stability issues, we are eager to help!

Contact us at applications@guerrilla-rf.com!

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Revision History

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