Stability Analysis of Microwave Circuits

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• Introduction
• Existing methods
• STAN tool and application examples
• Q&A
INTRODUCTION

- Stability analysis is a critical step of RF design flow
- Classical methods are either not complete or too complex...
- Stability analysis need to be efficient (especially in large signal)
  - Rigorous
  - Fast
  - User-friendly
  - Compatible with commercial CAD softwares
EXISTING METHODS

Linear analysis “small signal”
- K factor
- Normalized Determinant Function (NDF)
- Stability envelope
- Pole-zero identification

• Non-linear analysis “large signal”
- Nyquist criterion
- NDF
- Bolcato, Di Paolo & Leuzzi, Mochizuki, …
- Pole-zero identification
Linear analysis

• Widely used: K factor (also μ and μ’ now)
  - K>1 & |Δ| <1: unconditional stability of two port network
  - K<1: conditional stability → stability circles

Limitations:

Only indicates that a stable circuit will continue to be stable when loading it with passive external loads at the input or output

Do not guarantee the internal stability of the circuit!
Linear analysis

- Potentially unstable architectures for which K factor is not enough

Multi-stage power amplifier

Multi-fingers transistor

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EXISTING METHODS

Pole-Zero Identification Principle

\[ H(j\omega) \]

Frequency domain Identification techniques

\[ \hat{H}(s) = \prod_{i=1}^{n} (s - z_i) \]

\[ \prod_{j=1}^{p} (s - \lambda_j) \]

Complex conjugate poles with positive real part -> start-up of an oscillation

Oscillation frequency = Module of the imaginary part


STAN TOOL

Key Elements

• Suitable for both linear and non-linear stability analysis
• Very easy to use with any CAD tool
• Very easy to analyze results
• Relative stability information delivered
• Oscillation mode knowledge -> Help to find the suitable stabilization strategy
• Parametric Analysis implemented
• Monte-Carlo Analysis

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STAN TOOL

Integration in CAD Environment

EDA Tool
Templates for ADS, MWO...
AC simulation for linear
HB simulation for non-linear

STAN tool
integrated in IVCAD software
User-friendly GUIs

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Automatic mode

- The order of $\hat{H}(s)$ is a priori unknown

- Automatic algorithm for pole-zero identification in the context of stability analysis is integrated in STAN tool

\[ \hat{H}(s) = \frac{\prod_{i=1}^{n} (s - z_i)}{\prod_{j=1}^{p} (s - \lambda_j)} \]

- This routine eases the use of pole-zero identification for multivariable stability analysis

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Multi-nodes

A- No oscillation detected in the common node

B- Oscillation detected in the transistor node

⇒ Odd mode (parametric frequency division)
⇒ will determine the stabilization strategy
Multi-parameters

- Analysis with swept parameter(s)
- Verification for various conditions (Pin, Zload, …)
- Optimization of stabilization networks
Multi-parameters

Example: 3-stage LDMOS DPA for SDR applications

- Application requires absence of spurious for a wide range of operating conditions

- Multivariable large-signal stability analysis versus input frequency, input power and real and imaginary parts of load termination $Z_L$.

Frequency division ($f_{in}/2$) detected

Stable and unstable regions in the $\Gamma_L$ plane for $f_{in}=500$ MHz and $Pin=17.1$ dBm

Example: L-Band medium power FET amplifier

- Low frequency instability related to the input bias network
- Stabilization by the inclusion of a gate-bias resistor $R_{STAB}$
- Monte Carlo sensitivity analysis for different $R_{STAB}$ (5% dispersion in all circuit parameters)

![Monte Carlo analysis graphs]

- $R_{STAB} = 44 \, \Omega$
- $R_{STAB} = 70 \, \Omega$
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