Improvements in pole-zero identification for stability analysis and characterization

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Pole-zero identification for stability analysis

Stable

Unstable (malfunctioning)
Pole-zero identification for stability analysis
Beyond the local stability analysis of amplifiers

Shortening of the transient in microwave oscillators

Beyond the local stability analysis of amplifiers

Global stability and bifurcation analysis on non-linear microwave circuits

Beyond the local stability analysis of amplifiers

Verification of Rollet proviso
Outline

1 – Residue analysis in pole-zero identification

2 – In-circuit characterization of critical poles
Frequency domain identification

The order of the transfer function is a priori unknown

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

\[ H(j\omega) \]

\[ H(s) = \prod_{j=1}^{p} (s - p_j) \]
Algorithms for automatic pole-zero identification

1 - Residue analysis in pole-zero identification

Control parameter
Warning: Over-modeling $\rightarrow$ risk to identify the noise

Pole zero quasi-cancellations modeling the noise

Control parameter too strict
1 - Residue analysis in pole-zero identification

Even with very low numerical noise, a too strict value of the control parameter may lead to over-modeling.
Different ways to distinguish physical poles from over-modeling quasi-cancellations:

1 – Parametric stability analysis

2 – Analysis at various nodes

3 – Peeling algorithms to clean over-modeling poles

1 - Residue analysis in pole-zero identification
Residue analysis

Automatic fitting algorithm in the form: 

\[ H(s) = \sum_{k=1}^{N} \frac{r_k}{s - p_k} \]  

(Partial fraction representation)

A low residue \( r_k \) implies poles with low effect on the transfer function \( \rightarrow \) it serves to detect and quantify quasi-cancellations.
Residue analysis

Normalized Factor $\rho$

Different types of responses (nodes/branches $\rightarrow$ Z/Y) = different magnitudes $\rightarrow$

**normalization required**

The contribution of a pair of unstable poles ($H_k$) is weighted by the effect of the rest of the poles ($H-H_k$) at the resonant frequency ($\omega_r$).

$$\rho_k = \frac{|H_k(j\omega_r)|}{|H(j\omega_r) - H_k(j\omega_r)|}$$
Eases the distinction between the physical poles and the numerical quasi-cancellations
Peeling process based on parameter $\rho$ to eliminate over-modeling quasi-cancellations
Outline

1 – Residue analysis in pole-zero identification

2 – In-circuit characterization of critical poles
• Undesired effects of low damping LHP poles

- Increase the risk of oscillation (lower robustness)
- Noise bumps
- Long transients
- High resonant effect
- Troubles for digital pre-distortion systems
Experimental characterization of the low frequency critical poles

Non-connectorized solution to obtain the position of the low-frequency critical poles at internal nodes.

\[ H_{vn} = \frac{v_n}{v_{gen}} \]
Technique based on the use of an active high impedance probe (Keysight 85024A).

2 – In-circuit characterization of critical poles
Two step process

\[ H_{vn} = H_{input} H_n = \frac{v_{ref}}{v_{gen}} \frac{v_n}{v_{ref}} \]

Step 1

\[ H_n = \frac{v_n}{v_{ref}} \]

Step 2

\[ H_{input} = \frac{v_{ref}}{v_{gen}} = \frac{Z_{in}}{Z_{in} + 50\Omega} \left( S_{21} + \frac{(\Gamma_{in} - S_{11})(1 + S_{22})}{S_{12}} \right) \frac{1}{1 + \Gamma_{in}} \]

2 – In-circuit characterization of critical poles
The non-perturbing condition of the probe is key

For accurate measurements, the impedance of the probe must be significantly larger than the impedance of the sensing node.

- Select nodes with low impedance, preferably on the bias lines.

The frequency range is limited by the loading of the probe.

The active probe (Keysight 85024A) has an impedance of about 1100 Ω at 180 MHz that lowers down to 458 Ω at 500 MHz.
Validation

Single stage L band FET amplifier

Low frequency oscillation (180 MHz) for some bias ($V_{DD} = 3.1V$)
Validation

2 – In-circuit characterization of critical poles

![Graph showing in-circuit measurement with probe, connectorized from port G, no probe, and connectorized from port G, probe at input node and node n. The graph plots imaginary and phase axis vs. frequency with different voltage levels (1.5 V to 2.9 V). The real axis (MHz) is also plotted with voltage levels.]

$V_{DD}$ 1.5 to 2.9 V

- in-circuit measurement with probe
- connectorized from port G, no probe
- connectorized from port G, probe at input node
- connectorized from port G, probe at node n
L-band three stage amplifier

Increasing stability margin

2 – In-circuit characterization of critical poles
2 – In-circuit characterization of critical poles

• Only valid for low-frequency poles.
• Loading of the probe augments as frequency increases.

• It can be generalized to large-signal operation → Sensing nodes must be decoupled from RF signal.
Conclusions

• Peeling method to minimize over-modeling in pole-zwro identification. It is based on a residue analysis of the identified poles.

• Experimental technique to obtain the low-frequency critical poles of the amplifier at internal nodes making use of a high impedance probe.