Measuring Transistor Dynamic Loadlines and Breakdown Currents under Large-Signal High-Frequency Operating Conditions

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Measuring Transistor Dynamic Load Lines and Breakdown Currents under Large-Signal High-Frequency Operating Conditions

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Overview

- Introduction
- The Measurement System
- Dynamic LoadLines
- RF Breakdown Currents
- Degrading Devices under Stress
- Conclusions
Introduction

New Measurement Technology: Nonlinear Network Measurement System

• Periodic Large-Signal High-Frequency Voltage & Current Waveforms

Exciting Applications:

• State-of-the-Art Power Amplifier Design
• Studying Reliability Issues: Breakdown and Degradation
Nonlinear Network Measurement System

NNMS measures $V_1, I_1, V_2, I_2$ time domain waveforms (under periodic excitation)
Measuring the Dynamic Loadline

![Diagram showing Drain Voltage vs. Drain Current with dynamic load line and gate voltage labels.](image)

- Drain Voltage (V):
  - 0.0V
  - -0.5V
  - -1.0V
  - -1.5V
  - -2.0V

- Drain Current (mA):
  - 0
  - 20
  - 40
  - 60
  - 80

- Gate Voltage:
  - 1 GHz

Network Measurement and Description Group
Time Domain Waveforms

- Gate voltage vs. time: $V_{gs} \ (V)$
- Drain voltage vs. time: $V_{ds} \ (V)$
- Gate current vs. time: $I_{gs} \ (mA)$
- Drain current vs. time: $I_{ds} \ (mA)$
Gate - Drain Breakdown

$V_{gs}$ (V)  

$V_{ds}$ (V)  

$I_{gs}$ (mA)  

$I_{ds}$ (mA)  

$I_{breakdown}$  

1 GHz
Drain - Source Breakdown

\[ V_{gs} (V) \]

\[ V_{ds} (V) \]

\[ I_{gs} (mA) \]

\[ I_{ds} (mA) \]

1 GHz
<table>
<thead>
<tr>
<th>$V_{gs}$ (V)</th>
<th>$V_{ds}$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2.2 to -1.6</td>
<td>12.5 to 13.0</td>
</tr>
<tr>
<td>-4.0 to -2.0</td>
<td>11.5 to 12.0</td>
</tr>
<tr>
<td>-6.0 to -4.0</td>
<td>10.5 to 11.0</td>
</tr>
<tr>
<td>-8.0 to -6.0</td>
<td>9.5 to 10.0</td>
</tr>
<tr>
<td>-10.0 to -8.0</td>
<td>8.5 to 9.0</td>
</tr>
<tr>
<td>-12.0 to -10.0</td>
<td>7.5 to 8.0</td>
</tr>
</tbody>
</table>

$I_{gs}$ (mA) and $I_{ds}$ (mA) graphs show similar patterns with peaks at specific intervals. $I_{breakdown}$ is indicated at 1 GHz on the diagram.
### Forward Gate Conductance

<table>
<thead>
<tr>
<th>$V_{gs}$ (V)</th>
<th>$V_{ds}$ (V)</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
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<th>$I_{gs}$ (mA)</th>
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<tbody>
<tr>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
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</table>

Network Measurement and Description Group
Degradation under RF Stress

\[ V_{gs} \text{ (V)} \quad V_{ds} \text{ (V)} \]

\[ I_{gs} \text{ (mA)} \quad I_{ds} \text{ (mA)} \]

1 GHz

I\text{breakdown}

1 GHz
Evolution of Gate Current

I_{gs} (mA)

time under stress (minutes)

time (ns)
Evolution of Minimum Gate Current

Minimum $I_{gs}$ versus time

$log\left(\frac{\text{min}(I_{gs})}{1A}\right)$

opposite phase

in phase

$\sqrt{\text{time}}$ (\sqrt{\text{minutes}})
Change of Transconductance

$g_m \text{ (mS/mm)}$

$V_{gs} \text{ (V)}$

B E F O R E

A F T E R
Conclusions

It has been shown how the NNMS measures:

• dynamic load lines
• breakdown current and voltage waveforms
• component degradation under stress under high-frequency large-signal operating conditions