PROOF: POTENTIAL SUBJECT FOR TAS

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TAS MOTIVATION FOR PROOF

/// Thales Alenia Space is strongly supporting the PROOF Platform in LAAS

/// Large commonality of interests among the different stakeholders at local level: industry, LAAS, IRT StEx, CEA-Tech, CNES, …

/// GaN is a major priority in our EEE components roadmaps both for Microwave applications and DC/DC Supply applications.

/// TAS has already a large experience with these technologies and also a long history of collaboration with LAAS on this field.
POTENTIAL AREAS OF COLLABORATION

/// Ponctual short-term study about Noise performance assessment and modelling of mw GaN transistors

/// Characterization of very advanced GaN/Diamond mw Transistors. TAS to provide the transistors to LAAS as a validated contribution

/// Prepare and plan a possible PhD Thesis on mW GaN, on Noise or Reliability or both, to be proposed to CNES for co-funding in summer 2021, selection of a candidate early 2022 and start of PhD for September 2022. This could be re-inforced with an engineer internship in TAS in spring 2022 with the future PhD candidate.

/// Support of PROOF to TAS in the H2020 ELEGANT project (just kicked-off in Jan. 2021). It concerns GaN transistors and ICs from IMEC technology. This could be put in place in 2022.

/// Collaboration and/or support in NANO2022 IPCEI led by ST on Power GaN Technology. Transistors supposed to be available in 2022.
INTRODUCTION

Plusieurs applications pour développer LNA GaN robustes :

- entre 22 GHz et 36 GHz.

Besoins :

- Validation modèle au niveau transistor en bruit et paramètres S dans des conditions de polarisations hors modèles (faibles Vds principalement, Vds=0V)
- Test des temps de recouvrement des transistors dans le cadre d’applications pulsées (état On / état Off), avec conditions d’overdrive état On/Off selon les profils de mission
- Test de tenue en robustesse des composants pour des conditions modèles poussées aux limites,
- Introduction de switch de protection permettant de protéger LNA dans certains cas de figure (Mauvaise manipulation au sol, court-circuit antenne)
MESURES DES 4 PARAMÈTRES DE BRUIT

Figure 1: Noise Characterization

- Determines the Four Noise Parameters
  - Minimum Noise Figure
  - Real Part (Magnitude of Optimum Z, Y, or Γ)
  - Imaginary Part (Angle) of Optimum Z, Y, or Γ
  - Equivalent Noise Resistance

\[
F = F_{\text{min}} + R_n / G_s \left| Y_s - Y_{\text{opt}} \right|
\]

\[
F = F_{\text{min}} + 4 \Gamma_n \frac{\left| \Gamma_s - \Gamma_{\text{opt}} \right|^2}{\left| 1 + \Gamma_{\text{opt}} \right|^2 (1 - \Gamma_s |^2)}
\]
Signal RF constitué d’un train d’impulsions de 120 µs, avec différents rapports cyclique. 1.5 ms de période.
Durée d’exposition: variable.
Test réalisé à plusieurs niveaux de puissance : -20dBm, 10dBm, 15dBm, 20 dBm (si possible) et Pmax(dBm)

Influence de la fréquence de travail sur les effets de piège, des conditions d’adaptation ou de polarisation.
Synthétiseurs d’impédances 8-40 GHz =>conditions d’adaptations
50 Ω en sortie, agression CW ou pulsée, durée 1 min, pas de 3dB.
Tuner revient sur 50 ohms après agression pour mesure linéaire,
Mesure sur transistor ou sur circuit complet, état on ou état off
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2011: survey on wide band-gap transistors

- **Cost driven:**
  - Wide-bandgap transistors seem less sensitive to radiations (TiD & SEE)
  - No need of special die design to cope with space application

- **Criteria:** replace Space qualified MOSFET
  - Normally off switches
  - Bi-directional in current

GaN selected (vs SiC)

- Tolerant to harsh environment (TID, SEE)
- Better integration
- Better Performance

- **But:**
  - Maturity was to be improved
  - Tricky Driving
  - Packaging & Temperature

Use of a theoretical Figure Of Merit on the application:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>FET Technology</th>
<th>Si</th>
<th>SiC</th>
<th>GaN</th>
<th>Comments</th>
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<td>Electrical</td>
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<td>13. Maturity</td>
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08/06/2017
TAS-F GAN FOR SPACE POWER SUPPLIES

TAS-F past experience:

- 2010: Survey start-up
- 2012: Evaluation in 10W for RF units
- 2014: Selection & evaluation in 250W for RF units
- 2018: Qualification & Production in 60W DCDC for digital unit
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Additional Tests

- New/early technology
- To understand failure mechanisms
- To ensure robustness
- To define the safe operating area linked to the applications
- To reveal the technical limits

Additional evaluation done:

- Confirm the radiation robustness (heavy ion, TID, TNID, ...)
- Electrical checks:
  - Gate-Source voltage limits
  - Leakage currents drifts
  - On-resistance (Rdson) mastering
  - Behavior at high temperature (190°C)
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Qualification for HiRel Parts Under ESCC9000

- validated by French Space Agency (CNES)
- Several Endurance subgroups on subsequent lots
- Above ESCC9000 in life-test
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Feedback & way-forward

- MOSFET replacement (200V & below: most quantities and applications)
- no EU/EC competitors: only asian/american manufacturers
- Almost no sensitivity to radiation
- Drivers and transistors shall be as close as possible
- Space de-rating rules to be revisited:
  - Not consistent with manuf. recomm.: Vgs recomm. at ~80%. Vgsmax and de-rating at <75%. Vgsmax
  - Limit application: temperature below 110°C
- But limited SOA, linear mode "adventurous", no equivalent to PMOS
- More and more new needs on very high current (@ very low voltages)
- Lowest Ron in switching application
- Thermal draining & packaging

Transistors alone

Transistors & drivers in same package

H2020 HeatPack

Transistors & drivers in same die

H2020 EleGaNT

GaNIC
ELEGANT

GaN Transistor Integrated Circuits
SPACE-10-TEC-2020 - Technologies for European non-dependence and competitiveness
01/01/2021 -> 31/12/2023  Budget: ~2.5MEuro
Consortium: IMEC (B), TAS-B (B), TAS-F (F), Wurth (D), Mindcet (B), IEIC (F)

Objectives:
- p-GaN enhancement mode HEMTs and driver, GaN IC technology platform for Point of Load converters
- GaN power IC for low voltage (<50V) enabling very high current (>40A) switching frequencies in the range from 500kHz to
- Robustness against radiation TID up to 120krad and heavy ions 62.5 MeV (Xenon)
- Reduction of the inductive parasitics through monolithic integration of drivers and power devices (GaN-IC)
- Reduce the weight and size of the power converter passive inductor by 50% compared to state-of-the-art solution
- Demonstration of prototype very high current space application. Input voltage 5-12V, output voltage 0.5-1V, output current >40A, efficiency >90%
- Demonstration of prototype low current space application. Input voltage 5-12V, output voltage 0.5-1V, output current 10A, efficiency >90%
- Evaluation of the technology for terrestrial applications. Datacenter PCL DCDC modules Input voltage 5-12V, output voltage 0.5-1V, output current >40A, efficiency >90%

Achievements up to date:
- Kick Off in January 2021