ARL-TN-1047 ● FEB 2021

DEVCOM ARMY RESEARCH LABORATORY

Gallium Nitride (GaN) RF Challenge: BAE Systems and Qorvo Submissions

by John Penn, Sami Hawasli, and Ali Darwish

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
February 2021	Technical Note	May–November 2020

4. TITLE AND SUBTITLE
Gallium Nitride (GaN) RF Challenge: BAE Systems and Qorvo Submissions

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
John Penn, Sami Hawasli, and Ali Darwish

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
DEVCOM Army Research Laboratory
ATTN: FCDD-RLS-ER
Adelphi, MD 20783-1138

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TN-1047

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES
ORCID ID(s): John Penn, 0000-0001-7535-0388

14. ABSTRACT
The DOD Gallium Nitride (GaN) RF Challenge is enabling development and fabrication of the best-competed concepts for high-performance, efficient broadband Monolithic Microwave Integrated Circuits (MMICs) related to the 5G expansion and to critical EW needs. The US Army Combat Capabilities Development Command Army Research Laboratory was one of the design teams for the BAE 0.18-µm GaN multi-project wafer fabrication and was also one of the design teams for the Qorvo 0.15-µm GaN multi-project wafer fabrication. This technical note is a brief overview of the DEVCOM Army Research Laboratory design submissions for the GaN RF Challenge.

15. SUBJECT TERMS
MMIC, GaN, microwave, RF, amplifier

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			John Penn
Unclassified	Unclassified	Unclassified	UU	12	19b. TELEPHONE NUMBER (Include area code) (301) 394-0423

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1. Introduction

The gallium nitride (GAN) RF Challenge is a DOD program to develop critical technology addressing two major areas in wireless communication needs. First, due to the emerging and evolving 5G wireless networks, DOD systems will have to operate in increasingly crowded and contested RF environments. Second, electronic warfare (EW) is a rapidly developing and changing arena that is critical to DOD applications and users. The GAN RF Challenge is enabling development and fabrication of the best-competed concepts for high-performance, efficient broadband Monolithic Microwave Integrated Circuits (MMICs) related to the 5G expansion and to critical EW needs. Two different GAN foundries, BAE Systems and Qorvo, will fabricate the many circuit ideas from the selected design teams. The US Army Combat Capabilities Development Command Army Research Laboratory was one of the design teams for the BAE 0.18-µm GAN multi-project wafer fabrication and was also one of the design teams for the Qorvo 0.15-µm GAN multi-project wafer fabrication. This technical note is a brief overview of the DEVCOM Army Research Laboratory design submissions for the GAN RF Challenge.

2. BAE 0.18-µm GAN Designs

BAE provided process design kits (PDKs) for their 0.18-µm GaN technology for use with Microwave Office (MWO) software. Providing kits for external customers was something new for BAE, and there were a few updates to the PDKs during the few months of the design schedule. There were some glitches in using an early version of the PDK, but nothing unexpected. BAE engineers were responsive to the designer's questions and to fixing issues as they were found. Design Rule Checking was a little difficult. The Design Rule Checking (DRC) rules built-in to MWO were reasonably easy to use but were incomplete, which led to surprises when the main foundry DRC rules were run. Often there were many errors from a design that seemed to be in good shape based on the DRC rules within MWO. There was no good way to translate the errors easily from BAE back into MWO, as with most other foundries. However, the BAE engineer was extremely helpful with the DRC checks and the tapeout was delayed a bit in order to clean up the designs. Lessons were learned by the designers and by BAE engineers, which should improve the process for future external designs, and also improve on the PDK. In the end, the designs were successful and two 9- × 6-mm die sites were filled.

The first chip contains many smaller designs for broadband amplifiers, RF switches, frequency multipliers, broadband amplifiers, distributed amplifiers, broadband power amplifiers, mixers, test high-electron-mobility transistors (HEMTs), and other test structures. A plot of the 9- × 6-mm submission is shown in Fig. 1.

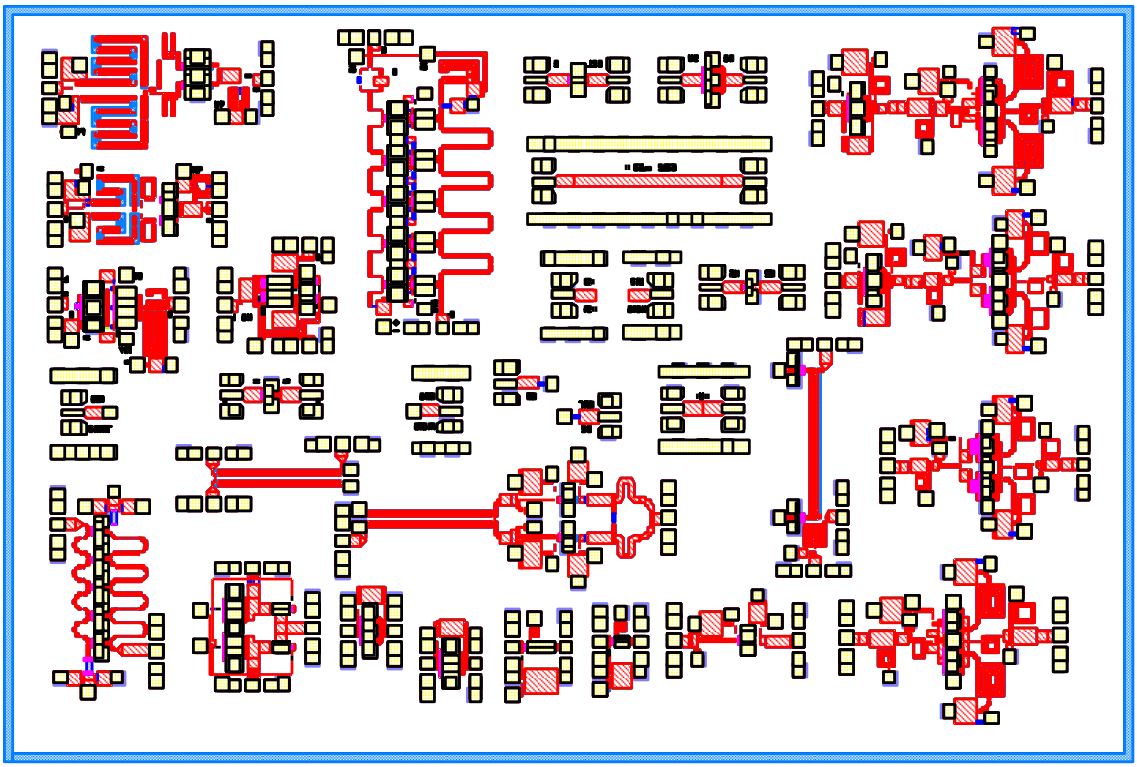

Fig. 1 Layout of CHIP1 9- × 6-mm die (various circuits and test structures)

The second chip contains a very complex broadband receiver circuit. Some of the subcircuits within this large design were added as testable subcircuits to the first chip. Since there was room in the upper and lower right corners, some of the subcircuits were also split out as smaller testable structures within the large overall design. Note the symmetry between top and bottom, as there are two signal paths that combine in the center, with an output on the far right, and a possible breakout point in the middle for analysis and additional testing. A plot of the 9- × 6-mm submission is shown in Fig. 2.

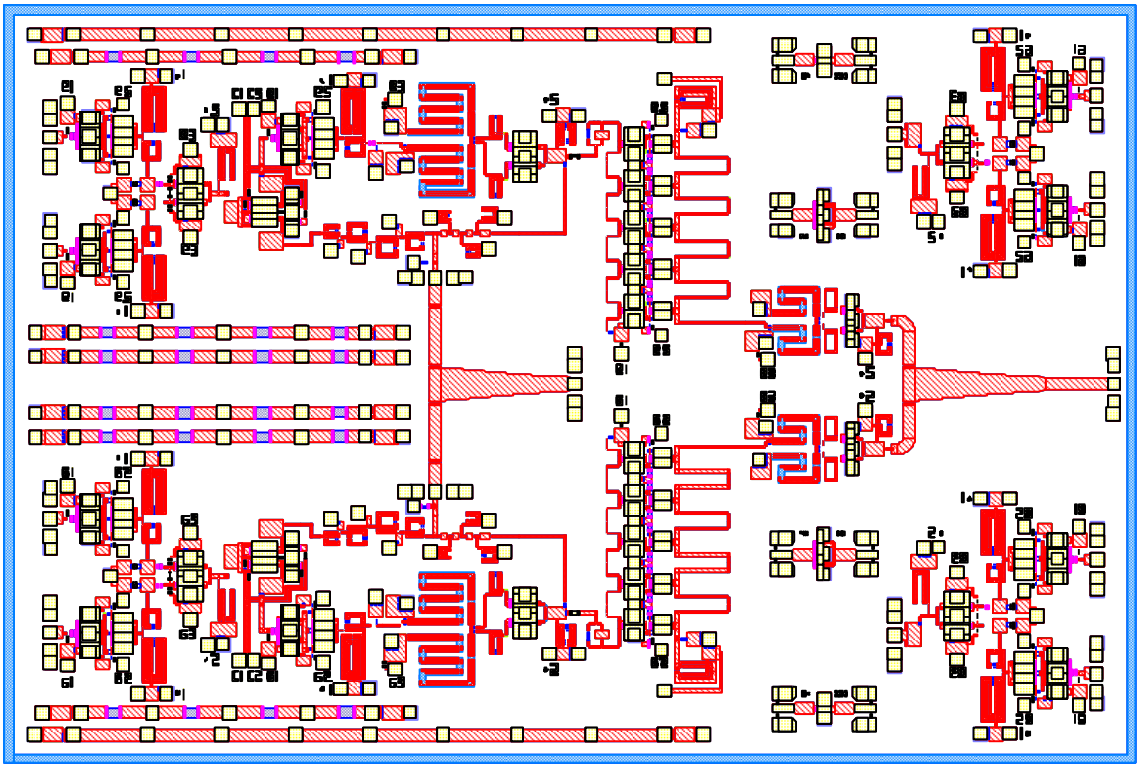

Fig. 2 Layout of CHIP2 9- × 6-mm die (extremely broadband transmitter)

3. Qorvo 0.15-µm GAN Designs

The ARL design team mostly focused on the BAE fabrication, but once it became known that space was available on the Qorvo fabrication that space was quickly filled up with promising designs. Some of the designs were based on improvements of prior designs. The team already had a lot of experience with Qorvo design kits and the process flow. PDKs and DRC checks were straightforward, as we already had a design flow in place. There were several die spaces available, though the Qorvo full reticle was smaller than the BAE full reticle. Instead of the large 9- × 6-mm die size, there were three sizes: 3.925 × 1 mm, 2.15 × 1 mm, and 2.15 × 3 mm. There were two sites available for each of the larger two sizes, but only one site for the small corner die site. Figure 3 shows a picture of the designs submitted to Qorvo for the GAN RF Challenge.

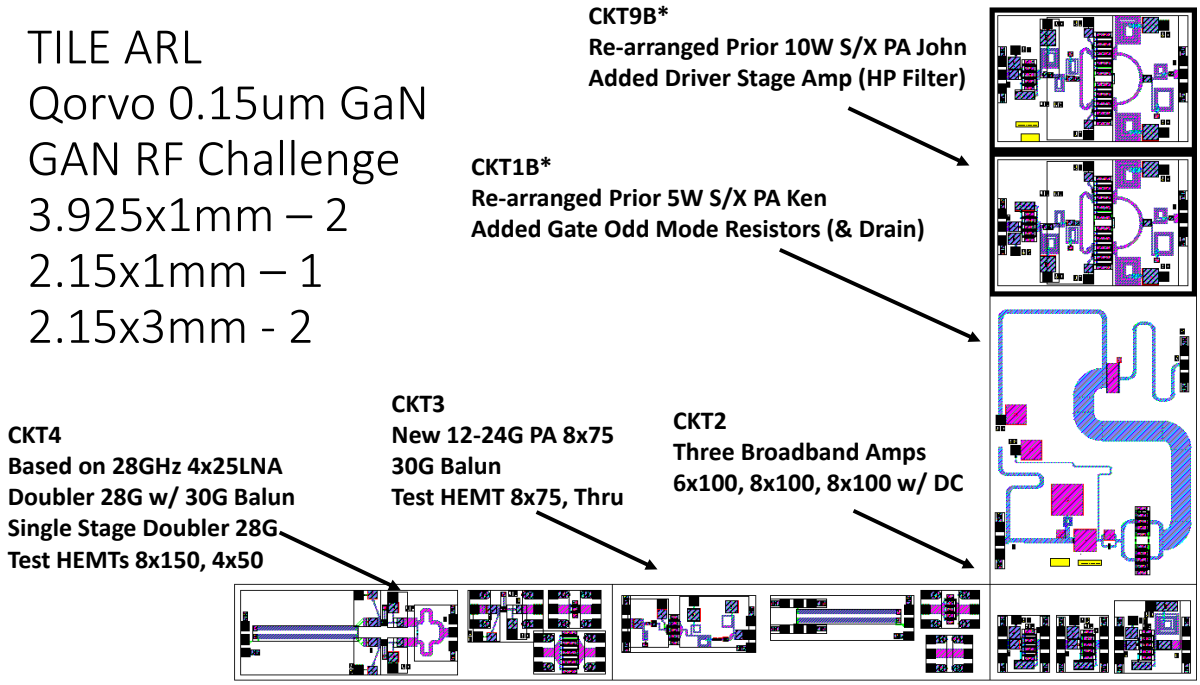

Fig. 3 ARL designs for GAN RF challenge (Qorvo 0.15-µm GAN)

4. Conclusions

The GAN RF Challenge effort included many teams exploring challenges focused on the broadband 5G development and EW needs, related to DOD needs. Parallel fabrication efforts using BAE's 0.18-µm GAN process and Qorvo's 0.15-µm GAN process will produce multiple designs to be returned in 2021 for test. Our ARL III/V Team was able to participate as a design team for both the BAE and the Qorvo multi-project wafer fabrications. These designs will be documented in separate technical reports. When the designs return, they will be tested, evaluated, and documented for future use and incorporation into DOD needs.

This GAN RF Challenge is expected to be a multi-year effort and may use more advanced GaN processes in future phases.

List of Symbols, Abbreviations, and Acronyms

ARL	Army Research Laboratory
DEVCOM	US Army Combat Capabilities Development Command
DOD	US Department of Defense
DRC	Design Rule Checking
GAN	gallium nitride
HEMT	high-electron-mobility transistor
MMIC	Monolithic Microwave Integrated Circuit
MWO	Microwave Office
PDK	process design kit
RF	radio frequency
EW	electronic warfare

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