High Power GaN Solutions for Next Generation Radar

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Introduction to RFMD GaN-on-SiC...

- Proven, reliable, volume supplier of III-V Compound Semiconductor solutions
- Released 2 GaN-on-SiC processes and 3rd in development
  - GaN1 optimized for peak power and efficiency
  - GaN2 optimized for linearity
- Largest capacity GaN fab & assembly, test facility able to meet volume/price demands
- Leader in GaN volume production, shipped >400K devices
- Product offering (Discrete/MMIC/MCM) for both commercial and military radar applications
Global Market for GaN Solid-State RF Power Devices

2012 Worldwide TAM by Region, ~$1B
- Americas: 45%
- Asia: 25%
- Europe: 30%

2012 Worldwide TAM by Application, ~$1B
- Industrial: 7%
- Milcom: 9%
- EW: 4%
- Radar: 22%
- Security: 4%
- Broadcast: 5%
- Cellular BTS: 49%

2012 Worldwide SAM for GaN RF HPA, ~$0.3B
- Commercial: 20%
- Defense: 80%

Source: RFMD
Civilian and Military Radar High Power Amplifiers

Highly efficient and reliable L- and S-Band radar systems

S-Band Ship Radar  L-Band Ground Radar

Radar Market Drivers

- Provide larger detection area
- Improve early detection
- Reduce size and weight
- Improve reliability

Why GaN?

- Higher efficiency
  - Reduce heatsink requirements, smaller size
  - Lower thermal, increase life expectancy
- Wide bandwidth
  - Replace 2 or 3 amplifiers with 1 amplifier
  - Improve engineering efficiency
- Higher power density and operating voltage; increase power with same form factor

Product Platforms

380W Pulsed Amplifier

Gain and Efficiency vs. Output Power (Pout = 3200MHz)

Gain (dB) vs. Drain Efficiency

Output Power (dBm)

9 10 11 12 13 14 15
40 50 60 70

Gain (dB)

Gain vs. Drain Efficiency

RFMD RFHA1020

RFMD RF3931

RFMD RF3928
GaN-on-SiC Offers Superior Performance & Excellent Reliability

Advantages & Benefits
- **Linearity & Bandwidth** - Improved BW performance
- **Green** - More power efficient per mW of RF power
- **Power and Size** - More RF power per mm²
- **Opex/Capex** - Lower BOM and operating costs

Reliability Results
- **MTTF (95% CB)**: $1.9 \times 10^7$ Hrs
- **$E_A$**: 2.1 eV
- **$T_{\text{CHANNEL}}$**: 200 °C
- **$V_{\text{DS}}$**: 65 V
High Volume, Low Cost Manufacturing

Automation using precision equipment adds consistency to the product

- RFMD Fab Learning Curve = 79% (Si Industry: 70% - 80%)
- 2X increase cumulative area shipped, manufacturing costs drop 21%
- GaN in a high volume GaAs fab lowers wafer manufacturing costs
GaN Production Process Flow

- Wafer-level “Known Good Die” testing
- WAT - Wafer Acceptance Test
- Product Assembly
- Early Life Screen testing
- DC/RF functional test (Guaranteed Data Sheet Mins)

Example of KGD Gate Leakage Sweep catching Gate Defect
GaN High Yield Production Test

- 100% RF testing at set $P_{\text{IN}}$ over frequency ($P_{\text{OUT}}$, gain, eff.)
- Single tune production test fixture with clamp
- Large distribution >1400 S-Band 380W
High Peak Power Radar Amplifiers

**Today**
- 50 to 65V Drain Bias
- 380W Pulsed Power
- 35 to 50ohm I/O
- 17mm x 20mm, Small Form Factor
- 1.1 W/sq mm
- 55% Drain Efficiency

**Next 6 to 12 Months**
- 50 to 65V Drain Bias
- 500W Pulsed Power
- 35 to 50ohm I/O
- 17mm x 20mm, Small Form Factor
- 1.4 W/sq mm
- 55% Drain Efficiency

**Next 24 Months**
- 65V+ Drain Bias
- 1000W Pulsed Power
- 35 to 50ohm I/O
- 17mm x 20mm, Small Form Factor
- 2.8 W/sq mm
- 60% Drain Efficiency
- Thermally Enhanced GaN-on-Diamond (NJTT Initiative)
Multi-Chip Module Solutions

• High level of integration
  - Hybrid GaN, GaAs & Passive Assembly
  - Large number of die placement
  - Eutectic and epoxy die attach

• >90% volume assembly yield

• Internal matching substrate provides high impedance at I/O

• Lowest cost multi-stage GaN power amplifiers

• Export controls either EAR99 or 3A001b.4.a
High Performance MCM Amplifiers

- **L-Band Pulsed Amplifier 1.2-1.4GHz**
  - Two stage, flange package 20mm x 17mm
  - Pulse condition 1ms PW, 10% DC
  - Operations $V_D = 45V$, $I_{DQ1} = 44mA$, $I_{DQ2} = 306mA$
  - Power output 160W
  - Power gain 25dB, DE ~50%
  - Export EAR99

- **S-Band Pulsed Amplifier 3.1-3.5GHz**
  - Two-stage, flange package 8mm x 8mm
  - Pulse condition 100us PW, 10% DC
  - Operation $V_D = 50V$, $I_{DQ1} = 42mA$, $I_{DQ2} = 220mA$
  - Power output 70W
  - Power gain 25dB, DE ~45%
  - Export 3A001b.4.a
Summary

- GaN-on-SiC technology adoption continues for high power commercial and military radar applications
- High efficiency GaN amplifiers provide robust, reliable solutions addressing need for more power in same footprint OR same power in smaller footprint
- High levels of integration provide compact, cost effective amplifier solution
- GaN products and services available include foundry, die, packaged discrete transistors, and amplifiers