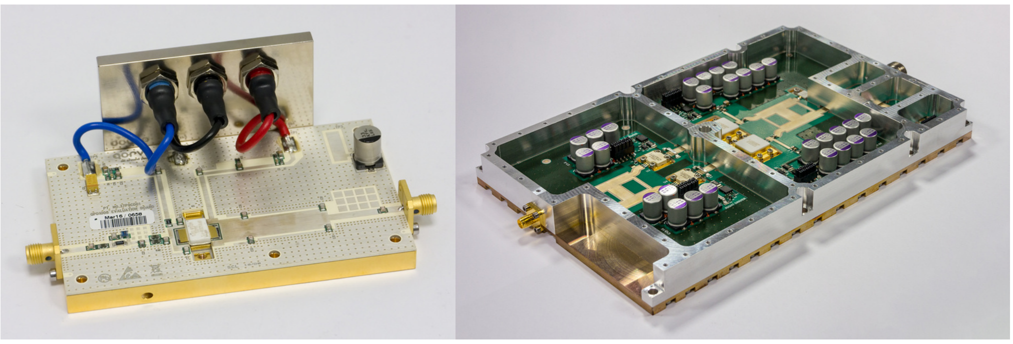
High Power GaN SSPA Module Development

Technical Briefing

GaN Transistor Technology

Gallium Nitride (GaN) can be used to realise RF and microwave transistors with much higher breakdown voltages than other solid-state RF technologies, resulting in increased power density and a simpler design process for broadband Power Amplifiers (PAs). The maturation of GaN transistor technology has allowed a step change in the RF output power available from Solid State Power Amplifier (SSPA) modules. It has also allowed impressive levels of miniaturisation, increased reliability and improved efficiency.



(a) QPD1008 EVB for Qorvo (b) 1 kW S-band SSPA Module

Figure 1: GaN SSPA Modules designed by PRFI.

GaN SSPA Design Examples

PRFI's GaN SSPA module design experience ranges from connectorized evaluation boards based on single unmatched GaN transistors to high gain multi-stage PA modules using multiple devices combined in parallel to increase RF output power. A custom designed housing is normally developed for these more complex modules, and they would typically include all bias setting and supply sequencing and conditioning circuitry to allow operation from a single positive supply. Current and temperature monitoring can also be included along with forward and reverse RF power monitoring and reverse overload shut-down.

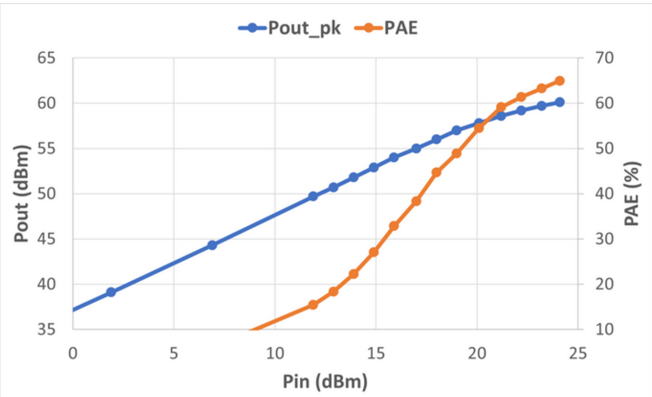


Figure 2: Plot of peak output power and PAE against RF input power for the module in Figure 1b.

The photograph in Figure 1a shows a connectorized evaluation board designed by PRFI for Qorvo to demonstrate the achievable performance of one of their unmatched transistors: the QPD1008. It has been optimised to cover 0.96 to 1.215 GHz and demonstrated a gain of 20dB and a saturated output power of 125W (at 3dB compression) with a PAE of 70%. This performance was achieved for the connectorized board including all PCB and connector losses and required careful design, EM simulation and optimisation of the matching networks and biasing structures.

As operating frequency increases the practical level of RF power that can be obtained from an amplifier using unmatched transistors reduces. This issue is addressed by device suppliers producing internally matched transistors that allow higher power levels to be achieved from a packaged transistor at a given frequency. Ultimately, as frequency increases further, pre-matched transistors give way to fully matched MMICs. PRFI has designed PA modules using all of these different combinations of GaN devices.

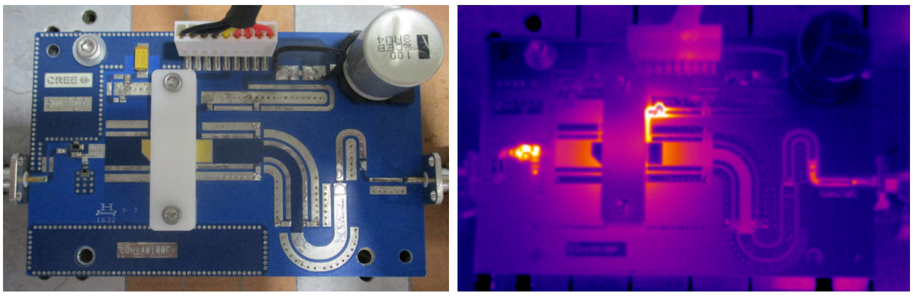


Figure 3: Photograph and thermal image of a GaN device evaluation PCB.

The module in Figure 1b is an S-band PA with a 1kW output power capability (pulsed at 10% duty cycle). It incorporates both GaN MMICs and pre-matched transistors from MACOM (ex-Wolfspeed) and uses custom designed PCB combining networks to combine RF power from multiple devices. The measured performance plot shown in Figure 2 is the RF output power and PAE versus RF input power measured at 3.25GHz.

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Thermal Design

Good thermal management is essential. GaN devices have high power densities and although they often operate with high efficiency there is still significant power dissipation in a small area. Effective power dissipation is all about spreading the heat as quickly as possible. High power GaN devices are normally supplied in Flange or Pil style packages, which are mounted directly onto the metal carrier/base-plate. It is the job of the designer to ensure that heat is transferred away from the device at an adequate rate to maintain the device junction temperature at an acceptable level. Operating devices at high junction temperatures will reduce lifetimes and can lead directly to device failure.

The SSPA module will normally be bolted to a heatsink in its system application. Some form of thermal management system will be in place at the system level. Knowledge of this system and the required operating temperature range will allow determination of the SSPA baseplate temperature. The SSPA must then be designed to operate over this range. PRFI has a liquid cooling system in its lab for use in the SSPA development process. It allows the baseplate temperature of the SSPA to be set to the desired value for evaluation so mimicking the situation in the end application.

Thermal considerations are also important in determining the choice of PCB material. Both the RF power dissipation and the DC power dissipation must be considered. If the wrong design choices are made excessive power dissipation can result in an unacceptable rise in the temperature of the PCB tracks and ultimately the failure of the PCB. The RF power dissipation can be reduced by using thicker substrates (wider RF tracks) and a low loss metallisation finish. For DC dissipation wider tracks and thicker metallisation help to increase current handling and reduce power dissipation. In both cases using a substrate material with a higher thermal conductivity will help reduce the temperature rise and allow improved power handling.

A high-quality thermal camera is a useful tool for assessing temperature rises in PCB tracking and components. Figure 3 shows a thermal image of a GaN device evaluation PCB taken using PRFI's thermal camera and clearly indicates which areas of the board are seeing the highest temperature.

The Future of GaN SSPA Modules

GaN device technology continues to develop with operating voltages, power level and frequencies all being pushed higher. It will continue with its march to replace tube devices and open up new applications.

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