50-volt GaN HEMTs Enable Wideband PA Design

In the VHF, UHF and microwave frequency ranges, there are numerous applications that require power amplifiers (PAs) with wide bandwidth. These include general purpose test equipment, component test systems, electromagnetic compatibility (EMC) susceptibility testing, electronic warfare (EW) and countermeasures (ECM) systems, frequency-agile military, government and public safety radio systems, multi-band wireless communications equipment, ultra-wideband (UWB) communications, and others. This paper presents the operating characteristics and applications of a family of unmatched 50-volt GaN HEMT power transistors from Cree, Inc - the CGHV40030 (30W, DC-6 GHz), CGHV40050 (50W, DC-4 GHz) and CGHV40100 (100W, DC-4 GHz). Two applications circuits covering 100 MHz to 1.0 GHz are described, the 100-watt TF-003 and its companion driver, the 10-watt TF-001. Both circuits are available as evaluation boards, or they may be used as reference designs (used directly or adapted) for power amplifiers in specific systems.

Cree’s Unmatched 50-volt GaN Devices

Many GHz-range power transistors include input prematching to simplify the design of power amplifiers for a specific band, or over a modest frequency range that includes a number of target applications. While this additional in-package circuitry is a valuable aid for particular applications, it places a significant restriction on the total bandwidth over which the device can operate. For wideband PAs, an unmatched device is the best option, allowing operation from DC to the maximum frequency of the device. The bandwidth of the completed PA is limited only by the ability of the designer to provide acceptable input and output matching over the desired frequency range.

To support wideband PA applications, Cree offers a family of three unmatched 50-volt GaN HEMTs with power levels from 30 to 100 watts. These devices use similar die geometry, scaled to provide the different power levels. The larger 50 and 100 watt devices have a maximum operating frequency of 4 GHz, and are offered in a 440193 two-lead flange package or a 440206 compression-mounted pill package (Figure 1). The 30 watt part is offered in a 440166 flange package, or a 440196 pill package, with the smaller die and package sizes allowing this device to operate up to 6 GHz. In practice, the 30 watt CGHV40030 is a suitable driver for the larger devices, operating well below its maximum power output when driving a PA with a single 50 or 100 watt device, or using more of its available power to drive a higher power multidevice PA.

Figure 1. The CGHV40050 and CGHV40100 devices are offered in two-lead flange or pill packages
Typical performance benchmarks for the CGHV40100 are shown in Figure 2. Small signal gain ranges from 17.7 to 14.8 dB with increasing frequency, minimum saturated power is 100 watts, and CW drain efficiency reaches 68 percent at lower frequencies and 54 percent at the upper end of this range.

![Typical performance over 500 MHz - 2.5 GHz](image)

**Figure 2.** Typical performance of the 100-watt CGHV40100 over 500 MHz – 2.5 GHz.

GaN devices offer low intermodulation distortion (IMD), and the two-tone 3rd order IMD performance of the CGHV40100 versus power output is shown in Figure 3. This data was obtained with test signals at 1 MHz spacing, and with the device biased for IDQ = 600 mA. Curves for three test frequencies shown.

![3rd order IMD versus average power at three test frequencies](image)

**Figure 3.** 3rd order IMD versus average power at three test frequencies.

Other pertinent specifications include absolute maximum drain-source voltage of 125 volts. This will handle the peak voltage of signal waveforms likely to result from the chosen class of operation and modulation type. At their rated maximum power output, all three devices will survive 10:1 VSWR at all phase angles without damage. S-parameter data is available over the operating frequency range, and customers may request Cree's recently-developed “6-port” models that allow simulation and analysis of drain waveforms at de-embedded intrinsic ports that are equivalent to probing right on the die.
The TF-003 Demonstration/Application Fixture

Evaluation of the CGHV40100F is supported with a broadband 100-1000 MHz test fixture. This unit can deliver 100 W or greater CW power across the entire band. A schematic diagram of the TF-003 is shown in Figure 4, with a summary of typical performance contained in the plots of Figure 5. Figure 6 is an assembly drawing of the TF-003, showing the general layout and parts placement.

Figure 4. Schematic diagram of the TF-003 100 watt demonstration test fixture.

Figure 5. Typical performance of the TF-003 with the unit adjusted for maximum bandwidth.
Referring to Figs. 4-5, the TF-003 is supplied with tuning that provides the maximum bandwidth rather than the flattest frequency response. With the adjustment of the value of a single matching component, C12, from 3.9 pF to 8.6 pF, the unit will provide 100 W over the entire 100-1000 MHz range, but power will be reduced at the high end of the range, above 900 MHz. Fig. 5 represents typical performance; component and manufacturing tolerances will introduce some variation in the performance (and shape of the response curves) from unit to unit.

A similar test fixture, the TF-001, is designed as a driver for the TF-003, covering the same frequency range of 100-1000MHz. This unit can deliver up to 10W of CW power using a CGHV27015S device at VD of 30 volts. Performance is tailored to match the drive power requirements of the TF-003. Together, the TF-001 and TF-003 offer the PA designer a means of evaluating the performance of the CGHV40100F device for broadband applications. Similarly, the bias and control board provides a reference for similar functions in the customer’s final design. The matching circuits of the TF-003 may be duplicated in the customer’s eventual PA design, although typically they will be used as a starting point for adaptation and optimization for an application’s specific frequency range and performance requirements. Cree’s advanced models enable accurate simulation for such an optimized design.

Summary
Wide bandwidth power amplifiers have many applications in the frequency range from below 100 MHz through L-Band, including broadband or frequency-agile communications, telemetry, test, radar, EW/ECM systems and more. Cree’s CGHV40030, CGHV40050 and CGHV40100 devices have the necessary unmatched inputs for broadband impedance matching to fulfill these applications. Their gain, bandwidth and distortion performance support high performance applications, along with the ruggedness of well-defined thermal behavior and 10:1 VSWR tolerance.

The TF-003 test fixture allows evaluation of the 100-watt CGHV40100F in a 100-1000 MHz broadband PA. The TF-001 driver fixture supports the overall evaluation system with 15 dB gain and 10 watts output power. The proven performance of these demonstration circuits offers the PA designer either a usable reference design or a known starting point for further performance optimization.