Multi-Stage Power Amplifier Reference Design Guide
For Military Communications, Operating at 50 V and 100 W

CMPA0527005F-AMP1, CGHV40030F-AMP2, CGHV40100F-AMP
Introduction

Wolfspeed, a Cree company, has developed application fixtures for three catalogue devices; the CMPA0527005F, CGHV40030F, and the CGHV40100F to cover 0.5 GHz to 2.5 GHz for Electronic Protect/jamming power amplifier, and other military communications (MilCom) applications. All devices are constructed with Wolfspeed’s GaN HEMT technology with the CGHV40100F and CGHV40030F being unmatched devices operating at 50V. The CMPA0527005F is a GaN MMIC device with the input matched to 50 Ohm and the output unmatched also operating at 50V. This application note describes the typical performance that has been achieved when three fixtures are assembled together. Key features of the lineup performance include:

- Frequency range 0.5 GHz - 2.5 GHz
- Over 52 dB of small signal gain
- Over 40% lineup efficiency
- 100 W saturated output power

Design

The design goal was to create a 0.5 GHz - 2.5 GHz CW capable lineup that can achieve over 100 W of output power using a single 50 V DC supply for the drain. By doing so, system complexity can be reduced to eliminate the need for multiple DC-DC converters thus reducing the overall system efficiency. The first stage utilizes the CMPA0527005F-AMP1 which has been matched to operate across the entire frequency range (delivering up to 8 W of CW output power), but can be narrowband matched if needed in other applications. The second stage utilizes the CGHV40030F-AMP2 GaN HEMT device which has been optimized for linearity under two-tone signal across the band and is operated backed off from $P_{SAT}$ to provide ample headroom to output stage. To complete the lineup, the third stage uses the unmatched CGHV40100F which is housed in a thermally viable package allowing it to deliver 100 W CW.

To test the lineup each fixture, the CMPA0527005F-AMP1 followed by, the CGHV40030F-AMP2, followed by, the CGHV40100F-AMP, as shown in Figure 1, were connected in the lab. To reduce the mismatch between the output of the CGHV40030F-AMP2 and the input of the CGHV40100F-AMP, the 7.5 pF capacitor (C2 on the CGHV40100F-AMP Application Circuit Schematic) was changed to 2.2pF. Overall small signal gain of over 52 dB was achieved with good input and output return loss, as shown in Figure 2. At saturated power, over 100 W is achieved across the band with a lineup efficiency of over 40% and typical large signal gain of 42 dB, as shown in Figure 3. When measured with a two-tone signal the IMD3 remained below -25 dBc across the full frequency range at an average output power of 47 dBm, as shown in Figure 4.
Figure 1. Three-Stage Lineup of MilCom Lineup
(100 W, 0.5 - 2.5 GHz, 50 V)

\[
\begin{align*}
\text{CMPA0527005F} & \quad 5 \text{ W} \quad 20 \text{ dB} \quad 22 \text{ dBm at Back Off} \quad 15 \text{ dB Back off} \quad -45 \text{ dBC} \\
\text{CGHV40030} & \quad 30 \text{ W} \quad 12 \text{ dB} \quad 34 \text{ dBm at Back Off} \quad -10 \text{ dB Back off} \quad -40 \text{ dBC} \\
\text{CGHV40100} & \quad 100 \text{ W} \quad 10 \text{ dB} \quad -30 \text{ dBC at 44 dBm} \\
\end{align*}
\]

\[P_{\text{IN}} = +8 \text{ dBM}\]

Figure 2. S-Parameters of 50 V MilCom Lineup
Full Lineup S-Parameters (\(V_D = 50 \text{ V}, I_{DQ} = 800 \text{ mA}\))
Figure 3. **Saturated Power Performance of 50 V MilCom Lineup**
Full Lineup Power, Gain, Efficiency at $P_{\text{SAT}}$ ($V_D = 50 \, \text{V}, \, I_{DQ} = 800 \, \text{mA}, \, I_G = 0 \, \text{mA}, \, \text{CW}$)

![Graph showing power, gain, and efficiency as a function of frequency](image)

Figure 4. **Two-Tone Performance of 50 V MilCom Lineup**
Full Lineup IMD3 - $P_{\text{OUT}}$ ($V_D = 50 \, \text{V}, \, I_{DQ} = 800 \, \text{mA}$, two-tone 1 MHz spacing)

![Graph showing IMD3 performance](image)
Space Study

Individually, the CMPA0527005F-AMP1 is constructed on a 2.6” x 1.7” PCB, the CGHV40030F-AMP2 circuit on a 2.6” x 1.7” PCB, and the CGHV40100F-AMP circuit on a 4” x 2.5” PCB. All three PCBs use a RO4350B 20 mil thick substrate. Together, the three circuits can be combined onto one 7” x 3.6” PCB without redesign. It is possible to further reduce this size by matching the device’s impedances to one another. Under their current format, the circuits match the gate and drain impedance of each Cree GaN HEMT to 50 ohms. Alternatively, space can be saved by matching the output impedance of the CMPA0527005F to the input impedance of the CGHV40030F, and the output impedance of the CGHV40030F to the input impedance of the CGHV40100F. The Z-Source, input impedance, and the Z-Load, output impedance, of each transistor can be found using Wolfspeed’s proprietary large signal models.

Conclusion

With its high power and high efficiency, the three-stage lineup presented in this application note is perfect for multiple MilCom applications. Running under saturated condition, the lineup generates over 50 dBm of output power, over 40% of drain efficiency, 42 dB of typical power gain. Under two tone testing, the worst case IMD3 is approximately -25 dBc when sweeping output power from 27dBm to 47dBm.