# RF Power Transistors for Broadband Applications White Paper

## 28 through 50 V, Si LDMOS from HF through L Band
## 28 through 50 V, GaN SiC HEMT from VHF through S Band

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## Overview

The evolving requirements of defense communication and counter measures continues challenge power amplifiers transistors with wide bandwidth and a mix-mode of waveforms from QAM, OFDM to constant-envelop (FM) with extended video bandwidth to support multi-carrier applications. This must all be done in a small form factor with a workable thermal management design. These software-defined radios with their frequency agile, multi-mode requirements continue to demand transistors that are more efficient and linear over a wide dynamic range and bandwidth.

Ampleon addresses these challenges and applications with two transistor technologies: Si LDMOS and GaN-SiC HEMT. For Applications below 1 GHz, we have a wide selection of options and power levels for Si LDMOS to address multi-octave bandwidth applications. For applications that operate above 1 GHz, GaN-SiC HEMT typically will be the right technology choice as the higher Ft and lower parasitic capacitances help support broadband at these higher frequencies. This whitepaper will review our products and reference design examples that demonstrate both Si LDMOS and GaN-SiC HEMT with their broadband linearity features at high efficiency set points.

Ampleon has a long heritage of Si LDMOS transistors and is now offering its 9$^{th}$ Generation of technologies in support of broadband applications. These Si LDMOS products are outlined below and come at a range from 28 V through 65 V operation. Further, Ampleon recently released its 3$^{rd}$ generation GaN-SiC HEMT. These devices were specifically engineered to deliver broadband power with unrivaled linear performance over a broad bandwidth. Ampleon's broadband selection options will help you match the application to the right device and reference design.

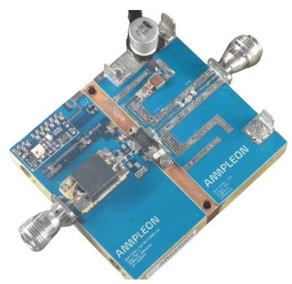
# 28 and 50 V, Si LDMOS Broadband Transistors and Reference Designs

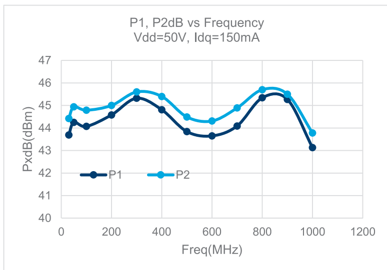
We focus on our generation 9 Si LDMOS products for broadband applications. The feature power ranges from 10 through 1600 W, typical bands range from 2 - 30, 30 - 512 MHz and a new stretch band reference power amplifier from 30 - 1 GHz. The table shows some of the available application reference designs and provides examples of these designs and performance graphs.

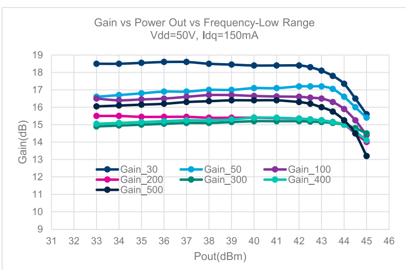
| Part Number | Operating Voltage | Frequency Range (instantaneous) | Power Level | Psat Eff | Package Type | Application Reports |
|---|---|---|---|---|---|---|
| **BLP15H9S10G** | 50 V<br>35 - 50 V | 2 through 30 MHz<br>30 through 512 MHz | >10 W<br>>4 W | >50 %<br>>25 % | SOT1482-1 | AR212123<br>AR212089 |
| **ART35FE** | 50 - 65 V | 2 through 30 MHz | >30 W | >35 % | SOT467C | AR212131 |
| **ART1K6FH** | 50 V | 2 through 30 MHz | >700 W | >55 % | SOT539AN | AR212082 |
| **BLP15H9S30**<br>**2 x BLP15H9S30** | 50 V | 30 through 1000 MHz<br>30 through 512 MHz | >25 W<br>>50 W | >35 % | SOT1482-1 | AR212026<br>AR212058 |
| **BLP15H9S100** | 50 V | 30 through 800 MHz | >75 W | >37 % | SOT1482-1 | AR212005 |
| **BLP15M9S30** | 32 V | 30 through 512 MHz | >25 W | >50 % | SOT1482-1 | AR192035 |
| **BLP15M9S100** | 32 V | 148 - 175 and 400 - 470 MHz<br>(Only Narrow Band) | >90/100 W | >45 % | SOT1482-1 | AR212114<br>AR202140 |
| **BLP974P** | 50 through 28 V | 30 - 512 MHz | 400 W at 50 V | >50 % | SOT539A | AR201250 |
| **BLP647P** | 32 V | 30 - 512 MHz | 100 W at 28 V | >58 % | SOT1121A | AR212016 |
| **ART700FE** | 62 V | 30 - 512 MHz | >600 W (pulse) | 45 % | SOT1214A | Work in Progress |
| **ART2K0FE** | 62 V<br>50 V | 20 through 100 MHz | >1400 W<br>>1000 W | >60 %<br>>60 % | SOT539AN | Work in Progress |

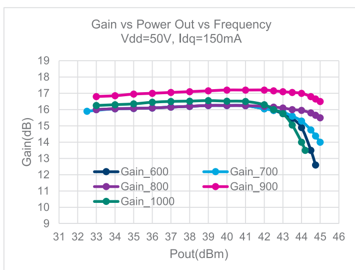
## BLP15H9S30 in a 30 - 1000 MHz HPA Reference Design

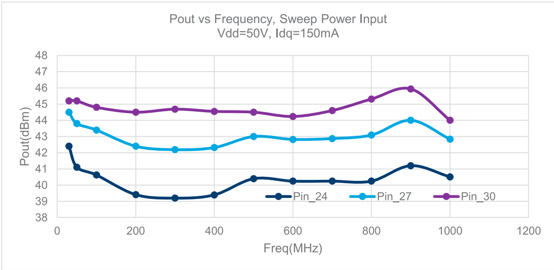
This HPA designs employs a 30 W Si LDMOS BLP15H030S transistor in a plastic SOT1482-1 style package. The amplifier utilizes a 12 to 50 Ohm transformer on the input match and a 2 section reactively match lump elements on the output. The instantaneous performance from 30 to 1000 MHz shows Gp > 15 dB at efficiencies at 25 W at 35 - 58 % depending on the frequency of operation.



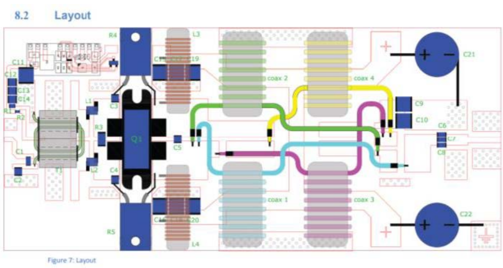



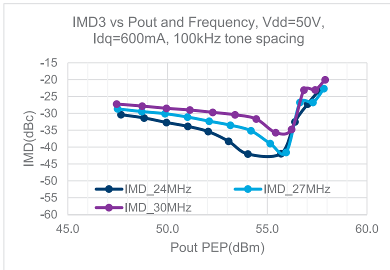



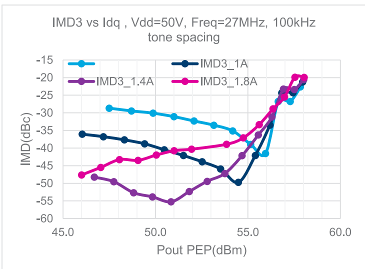



## ART700FH in 2 Through 30 MHz HPA Reference Design

This high-power amplifier deploys at 700 W Si LDMOS ART700FH housed in a SOT1214A ceramic package that is nested into a coax balun reference design. This design shows the 15:1 bandwidth product while delivering exceptional linearity of under -30 dBc at 400 W power. For optimal IMD3 products, Idq settings can be adjusted depending on frequency and power.

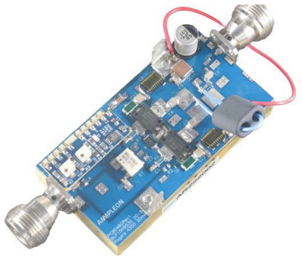


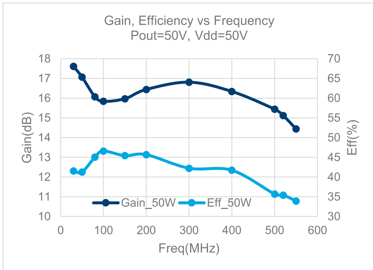



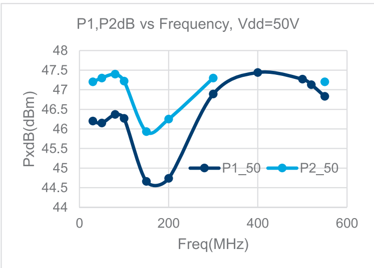



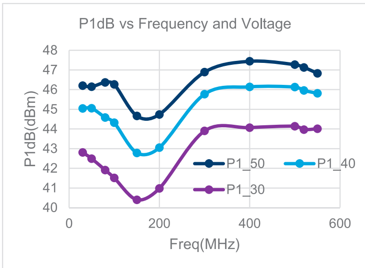
## 2-Way Combined (Push-Pull) BLP15H9S30S design from 30 - 512 MHz

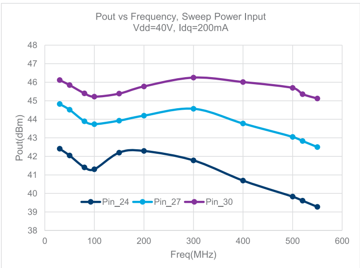
This HPA designs employs a 30 W Si LDMOS BLP15H9S30S transistor in a plastic TO-270 (SOT1482-1) style package. The amplifier utilizes two of the transistors in a push-pull configuration. An off-the-shelf SMT balun is used on the input and a simple coax and ferrite is used for the output. The instantaneous performance from 30 to 520 MHz shows Gp > 15 dB at efficiencies at 50 W at 35 - 45 % depending on the frequency of operation. The performance graphs below demonstrate P1 through P3 dB performance over the band at 50 V but shows capability to adjust Vdd from 50 through 28 V depending the power distribution features at Fixed Po and also at Fixed Pin power level.





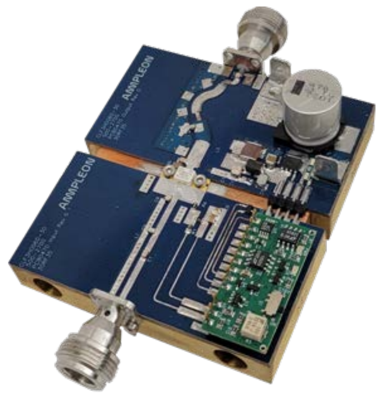
# 50 V GaN-SiC HEMT Broadband Transistors

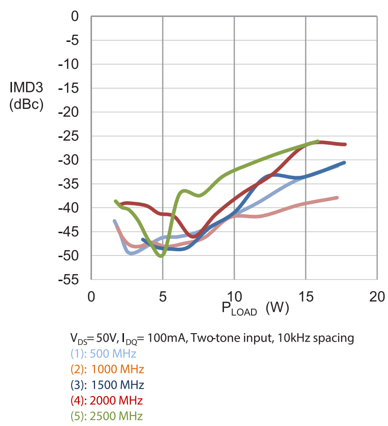
Ampleon recently released it new broadband GaN-SiC HEMT products in the initial release of the 3rd generation range from 10 through 100 W. These are the first in a series of 50 V broadband devices targeted to support linear bandwidth in concert with power bandwidth products. These rugged broadband devices are housed in thermal enhanced package to the optimal in thermal performance. The table below provides a summary and performance graphs of the broadband amplifiers show cases the outstanding linearity bandwidth capabilities.

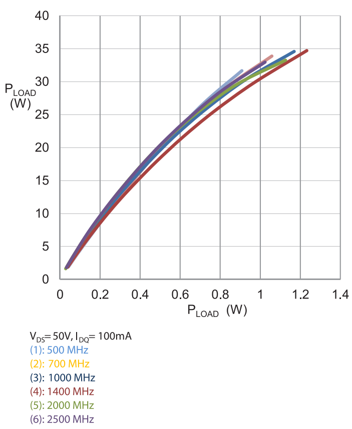
| Part Number | Operating Voltage | Frequency Range | Power Level | Package Type | Application Reports |
|---|---|---|---|---|---|
| **CLF3H0060L-10** | 50 V | 200 through 3200 MHz | >10 W | SOT1227A | AR212149 |
| **CLF3H0060L-30** | 50 V | 500 through 2500 MHz | >30 W | SOT1227A | AR202113 |
| **CLF3H0035L(S)-100** | 50 V | 500 through 2500 MHz | >100 W | SOT467C | AR202037 |

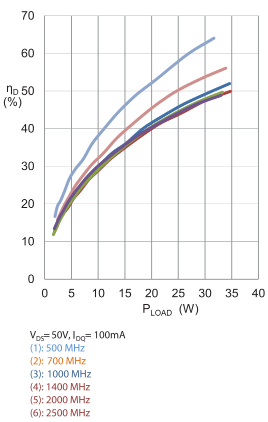
### 30 W 50 V GaN-SiC HEMT CLF3H0060L-30 Broadband Performance

The 500 to 2500 MHz reference design is the 30 W CLF3H0060L-30 GaN-SiC HEMT in a distributed matched amplifier tuned for optimal power, efficiency, and linearity feature over the entire bandwidth instantaneously. The results show IM3 linearity of less than –35 dBc at 7.5 Watts, 6 dB backed-off below saturated power. Further, the optimal linearity setting can be achieved by bias tuning between 50 mA to 100 mA quiescent gate current Idq depending on the application and power level required.



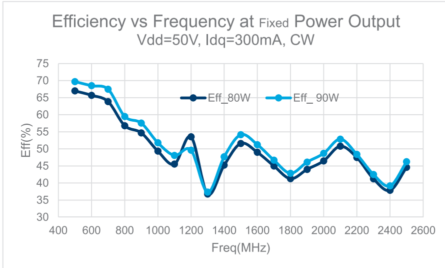



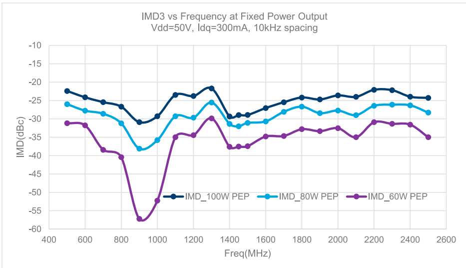



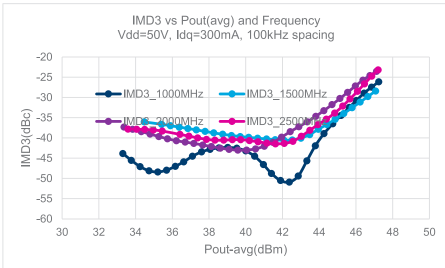
### 100 W CLF3H0035L(S)-100 GaN-SiC HEMT of Broadband Performance from 0.5 to 2.5 GHz

The amplifier is a 500 MHz to 2500 MHz instantaneous bandwidth 100 W GaN-SiC HEMT transistor operating at Vdd=50 V. The amplifier utilizes the CLF3H0035L(S)-100 nested into a Rogers 4350, 20 mil thick printed circuit board sweat, soldered to a heatsink. The transmission line match structure was optimized for best efficiency over the bandwidth while delivering the best achievable linearity. The performance graphs show P3 dB power performance over the band at 80 and 90 W Po.



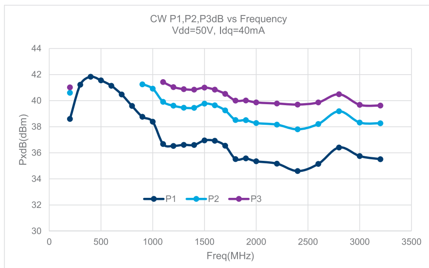

This graph shows the same amplifier IM3 performance plotted over the 500 MHz to 2500 MHz bandwidth at peak-envelop power from 60 through 100 W PEP which shows broadband linearity over the entire band. The second IM3 graph shows IM3 products over power at specific frequencies in the band.

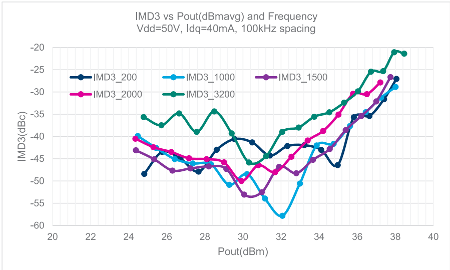



### 10 W CLF3H0060-10 GaN-SiC HEMT of Broadband Performance from 200 to 3200 MHz

The 10 W GaN-SiC HEMT device is showcased in a 200 - 3200 MHz Amplifier with similar matching topology as the higher power 30 and 100 W devices. The reference design demonstrates excellent third intermodulation products over power and over frequency with better than –35 dBc of IM3 products at 34 dBm. Further, power output over frequency shows power flatness over the band with P1 through P3 dB compressed power.






### Thermal Management

In broadband designs, the most important consideration is the thermal plan. This means the application requirements supported by the amplifier's thermal dissipation management to a suitable case temperature and desired reliability performance. This is often an iterative process of trading the transistor's RF and DC features in concert with footprint size and thermal stack considerations until the best option is selected. This is especially important in GaN-SiC HEMT as the transistors will run close to their thermal limit and thermal resistance in GaN-SiC will be more non-linear than Si LDMOS depending on operational dissipated power and thermal stack factors. Ampleon has taken exceptional care to thoroughly model our devices to support accurate thermal performance for both Si and GaN-SiC HEMT. For GaN HEMT, we have recently published an application note AN221012 to describe our methods and the associated details.

### Large Signal Models

Ampleon offers large signal models for both simulators in Keysight ADS and Cadence MWO for both Si LDMOS and GaN-SiC HEMT products. The models are posted on our website:

| Part Number | ADS Model | MWO Model | MWO Sumulation Example |
|---|---|---|---|
| CLF3H0035-100 | Download | Download | Download |
| CLF3H0035S-100 | Download | Download | Download |
| CLF3H0060-30 | Download | Download | Download |
| CLF3H0060S-30 | Download | Download | Download |

These models are accurate and geared to support your design projects through each step of the process. We use these same models to support our reference design work and rely on their effectiveness in our own amplifier designs for first pass success.

The accuracy of the models is shown below. The models on the website are locked which incorporate a scalable die model, passive network modeled with the reference plane to the package, lead/lid interface at the package wall.

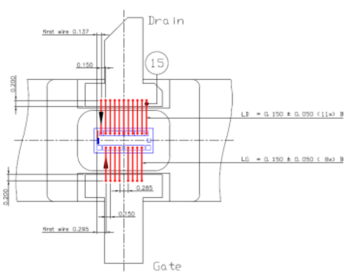
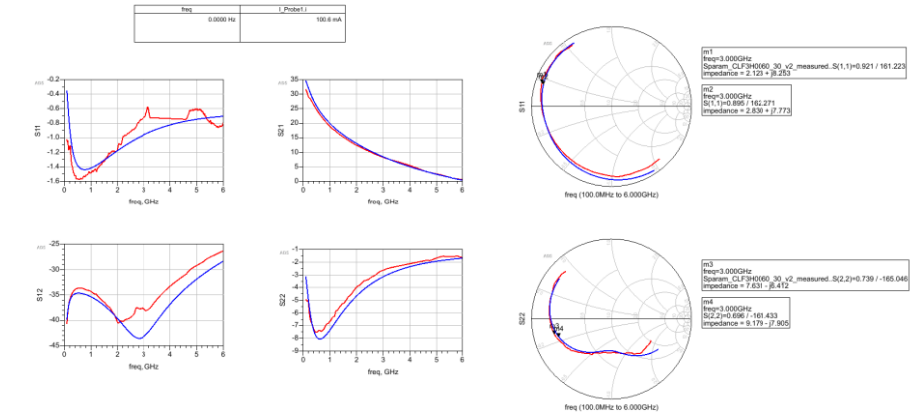
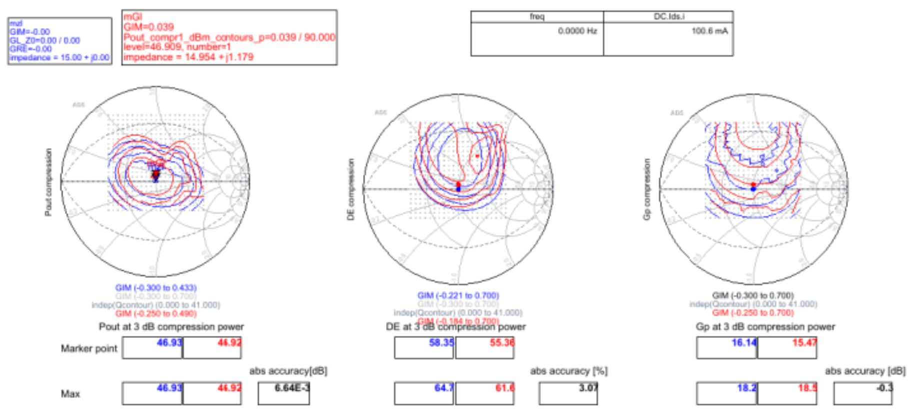



Diagram of CLF3H0060L-30




Small Signal over Frequency 0.1 – 6 GHz at Vds = 50 V, Idq=100mA




Load-Pull at 2.5 GHz under Vdd=50 V, 100 mA Idq (Red = Measured, Blue=Modeled)

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